USING DIRECT ENVIRONMENTAL ORDINATION TO MATCH PLANT SPECIES TO FLUVIAL RIPARIAN SITES PART 2: RESULTS[1]

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Abstract. The 3-D graphs resulting from the methods and procedures described in Part 1 indicate appropriate sites in which to seed or transplant locally common riparian species into the Silver Bow Creek floodplain, if seed or transplants are available. Ten graphs are presented, most of them representative of a broader class of plants and habitats. Two main patterns are evident. One class of plants is restricted to a rather narrow hydrologic range with particle-size class playing a minor role. Another class of species occurs in one of the wetter hydrologic classes on coarse substrates, and also on somewhat drier sites when combined with finer-textured substrates. Ordinations also identified a few species of broad amplitude that can be the best choices for revegetation where long-term hydrology cannot always be predicted with certainty or where it fluctuates greatly. For most species, the soils-hydrology ordinations provided a useful and relatively unambiguous approximation of where plants should be seeded or transplanted into a reconstructed riparian zone. Some species' edaphic habitats must be considered in the context of historical fluvial processes. For example, a set of species might typically establish on raw, moist substrates. Once established, the plants trap sediments during floods while stream downcutting lowers the water table, so that when sampled the remaining original plants are in a drier hydrologic regime than the one required for establishment. Some deep-rooted species persist in the drier habitat by maintaining contact with the capillary fringe; others are replaced by species better adapted to the new hydrologic regime and texture. A revegetation plan based solely on the observed hydrology of mature plants could erroneously indicate sites too dry for seedlings to survive. In some cases, therefore, our results must be tempered with a deeper understanding of species autecologies and fluvial processes. Matching plant species to appropriate habitats remains the basis for adapted-species revegetation. Preliminary practices and results along Silver Bow Creek are briefly mentioned.

Additional Key Words: revegetation habitat types, soil particle-size class, hydrology, adapted species.

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Introduction

In Part One, my coauthor showed how to sample and classify soil drainage and particle-size classes for fluvial riparian soils. He introduced a three-dimensional ordination framework and ordinated the number of samples in each site type, which can also be thought of as revegetation habitat types. Some site types are well-represented in samples; others were unsampled or barely sampled. The pattern represents the distribution of edaphic conditions in fluvial riparian areas in much of Silver Bow County, Montana and presumably will cover most revegetation habitat types there.

Results

Interpreting the Graphs

We now can ordinate useful species, meaning those that are common and/or abundant enough to be potentially important in revegetation and also commercially available, although availability changes. But first, a caution concerning interpretations.

The ordinations indicate environmental space in terms of hydrology (soil drainage class) and soil particle-size class where each species occurs. They also indicate the relative abundance of a species relative to site types. They do no necessarily indicate where a species should be seeded or planted. If the soil and hydrology haven't changed much since the species arrived, then the ordinations indicate what to plant in a revegetation habitat type, defined by hydrology and soils.

In a floodplain, sites are dynamic and sometimes transient. Autogenic processes (those originating with the plants themselves) interact with fluvial processes, causing sites to change far more rapidly and to a much greater extent than in uplands. Consider the following example.

A flood deposits a fresh, raw substrate. The texture is coarse due to the granitic parent material and high transport velocity. Initially, groundwater is less than three decimeters (one foot) from the ground surface for at least a few weeks during the growing season, making the site very poorly drained. Of many possibilities, two important species colonize this habitat: Booth willow (*Salix boothii*) and Northwest Territory sedge (*Carex utriculata*). The willows grow to become shrubs, while the sedges spread through scaly rhizomes and develop a dense network of roots. Subsequent floods of lesser magnitude cover these plants, but both are pliable and adapted to flooding. Rather than being destroyed, they slow floodwaters, causing finer sediments than were initially present to settle out. The floodplain aggrades.

At the same time, the stream channel deepens, so there are fewer floods. The water table recedes since groundwater drains from the floodplain in relation to stream elevation. Deposition and channel downcutting continue until, in just a few decades, the water table is one-half meter (1.6 feet) deeper than it was when the willow-sedge community established, and the ground surface is one-half meter higher than it was initially. The water table now is more than one meter (3.3 feet) below the ground surface, but capillary rise is only three decimeters in coarse-loamy sediments. The site that was initially very poorly drained now is somewhat poorly drained.

While they have similar initial habitat requirements and tolerances to periodic inundation and sediment accumulation, the rooting habits and water needs of our two species differ greatly. The willow has fewer, coarser, and deeper roots than the sedge, so it is able to maintain contact with the receding capillary fringe. Booth willow remains as abundant as ever (Figure 1), and arriving plants must deal with its stature (partial shade), root mass, allelopathy, etc. Northwest Territory sedge, however, is ill-suited to poorly drained soils of loamy texture (Figure 8) and absent from somewhat poorly drained sites. Its fibrous roots can't access deep groundwater. The density of sedges decreases because fewer plants can get enough water as direct precipitation dictates moisture availability in the upper six decimeters (two feet) of soil. Water sedge finds itself at a competitive disadvantage with arriving species, many of which are better-suited to the loamy surficial texture and upland hydrology. Eventually, the sedge disappears.

