GEORGIA DOT RESEARCH PROJECT 13-22
FINAL REPORT

TESTING THE SUCCESS RATE OF ESTABLISHING MULTITROPHIC VEGETATION FOR STREAM BUFFER MITIGATION ACCORDING TO GEORGIA DOT SPECIFICATIONS ON DIFFERENT SLOPE RATIOS

Georgia Department of Transportation

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GDOT Research Project 13-22

Testing the Success Rate of Establishing Multitrophic Vegetation for Stream Buffer Mitigation According to Georgia DOT Specifications on Different Slope Ratios

Final Report

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Contract with

Georgia Department of Transportation

In cooperation with

U.S. Department of Transportation
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Multitrophic vegetative mitigation is required for stream buffers, wetlands, and retention basins within state waters. Downslopes adjacent to linear road construction are typically steep, which creates challenges for establishment and erosion control in disturbed areas requiring vegetation. A field experiment was conducted to test the establishment rate, persistence, and erosion control provided by multitrophic vegetative buffer mitigation plantings. Over the three-year period, native seed mixture was able to establish and persist at all slope ratios tested including 2:1, 2.5:1, 3:1, and 4:1. The increase in slope ratios did not reduce the establishment of plantings. Topdressing with local soil improved plant establishment by about 5% on several dates in the first year, but there was no residual benefit to plant cover or erosion control in the second and third year. The hierarchical rank of erosion levels from high to low among slopes evaluated were 2.5:1 > 2:1 > 3:1 > 4:1. The native species that established exhibited vegetative growth during the summer and fall, but declined in cover throughout the winter and spring months. Although the native species were able to establish regardless of slope, agronomists will need to implement management programs to minimize the invasion of weed species such as Italian ryegrass and Johnsongrass for long-term culture. Further research is needed to evaluate the effects of mowing programs, erosion mats, and seeding rates on the competition of species established for multitrophic vegetation.

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INTRODUCTION

The Georgia Department of Transportation (GDOT) is responsible for mitigating disturbances where road construction impacts buffers of state waters. These areas are typically beyond the 50-foot exemption for a drainage structure variance. The Georgia Environmental Protection Division typically requires establishment of a multitrophic vegetative planting, which includes large canopy native trees, understory species, and a native riparian seeded ground cover mix. In areas within the clear zone, areas within the structural boundaries of sediment basins, or areas within power line easements, only the native riparian ground cover species are required. Multitrophic vegetative mitigation is required for stream buffers, wetlands, and retention basins. Downslopes adjacent to linear road construction are typically quite steep, which creates challenges for establishment and erosion control in disturbed areas requiring vegetation.

Multitrophic native species have potential for succession growth and for improving the aesthetics of stream buffer mitigation projects. In previous research, the potential of 29 native grass and forb species to establish was investigated for seeded, native riparian ground cover mitigation projects for Georgia roadsides (Georgia DOT 700 - Grassing specifications). These species, which include grasses and forbs, are adapted to soils and climates of Georgia that may allow for long-term growth and competition with weeds. Several of these species, such as black-eyed Susan (*Rudbeckia hirta*) and lanceleaf coreopsis (*Coreopsis lanceolata*), established in fall and spring despite competition with annual weeds (Johnston et al. 2015).

One of the challenges for successful multitrophic vegetation establishment is the differential slope gradient that affects soil stabilization after planting. Removing vegetation during roadside construction is a major contributor to soil degradation and subsequent erosion (Castillo et al. 1996; Mohammad and Adam 2010; Hacisalihoglu 2007). The establishment of native species on various slope gradients for erosion control is a function of root system architecture and soil characteristics (Reubens et al. 2007; Fan and Lai 2014). Grasses and forbs that establish on sloped areas buffer the soil against sediment losses for erosion control (Chuanwei et al. 2008; Zhilin et al. 2005). Collins et al. (2004) modeled the effects of erosion on landscape evolution. A model was developed that quantified vegetation-erosion dynamics that consisted of plant growth, plant death, and rigidity on plants to resist erosion. In some instances, plants with more susceptibility to erosion may enhance topography steepening and reduced drainage density to make some erosion events more extreme. The susceptibility to erosion for species evaluated in riparian mixtures for the Georgia DOT could influence the slope ratio that is appropriate for construction in these areas.

