Use of Prairie Vegetation on Disturbed Sites

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Interest and activity in the use of native prairie vegetation on disturbed sites have increased in the past decade. The primary objective in this paper is to summarize and document the observations and experiences of researchers who have studied prairies, prairie vegetation, and prairie-restoration techniques. Particular emphasis is placed on design and implementation techniques that might be applied in the design and establishment of prairie vegetation on relatively large land areas, such as those associated with transportation rights-of-way. Quantitative and qualitative analyses of natural prairie stands as models for prairie plantings on disturbed sites are presented (e.g., species density, plant distribution patterns, and resulting aesthetic effects). Design implications for prairie restorations are drawn from these observations. An example of a sizable prairie-restoration project on a construction site is presented. Its success after six growing seasons is evaluated relative to the original design objectives of developing a prairielike vegetational cover on a corporation headquarters site with a low maintenance requirement. It is assessed in terms of prairie species presence and distribution, presence of exotic species, and visual similarity to natural prairie stands.

This paper explores the use of native prairie vegetation on land disturbed by construction activity, with implications for applying information gained from past work to other situations. Such work is identified as "prairie restoration" in this paper. Technically, prairie restoration is the reestablishment of the prairie ecosystem to sites that once supported such a system, but from which all or nearly all of the original vegetation has been removed through a series of disturbances or manipulative actions over time, such as those associated with agriculturization and urbanization. It is unrealistic, however, to expect that a complex ecosystem can be totally reinstated on sites that have been dramatically altered. Hence, in practice and in this paper, prairie restoration refers to the establishment of native prairie plant species to disturbed sites that can reasonably be expected to support them, whether or not the sites were covered originally by prairie vegetation. Such plantings will almost always be simplifications in that there will initially be fewer species than in a natural prairie; however, the goal is usually to achieve the outward appearance of true prairie within 5-10 years.

The concept of using native prairie species in the designed landscape is increasingly mentioned as an alternative to mowed lawns for a variety of ecological, educational, and aesthetic reasons (1). In the recent past, potential or real shortages of fuel, fertilizer, and water have provided additional impetus for considering vegetation that is functionally and aesthetically acceptable without requiring mowing and without inputs of supplemental fertilizer and water. These considerations become particularly important to corporations or public agencies with large land areas to maintain (2).

In this paper, I first relate the current attention being given to prairie plantings in its historical context, with a brief summary of the use of native prairie vegetation in designed landscapes and the development of a body of knowledge to help prairie restorationists. Next, some of the research findings that relate to the design and establishment of prairie plantings, as well as observations made in actual prairie-restoration projects (with emphasis on findings that seem most applicable to moderately large acreages, such as those associated with transportation corridors), are summarized and synthesized. Finally, an example of a prairie-restoration project on a construction site is described. The design and implementation of an 80-acre planting on the General Electric Medical Systems site near Waukesha, Wisconsin, are assessed as to its success in terms of species composition, distribution patterns, and visual character after six growing seasons.

HISTORICAL PERSPECTIVE

Although the conscious planting of prairielike combinations of native species in the designed landscape is considered to be a new direction, there are precedents for this approach in the history of American landscape architecture. Probably the most notable proponent of the use of native plant species in the designed landscape was Jens Jensen, a Danish-born landscape architect who worked in the Chicago Park System and throughout much of the Midwest from the mid-1880s to the 1940s (3). In 1888 he designed and planted the American Garden in a corner of Chicago's Washington Park, which was a collection of native wildflowers that he had dug up and brought in from the country. The garden gained immediate popularity with park visitors who recognized the plants as species that were being lost as the city expanded.

Although Jensen's first avowed native garden in Washington Park was small in size, it was followed by many works later in his career that were much larger in size and impact, which demonstrated the design potential of a group of plant species that had previously been rejected by most landscape architects and horticulturists as being too coarse for landscape use. Among these projects were Jensen's prairie rivers in Humboldt Park and Columbus Park in Chicago. Both of these rivers were curving lagoons bordered by plantings of wetland and prairie species with large open-mowed meadows adjacent to them. The borders were planted with native Illinois prairie grasses and flowers, along with cattails, reeds, and other wetland plants. They were symbolic representations of the prairie, which suggested the power and movement of the native tallgrass prairie, but the land area devoted to them was quite limited.

Wilhelm Miller (4) of the University of Illinois promoted the prairie style of landscape gardening in a publication with that title in 1915, which suggested that Jensen and a small corps of other Chicago-area landscape architects were developing a regional style of landscape design, parallel with the Prairie School of architects, epitomized by Louis Sullivan and Frank Lloyd Wright. Miller's treatise went on to propose preservation of at least one 1000-acre prairie park in each of the prairie states and restoration of 2- to 5-acre prairies in the city parks of Illinois. He provided lists of woody and herbaceous plants appropriate for different types of states, but did not suggest relative proportions or techniques for implementing the proposed restorations.