The situation can be reversed: a beaver dam floods plants that are sampled while they are slowly drowning. The lesson is that some graphs unambiguously indicate the species' fundamental niche -- where it can complete its life cycle, hence where to plant it. For other species, the graphs indicate where a species can survive and even prosper, but not reproduce sexually. These environments are poor choices for propagation despite the presence of mature plants in similar sites.

In the plant communities we sampled, soil stratigraphy often indicates the initial habitat colonized. Although it varies on a site-by-site basis, this habitat was often wetter and generally coarser. Some species (e.g., colonizers of fresh, raw substrates) should be planted in a site one to two drainage classes wetter than where the species is observed. A coarser substrate than the one indicated in the graph may be suitable if not necessary. Other species arrive after a site has more-or-less equilibrated; the graphs unambiguously indicate where to propagate them.

Ordinations of Ten Species

Ten species were ordinated for this paper, many of them representative of a broader class of plants. Two are shrubs (both willows), three are forbs, and five are graminoids. Sample sizes are indicated in parenthesis for each species.

Booth willow (n=18), named by Robert Dorn for his professor at Montana State University, is the most common nonrhizomatous willow in our area at elevations below 1,830 meters (6,000 feet. It occurs on very poorly drained to moderately well-drained sites, but it is most abundant on poorly drained and somewhat poorly drained sites (Figure 1). The typifying soil particle-size class is coarse-loamy. Numerous soil profiles indicate that Booth willow often establishes on poorly or very poorly drained sites where the initial texture may be very coarse. Finer sediments typically have accumulated on the surface, covering the initial raw substrate. In interpreting Figure 1 for revegetation, shift one drainage class to the left (wetter). Thus, Booth willow should be planted in very poorly drained or poorly drained sites along Silver Bow Creek. The chance of survival is good on somewhat poorly drained sites if first-year precipitation is adequate for the seedlings to survive until their roots reaching the capillary fringe in this hydrologic zone. Growth of Booth willow is stunted on ponded and very poorly drained sites; when it occurs there, it is a relatively unimportant member of the plant community (Figure 1).

Slenderleaf willow (*Salix exigua*), our only willow that reproduces from underground runners (prevalent in section *Longifoliae*), exhibits a broad tolerance of soil moisture conditions (Figure 2). With a geographic range from the desert southwest to British Columbia, it could hardly be otherwise. It is the safest willow to use in revegetation when soils and hydrology are not accurately mapped. It is also the best choice for streambanks due to its capacity for vegetative reproduction.

Figure 2 introduces the L-shaped distribution pattern representative of a number of riparian species in our area. Slenderleaf willow can occur on very wet sites with coarse substrates or on drier sites with finer-textured soils. (With just 12 samples, there are some gaps in the graph.) Like Booth willow, it occurs on very poorly drained to moderately well-drained sites, where survival has been excellent. It is, however, a better choice for somewhat poorly drained sites than Booth willow (Figures 1 and 2). In some cases, transplants have done very well (survival >80%) on somewhat poorly drained sites; in other cases, mortality was about 80%. Plant competition and seasonal precipitation are major determinants of survival where the roots can't tap the capillary fringe for a year or two.

The variety of commercially available forbs is very limited compared to the tremendous variety found in nature. Silverweed (*Potentilla anserina*, n=16) is an introduced, naturalized species that occurs from Alaska to southern California. It would be on the long list of promising but unavailable candidates had not our grower collected and propagated it. It has done very well in revegetation. This stoloniferous member of the rose family is best-suited to coarse, very poorly drained sites, or poorly drained sites of somewhat finer texture (Figure 3). There is no confounding interpretation for this species; Figure 3 indicates where to plant it. It has done very well in revegetation.

Field mint (*Mentha arvensis*) is an aromatic herb often found along streams. Figure 4 indicates that it could be seeded into poorly to very poorly drained sites with sandy to coarse-loamy particle-size classes. It's a good streambank candidate of narrow ecological amplitude. Seed is available but currently very expensive, and we haven't used it yet.

A species of broader application is giant goldenrod (*Solidago gigantea*, n=11). Although there are some gaps in Figure 5, this tall, rhizomatous forb can share coarse, wet sites with field mint but prosper equally on fine-loamy soils of drier hydrology. Like many other species requiring enhanced soil moisture, it can occur on drier sites if plant competition is limited, e.g., by livestock grazing. Seed isn't always available, but we would use it on coarse, wet sites for which few commercial candidates are available as seed.

Graminoids usually carry the brunt of revegetation, and this project is no exception. A broad selection is commercially available as seed and transplants. Our first example, slender wheatgrass (*Elymus trachycaulus*), is one of the revegetation all-stars in uplands, a strong-establisher useful in short-term erosion control but not always persisting. Based on nine samples, Figure 6 indicates why it is better-suited to riparian areas than uplands: poorly and somewhat poorly drained sites of fine-loamy texture are its preferred habitat. In a seed mix, the amount of slender wheatgrass must be limited, or it can dominate the establishment phase to the detriment of species better-suited for long-term occupancy.

