Final report to Maryland State Highway Administration

A grade report for turfgrasses suitable for Maryland right-of-ways

Katharina A. M. Engelhardt
Kara Hawkins

University of Maryland Center for Environmental Science
Appalachian Laboratory
301 Braddock Road
Frostburg, MD 21532

Photo of Intersate 70 in Howard County, courtesy of wikipedia (https://en.wikipedia.org/wiki/File:Interstate70HowardMD.jpg) by author JBoulin94.

INTRODUCTION and PURPOSE

Turfgrasses are widely used as vegetative ground cover to reduce soil erosion, filter runoff, improve air quality, provide food resources and habitat to native fauna, and to provide surfaces for recreation and aesthetic appeal (Brown and Gorres 2011, Brown et al. 2011, Friell et al. 2012, Uddin and Juraimi 2013). They are therefore used for sports recreation surfaces and lawns as well as in parks, cemeteries, airports, roadsides, and mine reclamation. In the Chesapeake Bay watershed, turfgrass covers over 3,800,000 acres with 23% (1,300,000 acres) located in Maryland (Schueler 2010). Over 4% (52,000 acres) of the turfgrass acreage in Maryland is distributed on roadside right-of-ways.

The State Highway Administration (SHA) of Maryland maintains turfgrasses along highway right-of-ways to provide sight distance and an aesthetic landscape to motorists. Mowing also reduces wildlife use of areas near roadsides to decrease risk of vehicle impacts, and reduces fire hazards from roadside vegetation catching on fire. However, the turfgrass seed mixtures currently used in Maryland require frequent mowing in often narrow and congested areas. Thus, maintenance of roadsides remains costly and often places maintenance staff in danger, highlighting the need to identify turfgrasses and seed mixtures that require less maintenance but that will establish rapidly, be resilient in the harsh roadside environment, have neutral or positive effects on ecosystems and watersheds, and are available and affordable through commercial growers.

Using a broad literature review, we evaluated grass species for use along roadsides in Maryland, paying particular attention to commercial cost, rate of establishment, ease of maintenance, potential for erosion control, ecosystem benefits, and resilience. Resilience is multi-faceted and includes tolerance to drought, low fertility, freezing, salinity, acidity, wear, and competition. The literature summarized observational and experimental studies throughout the world; thus, not all studies were relevant to the varied climates found in Maryland. Studies from Maryland and surrounding states were therefore weighted more heavily. Most of the reviewed species are cultivated turfgrasses with known cultivars or ecotypes. Some species are nursery-grown native species that are not developed as turfgrass but are used in native landscaping, grassland restoration, or mine reclamation. We focus solely on graminoids although forbs, such as clovers, may also be used with success along roadsides (Andres and Jorba 2000, Karim and Mallek 2008, Strelkute and Braduliene 2014).

Commercial availability and cost: Seed that is used for roadside turfgrass establishment needs to be commercially available and be affordable. We consider grass species and cultivars as viable candidates for roadside planting if they are currently commercially available, although promising but undeveloped species or cultivars are noted. Ratings are based on cost per acre, which reflects not only the quantity available for purchase but also seed size and recommended seeding rate. We received this information from Chesapeake Valley Seed.

Rate of establishment: Contractors will get paid only when 90-92% grass cover has been established (Chesapeake Valley Seed Inc. *personal communication*). Thus, rapid establishment of turfgrasses is desired for pure economic reasons, as well as for reducing erosion on new cut slopes and roadside fills (Andres and Jorba 2000). We assessed rate of establishment by reviewing germination rate of grass species under laboratory, greenhouse, and field conditions. We also reviewed the literature that monitored percent cover and/or quality through time, including the establishment year.

Ease of maintenance: Vertical growth rate and overall short stature are important traits in roadside vegetation owing to budget constraints that limit the frequency with which the grass is mowed (Brown and Gorres 2011). In addition, turfgrasses that require no fertilization, liming, or irrigation will decrease the need for continued maintenance past establishment therefore reducing long-term maintenance costs. We therefore determined the stature of each species through information provided by nurseries and species fact sheets, and reviewed scientific papers that focused on the performance of species under low-maintenance conditions (Dernoeden et al. 1994, Mintenko and Smith 1999, Brede 2002, Johnson 2000, 2003, Bunderson et al. 2009, Watkins et al. 2011, 2014.

Erosion control: Turfgrasses that produce deep roots and dense sod, and that can increase infiltration capacity will stabilize soils, draw water away from road sides, and decrease run-off, providing erosion control and local nutrient retention. We determined the potential of each species to provide erosion control by reviewing papers that studied rooting depth and sod density under greenhouse and natural conditions (Weaver 1958, Simon and Collison 2002, Bonos et al. 2004, Brown et al. 2010).