The rate of establishment for seeded multitrophic species can be an important factor for mitigating slope erosion on roadsides. Gray (1994) found that herbaceous vegetation that includes grasses and forbs were most effective for improving the resistance to erosion, whereas woody vegetation was more effective for the prevention of shallow mass wasting. The rate of vegetation establishment on hillslopes will also influence the mass stability of the soil by root reinforcement. Kinnell (1999) found sediment concentration flow due to erosion was linearly related to the intensity of rainfall and slope gradients. These effects on erosion are associated with the increased velocity of water flow as slope increases (Changxing 1996; Zhilin et al. 2005; Woo and DiCenzo 1997).

Native vegetation enhances soil water storage, growth, and infiltration to reduce erosion (Ludwig et al. 2005). Runoff also increases on disturbed hillslopes without vegetation compared to slopes that were not disturbed. The erosion intensity often depends on the intensity of rainstorms and type of topography, soils, and vegetation present (Duley and Hays 1932). Most work in riparian seed establishment research has been conducted on level ground, but undulations or variability in slopes could affect seed establishment and subsequent soil stabilization. Road designers have traditionally defaulted to the maximum 2:1 slopes with erosion control blankets and other structural best management practices. However, these areas often have poor plant establishment and unacceptable levels of erosion. Further research is warranted to evaluate the establishment rate of multitrophic plantings on different slope ratios to improve the Georgia DOT Special Provision 700-Grassing and Georgia DOT 702-Vine, Shrub, and Tree Planting specifications for disturbed areas.

OBJECTIVE

The objective of the proposed research is to develop new slope recommendations for establishing multitrophic vegetative buffer mitigation plantings at four slopes of clay loam soils during the required dormant planting season.

PROCEDURES

The experiment was conducted at the Research and Education Gardens at the University of Georgia Griffin Campus. The soil was a clay loam (42% sand, 20% silt, 38% clay) with a 5.4 pH and 2.6% organic matter. The plots were constructed from

March 13 to 15 in 2014. A backhoe was used to remove existing grasses and soil (Picture 1). The soil was then prepared using a leveler to determine the appropriate slope and the soil was rolled to firm the surface. The plots were graded to one of four slope ratios including 2:1, 2.5:1, 3:1, and 4:1 (Pictures 1 and 2).

Plots were then seeded on March 24, 2014 according to GDOT 700 and 702 specifications. Each plot was established in bare root seedlings of red maple (*Acer rubrum* L.) and elderberry (*Sambucus nigra* L.) spaces 8 feet on center, underplanted with a native riparian seed mix of Canadian rye (*Elymus canadensis* L.), purpletop (*Tridens flavus* (L.) Hitchc.), switchgrass (*Panicum virgatum* L.), black-eyed susan (*Rudbeckia hirta* L.), and partridge pea (*Chamaecrista fasciuclata* (Michx.) Greene). Due to poor initial establishment, the plots were reseeded on July 8, 2014 as recommended by DOT cooperators.

Two different methods of site preparation were evaluated. One set of installations included a top-dressing with a 0.6-cm layer of topsoil. The other set was established without topsoil added. The treatment was applied by topdressing half of each plot per replication. Seed was then covered with wheat straw and seedlings were staked with tree protection mesh rigid tubes. Plots were mowed with hand trimmers on May 6, 2015 and April 26, 2016 to enhance the release of native species from winter weeds that established during the dormant seasons.

Measurements included percentage of ground stabilized within the planted plots. Ground cover of the native species was visually measured on a percent scale throughout the experiment. Native plants that were seeded in the riparian mixture were counted per plot. The experimental design was a split-plot with four replications of 20 x 20-foot plots. Data were subjected to the analysis of variance with the General Linear Model Procedure in SAS. Means were separated using standard errors (Table 1).

