Miscanthus sinensis

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FEIS ABBREVIATION:
MISSIN

NRCS PLANT CODE [108]:
MISI

COMMON NAMES:
Chinese silvergrass
Chinese silver grass
eulalia

Japanese silver grass
zebra grass

TAXONOMY:
The scientific name of Chinese silvergrass is *Miscanthus sinensis* Andersson (Poaceae) [24,36,38,50,65,116]. Hitchcock [38] recognizes 3 varieties in the United States:

Miscanthus sinensis var. *gracillimus* Hitchc. (narrow blades)
Miscanthus sinensis var. *variegatus* Beal (blades striped with white)
Miscanthus sinensis var. *zebrinus* Beal (blades banded or zoned with white)

Various Chinese silvergrass infrataxa occur in Taiwan and Japan ([8], review by [96]).

Under cultivation, Chinese silvergrass is often hybridized with other species of this genus [12], particularly with *M. sacchariflorus* to create the hybrid *Miscanthus* × *giganteus* [49]. More than 50 cultivars of Chinese silvergrass have been introduced to North America since 1980 [70].

SYNONYMS:
None

LIFE FORM:
Graminoid

DISTRIBUTION AND OCCURRENCE

SPECIES: Chinese silvergrass

- GENERAL DISTRIBUTION
- HABITAT TYPES AND PLANT COMMUNITIES

GENERAL DISTRIBUTION:
Chinese silvergrass is nonnative to North America. It occurs in "pockets" [31] in most eastern states from Massachusetts south throughout the mid-Atlantic and southeastern states to Florida and across the South to Louisiana. It occurs in several Great Lakes states including Ohio, Michigan, and Illinois and also in Ontario, Canada. In the West, it occurs in Colorado and California [81,108]. Because it is widely used as an ornamental in many parts of North America [71,72,98] and escapes cultivation [40,65,70,77], Chinese silvergrass may occur in other locations in North America. At the time of this writing (2010), Chinese silvergrass was not considered a major invader of wildlands in any area of North America; however, based on invasive species rankings and publications, there appears to be more concern over its spread in the eastern half the United States than in the western half [17,31,61,104,114]. Plants Database provides a distributional map of Chinese silvergrass's North American range.

Chinese silvergrass is native to Asia [36,38,72,98,117]. Its range extends north to the Kuril Islands (Russia) in the subarctic and to the islands of Hokkaido (Japan), south and west throughout the main islands of Japan, the Korean peninsula, eastern China, and to the subtropics in Ryukyu (Japan) and Taiwan ([83], review by [96]). The islands of Habamai and Yuzhno-Sakhalinsk in Russia may be the northern limit of Chinese silvergrass (Shimada and others 1992 cited in [96]).

Although it is unclear exactly when and where Chinese silvergrass was introduced to North America, several floristic surveys from the eastern United States indicated that by the early 1940s, Chinese silvergrass occurred along roadsides, railroad tracks, and many other places in New Jersey [76], Pennsylvania [76,77], and West Virginia [16]. In 1942, Moldenke [76] described Chinese silvergrass as "abundantly naturalized" in Washington, DC. Chinese silvergrass

continued to spread in the eastern United States and to other parts of North America, but it is unclear how or when this occurred.

HABITAT TYPES AND PLANT COMMUNITIES:
In North America, Chinese silvergrass primarily invades anthropogenically altered sites (see General habitat); there are few examples in the literature of it invading wildlands. Invasive plant guides indicate that Chinese silvergrass invades native grasslands on Cape Cod [112] and in the Upper Great Lakes area [17]. In Maryland, Chinese silvergrass occurred in deciduous woodlands dominated by oaks (*Quercus* spp.) and other deciduous trees. The woodlands were generally wet to mesic and often occurred near the edges of swamps [95]. Chinese silvergrass occurred but was rare in a longleaf pine (*Pinus palustris*) ecosystem in the Sandhills region of the southeastern United States [93].

In Japan where it is native, Chinese silvergrass is the dominant species in many grasslands [46,54,83,100,111,113]. One publication estimated that Chinese silvergrass grasslands represented about 25% of all natural or seminatural grassland area in Japan [46]. In Japan, Chinese silvergrass grasslands typically contain a diverse assemblage of herbaceous species [96]. A 15-year-old Chinese silvergrass-dominated grassland in Japan contained 96 plant species representing 42 families. The upper vegetation stratum (3-7 feet (1-2 m) tall) was comprised solely of Chinese silvergrass; the intermediate stratum (2-3 feet (0.5-1 m) tall) contained several tall herbs, shrubs, lianas, and tree seedlings; and the lowest stratum (0-2 feet (0-0.5 m) tall) contained short herbs and rosettes of taller herbs [78]. Another Chinese silvergrass-dominated grassland in Japan contained about 25 species [83]. Chinese silvergrass grasslands occurring on slopes may have greater species diversity than those on the valley floor (Koyanagi and others 2008 cited in [96]). In some Chinese silvergrass grasslands, dense shade from its leaves may prevent other species from establishing [21], and species diversity may be lower in Chinese silvergrass grassland occurring on degraded sites [83].