Ecosystem benefits: As living organisms, grasses contribute to the functioning of ecosystems. Benefits to ecosystems include erosion control, nutrient retention, plant and animal biodiversity, and habitat for pollinators and wildlife. Wildlife, however, may be a hazard near roadsides and could therefore be viewed as a risk rather than a benefit adjacent to roads. Further from the road, benefits to wildlife could be valued more highly. Many turfgrasses are non-native and were specifically selected for their growth habit. Thus, turfgrasses may be invasive to native habitats and be reducers of native biodiversity. We review these potential positive and negative ecosystem effects paying particular attention to whether species are native or considered to be potentially invasive or weedy.

Resilience: The roadside environment in Maryland is an extreme environment that is dry and hot in the summer and cold in the winter with soils that are compacted, low in fertility, generally acidic, and sodic due to road deicers. As highly disturbed ecosystems, roadside environments receive propagule pressure from surrounding ecosystems such that desirable species have to compete with volunteers, many of which are weedy and invasive. Thus, species require a combination of traits for optimal survival. We rate each turfgrass for 7 traits that together provide an overall resilience rating as well as information that determines which climatic zones in Maryland may be the most suitable for the species or cultivars of a species. For example the climate in Western Maryland is very different from the climate on the Eastern Shore and, hence, species may be resilient in one loacation in Maryland but not in another.

Drought and heat tolerance: Heat reflected from the pavement and the constant wind from passing vehicles results in a microclimate along roadsides that is droughty. In addition, roadsides are engineered to rapidly drain water away from the roadside into swales, storm drains or storm water retention ponds (Brown and Gorres 2011), decreasing the availability of water to roadside vegetation. Providing supplemental irrigation for roadside vegetation is cost-prohibitive such that turfgrass species selected for roadsides need to be drought tolerant to survive. Drought tolerance is conferred through a range of morphological and physiological mechanisms (Beard 1973, Carrow 1995, McCann and Huang 2008), the most common of which are deep root systems that allow plants to avoid drought by accessing water resources deep in the soil column; low evapotranspiration rates that conserves water within leaves; and dormancy during the hottest and driest times of the summer.

Tolerance to low fertility soils: Soils after construction are generally poor, low in organic matter, microbial activity, and cation exchange capacity (Booze-Daniels et al. 2000, Brown and Gorres 2011). Brown and Gorres (2011) recommend amending roadside soils with compost after showing that the soil amendments were able to enhance persistence as opposed to using salt and drought tolerant cultivars. Nitrogen deposition is higher along roadsides owing to vehicle exhaust (Brown and Gorres 2011), which can interact with salt to increase plant uptake of nitrogen.

Cold and freezing tolerance: Maryland is located in the transition zone between warm climates of the southern United States that are suitable for warm season grasses with the C4 photosynthetic pathway, and cool climates in the northern U.S. that are more suitable for cool-season grasses with the C3 photosynthetic pathway. The transition zone provides opportunities for using a diversity of turfgrass species in roadside plantings but also places many species at the edge of their range. Maryland, for example, delineates the northern edge of the bermudagrass range and may be close the southern edge for red fescue. Furthermore, Maryland spans a wide elevation range from sea level to over 3000 feet (=1000 m) on the Appalachian Plateau and thus offering a range of climates. Cold temperatures and freezing soils and sod are therefore important considerations for assessing the suitability and potential for success of turfgrasses along roadsides in Maryland.

Salinity tolerance: Deicers are used in winters to keep roads free of ice. These salts leach into the soils along roadsides (Butler et al. 1971, Hughes et al. 1975) and leave residues on above-ground plant parts that can negatively impact germination, growth, and survival (Harivandi et al. 1992, Biesboer et al. 1998, Marcum 2008). In contrast, Brown and Gorres (2011) and Brown et al. (2011) found that salt was the primary cause of turfgrass failure along roadsides but that persistence could be significantly improved by amending soils. Both sodium and chloride are toxic to plants and can interfere with a plants' water holding capacity (Brown et al. 2011), but tolerance to high salt levels vary among species and cultivars (Marcum 2009) and with plant developmental stage (Friell et al. 2012). Friell et al. (2013) observed that foliar exposure was most likely an important aspect of relative salinity tolerance assessments and argue that under prolonged exposure to salinity, cultivar selection is of little importance relative to species selection.