Picture 1. The construction of the plots on March 13, 2015 in Griffin, GA.

Picture 2. A replication in the experiment consisting of the four slope ratios evaluated.

Picture 3. The plot area before plant establishment on March 15, 2014.

FINDINGS

There was no statistical interaction between slope ratios and topdressing, and thus main effects of these parameters are presented independently in figures. The establishment of the native species took approximately two to three months after the initial planting (Figure 1). This is consistent with previous research with these species from field experiment in Georgia (Johnston et al. 2015). During the establishment period, rainfall began to contribute to erosion in the plots due to a lack of vegetation cover. The slow germination and establishment period for these mixtures should be a consideration for agronomists that are concerned over erosion of riparian mitigation projects. Researchers have found that adjusting seed mixes in favor of dominant species associated with different slope types could improve the success of establishment for roadsides (Bochet and Garcia 2004). In this experiment, the plots were reseeded to enhance the establishment of these species and significant ground cover was obtained by June 2014. These results suggest the rate of establishment of these seeded species is not conducive to immediate erosion control.

Riparian seed mixtures can help reduce roadside erosion when roots penetrate across the soil mantle into fractures or fissures in the underlying soil (Quinton et al. 1997). These effects are enhanced when roots penetrate into a residual soil or transition zone whose density and shear strength increase with depth (Gray 1994). The rate of plant establishment may also vary by location throughout Georgia as the impact of microenvironment, soil, and weather influence roadside vegetation (Wang et al. 2008).

The multitrophic mixture was able to establish at all slope ratios tested, and the increase in slope did not reduce the establishment of plantings (Figure 1). However, the potential for erosion was not mitigated by the presence of these species that established in the plots and the effect of slope ratio was significant on most dates. The hierarchical rank of erosion levels from high to low among slopes were 2.5:1 > 2:1 > 3:1 > 4:1 (Figure 2). On several dates there was more erosion in the 2.5:1 slopes than the 2:1. Erosion in these plots generally was comparable over the course of the experiment, and was almost always greater than the other slopes tested.

Several factors that influence slope erosion can be altered by the presence of multitrophic vegetation. Wynn and Mostaghimi (2006) found that riparian vegetation reduced erosion through root reinforcements on the soil and altered the microclimates that affected local freezing and thawing cycles. This may be beneficial on soil structure after native species have been established in the spring, but transition to dormancy during the winter in Georgia. There is also a major influence of climate on soil properties associated with roadside erosion. Seasonal variations in soil aggregation and shear strength may result from rainfall distribution and frosts (Bryan 2000). There may also be notable changes in shorter time scales as a result of soil water conditions, organic composition, microbiological activity, hardening, and the structural effects of applied stresses.

Vegetation establishment and erosion control on roadsides by native vegetation is influenced by the levels of organic matter, available phosphorous, and water content among slope type on road cuts or road fills. Researchers in Spain have documented the difficulty of revegetating slopes with angles greater than 45 degrees where the probability of seeds moving downhill is high (Bochet and Garcia 2004). Techniques to increase surface roughness at regular intervals and favor seed trapping were suggested as methods to enhance germination of native species.

The species that established exhibited vegetative growth in the first and second years, but declined considerably by the third year due to weed competition. This decline may require re-establishment of native species over time or weed control strategies to enhance multitrophic plant competition. Plant establishment on sloped areas for erosion control has shown to take several years for success in previous research. Gyssels et al. (2005) found soil loss reduction to the above-ground biomass only, whereas in reality this reduction results from the combined effects of roots and canopy cover.