In 1929, a book entitled American Plants for American Gardens (5), written by Edith A. Roberts, a plant ecologist, and Elsa Rehmann, a landscape architect, promoted the use of native plants in groupings based on natural plant communities. This collaborative work provided underlying ecological concepts as well as recommended lists of predominantly native plant species for use in landscape design. The geographic area covered in the book is the northeastern United States, and it includes discussion of the open field association. The list of plant species for use in the open field includes a number of naturalized Eurasian species as well as true native vegetation of open, sunlit areas. The authors do not purport to provide propagation or establishment information in their book.

There is little evidence that the ideas espoused by Jensen, Miller, or Roberts and Rehmann were widely accepted or adopted by other landscape architects during the 1930s and 1940s. However, valuable work in studying prairies and techniques for prairie restoration was being done by plant ecologists during this period. Foremost among these researchers in Wisconsin were John T. Curtis and Henry C. Greene of the University of Wisconsin Botany Department. They began their first attempts at reestablishment of the prairie in 1935. By 1950, the two reported that it had become abundantly clear that such restoration could be successful (6). They began their work, logically enough, with studies of as many remnant prairies as they could find, listing species most commonly found on wet, mesic, and dry prairies in the region, along with their average numbers per acre (7). The two prairie restorations that they established in the University Arboretum, each about 40 acres in size, now bear their names. Their original notes and publications, as well as subsequent studies of the two restoration sites, continue to provide valuable information to landscape restorationists and managers.

Somewhat farther west, but still in the tallgrass prairie region, John E. Weaver, a plant ecology professor at the University of Nebraska, studied prairies, prairie vegetation, and their dynamics for half a century beginning in 1916. His own work and that of his students are well documented (8,9) and provide substantial insight into the natural models on which restorationists can draw.

After 1960 a number of other ecologists and naturalists began to use the knowledge generated by Weaver, Curtis, and Greene to reestablish small plots of prairie vegetation and experiment with new techniques. One example of such a project is the prairie planting at the Morton Arboretum at Lisle, Illinois, executed under the direction of Ray Schulenberg. For much of the original prairie restoration at this site, seed was hand collected from local remnants, germinated in flats in the greenhouse, transplanted to the field site, and hand weeded for the first several growing seasons.

However, not until the last decade has the landscape architecture profession again considered the reestablishment of prairielike plantings as a viable alternative to standard lawns and woody ornamental plantings seen throughout most of the country's cities and suburbs. Evidence of a degree of acceptance of this alternative occurred with the publication in October 1975 of a special issue of Landscape Architecture, the official journal of the American Society of Landscape Architects, entitled The Search for a Native Landscape, which included two articles with strong prairie orientation (10,11).

Meanwhile, a series of biennial prairie conferences has been held in the states of the tallgrass prairies, which began in 1968 with the First Midwest Prairie Conference at Knox College, Galesburg, Illinois. Broadening into the North American Prairie Conferences, these meetings bring together a mix of scientists, landscape architects, and interested lay people to hear wide-ranging papers, such as detailed studies of prairie ecosystems, which include various strategies and techniques for preservation, management, rehabilitation, and restoration of prairie vegetation in a variety of settings. The proceedings from the various conferences provide a wealth of specific research results and personal observations of value to present restorationists (12-16).

In summary, there has been a thread of interest in native prairie restoration in the designed landscape during much of the past century, although early proponents' concepts were not widely accepted or adopted. A body of knowledge based on restoration experience has been developing since the 1930s, primarily through the efforts of botanists such as Curtis and Greene. In the last decade, landscape architects have begun to merge this knowledge with their own aesthetic judgments by using prairie vegetation in designed landscapes ranging from residential (17) to industrial sites (2).

DESIGN AND ESTABLISHMENT OF PRAIRIE VEGETATION

Although prairie-restoration efforts have increased markedly during the last decade, there is not, and indeed there cannot be, a single recipe for the design and implementation of a successful prairie planting. First, goals and objectives vary with different projects. Some may be educationally oriented, with a primary goal of introducing people to a large number of native species. Some may be functionally oriented, with a primary goal of controlling erosion and runoff. Some may be aesthetically oriented, with a primary goal of recreating the visual essence of a prairie with tall grasses waving in the wind, interspersed with contrasting colors and textures of prairie forbs. Whatever the goal, however, the likelihood of attaining it is enhanced by a basic understanding of natural prairies, their structure, and their composition.

Another factor that precludes development of a formula for prairie restoration is the fact that widely varying individual site characteristics and growing conditions make it difficult or hazardous to generalize. Nevertheless, each new project that is carried out can provide new information that may be of use in subsequent work as long as the local conditions and multiple variables are considered.

Following, then, is a compilation of research findings of ecologists, as well as observations by myself and others, who have studied prairies or worked with the restoration of prairie vegetation. Taken together, this research provides some basic guidelines in (a) natural prairie composition and (b) restoration techniques appropriate to different settings.