Tolerance to acid soils: Most soils in Maryland (without addition of agricultural lime) tend to be acidic and buffered by the Al system. Thus, native soils are generally between pH of 4.0 to 5.5. Some surface horizons enriched in organic materials may have even lower pH values. Exceptions to these would be particular types of geological parent materials that are less extensive, and which are more base-rich; limestone and dolomite (for sedimentary rocks) and mafic igneous and metamorphic rocks (such as in the Baltimore gabbro complex, the Boyds diabase sill in Montgomery county, and various diabase dikes associated with the triassic rocks of the piedmont.) These exceptional cases could have subsoil pH values that range into the mid-6s, although surface horizons may be more weathered, organic rich, and thus, have lower pHs than the subsoils. The soils along highways are challenging, because the earth has been disturbed during construction. Thus, it is often unclear what soil horizons might be exposed at the surface and therefore hard to predict what soil pH would be. Topsoils that are tested along MD roadsides immediately after road construction can have high pH (Robert LaRoche personal communication) but it is unclear how long this condition lasts. We rated species more highly if they could tolerate a wide range of pH's, including acid soils (Booze-Daniels 2000) and high aluminum tolerance (Liu et al. 2008).

Wear tolerance: Roadside environments need to be mowed regularly to maintain aesthetic appeal, provide sight distance, and minimize fire hazards. Roadsides also see some traffic from cars that pull over during emergencies. Thus, turfgrasses planted along roadsides have to be able to withstand frequent mowing and traffic from vehicles.

Tolerance to competition: To survive in a community with other plant species, a grass species needs be competitive enough to withstand competition pressure for light, nutrients, and water from other species. This includes resisting the invasion of weeds, which are successful when resident species do not provide adequate ground cover and hence offer niche opportunities for new colonizers.

METHODS

Through an extensive literature review of over 500 journal articles, white papers, reports, and fact sheets and detailed discussions with turfgrass experts, we graded 21 turfgrass species and species groups for their ability to provide six services to roadside management and to be resilient towards the stressful conditions that are frequently encountered along roadsides. Because the geography of Maryland is diverse ranging from coastal to mountain habitats, we assessed the suitability of turfgrasses to grow in four regions of Maryland – Southern Maryland, Eastern Shore, Central Maryland, and Western Maryland.

We first developed a list of potential grass species that are currently commercially available. Commercial availability is important to ensure that seed would be available in a high enough quantity to be used for roadside planting. To develop this initial list of species, we consulted nurseries and seed suppliers within the region, including Chesapeake Valley Seed, Ernst Conservation Seed, and Newsome Seed, as well as companies with an internet presence. In all, we identified 32 companies and reviewed species catalogues from 28. We also consulted published seed mixes of state transportation agencies within the mid-Atlantic area to identify which species have been used along roadsides within the region.

After developing a list of grass species that are commercially available, we selected species from the list that were low growing and will grow on dry land. Wetland species were therefore immediately excluded. Another consideration included whether the species has a presence within the region and therefore has a proven track record to persist within the mid-Atlantic climate. We consulted the Maryland Biodiversity Project and the USDA NRCS Plants Database to identify those species that already have known occurrences in Maryland. Because roadsides bisect a variety of habitats such that they are corridors for species movements, we also considered weediness or invasiveness.

In the end, we constrained our final list of species to 25 grass species that have either been planted in the past along mid-Atlantic roadsides or have promise for the future. Our list could be expanded. However, our approach provides a thorough sampling of grass species that are currently available commercially and for which literature exists.

After selecting a focused list of species, we consulted Chesapeake Valley Seed to assess cost of planting each species. The company provided us with information on number of seeds per pound, cost per pound, and cost per acre. These data were then used to rank the species by their cost of establishing an even monoculture.

We then conducted an in-depth literature search of turfgrass species to assess establishment rate, maintenance requirements, ability to stabilize soil and provide ecosystem benefits, and traits that confer resilience to a variety of roadside conditions such as acid and infertile soils, drought, freezing, salt, traffic and competition. Searches were conducted on Web of Science and Google Scholar with the terms in many combinations. General search terms included:

- Roadside
- Restoration
- Turf
- Road

Species were searched using common and scientific names:

- Tall fescue, *Schedonorus arundinaceus, Festuca arundinacea*
- Hard fescue, *Festuca trachyphylla, Festuca ovina var. duriuscula*
- Sheep fescue, *Festuca ovina*
- Blue fescue, *Festuca glauca, Festuca ovina var. glauca*
- Chewings fescue, *Festuca rubra ssp. commutata*
- Creeping red fescue, *Festuca rubra ssp. rubra L.*
- Fine fescue as a more general term
- Zoysiagrass, *Zoysia*
- Bermudagrass, *Cynodon dactylon*
- Kentucky bluegrass, *Poa pratensis*
- White clover, *Trifolium repens*
- Micro clover
- Purple prairie clover, *Dalea purpurea*
- White prairie clover, *Dalea candida*
- Annual ryegrass, *Lolium multiflorum*
- Perennial ryegrass, *Lolium perenne*
- Seashore paspalum, *Paspalum vaginatum*
- Buffalograss, *Buchloe dactyloides*
- Blue grama, *Bouteloua gracilis*
- Alkaligrass, *Puccinellia distans*
- Switchgrass, *Panicum virgatum*
- Prairie junegrass, *Koeleria macrantha*
- Poverty oat grass, *Danthonia spicata*
- Poverty dropseed, *Sporobolus vaginiflorus*
- Weeping lovegrass, Lehmann's lovegrass, *Eragrostis curvula*

- Purple lovegrass, *Eragrostis spectabilis*
- St. Augustine, *Stenotaphrum secundatum*
- Deertongue, *Dichanthelium clandestine*
- Tufted hairgrass, *Deschampia cespitosa*
- Kalm's brome, Prairie brome, Arctic brome, *Bromus kalmii*
- Side-oats grama, *Bouteloua curtipendula*
- Little bluestem, *Schizachyrium scoparium, Andropogon scoparium*

The literature search yielded over 300 journal papers and book chapters from different states and countries and therefore many different climates. All information was considered useful but research from within Maryland and surrounding sates was given greater weight. ISI sometimes did not yield many results. In those cases we consulted literature citations, agency reports, and fact sheets. Of particular help were the Forest Service Fire Effects Information System (http://www.feis-crs.org/feis/) and USDA Plant Fact Sheets and Plant Guides.

We consulted with turfgrass experts that have had experience with roadside grasses or growing grasses under low-maintenance conditions. Experts included:

Ms. Jody Booze-Daniels – Virginia Tech University
Dr. Rebecca Brown – University of Rhode Island
Mr. Mark Fiely – Ernst Conservation Seeds
Dr. Mike Goatley – Virginia Tech University
Mr. Gordon Kretser – Chesapeake Valley Seed
Dr. Pete Landschoot – Pennsylvania State University
Dr. Bill Meyer – Rutgers University
Dr. Kevin Morris – National Turfgrass Evaluation Program
Mr. Jon Straughn – Chesapeake Valley Seed
Dr. Tom Turner – University of Maryland College Park
Dr. Eric Watkins – University of Minnesota

After compiling a literature database, we summarized information for six economic and ecological services summarized above by reviewing, categorizing, and synthesizing the literature for the 25 species. In lieu of a statistical meta-analysis, we focused particularly on literature that compared different species such that we could score species relative to each other. For example, Beard's (1973) book on turfgrasses assessed and compared many of the turfgrasses we synthesize. Although over 40 years old, it provides information for relative differences among species, realizing that cultivars within a species can vary widely in traits. Much research has gone into cultivars over the last decades and some ratings have changed as denoted by an * (Turner, *pers. communication*).

Turfgrass	Temperatures	Heat	Low temperature	Drought resistance	Optimum pH	Salinity	Wear	N requirement
Bermudagrass	Warm	Excellent	Poor-Fair	Excellent	7.0-6.0	Good	Excellent	High
Creeping bentgrass	Cool	Medium	Excellent	Poor	6.5-5.5	Good	Poor	High
Kentucky bluegrass	Cool	Medium	Good	Medium	7.0-6.0	Poor	Medium	High
Perennial ryegrass	Cool	Fair	Poor	Fair	7.0-6.0	Medium	Medium	Medium
Red fescue	Cool	Fair	Medium	Good	6.5-5.5	Poor	Poor	Low
Sheep fescue	Cool			Good	5.5-4.5			
Tall fescue	Cool	Good	Medium	Good	6.5-5.5	Medium	Good	Medium
Zoysiagrass	Warm	Excellent	Medium	Excellent	7.0-6.0	Good	Excellent	Low
Buffalograss	Warm	Excellent		Excellent				Very Low
Chewings fescue	Cool	Fair			6.5-5.5			Low

After writing a synthesis for each species or species group, we gave each species an overall grade (A=Excellent, B=Good, C=Fair, D=Poor, and F=Very poor). This report card approach has been used effectively in Maryland and the Chesapeake Bay (CB) region to evaluate and communicate the health of CB tributaries (Williams et al. 2009).