Although grasses are used in mixtures with forbs in these riparian areas, the potential for perennial grasses to establish in these areas may improve the long-term establishment rate and soil erosion reductions. The benefits of using grasses rather than forbs have been previously attributed to the alteration of water placement on the slope, rather than stabilization of the soil by grass roots. In field experiments, sheep fescue (*Festuca ovina*) and Kentucky bluegrass (*Poa pratensis*) planted in strips on a 5 degree slope reduced soil runoff and losses compared to bare soil alone, by ponding water upslope (Melville and Morgan 2001). Soil deposition occurred above the barrier in the ponded areas instead of the grasses acting as a filter for sedimentation within the barrier. The combination of perennial grasses with trees has shown to enhance erosion control compared to exclusive use of either plant. In Kenya, researchers observed near uniform terrace formations when trees were planted with grasses, but the slope steepness increased without these mixtures(Angima et al. 2000).

The current DOT specifications for establishing vegetation on sloped areas in riparian mitigation projects recommend covering the seed with local soil. Topdressing with local soil improved plant establishment by about 5% on several dates in the first year (Figures 1 and 2). However, there was no residual benefit to plant cover or erosion control from topdressing the seed with local soil after planting. Perhaps, topdressing could have reduced erosion by enhancing plant establishment for species with faster germination in spring than those in the multitrophic mixture. Meyer et al. (1970) reported that covering steep slopes with 0.56-metric tons per hectare of straw mulch reduced the runoff velocity of soil by half as compared with areas that received no mulching. It was also found that the increasing mulching rates enhanced the soil preservation levels under simulated rainfalls.

The benefits of topdressing material could also influence the success rate of establishing riparian seed mixtures. In Georgia, erosion mats effectively reduced soil erosion until sufficient vegetation has been established on roadsides (Hann and Morgan (2006). Erosion mats are applied to sloped areas and may include wood excelsior, native species, and exotic species (Grace et al. 1999). Researchers in Alabama found erosion mats reduced losses 98% and 88% in cut slope and fill slope sediment yield, respectively (Grace et al. 1999). Surface covers may also be introduced after seeding riparian species mixtures that may reduce seed movement for better stabilization on sloped areas (Harbor 1999). Further research is needed to evaluate differences in mulch, native soil, straw, and other organic materials that could be applicable for use by the Georgia DOT during plant establishment.

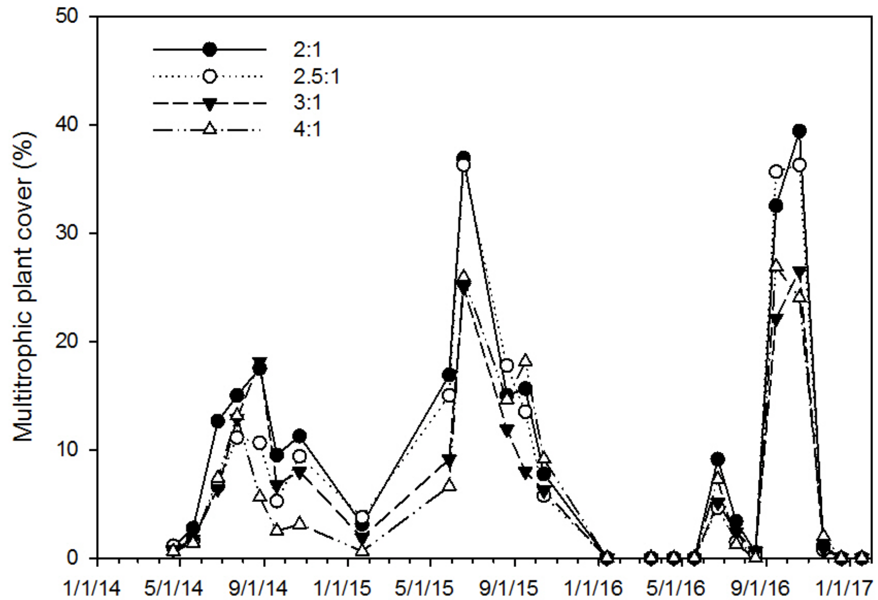
The plants used in the riparian mixture exhibited the greatest cover during the summer and fall, but declined throughout the winter and early spring months. The decline of multitrophic plantings due to seasonal changes in growth could impact erosion potential during the winter. In southeastern Spain, runoff sediment concentration was found to be highest in autumn, but decreased in winter and spring due to the exhaustion of erodible soil and the vegetation growth (Cerda 1998). The seasonal variability effects on plants and soil behavior are directly associated with soil loss rates. Nearing et al. (1990) found changes in soil and plant canopy caused changes erosion over time. These were associated with precipitation, rill erodibility, rill residue cover, and rill hydraulic friction factors.