We don't seed creeping bentgrass (*Agrostis stolonifera*) because it's an invasive species of extremely low wildlife value, but its broad habitat preferences (Figure 7) indicate why it is found in so many riparian areas and fully half our samples (n=32). Many cultivars as well as local-origin collections are commercially available. This rhizomatous to stoloniferous, metal- and acid-tolerant species sometimes volunteers and flourishes on moist, contaminated sites where few other species can survive, and it is present in some Silver Bow Creek revegetation despite not being seeded, most likely having propagated from root parts not removed during remediaton.

Northwest Territory sedge was chosen to represent a number of wetland graminoids locally abundant: water sedge (*C. aquatilis*), small-fruit bulrush (*Scirpus microcarpus*), American mannagrass (*Glyceria grandis*), and others. It is an obligate wetland species of circumboreal distribution that reproduces vegetatively from stout creeping rhizomes. The distribution in Figure 8 (n=19) can be interpreted to represent the example of wetland succession given earlier. Any but the coarsest particle-size class is suitable, but hydrology must be ponded or very poorly drained for it to be abundant. NW Territory sedge and the other wetland graminoid species just mentioned are very productive and build-up a tremendous amount of organic matter in the soil. Decomposition is limited by anaerobic conditions and cold soil temperature, so an O horizon develops at the surface just a few decades after colonization. Rhizomatous wetland sedges are extremely effective in preventing erosion, and we transplant it along streambanks as well as into floodplain wetlands. Young transplants put a lot of resource into roots rather than reproduction, so transplant spacing should be <45 cm (<18 inches) or closer to promote development of a thick stand.

Nebraska sedge (*Carex nebrascensis,* n=25,), while sometimes grouped with beaked sedge and water sedge, exhibits a broader hydrologic amplitude. It may occupy sites fully as wet as the just-named associates, but it also occurs on poorly drained and somewhat poorly drained sites of fine-loamy texture. For this reason, Nebraska sedge is a safer choice for revegetation in fine-loamy riparian soils (note the similarity of Figure 9 and Figure 2, slenderleaf willow) and is alkaline tolerant. Hitchcock et al. (1977) says it "tolerates dry air…so long as its feet are wet" – the same thing Figure 9 indicates. Even where hydrology is known, the soil moisture regime in a particular year (i.e., the year of planting) may be aberrant, so species of broad hydrologic amplitude can be the best revegetation choices. Nebraska sedge spreads vegetatively from stout, scaly rhizomes, but due to the need to space transplants closely, transplanting wetland herbs is very expensive per unit area.

If Nebraska sedge is in some respects a safer revegetation choice than NW Territory sedge, Baltic rush (*Juncus balticus*, n=31) has to be the safest choice among wetland plugs. This very broadly adapted species spreads vegetatively soon after planting, more so than the sedges in our experience. This native and Eurasian species is well-adapted to a broader array of soil textures and soil moisture regimes than any other native species we sampled (Figure 10) also tolerates saline and alkaline soils. (We sampled it in soils with pH >8.) It can be dominant or subdominant on inundated to moderately well-drained soils of coarse-loamy to fine-loamy texture. It is, however, poorly suited to sandy or gravelly substrates. We usually transplant it in poorly to very poorly drained sites because rather few species establish well from seed there, whereas a good variety of grass seed is available for drier habitats. We have transplanted it successfully into soils with a salty white crust on the surface.

Putting Species Ordinations to Use

We ordinated about 60 species. Preliminary information provided by direct ordinations has been used to revegetate upper Silver Bow Creek following floodplain reconstruction. Now that this investigation is complete, the information can be applied more systematically. We monitor revegetation initially using seedling density measurements for seeded plants and survival measurements for transplants, providing a basis for quickly gauging the effectiveness of the revegetation plan and implementation.

Along Silver Bow Creek, the woody plants discussed here were transplanted as 10-cubic-inch (65 cc) seedlings. Silverweed, sedges, and rushes, and all other wetland herbs were transplanted as 3-cubic-inch (20 cc) seedlings, also called plugs. The other grasses and forbs were seeded if available at reasonable price.

We stipulated that our main family of woody transplants, Salicaceae, originate with stock indigenous to the Upper Clark Fork Valley. Due to the number and expense of these transplants, we could not gamble on plants genetically unsuited to climatic conditions.

Reviewing the graphs indicated that two promising species have not yet been used: Bebb willow (*Salix bebbiana*) and clustered field sedge (*Carex praegracilis*). Thus the formal data analysis has had another benefit.

Soil texture and hydrology are not the only factors that define riparian plant habitats, and habitat isn't the only guide to revegetation choices. But matching plants to habitats is the core around which revegetation prescriptions are spun. The first reach of Silver Bow Creek was seeded and planted in spring 2001, with two additional reaches revegetated in fall 2002. While it is too early to evaluate revegetation success, the approach explained here provided a scientific basis for initial revegetation choices.