Priorities for managing roadsides will differ depending on proximity to the road surface and roadside conditions. For example, ecosystem benefits may not be a management priority near the road but can be a management priority elsewhere. Erosion control is an important consideration for sloped roadsides but management may be less concerned with erosion of flat roadsides. Further, establishment and maintenance may be ranked as the top two management priorities with the other four services secondary. For these reasons we developed 4 grading scenarios:

1. All six services weighted equally
2. Establishment and maintenance weighted twice as important as the other 4 services
3. All services weighted equally with ecosystem benefits removed from grading
4. All services weighted equally with ecosystem benefits and erosion control removed from grading.

RESULTS

Species identification. We initially identified 88 grass species, two rushes and 14 sedges for a total of 103 commercially available graminoid species. Of these, 53 species were immediately rejected for one or more reasons:

- Prohibited weed - annual bluegrass (*Poa annua*);
- Potentially weedy - orchardgrass (*Dactylis glomerata*); path rush (*Juncus tenuis*); bottlebrush squirreltail (*Elymus elymoides*); smooth brome (*Bromus inermis*); smut grass (*Sporobolus indicus*); chess (*Bromus secalinus*); Canada bluegrass (*Poa compressa*);
- Obligate or facultative wetland species, or upland species that require moist soils – 35 species including, e.g., Virginia wild rye (*Elymus virginicus*);
- Shade loving species - 8 species including, e.g., Pennsylvania sedge (*Carex pensylvania*); and
- Southern species not suited for Maryland climates - St. Augustine grass (*Stenotaphrum secundatum*), seashore paspalum (*Paspalum vaginatum*);

Fifty-one species were considered potentially suitable after the initial filtering of candidate species. Of these, 26 were not assessed owing to:

- Tall stature - 16 species have a tall stature but would otherwise be suitable for roadsides if they can be maintained as tall grasslands. Species include indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and big bluestem (*Andropogon gerardii*).
- Limited commercial supply - 2 species are suitable but commercial supply is extremely limited. These species include puffsheath dropseed (*Sporobolus neglectus*) and poverty dropseed (*Sporobolus vaginiflorus*). A third species – hairy lens grass (*Paspalum setaceum*) – was used in Jenkins et al. 2004 and recommended in Brown et al. (2011) as a drought hardy species that requires little management. However, its seed availability is limited as well as unreliably among years.
- Nurse grasses - 4 species are used as nurse grasses including foxtail barley (*Hordeum jubatum*), common oat (*Avena sativa*), common barley (*Hordeum vulgare*), and common wheat (*Triticum aestivum*). Although they may be used in mixes to facilitate establishment, they were not considered as primary turfgrass species.
- Limited information - 4 species were not assessed because information on the species was extremely limited. These species included hairawn muhly (*Muhlenbergia capillaris*), Leavenworth's sedge (*Carex leavenworthii*), green needlegrass (*Stipa viridula*), and sweet vernalgrass (*Anthoxanthum odoratum*).

In the end, 25 species were assessed and graded. Three Sporobolus species were grouped into one assessment, as were annual and perennial ryegrass, and two Puccinellia (alkaligrass) species. Thus, 21 summaries were developed to represent 25 commercially available species.

Economic and ecological services

Commercial availability and cost: Cost of grass seed per pound is misleading because the end-result of establishing an even monoculture (used as a measure to standardize across species) may require different amounts of seed. We therefore assessed cost of planting as the cost of planting an acre of each species. This information was provided by Chesapeake Valley Seed, Ernst Conservation Seed, and T. Turner (*pers. communication*). Although the fescues have low seed costs per pound, their seeding rate is relatively high, which substantially increases their cost per acre. In contrast, small seeded species, such as Sporobolus, require a lower seeding rate such that even though the cost per pound may be relatively high, the cost of seeding an acre is not. The cost of planting zoysia and bermudagrass is high because both species are best sodded rather than seeded, which increases cost.

	Price per LB	Seeds per LB	Seeding Rate LB per Acre	Price per Acre
Sand dropseed	$ 10.00	5,600,000	1	$ 10.00
Weeping lovegrass	$ 8.00	1,482,000	3	$ 24.00
Tufted Hairgrass	$ 17.64	1,308,000	2	$ 35.28
Alkaligrass	$ 4.23	1,200,000	20	$ 84.60
Prairie Junegrass	$ 65.55	2,315,000	2	$ 131.10
Side-oats grama	$ 12.00	159,000	12	$ 144.00
Little bluestem	$ 16.00	225,000	12	$ 192.00
Perennial Ryegrass	$ 1.85	230,000	130	$ 240.50
Kentucky Bluegrass	$ 2.95	2,200,000	87	$ 256.65
Red fescue	$ 1.80	615,000	175	$ 315.00
Tall Fescue	$ 1.60	227,000	200	$ 320.00
Chewings fescue	$ 2.38	500,000	175	$ 416.50
Upland bentgrass	$ 14.65	8,000,000	30	$ 439.50
Blue grama	$ 15.00	710,000	35	$ 525.00
Hard fescue	$ 3.45	592,000	175	$ 603.75
Sheep fescue	$ 3.75	700,000	175	$ 656.25
Bermudagrass	$ 15.00	725,000	45	$ 675.00
Purple lovegrass	$ 180.00	4,480,000	5	$ 900.00
Buffalograss	$ 16.00	335,000	125	$ 2,000.00
Zoysia	$ 75.00	1,000,000	45	$ 3,375.00
Poverty Oatgrass	$ 480.00	400,000	10	$ 4,800.00