Emphasis will be on design considerations and implementation techniques for relatively large plantings, i.e., 5-100 acres, with the goal of achieving the visual character of natural prairie within five years, more or less. This assumes a less-than-complete ecosystem restoration, with all the species diversity and complex interactions implied by that, but it does suggest a vegetational cover that includes a variety of dominant species that occur in naturally evolved prairies with macrodistribution patterns similar to those of natural prairies.

In designing a prairie planting, there are two major considerations. First, there are species selection and determination of relative proportions of species. Second, there is the placement or distribution of species relative to each other and to the varied microenvironments that may occur on the site. The logical place to begin to determine appropriate species composition and distribution for restoration is from the natural stands that have been studied.

Species Selection

One of the initial questions to explore relates to the number of species typically growing in natural prairie stands. Curtis (18) studied species density in stands of different prairie types based on soil moisture and determined species density (average number of species per stand) as shown in the table below:

Prairie Type	Species Density	No. of Stands
Dry	47	17
Dry-mesic	55	66
Mesic	55	45
Wet-mesic	62	31
Wet	44	22

A species density range of 40-70 species/acre in relic prairies in Illinois further suggests that the typical number of species in small areas is not excessive (19).

Studies in Wisconsin dry lime prairies, reported by Curtis, indicate that 10 species constitute the great majority of the flora. From this, we can interpret that a prairie planting within a relatively homogenous environment (i.e., in terms of soil moisture, soil depth, and slope orientation) might look much like a true prairie with as few as 10 of the most prevalent species on natural prairies with similar physical properties. If these can be supplemented with an additional 10-15 species in smaller numbers, so much the better.

In regard to grass species composition, Weaver's studies (9) in Nebraska, Kansas, and Iowa revealed that 95 percent of the grass population in 135 different stands consisted of 10 species. He separated the prairie environment into two segments: lowlands, identified as sites with relatively high soil-water content, and uplands, sites with low soil-water content.

The five most prevalent grasses in his summary of lowland sites are Andropogon gerardi, big bluestem; Spartina pectinata, cordgrass; Sorghastrum natans, Indian grass; Panicum virgatum, switch grass; and Elymus canadensis, Canada wild rye. The five most prevalent species on upland sites were Andropogon scoparius, little bluestem; Sporobolus heterolepis, prairie dropseed; Stipa spartea, needlegrass; Bouteloua curtipendula, sideoats grama grass; and Koeleria cristata, Junegrass.

Note that in the prairie stands studied by Weaver, the two bluestems (Andropogon gerardi and A. scoparius) constituted 70 percent or more of the vegetation. He found that big bluestem provided 80-90 percent of the cover on well-watered but well-aerated soils. Little bluestem exceeded all other upland species combined, as it comprised 50-75 percent of the vegetation on drier sites as a whole and up to 90 percent on steep loess hills (9). These data reinforce the idea that in these geographic areas, a natural prairielike effect can probably be achieved without having extremely large species numbers.

Within the general category of species selection, an important consideration in ultimately achieving the appearance of a prairie is the proportion of grasses to forbs. In the prairie stands studied by Weaver, he found that grasses constituted 95 percent of the vegetational cover. The importance of grasses is not only in quantitative terms but also in terms of the visual character of prairies. The linear form of the grass blades, repeated throughout a prairie composition, unify it visually. Further, this screen of narrow, predominantly vertical lines filters the sometimes blatant flower colors and modifies the effect of coarse-textured leaves. Extending a bit further into the subjective evaluation of the effects of grasses on prairie aesthetics, there is the important element of movement displayed by them. This quality, perhaps more than any other, is critical in imparting a prairie spirit to a landscape (20).

If grasses constitute the unifying element within a prairie landscape, the forbs, or broad-leaved flowers, provide the diversity within it. There is less species homogeneity between regions among the forbs than among the grasses (18). Therefore, it is difficult to generalize about the most abundant forb species for consideration in restoration plantings. Specific forb composition of local remnant prairies on sites similar to the restoration site would, of course, be very helpful to a restorationist in a specific region. With such background information, forb species could be selected for planting on the basis of (a) numerical importance and/or (b) visual significance in local prairies.

Species Distribution

Closely related to species selection for a prairie planting is a determination of the placement or distribution patterns within a stand. Once again, a starting point for determining this characteristic is to look at patterns in natural models.

In a naturally evolved prairie, as well as restoration plantings, the first requirement is for propagules (e.g., seeds, roots, and tubers) to be introduced to the site. Beyond this, two major categories of factors influence the distribution patterns: (a) environmental factors, such as soil moisture, soil depth, and biotic competition, which includes allelopathic relations; and (b) the individual species' manner of reproduction and spreading.