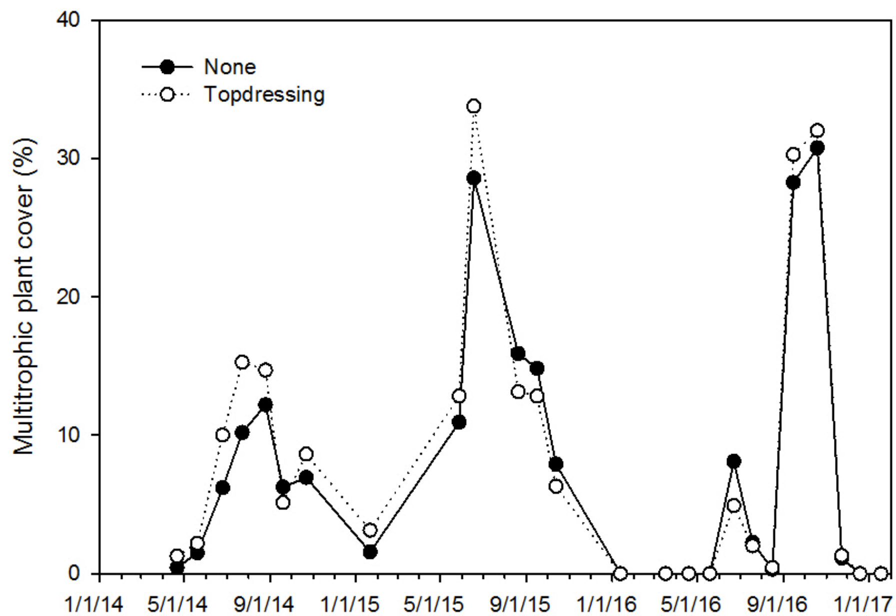
A major impact on seasonal changes in vegetation cover is weed pressure. Native species vegetation can generally be as effective as the exotic or weedy species in reducing sediment yield from the road side slopes (Benik et al. 2003; Grace 2002). However, many exotic species common to Georgia roadsides, such as Italian ryegrass (*Lolium multiflorum*) are annuals that exhibit competitive growth with multitrophic plantings in spring. These weeds were mechanically suppressed in this experiment to help enhance the release of the plantings in late spring. Further research is needed to formalize weed control recommendations for these plantings on Georgia roadsides.

The current DOT mixture for riparian mitigation may require modifications in sloped areas to enhance vegetation establishment and inhibit erosion. Researchers have previously reported that the selection of planting material will impact erosion control in areas with slope instability. Collison et al. (1995) created a model that accounts for the dynamic mechanical and hydrological responses of a vegetated slope to rainstorms. If the vegetation is inappropriately planted or unsuitable for a specific area, the impact could be detrimental on erosion control. There is also a major impact on the spatial distribution of vegetation on hillslope erosion. Generally, erosion levels on slopes with spatially structured distributions of vegetation and soil can be mitigated compared to hillsides with spatially uniform distributions (Boer and Puigdefabregas 2005).

Picture 4. Seedlings of native species that established in May 2014.