Rate of establishment: Rate of establishment varied across species. Perennial ryegrass is the best example of a fast establishing species and for that reason is used as a nurse grass in many projects. Other species, however, can establish just as rapidly including seeded bermudagrass, followed closely in rank by alkaligrass, poverty oatgrass, lovegrass (purple and weeping), and then by side-oats grama, and Sporobolus. Most fescues establish at an intermediate rate with tall fescue establishing faster on average than the fine fescues. Some grasses that are slow in establishing include little bluestem, upland bentgrass, prairie junegrass, buffalograss, Kentucky bluegrass and zoysia, suggesting that when fast establishment is a management priority, these species should not be selected.

Ease of maintenance: Maintenance is a major management concern for state highways. Because we selected species to represent a low-statured growth habit, maintenance generally ranked highly among species. Therefore, the only species that received a low rank for maintenance because it requires a high mowing frequency was tall fescue, which we included in our list to serve as a reference species. All other species that ranked low for maintenance (bermudagrass, alkaligrass, Kentucky bluegrass, perennial ryegrass) require high inputs of fertilizer, liming, or herbicides.

Erosion control: Erosion control ranked high for most species because many of the species are commercially selected owing to their ability to produce a dense sod through their extensive root system. The one exception is prairie junegrass, which has a shallow and sparse root system.

Ecosystem benefits: Ecosystem benefits tended to be ranked lower for non-native species and higher for native species. However, other considerations included information on leaching losses, soil stabilization, food web support, and invasiveness. Therefore, bermudagrass, Kentucky bluegrass, zoysia, and perennial ryegrass ranked as ‘very poor’ followed by weeping lovegrass, red fescue, chewings fescue and tall fescue, which ranked ‘poor’.

Resilience: Each grass species has traits that allow the species to be resilient to environmental stress or disturbance. Many species were remarkably resilient when averaged across six traits although even very resilient species may be particularly vulnerable to one environmental stressor. The most resilient species across all resilience parameters is purple lovegrass, followed closely by Sporobolus. The least resilient species (with an average resilience score of Fair or Poor) are prairie junegrass, upland bentgrass, alkaligrass, perennial ryegrass, and Kentucky bluegrass. Upland bentgrass, however, included several unknowns and we are therefore less confident with its resilience score.

	Resilience Parameters							**Grade**
Species	*Drought*	*Fertility*	*Freezing*	*Salinity*	*Acidity*	*Wear*	*Competition*	Resilience
Purple lovegrass	100	100	100	100	100	100	90	99
Sporobolus	100	100	100	95	100	100	85	97
Little bluestem	90	100	100	75	100	85	100	93
Weeping lovegrass	100	100	60	100	100	100	90	93
Poverty oatgrass	100	100	100	unknown	100	100	55	93
Hard fescue	100	95	85	80	100	85	100	92
Blue Grama	100	90	100	85	82	100	80	91
Side-oats grama	100	100	100	80	100	85	70	91
Zoysia	85	90	75	97	100	95	90	90
Sheep fescue	100	95	80	80	95	80	95	89
Buffalograss	100	90	100	90	85	100	60	89
Tall fescue	85	95	75	88	100	95	83	89
Red fescue	85	87	85	90	95	80	95	88
Chewings fescue	85	87	78	75	100	85	95	86
Tufted hairgrass	35	97	95	85	100	90	85	84
Bermudagrass	100	65	20	100	100	89	100	82
Prairie junegrass	40	90	95	70	100	95	40	76
Upland bentgrass	60	unknown	100	30	100	unknown	unknown	73
Alkaligrass	65	50	100	100	50	50	80	71
Perennial ryegrass	40	50	20	85	100	100	100	71
Kentucky bluegrass	40	30	100	45	85	85	100	69

After averaging across six services scores and seven resilience scores, the majority of species received a score of "Good" (B +/-). However, grades ranged from A to D. Species with grades lower than D were not identified owing to the initial filtering of species and because each species has at least one trait that allows it to excel in at least one service. Overall, the grade report (equal weighting of all 6 services) includes:

A	Sporobolus
A-	Side-oats grama and Purple lovegrass
B+	Little bluestem, Weeping lovegrass, and Blue grama
B	Tufted hairgrass, Hard fescue, Upland bentgrass
B-	Red fescue, Sheep fescue, and Buffalograss
C+	Chewings fescue, Poverty oatgrass, and Tall fescue
C	Bermudagrass, Prairie junegrass, and Alkaligrass
D+	Zoysia and Kentucky bluegrass
D	Perennial ryegrass

Species	Cost	Establishment	Maintenance	Erosion	Ecosystem	Resilience	Overall Grade	
			Equally weighted services					
Sporobolus	100	90	90	100	100	97	96.2	A
Side-oats grama	86	90	90	100	100	91	92.8	A-
Purple lovegrass	55	95	100	100	100	99	91.4	A-
Little bluestem	80	65	100	100	100	93	89.6	B+
Weeping lovegrass	98	95	85	100	65	93	89.3	B+
Blue Grama	66	80	90	100	100	91	87.8	B+
Tufted hairgrass	96	85	82	82	92	84	86.8	B
Hard fescue	63	75	100	88	89	92	84.5	B
Upland bentgrass	67	65	100	95	100	73	83.3	B
Red fescue	75	80	100	85	65	88	82.2	B-
Sheep fescue	61	65	100	88	89	89	82.0	B-
Buffalograss	45	75	80	100	100	89	81.5	B-
Chewings fescue	69	80	100	83	60	86	79.7	C+
Poverty oatgrass	20	95	100	80	85	93	78.8	C+
Tall fescue	72	85	60	100	60	89	77.6	C+
Bermudagrass	60	100	70	100	50	82	77.0	C
Prairie junegrass	87	50	100	60	85	76	76.3	C
Alkaligrass	92	95	20	85	90	71	75.5	C
Zoysia	35	60	100	80	50	90	69.2	D+
Kentucky bluegrass	77	70	65	85	40	69	67.7	D+
Perennial ryegrass	78	100	20	90	30	71	64.8	D

Weighting services or omitting some services altogether only slightly changed some grades and the rankings of species. Weighting establishment and maintenance or removing ecosystem benefits from the grading tended to enhance grades for some species, whereas removing both ecosystem benefits and erosion control tended to decrease the grades of the better performing species and increase the grades for the worse performing species.

Four species received an excellent grade for 1 or more of the grading scenarios. These species include Sporobolus (3 out of 4), side-oats grama (3/4), purple lovegrass (3/4), and weeping lovegrass (2/4). An additional five species consistently received a B or B+ grade with no lower grade in any of the 4 scenarios. These species include little bluestem, blue grama, tufted hairgrass, hard fescue, and red fescue.

Owing to their consistent high performance across the 4 grading scenarios, we recommend the above 9 grasses for their ability to provide a variety of services. However, even though we are recommending these species, they may not be suitable for all situations along roadsides. For example, tufted hairgrass ranks high enough to be included in the recommended list; however, it has poor resilience under drought conditions and may therefore not be a good choice for many, if not all, roadside settings. Red fescue is also recommended; yet, it has shown poor summer-time performance in trials in Maryland and should therefore be used only in cooler climates of Western Maryland.

The selection criteria here are stringent. If they are relaxed to include all species that received a B in at least one of the 4 scenarios, seven additional species can be recommended including upland bentgrass, sheep fescue, buffalograss, chewings fescue, poverty oatgrass, tall fescue, and bermudagrass. The turfgrasses that are not recommended for widespread use include prairie junegrass, alkaligrass, zoysia, Kentucky bluegrass, and perennial ryegrass.

Species	Equal weighting		Weighted establishment & maintenance		Without ecosystem benefits		Without ecosystem benefits and erosion control	
Sporobolus	96.2	A	95	A	95	A	94	A
Side-oats grama	92.8	A-	92	A-	91	A-	89	B+
Purple lovegrass	91.4	A-	93	A	90	A-	87	B
Little bluestem	89.6	B+	88	B+	88	B+	84	B
Weeping lovegrass	89.3	B+	89	B+	94	A	93	A
Blue Grama	87.8	B+	87	B	85	B	82	B-
Tufted hairgrass	86.8	B	86	B	86	B	87	B
Hard fescue	84.5	B	85	B	84	B	83	B
Upland bentgrass	83.3	B	83	B	80	B	76	B
Red fescue	82.2	B-	84	B	86	B	86	B
Sheep fescue	82.0	B-	82	B-	81	B-	79	C+
Buffalograss	81.5	B-	81	B-	78	C+	72	C-
Chewings fescue	79.7	C+	82	B	84	B	84	B
Poverty oatgrass	78.8	C+	83	B	78	C+	77	C
Tall fescue	77.6	C+	76	C	81	B-	76	C
Bermudagrass	77.0	C	79	C+	82	B-	78	C+
Prairie junegrass	76.3	C	76	C	75	C	78	C+
Alkaligrass	75.5	C	71	C-	73	C	69	D+
Zoysia	69.2	D+	72	C-	73	C	71	C-
Kentucky bluegrass	67.7	D+	68	D+	73	C	70	C-
Perennial ryegrass	64.8	D	64	D	72	C-	67	D