Summary

Riparian settings contain such a broad array of plant habitats that they must be partitioned for successful revegetation, and adapted species identified for each zone. Silver Bow Creek was so thoroughly contaminated with mine tailings that it offered few clues for riparian revegetation following remediation. Based upon sampling soils and vegetation in uncontaminated nearby fluvial riparian areas, habitat affinities of important, naturally occurring species were graphically portrayed by ordinating species cover as a function of two influential soil characteristics: particle-size class and hydrology. To a degree useful for revegetation, these graphs define a species' habitat. The same two site factors are mapped for revegetation planning, where they may be considered revegetation habitat types. The species graphs indicate whether inventoried species should be transplanted into a particular habitat type, and if so which species. The graphs are less useful for seedings because of the limited availability of seed of many riparian species. Riparian plants sometimes establish a habitat, which is then modified. Deep-rooted species may persist in sites where they can no longer reproduce and where transplanting them would fail. Thus, the habitat preferences indicated by the ordinations must sometmes be augmented in revegetation planning with additional information about historic fluvial processes as they affect hydrology and particle-size class.

Literature Cited

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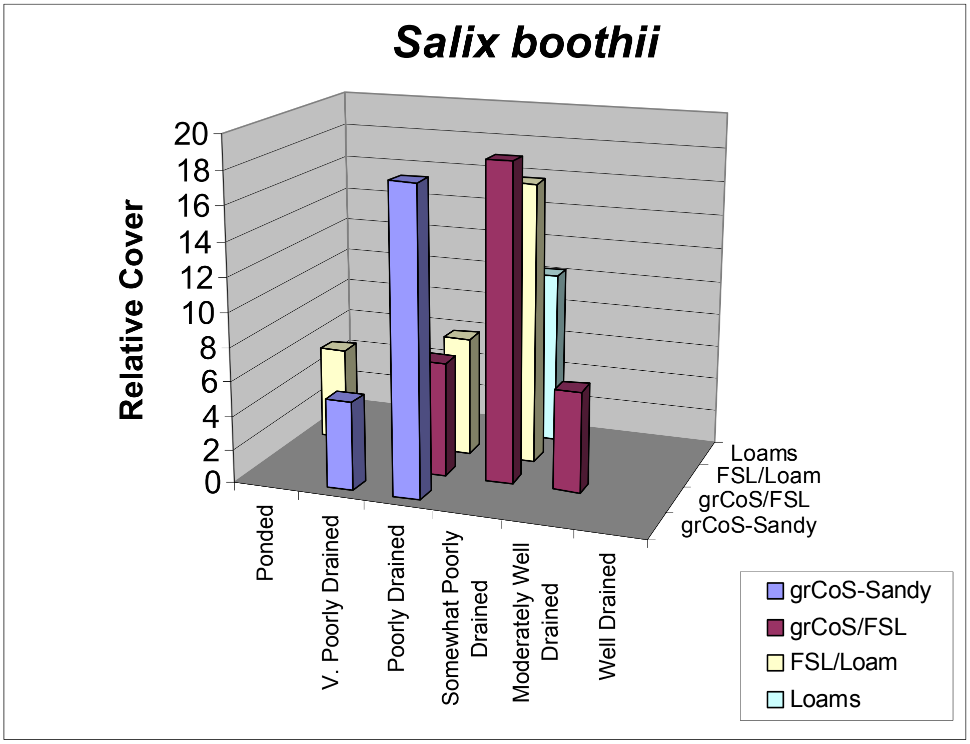

Figure 1: Soil Drainage and Particle-size Classes Associated with Booth Willow.

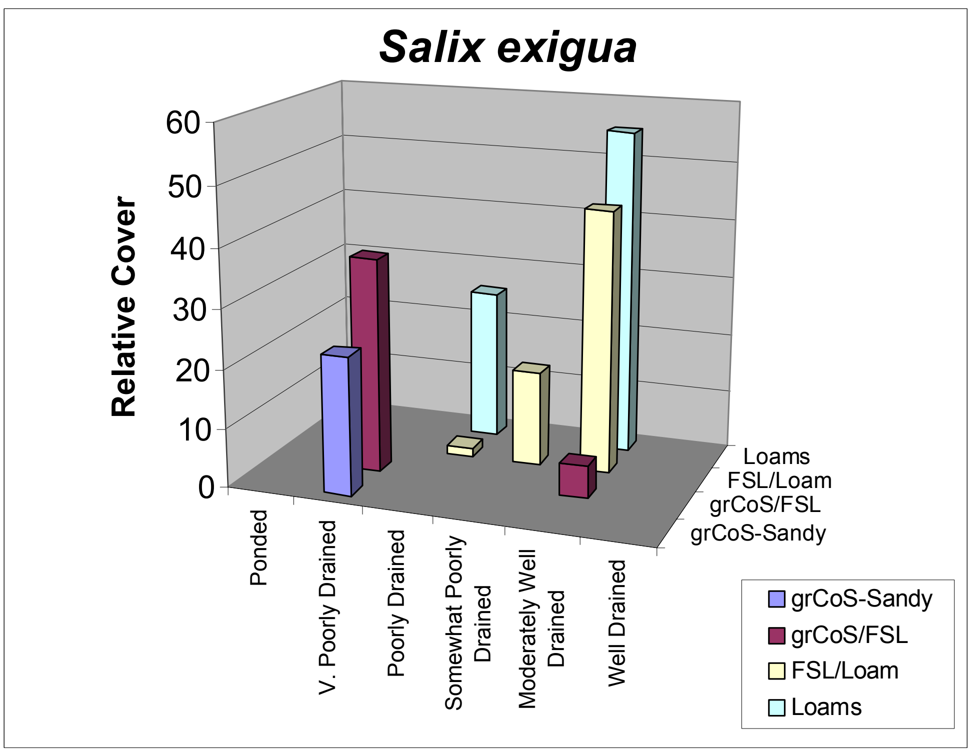

Figure 2: Soil Drainage and Particle-size Classes Associated with Slenderleaf Willow.