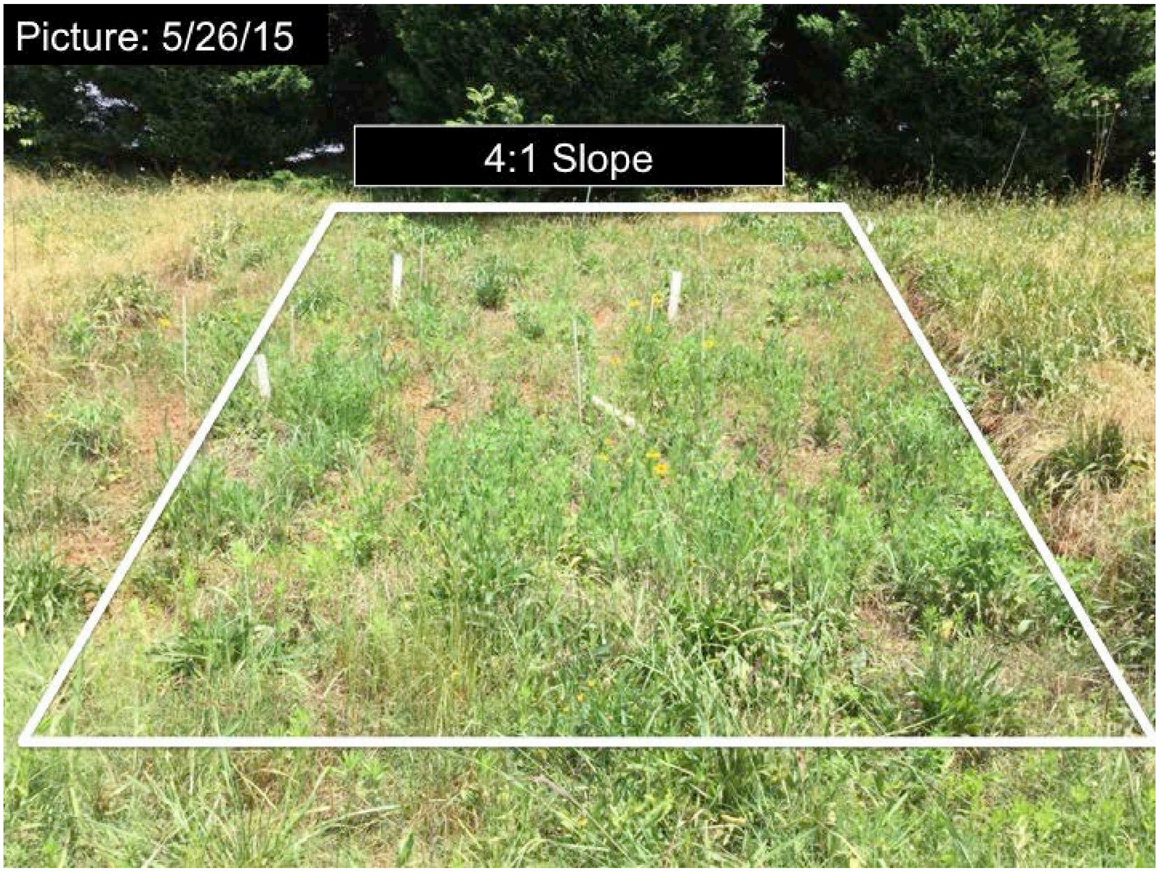
Figure 1. Ground cover of the multitrophic mixture planted on four slopes in a field experiment, 2014-2017, Griffin, GA.