CONCLUSIONS AND RECOMMENDATIONS

Roadsides are planted to be managed as mowed turfgrass that improves aesthetics, prevents erosion, maintains visibility and provides a safety zone for stopped vehicles (Brown et al. 2011). As such, roadside vegetation is often managed as a high maintenance front yard using mostly non-native turfgrass species (Harper 1988) that need to be mowed several times each growing season to look manicured. However, managing the roadside as a lawn is expensive and often results in problems with invasive species and failed plantings. Here, we explore grass species that are commercially available but may reduce maintenance costs while providing economic and ecological services such as fast establishment, erosion control, ecosystem benefits, and resilience.

We recommend that grass species consistently receiving an average grade of good (B) or higher across the 4 management scenarios should be considered for planting along Maryland roadsides. We therefore recommend 5 species as highly suitable under a variety of management situations and climates and an additional 4 species under more restricted conditions where quick establishment is not a concern (little bluestem, blue grama), the roadside is wet (tufted hairgrass), or the climate is cool (red fescue).

Recommended	Species
1	Sporobolus
2	Side-oats grama
3	Purple lovegrass
4	Little bluestem
5	Weeping lovegrass
6	Blue Grama
7	Tufted hairgrass
8	Hard fescue
9	Red fescue

We further recommend that some species that are currently planted frequently along roadside be used in limited quantities. For example, although frequently seeded along Maryland roadsides owing to its vigorous growth and resilience, tall fescue received a rating that was below the median grade. Although seed cost per pound is low, the recommended seeding rate is high, resulting in a cost per acre that is higher than 50% of the assessed species. In addition, this species has high maintenance costs and has poor ecosystem benefits yet, tall fescue has excellent mowning tolerance and can therefore withstand the stringent mowing regime applied by highway management. Similarly, Kentucky bluegrass and perennial ryegrass are not recommended to be planted in high quantities owing to maintenance costs, low ecosystem benefits, and, for Kentucky bluegrass, high seed cost.

Several native grass species received high grades and are therefore excellent alternative species to the commonly used non-native species that are produced and used widely. National highway policy strongly encourages the use of native vegetation in highway right-of-ways (Clinton 1999), and Harper (1988) argues that the use of native plants can help in reducing costs while providing ecosystem functions and services. Similarly, Brown and Sawyer (2012) argue that roadsides along Rhode Island highways are not wastelands but can be habitat for a diversity of species, some even rare and endangered. They further found that many of the grasses that were seeded did not survive but were replaced by native species that had dispersed into the roadside environment from elsewhere (Brown et al. 2011). Thus, Brown et al. (2011) recommend using standard seed mixes as temporary vegetation for the first 5 years with a plan for succession by slower-growing native species. Johnson 2008 also argues for use of native species in turf lawn to decrease maintenance, which also decreases the risk of non-native species becoming problem invaders (Jenkins et al. 2004) into neighboring agricultural areas or native habitats.

NEXT STEPS

We have identified a diversity of native and non-native grass species that are suitable for seeding along Maryland roadsides. Although the assessment and grading of the species was based on a careful literature review that was followed up by extensive discussions with experts, our grading and ranking of species is effectively still a hypothesis that needs to be tested. Maryland is a diverse state that varies considerably in climate and soil conditions, which will impact establishment, survival and long-term persistence. The next step therefore is to plant the recommended species in various climatic zones and site conditions to test resilience to a variety of environmental conditions and the rankings of economic and ecological services. A further step is to consider some of the grass species that were filtered out owing to their height or lack of information, as well as consider promising forb species such as microclover, *Trifolium repens, Dalea purpureum, Asclepias tuberosa, Coreopsis palmate, Allium stellatum, Ratibida columnifera, Anaphalis margaritacea, Thermopsis caroliniana, Polemonium reptans, and Medicago lupulina.*

Symbols courtesy of Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).