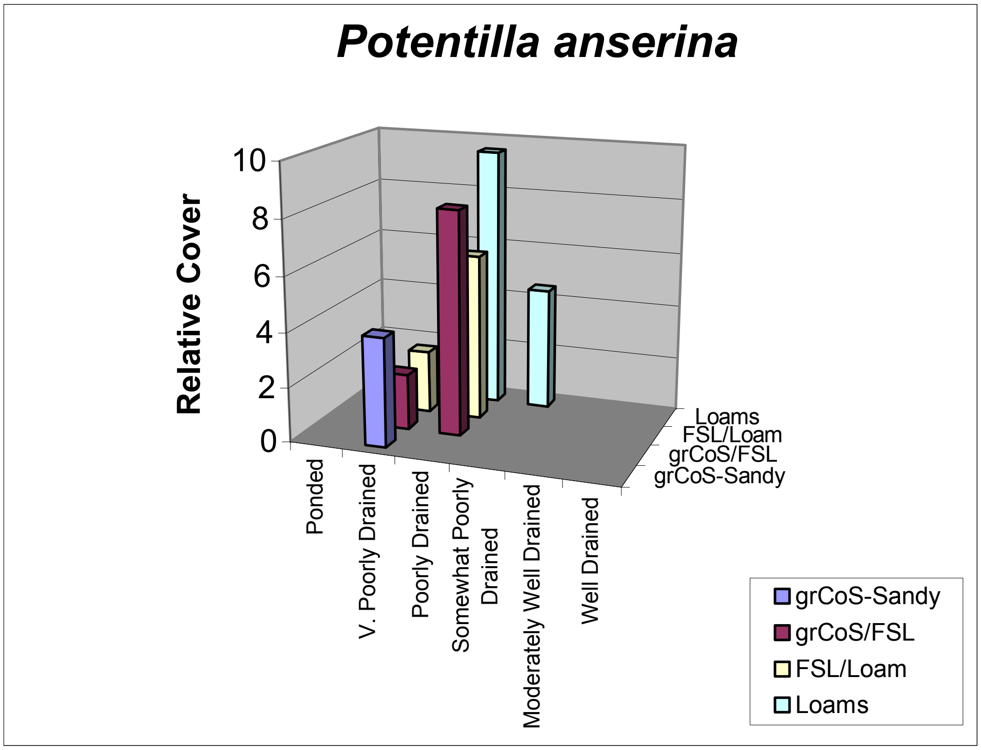

Figure 3: Soil Drainage and Particle-size Classes Associated with Silverweed.

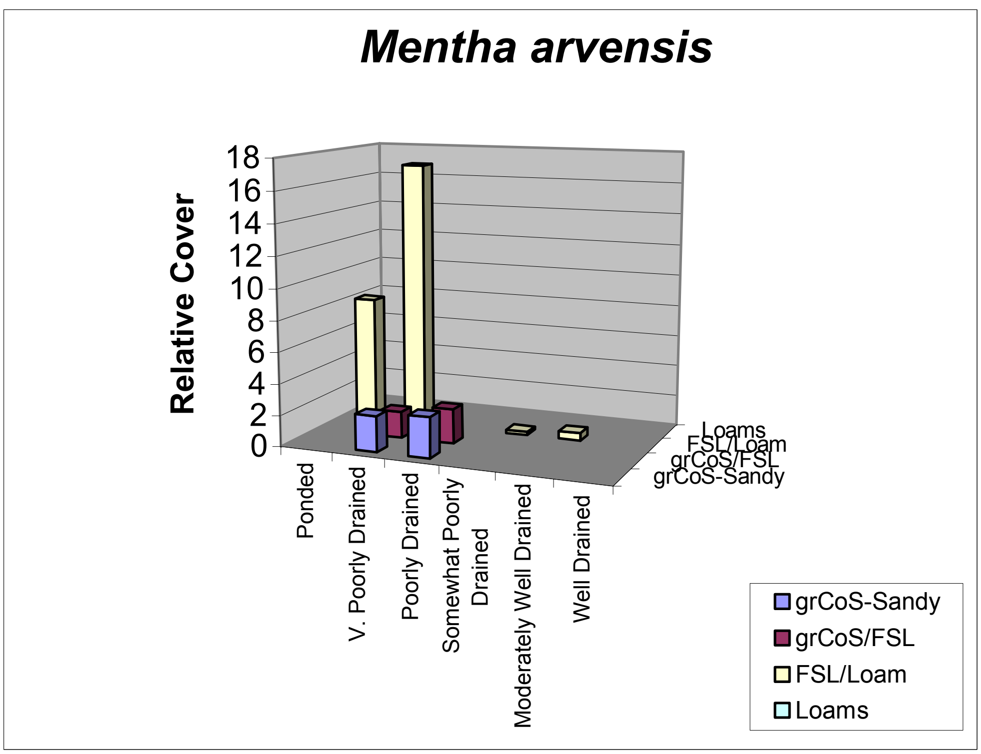

Figure 4: Drainage and Particle-size Classes Associated with Field Mint.