A visual analysis of natural prairies from a distance often reveals a degree of zoning of species, seen as bands or drifts of different colors or textures, which blend or grade one into the next. Typically, these zones are not sharply defined, but in some cases, they may be quite apparent. Weaver (9) found changes along a topographic gradient for the two bluestems (Andropogon gerardi and A. scoparius). He found hillcrests and dry slopes to be dominated by A. scoparius. On moist midslopes, A. scoparius and A. gerardi shared dominance. On lower slopes and ravines, A. gerardi was dominant. Similar phenomena are displayed by other species combinations, gradually changing positions of dominance along an environmental gradient. Note that it is usually a gradual change, with an intermediate zone that includes individuals of both species.

On the other hand, with abrupt environmental changes, there may be almost a clear line where one species or set of species ends and another begins. Sometimes these environmental differences, such as differences in soil depth, may not be apparent at the surface. Anderson (21) studied this phenomenon in Wisconsin dry lime prairies and classified the species in three groups: (a) those found only in quadrats of very thin soil, (b) those found only in quadrats with deep soil, and (c) those that occurred in either type of quadrat.

Competition from other species can contribute to the appearance of different zones of different colors and textures. For example, both cordgrass (Spartina pectinata) and big bluestem (Andropogon gerardi) may nearly eliminate shorter species, primarily because of shading (9). Further, a number of prairie plants are considered to be allelopathic, which produces an antibiotic effect that inhibits other species. Examples in Wisconsin prairies include Helianthus laetiflorus, Coreopsis palmata, and Antennaria neglecta (all composites). They may appear as almost solid clonal stands of contrasting color and texture within a prairie because of their ability to exclude competition.

In addition to environmental factors that affect distribution, reproduction methods may have a noticeable effect. Those species that depend primarily on vegetative reproduction means, such as underground rhizomes, tend to exhibit tightly aggregated colonies (22). Curtis (18) also noted that aggregated species were typically rhizomatous. On the other hand, randomly distributed species were typically annuals, biennials, or nonspreading taprooted perennials.

All of the above studies on distribution patterns reinforce the idea that a prairie is not a homogenous blend of species that are randomly or equally spaced. Instead, it has a highly complex organization with certain areas dominated by closely spaced individuals of one or a few species and with resulting contrasts in color and texture.

In planning a prairie restoration, one philosophical approach would be to plant a homogenous, uniform seed mix over an entire site, with the expectation that, over time, a natural sorting out will occur, with each species doing well in its own microhabitat so that a natural-looking pattern will result. A contrasting approach, and one I subscribe to, is to analyze the physical characteristics of the site sufficiently to determine differences in microhabitat and then match different species mixes to different parts of the site.

IMPLEMENTATION OF PRAIRIE RESTORATION PLANTINGS

To be practicable on large sites, it must be possible to implement prairie restorations primarily through the use of mechanical equipment, without the luxury of intensive hand labor by highly trained workers under close surveillance. To be practical, planting will be predominantly by seeding, with seed mixtures designated for different areas of the site.

Seed for such plantings should be from a local seed source, if at all possible. Not only is the likelihood of successful germination and survival increased but this practice eliminates the possibility of interbreeding of foreign varieties of native species with local varieties, which could possibly lead to a long-term loss of the local genetic type. [The Soil Conservation Society of America provides a list of native seed and plant suppliers, listed by state, in Sources of Native Seeds and Plants (23). It may be obtained from the society at 7615 Northeast Ankeny Road, Ankeny, IA 50021, for $2.00.]

Native grass seed is available in quantity from commercial sources in areas where those species are planted on rangeland. Such suppliers typically sell the grass seed on the basis of pure live seed (PLS), which takes into account the germination rate and percentage of purity.

Forb seed, even from some commercial suppliers, is often hand collected from prairie remnants. It is highly variable in both germination and purity, which makes it extremely difficult to predict reliably the number of plants that might germinate from a given amount of seed. Seed costs from commercial sources range from $6 to $10/lb of PLS for grasses to $50-$80 or more/lb for forb seed.

Soil Preparation

In addition to providing a good medium for seed germination and growth, a major objective in preparing soil for prairie plantings is to reduce the potential competition from cool-season grasses and agronomic weeds. If one has the luxury of a year's lead time, two different soil treatments are possible. One is fallowing the soil, i.e., first deep plowing it and then disking it throughout the growing season, whenever a new crop of weeds germinates.

If fallowing the soil is unacceptable because of potential erosion or other reasons, a preparatory cover crop can be planted. Annuals such as oats, soybeans, or buckwheat are possibilities. These crops may be harvested and the stubble permitted to remain.

The following year, if cool-season weed species appear before the prairie planting date, the site may be disked lightly to remove them, and the seeding can follow. If the fallowing process or the cover crop is used, deep plowing should not be repeated during the spring of the prairie seed planting, since this potentially would only bring a new crop of weed seed to the surface. In cases where weeds are not apparent prior to planting, and if a drill is used, the seeding may take place directly in the stubble of the cover crop.