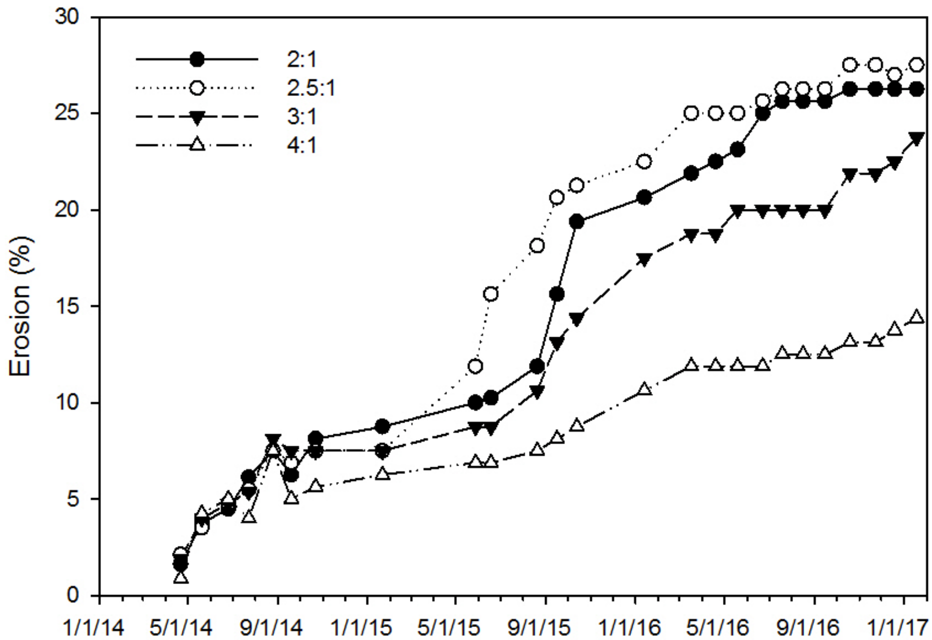
Picture 5. Native vegetation growth on May 26, 2015 on a plot sloped at 2.5:1.

Picture 6. Native vegetation growth on May 26, 2015 on a plot sloped at 4:1.



Picture 7. Erosion on May 20, 2014 after establishment on the 4:1 slope ration

Figure 2. Erosion levels following the plantings of multitrophic plant mixtures on four slopes in a field experiment, 2014-2017, Griffin, GA.



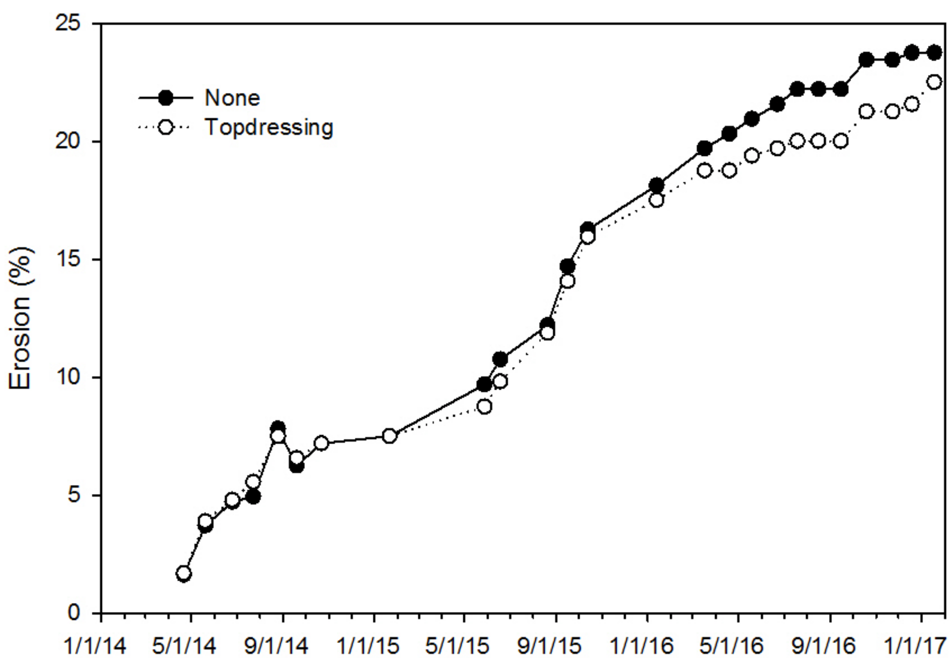


Table 1. Standard errors of the means presented in figures.