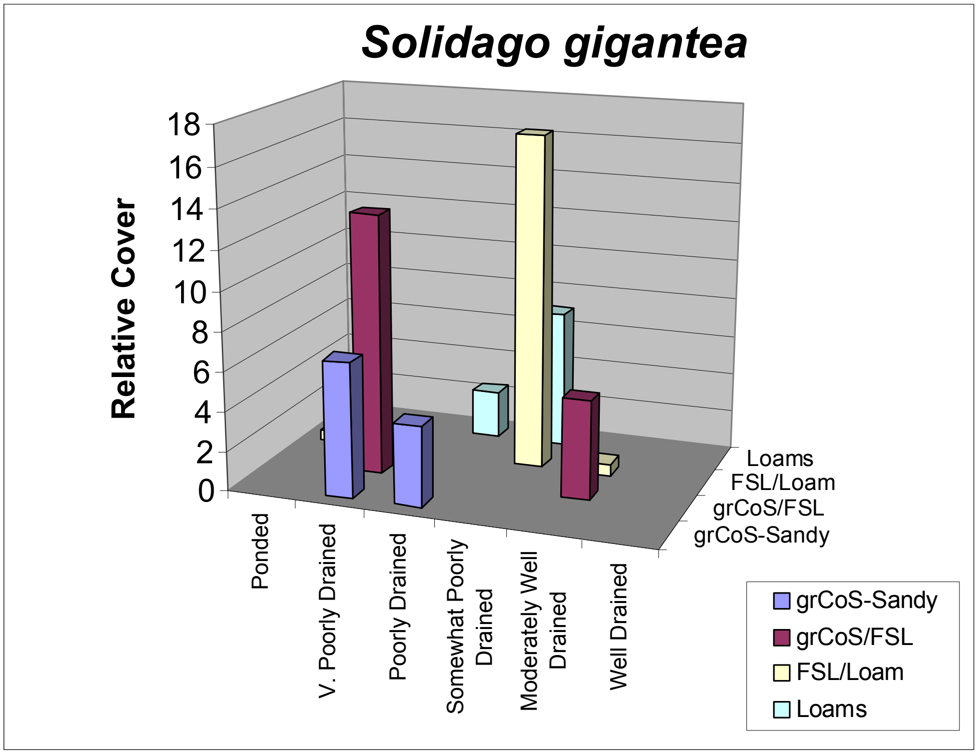

Figure 5: Drainage and Particle-size Classes Associated with Giant Goldenrod.

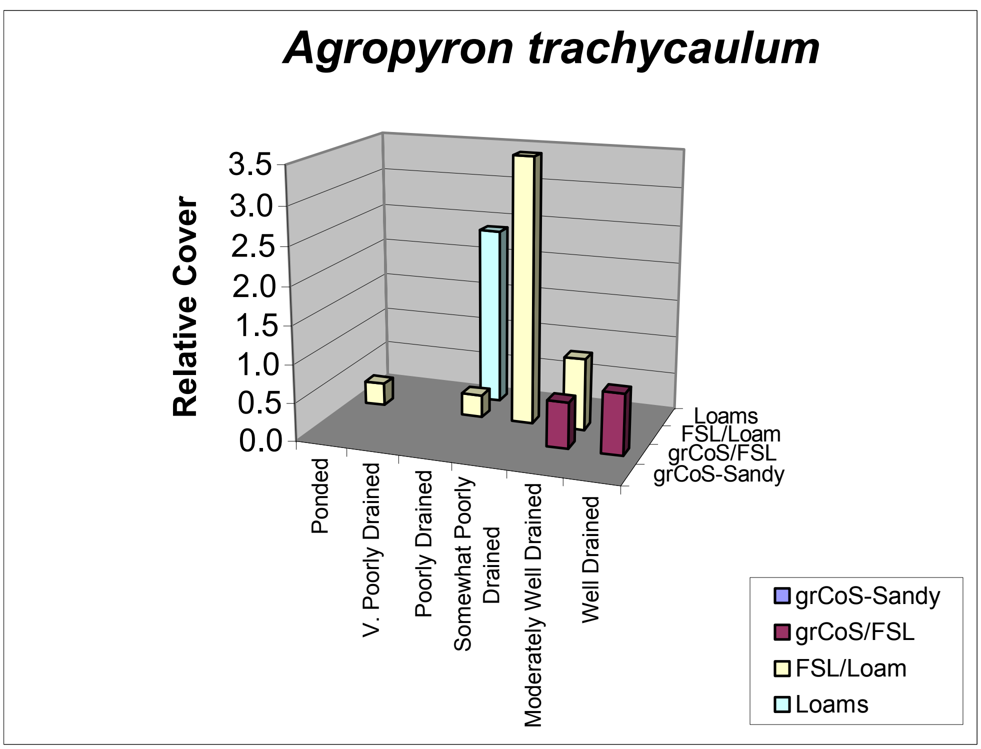

Figure 6: Soil Drainage and Particle-size Classes Associated with Slender Wheatgrass.