If the year's lead time is not feasible, an alternative soil preparation procedure is to deep plow (10-12 in) as soon as the soil is workable in the spring and follow this by one or more diskings to remove germinated weeds, with the last disking just before seeding. The seedbed does not have to be prepared to as fine a texture as a lawn seedbed, however, since it will not be mowed to a short height. Fertilizing is not usually recommended for prairie plantings, since it is inclined to favor the undesirable agronomic weeds more than it does the native species.

Curtis and Greene (6) reported success with a technique that might be adopted on sites where there is already some vegetational cover that cannot be removed practically because of erosion potential. The technique was to scarify an open sod of Canada bluegrass and redtop in the fall, which exposed the soil without necessarily breaking the sod, and then seeding into it with a mix of native species. They reported prairie cover in five years, with the bluegrass and redtop suppressed.

Planting Techniques

For seeding, two basic techniques, with variations, are available. The first is broadcasting into a prepared seedbed, followed by raking to cover the seed with soil and compacting it with a "cultipacker" or other roller to ensure contact between soil and seed. It is possible to broadcast by hand for small areas of a couple of acres or less. Some advantages to hand broadcasting are the small investment in equipment and the natural distribution of seed where it falls, which is enhanced even more by a slight wind. Some disadvantages include the near impossibility of getting a uniform distribution, coupled with the difficulty of a uniform covering.

Recommended depth of seeding varies. Briggs (24) of the Soil Conservation Service recommends a depth between 0.25-0.50 in. A compromise at 0.48 in is appropriate for many species.

The second basic technique is to drill the seeds, preferably by using a drill designed for prairie planting. A popular brand in the past has been the Nesbit drill, which is no longer manufactured. More recently, Jim Traux, who has done extensive prairie plantings in Minnesota, has developed the Truax model grass drill for this purpose.

This tractor-drawn drill has 12 pairs of discs, 8 in apart, which cut furrows into which seed is dropped from a seedbox, followed by a rubber-tired wheel that closes the furrow and compacts the soil. The advantages of drilling include its labor efficiency and the predictability of seeding rates and depth. The major disadvantage is the fact that seed is planted in rows, which may be apparent for some time.

For planting of steep slopes that are not negotiable with a drill, hydroseeding and/or hydromulching techniques may be considered. By using this procedure, seed is sprayed onto a slope in a liquid slurry. Wood-fiber mulch can be applied in the same slurry, but there is evidence that better results may be obtained by applying the mulch in a separate, second operation because the seed should be in contact with mineral soil in order to germinate and grow (25).

Planting Time

For southern Wisconsin, planting is recommended in the last half of May, or about the same time that corn is planted in the area. Warm-season grasses, as well as many forbs, do not germinate until the soil is 60°F or above. Planting at this date permits the removal of the first wave of cool-season weeds before planting the prairie species. If weeds are well under control, an earlier seeding in the spring, or even during the preceding October or November, permits a more natural stratification of the seed in the soil before germination.

Seeding later than June 1 presents a greater probability that rainfall needed for germination and early growth will diminish or be nonexistent. However, if water can be supplied at a rate equivalent to 1 in of rainfall per week, prairie planting may be continued through July, with a reasonable expectation of some success during the first year. Further, a straw mulch applied at a rate of 1.5 ton/acre will help retain some of the moisture.

For added species diversity, seedlings can be introduced into a prairie planting as roots or tubers early in the spring (e.g., up to mid-May), before lush new growth begins. Fall transplanting of seedlings has also proved quite successful in some experiments. For example, Christiansen and Landers (26) report 87 and 92 percent winter survival for two groups of fall transplants in an Iowa experiment.

Seeding Rates

Various individuals' opinions on the amount of seed to use is highly variable. Site characteristics and weather conditions during any specific growing season are factors that affect the seeding rate. Great fluctuations in the degree of purity of seed (i.e., freedom from other plant parts) and germination rates further complicate the already cloudy picture.

For the establishment of a prairielike planting in a reasonably short time period, a range of 15-20 lb of PLS per acre has been successful. For hand-broadcast plantings, the upper end of this range is appropriate. For drilled seedings, the lower end of the range is suitable because of the greater efficiency of this method.

What to Expect the First Year

With sufficient rainfall, some of the prairie species planted as seed will appear the first year, but they are not likely to make a very dramatic showing. Except under truly optimum conditions of soil and moisture, grasses will not flower or seed with any abundance the first year. With a shortage of moisture or poor soil, the tops of many species will be no more than 2-3 in tall by the end of the first growing season. They may be imperceptible before frost. After a frost, which kills annual weeds and stimulates the natural fall coloring of native perennials, they may be more visible. Although the visible parts of the plants are inclined to be undramatic, activity beneath the surface may be much more exciting, with root growth two to three times the length of above-ground shoots.