Slope	4/21/14	5/20/14	6/25/14	7/23/14	8/25/14	9/19/14	10/22/14	1/21/15	5/28/15	6/18/15	8/20/15	9/16/15	10/13/15	1/13/16	3/17/16	4/19/16	5/19/16	6/22/16	7/19/16	8/16/16	9/15/16	10/19/16	11/23/16	12/19/16	1/18/17
Plant Cover																									
2	0.48	0.63	7.73	2.95	7.77	2.22	3.29	3.13	6.95	10.61	4.93	8.13	4.66	0	0	0	0	3.5	1.58	1	15.33	17.06	0.59	0	0
2.5	0.31	0.38	1.18	1.34	2.13	1.88	2.37	2.17	6.18	9.66	3.46	3.47	1.18	0	0	0	0	1.75	0.41	0.13	10.67	10.63	0.32	0	0
3	0.25	0.66	0.83	1.26	6.49	1.65	3.31	1.88	3.31	8.66	3.87	1.59	1.31	0	0	0	0	1.55	1.03	0.38	6.86	6.99	0.24	0	0
4	0.24	0.31	1.96	1.16	0.63	1.72	2.37	0.63	2.73	7.38	6.08	5.14	2.31	0	0	0	0	4.75	0.95	0	4.13	6.35	0.35	0	0
Topdressing																									
No	0.16	0.25	0.9	1.1	2.62	0.66	1.76	0.94	4.22	8.43	3.11	2.35	1.03	0	0	0	0	3.1	0.47	0.12	6.68	7.4	0.22	0	0
Yes	0.06	0.32	1.72	0.83	1.98	0.43	1.82	1.88	4.38	7.42	1.66	2.16	0.87	0	0	0	0	1.11	0.37	0.3	6.46	6.7	0.18	0	0
Erosion																									
2	0.55	1.31	1.31	1.08	2.5	3.15	2.39	2.89	1.88	1.77	2.04	2.58	3.44	3.87	3.29	3.15	2.5	3.15	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2.5	0.63	0.65	1.18	0.61	1.02	1.2	1.44	1.44	1.2	1.88	1.57	1.57	2.17	1.77	1.02	1.02	1.02	1.2	1.61	1.61	1.61	1.02	1.02	1.02	1.02
3	0.43	1.35	1.18	1.46	1.57	1.44	1.44	1.44	1.61	1.61	2.13	3.73	3.87	4.79	4.62	4.62	5.68	5.68	5.68	5.68	5.68	6.56	6.56	7.14	7.74
4	0.38	1.44	1.22	0.41	1.02	1.02	1.57	1.25	1.2	1.2	1.77	2.37	2.98	3.59	4.15	4.72	4.72	4.72	5.3	5.3	5.3	5.9	5.9	6.5	7.1
Topdressing																									
No	0.26	1.27	1.13	0.71	1.07	0.51	0.79	0.51	1.07	1.14	1.39	1.8	2.1	2.31	2.62	3.24	3.48	3.24	3.87	3.87	3.87	4.34	4.34	4.65	4.65
Yes	0.33	0.72	0.76	0.52	0.88	0.6	0.6	0.51	0.79	0.88	0.63	1.56	1.94	2.1	2.93	2.93	3.24	3.44	3.75	3.75	3.75	3.87	3.87	4.18	4.72

CONCLUSIONS AND RECOMMENDATIONS

The multitrophic seed mixture used by the Georgia DOT can establish and persist at all slope ratios tested. The increase in slope ratios did not reduce the establishment of plantings. Topdressing with local soil improved plant establishment by about 5% on several dates in the first year, but there was no residual benefit to plant cover or erosion control in the second and third year. Soil erosion was exacerbated by increase in slope. These effects suggest that the presence of the multitrophic vegetation mixture did not overcome the influence of slope steepness. The native species that established exhibited vegetative growth in the summer and fall, but declined considerably in the winter and early spring. Although the native species were able to establish regardless of slope, agronomists will need to implement management programs to minimize the invasion of weed species, such as Italian ryegrass and Johnsongrass, for long-term culture. It is recommended that multitrophic seed mixtures receive topdressing from local soils after planting to enhance establishment and competition with invasive weeds. The Georgia DOT will also need to seed these mixtures in early spring to optimize germination prior to the emergence of warm-season perennial weeds. Further research is recommended to evaluate the effects of mowing programs, erosion mats, and seeding rates on the long-term persistence of species established for multitrophic vegetation.

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