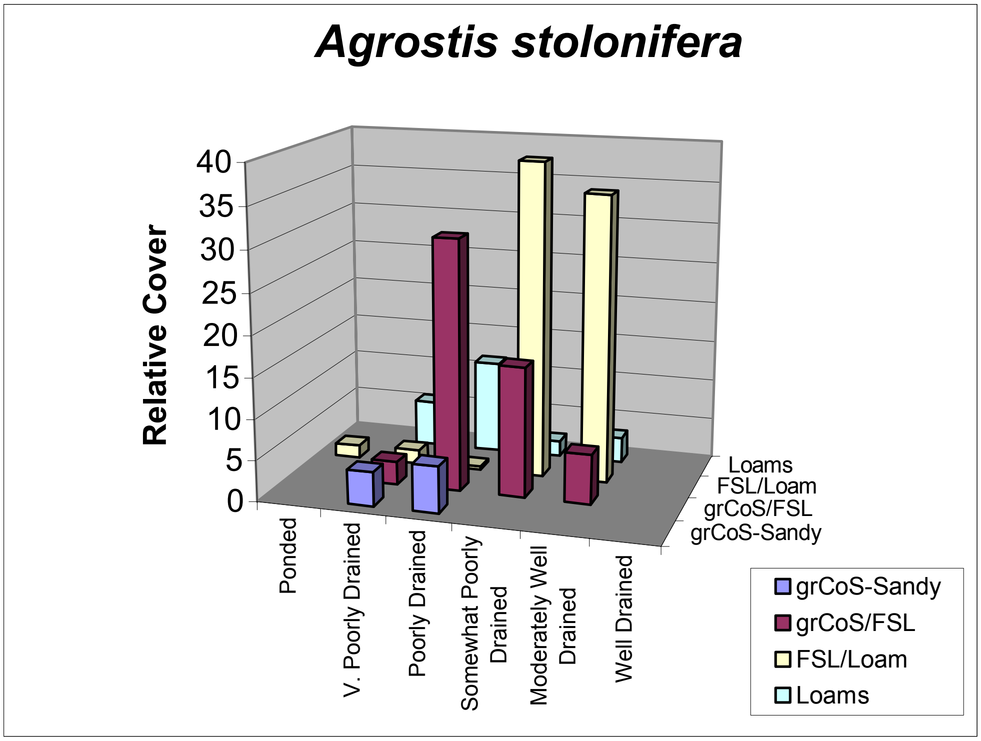

Figure 7: Soil Drainage and Particle-size Classes Associated with Creeping Bentgrass.

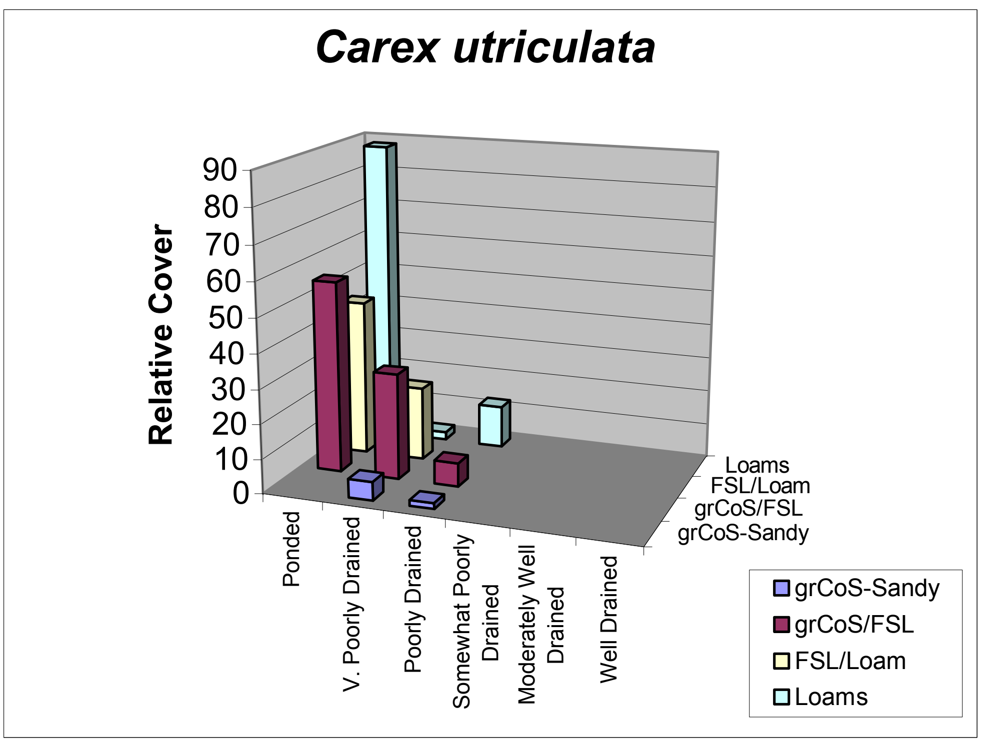

Figure 8: Soil Drainage and Particle-size Classes Associated with NW Territory Sedge.