Meanwhile, annual weeds will have germinated and may visually dominate the prairie planting. A common invader during the first year is foxtail (Setaria spp.), but it is not likely to persist. Broad-leaved species, such as lambsquarter (Chenopodium album), pigweed (Amaranthus retroflexus), ragweed (Ambrosia artemisiifolia), dandelion (Taraxacum officinale), and curled dock (Rumex crispus), are all frequent invaders in the open habitat of a new prairie planting.

Conveniently, the fact that the prairie perennials are putting their major first-year effort into root development, rather than into tops, means that the planting can be mowed two or three times the first year to suppress the weeds without damaging the prairie plants. Actual cutting times and heights vary with the growing season and should be determined in the field. As a general suggestion, a mowing approximately a month after planting and a second mowing about one month later can be beneficial. Besides making the planting more visually acceptable to the public, mowing serves the useful function of keeping the annual weeds from flowering and seeding. It also permits sunlight to reach the small prairie seedlings. The height of mowing, which stays above the tops of the taller prairie seedlings (i.e., heights that range from 4 to 8 in), may increase as the growing season progresses.

What to Expect the Second Year

Prairie plants that have remained very conservative during their first year may become much more assertive the second. With an average amount of moisture, most of the grass species will flower and produce seed although they may not attain their typical mature height.

Several early-successional forb species will bloom the second year, assuming their roots have become established the first growing season (e.g., Monarda fistulosa, Ratibida pinnata, and particularly the biennial Rudbeckia hirta).

There may be new germination of prairie species during the second year if they did not have optimum conditions the first year. This delayed germination may continue for five years or more, as conditions become right for more species to germinate and grow.

Foxtail will have diminished by the second year in most prairie plantings. Daisy fleabane (Erigeron strigosus) may appear abundantly, but is no cause for alarm because it will be succeeded by long-lived prairie perennials. On the other hand, quackgrass (Agropyron repens) may appear and does represent a problem. In small patches, actual removal of the plants, including rhizomes, may be a possibility. For larger areas, a long-term suppression program for quackgrass should be instituted. Its ability to start growth early in the season makes it possible to suppress by strategically timed burning in the spring. Burning should occur after the quackgrass has started photosynthesizing but before the native species have done so (usually mid-April in the Madison, Wisconsin, area).

Subsequent Management

By the third season, prairie plantings usually benefit from a spring burn and, with sufficient rainfall, can take on the characteristics of real prairies. If the planting has been successful, it may be hard to introduce new species.

CASE STUDY: PRAIRIE RESTORATION IN WAUKESHA COUNTY, WISCONSIN

An 80-acre prairie-restoration planting that was implemented in 1974 in Waukesha County, Wisconsin, at the General Electric Medical Systems site provides an illustration of the application of restoration techniques to a large area with minimal on-site supervision and monitoring. After six complete growing seasons, it is possible to begin to assess the degree of success achieved by these techniques.

Design Objectives

The primary objective in the design of this planting was to provide an erosion-controlling vegetational cover with the visual character of a natural prairie on the extensive land area that surrounded a central building and parking complex. It was expected that after the first year maintenance input would be very low and that there would not be major opportunities for enrichment through the addition of plant species after the initial planting in 1974.

The site is in an urban area, with suburban development occurring around it. Interstate 94 and its access road provide the southern boundary and county highway "T" constitutes its eastern boundary.

Site Characteristics

The topographic character of the prairie planting site is generally rolling with up to 6 percent slopes with a variety of solar orientations. There were natural swales throughout the site and constructed swales adjacent to the driveway that separate the prairie planting from the building and parking complex.

At the time of planting, the soil had been greatly disturbed adjacent to the building and road construction sites. The compacted rocky clay soil was covered by a 4- to 6-in layer of topsoil in late summer 1973 in those areas disturbed by construction. Outlying portions of the site were predominantly farm fields in the early stages of old-field succession, which had not been cultivated in 1973. Soil there could be characterized as a clay loam with poorly drained areas at low points.

Vegetation that existed on the site included predominantly exotic weed species in the former farm fields, with an abundance of curly dock (Rumex crispus), velvet leaf (Abutilon theophrasti), mullein (Verbascum thapsus), thistle (Cirsium spp.), fleabane (Erigeron spp.), and foxtail (Setaria spp.). Fencerow vegetation at borders of the prairie planting included predominantly oaks (Quercus spp.), black cherry (Prunus serotina), and boxelder (Acer negundo). Cattails (Typha latifolia) and sedges (Carex spp.) dominated some of the poorly drained low areas not disturbed by construction activity.

After placement of the 4- to 6-in topsoil layer during August 1973, a seeding of annual ryegrass was specified for the areas disturbed by construction. This seeding was effective in controlling erosion during the fall and winter 1973. It reappeared, vigorously, in early spring 1974. Instead of annual ryegrass, perennial ryegrass (Lolium perenne) had apparently been seeded.

Planting Plan

As the prairie-restoration consultant on this project, I prepared a two-layer planting plan for the site. The plan consisted of (a) a grass seeding plan with five different combinations of grasses matched up with apparent environmental conditions, with potential aesthetic effect and seed availability also entering into the determinations, and (b) a forb plan with nine different forb seed combinations superimposed over the grass planting by using similar criteria for selection.