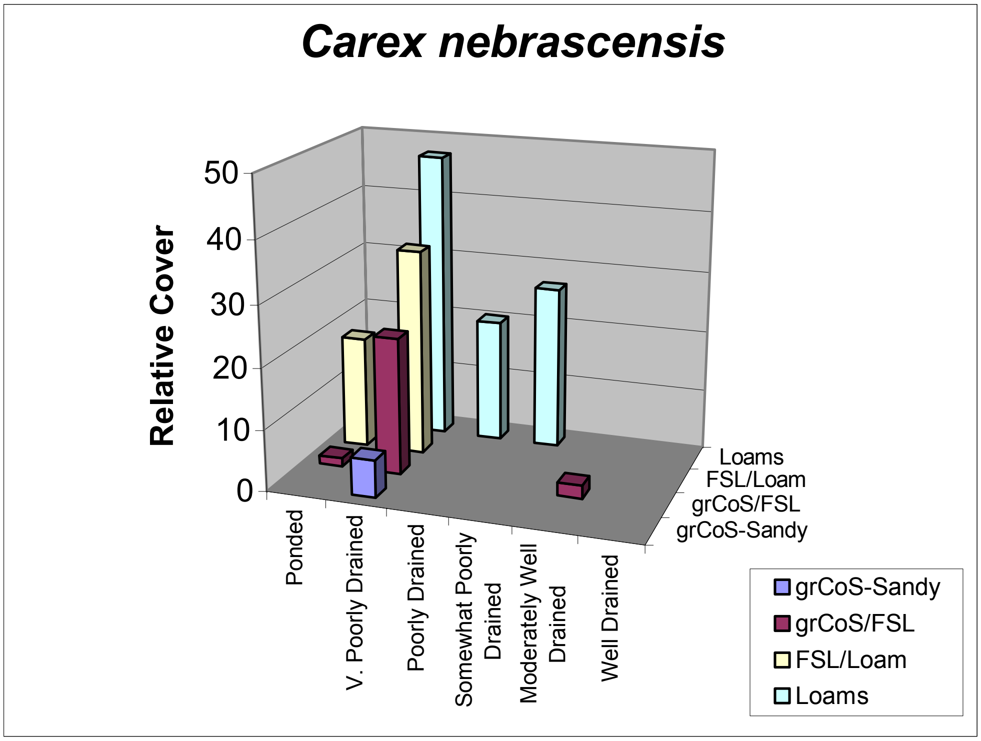

Figure 9. Soil Drainage and Particle-Size Classes Associated with Nebraska Sedge.

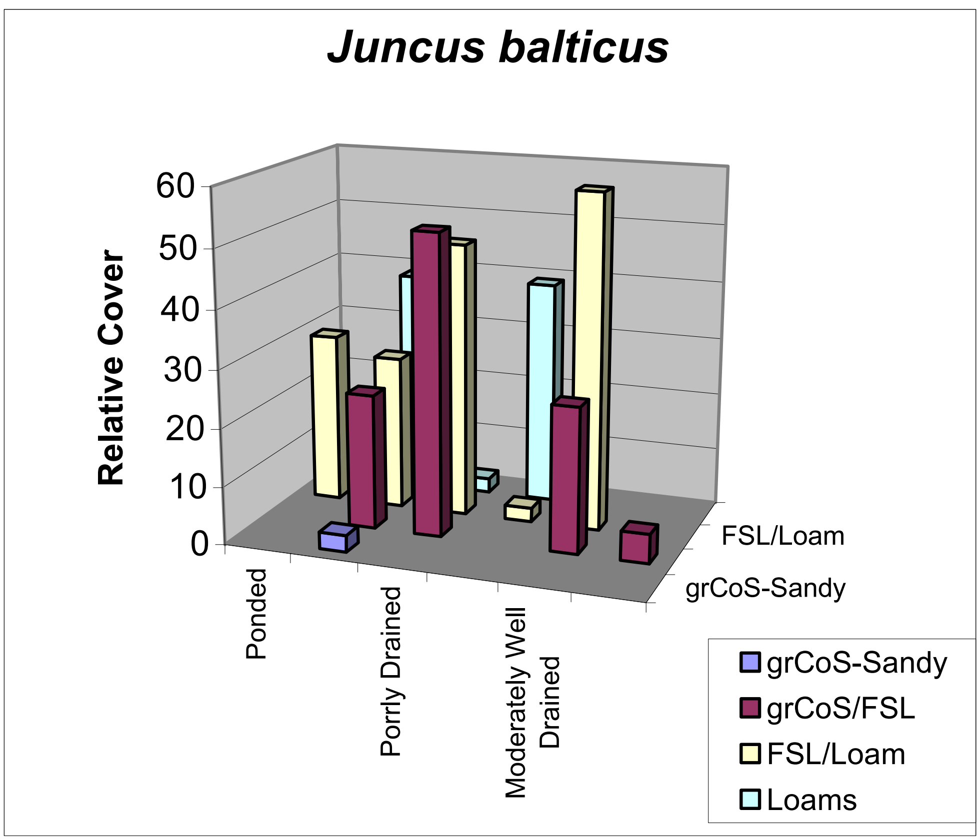

Figure 10: Soil Drainage and Particle-size Classes Associated with Baltic Rush.