Table 1 lists the grass seed mixes used at the General Electric site. The mixes should not be construed as recommended mixes for all sites, but were derived for this site on the basis of (a) microenvironmental factors (soil, slope, and moisture), aesthetic considerations (degree of refinement, size, and color), and (c) seed availability (species not commercially available were used in smaller proportions). The grasses were drilled with a Nesbit seed drill during the period May 15 to June 6, 1974, at the rate of 24 lb PLS/acre.

The following list of forb species was broadcast in drifts (i.e., superimposed over the drilled grass planting) with forbs concentrated in relatively conspicuous portions of the site.

1. D-1, dry prairie mix 1: Coreopsis palmata, Liatris cylindracea, Lespedeza capitata, Petalostemum purpureum, Solidago nemoralis, and Solidago speciosa;
2. D-2, dry prairie mix 2: Amorpha canescens, Lespedeza capitata, Ratibida pinnata, Rudbeckia hirta, and Solidago rigida;
3. M-1, mesic prairie mix 1: Amorpha canescens, Baptisia leucantha, Echinacea pallida/purpurea, Liatris aspera, Rudbeckia hirta, Solidago rigida, and Solidago speciosa;
4. M-2, mesic prairie mix 2: Amorpha canescens, Lespedeza capitata, Monarda fistulosa, Ratibida pinnata, and Solidago rigida;
5. M-3, mesic (semi-shade tolerant) mix 3: Anemone cylindrica, Helianthus strumosus, Monarda fistulosa, Rudbeckia hirta, Rudbeckia subtomentosa, and Veronicastrum virginicum;
6. M-4, mesic mix 4: Ascelpias tuberosa, Ceonothus americana, Echinacea pallida/purpurea, Liatris aspera, Solidago speciosa, and Veronicastrum virginicum;
7. W-1, wet prairie mix 1: Liatris pycnostrachya, Pycnanthemum virginianum, Ratibida pinnata, Rudbeckia subtomentosa, and Veronicastrum virginicum;
8. W-2, wet prairie mix 2: Aster novae-angliae, Rudbeckia subtomentosa, and Solidago graminifolia; and
9. W-3, wet (tall) prairie mix 3: Asclepias incarnata, Eupatorium maculatum, and Rudbeckia subtomentosa.

Aesthetic considerations led to the exclusion of the tallest prairie grass species immediately adjacent to the interior driveway, even though the physical characteristics of the site would have been suitable for them. It was felt that the tallest species would block the more distant prairie views and would contrast too extremely with the mowed lawn on the other side of the driveway. Aggregations of forbs were placed, in part, where they would create the greatest visual impact.

All forb seed was hand collected during the fall and winter 1973, with more than 150 lb of 27 forb species collected by students who were paid by General Electric. Prairie dropseed (Sporobolus heterolepis) and cordgrass (Spartina pectinata) were also hand collected and provided to the landscape contractor for planting in the spring. All remaining grass seed was obtained from a commercial source in eastern Nebraska.

Site Preparation

Originally, on the suppostion that annual ryegrass had been seeded in August 1973, the plan was to mow the erosion-controlling ground cover in the spring 1974, drill the grasses into the stubble, and then broadcast forb seed into it. In practice, the

Table 1. Grass seed mixes, General Electric prairie restoration.

Mix	Species	Percentage by Weight
Short grass 1	Andropogon scoparius	75
	Bouteloua curtipendula	10
	Stipa spartea	15
Short grass 2	Andropogon scoparius	70
	Sporobolus heterolepis	10
	Bouteloua curtipendula	10
	Stipa spartea	10
Dry hillside	Andropogon scoparius	40
	Andropogon gerardi	10
	Sporobolus heterolepis	10
	Bouteloua curtipendula	20
	Stipa spartea	10
	Sorghastrum nutans	10
General	Andropogon gerardi	40
	Sorghastrum nutans	30
	Panicum virgatum	15
	Andropogon scoparius	15
Swales and low area	Andropogon gerardi	50
	Spartina pectinata	10
	Panicum virgatum	40

annual ryegrass came back vigorously in the spring 1974 and, as a way of suppressing the lush new growth, much of it was sprayed with paraquat in early May 1974. This is not a recommended treatment today, and roundup would now be considered for this situation.

The portions of the site in the early stages of old-field succession were plowed deeply (12 in) as soon as the soil could be worked in 1974, and disked just before planting time with the objective of killing any already germinated weedy species.

Seeding and Planting

A rented Nesbit seed drill was used by a local landscape contractor for seeding the grasses into the site during the May 15-June 6 period. The drill was run in one direction, and then a second pass was made over the same area, this time perpendicular to the first pass. Different seed mix zones were laid out in the field by using stakes and colored flagging tape based on the previously prepared grass planting plan.

Forb islands were hand broadcast and hand raked within a few days of the grass seed drilling. These areas were also marked on the ground by small stakes with colored flagging tape color-coded to the seed mix. In addition to the seeding, year-old transplants of nine forb species were planted in relatively conspicuous locations in an effort to accelerate flowering on the site.

Early Maintenance

The entire prairie planting was mowed to about 4 in on or about July 20, 1974. Grasses had appeared and were, in many cases, 1-4 in tall at this time. Dense areas of forbs had also appeared but were very short (i.e., less than 2 in tall for the most part), so the mowing was not detrimental to them. A slightly higher August and September mowing occurred for the purpose of cutting fast-growing annual weeds that otherwise would have provided unnecessary competition for light and nutrients.

Almost no maintenance or management of the planting was performed during the subsequent five years, i.e., through the 1979 growing season. Because of this, the General Electric restoration provides some insight into what can happen with a plant-and-neglect approach.

A record or near-record drought occurred during 1976. Its occurrence in the third growing season, after the reintroduced native species had established their deep and fibrous roots, gave them a competitive edge over many non-native species such as quackgrass (Agropyron repens) with its shallow network of rhizomes.

On April 19, 1980, a controlled burn of almost the entire prairie planting was conducted. It was overdue in the sense that a great quantity of dead material from the six previous years' growth had accumulated and was suppressing new growth.

Assessment of General Electric Prairie Planting

In late 1978 and 1979, visual analyses of the prairie planting suggested that it was providing the erosion-controlling cover that was part of the original intent. At a broad level of visual analysis, it also had the character of prairie, with the different combinations of grasses blending into each other and with somewhat more pronounced aggregations of forbs in the originally planted drifts.

In the fall 1979, a more detailed analysis was initiated, when a permanent sampling grid was established with 110 sampling points located and marked at 100-ft intervals throughout a central portion of the planting. In addition, three north-south transects, 150 ft in length, were laid out to determine presence of species at 1-ft segments of the line. The transects crossed an area in which the dry hillside grass mix was drilled in 1974 and in which forb mixes M-1, M-2, and M-3 were broadcast.

Of the six grass species planted, four occurred in more than 5 percent of the 1-ft segments. These were Andropogon scoparius (64.4 percent), Panicum virgatum (25.6 percent), Bouteloua curtipendula (14.0 percent), and Sorghastrum nutans (5.8 percent). Andropogon gerardi occurred in less than 4 percent of the segments. Sporobolus heterolepis did not appear along the transect.

Of the 15 forb species planted in zones crossed by the transects, 8 appeared along the transect and others were noted as occurring but not crossing the transect. By far the most abundant forb, on the basis of its observed frequency, was yellow coneflower (Ratibida pinnata), followed by bergamot (Monarda fistulosa), black-eyed susan (Rudbeckia hirta), and showy goldenrod (Solidago speciosa).

Eight exotic weed species occurred in more than 2 percent of the 1-ft segments of the transects. These included, in descending order, Kentucky bluegrass (Poa pratensis), sweet clover (Melilotus alba), dandelion (Taraxacum officinale), thistle (Cirsium spp.), alfalfa (Medicago sativa), timothy (Phleum pratense), quackgrass (Agropyron repens), and meadow goatsbeard (Tragopogon major).

Observations continued during the summer 1980 to determine both the overall visual aspect and more detailed presence and absence data. Initial analyses indicate that the planting has benefitted from the April 1980 burn. The distant views are increasingly prairielike. Close-up views are highly variable. Some of the most prairielike segments of the property are wet areas where cordgrass (Spartina pectinata), swamp milkweed (Asclepias incarnata), joe pyeweed (Eupatorium maculatum), and sweet black-eyed susan (Rudbeckia subtomentosa) occur with no visible exotic species.

The plantings of forbs in dense aggregations have not changed in form to any degree. As a result, they appear almost too pronounced, especially when the yellow coneflowers are in bloom. Meanwhile, the areas with only grasses planted would benefit visually from some contrasting color and texture, if only in small quantities.

Overall, the planting is achieving the original objectives. Refinements and modifications are suggested for future plantings of this nature--e.g., the inclusion of more species that bloom earlier in the summer and a thin seeding of forbs included with the grass seeding. However, the visual effect, especially as seen late in the season, is becoming more like a true prairie. With a continuing program of management by carefully timed burns, the prognosis for this planting is bright.

SUMMARY

There is now sufficient experience and documentation of prairie-restoration work to suggest that this alternative is a viable one to pursue, particularly on large land areas. Continuing study of already planted projects, such as the General Electric restoration, will yield additional helpful information.

Some areas of future research are also worth noting. We need more information on actual seeding densities and reliable information on expected purity and germination rates. We need a more reliable way to measure success of a planting, at one, two, and three years after planting, especially for plantings that are done under contract. Sources of local seed in quantities sufficient for large sites are needed in many areas.

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