Species most commonly associated with Chinese silvergrass grasslands in Japan include western bracken fern (*Pteridium aquilinum*) ([27,34,35,43,46,83], Koyanagi and others 2008 cited in [96]) and bicolor lespedeza (*Lespedeza bicolor*) ([35,83,103], Koyanagi and others 2008 cited in [96]), although a variety of other herbaceous species may also be present [6,35,46,83,103,113]. In Chinese silvergrass grasslands, C_3 grasses typically dominate in early spring; by summer and fall, dominance shifts to C_4 species, including Chinese silvergrass (review by [96]).

In its native range, Chinese silvergrass is occassionally an understory dominant in forest or shrubland. In Japan, Chinese silvergrass occurred in a Japanese red pine (*Pinus densiflora)* forest [28] and was a characteristic species in a ring-cup oak (*Quercus glauca*)-Japanese red pine evergreen broadleaf forest [105]. In subtropical Asia, Chinese silvergrass is a codominant groundlayer species in Benguet pine (*P. kesiya*) forests [27]. In the Philippines, Chinese silvergrass was a dominant ground layer species in a Benguet pine-dominated forest. Its dominance was greatest on slopes around 7,500 feet (2,300 m) in elevation and declined with decreasing elevation [60]. On a slope of an active volcano (last major eruption 1929) in Japan, Chinese silvergrass occurred on bare ground and in shrubland dominated by Miquel's spicywintergreen (*Gaultheria miqueliana*) and *Salix reinii* [110].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Miscanthus sinensis

- GENERAL BOTANICAL CHARACTERISTICS
- SEASONAL DEVELOPMENT
- REGENERATION PROCESSES
- SITE CHARACTERISTICS
- SUCCESSIONAL STATUS

GENERAL BOTANICAL CHARACTERISTICS:

- **Botanical description**
- **Raunkiaer life form**

Botanical description: This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [24,36,36,38,65,87]).

Aboveground: Chinese silvergrass is a perennial [37,84] grass. In North America, Chinese silvergrass is 3 feet (1 m) [87] to 10 feet (3 m) tall [23,36,38,98]. Studies from Japan indicate that Chinese silvergrass does not get taller than 6 feet (2 m) [34,78,100,103,113], but in the Philippines it may grow taller than 10 feet (3 m) [21]. Chinese silvergrass may be taller in warmer climates [14]. A clump of Chinese silvergrass may attain a width equal to its height at maturity [29]. Individual leaf blades are up to 3 feet (1 m) long and from 0.8 inch (2 cm) [38,87] to 4 inches (10 cm) wide [36]. Its flowers occur in a panicle [31,65] that is 6 to 24 inches (20-61 cm) long [31] and consists of an aggregate of racemes 4 to 8 inches (10-20 cm) long [38]. Chinese silvergrass seed collected from a Japanese grassland measured an average of 2.1 mm long × 0.8 mm wide [35].

Belowground: Chinese silvergrass is rhizomatous [14,31,57]. Information pertaining to Chinese silvergrass's underground structure is limited to what is known about it from its native range, primarily Japan. In a grassland where Chinese silvergrass was the second most dominant species, most of the rhizomes were restricted to the top 8 inches (20 cm) of the soil [34]. In another grassland, most Chinese silvergrass rhizomes were in the upper 4 inches (10 cm) of soil, and most of the roots were in the upper 20 inches (60 cm) of soil, although some roots extended as far down as 47 inches (120 cm) (review by [96]).

Fifty percent of Chinese silvergrass's biomass is underground [33]. In Japan, Chinese silvergrass rhizomes branched 3 times/year on average, and 62% of the new branches developed aboveground shoots during that year. The average length of newly branched rhizomes producing shoots was 1.9 inches (4.7 cm) (Matumura and others 1986 cited in [96]).

Stand structure: In Japan, Chinese silvergrass forms distinct patches that may be monoclonal [57]. Shoots within a patch are connected by branching rhizomes. In a grassland in Japan, Chinese silvergrass patches ranged from 1 to 3.75 square feet (915-3,480 cm²) in size and contained 98 to 339 shoots/patch [58]. In another Japanese grassland, the average number of Chinese silvergrass patches in 20-foot² (2 m²) plots was 6.0. The estimated age of the largest patch was 15 years. Chinese silvergrass cover within the plot ranged from 6% to 50% [78]. In an international study of 5 countries, Chinese silvergrass's average shoot density ranged from 57 shoots/m² to 167 shoots/m² [14]. In the Philippines, Chinese silvergrass culms radiate upward and interlock with those of adjacent clumps, often forming a passageway about half a meter high, leaving the ground rather open between clumps. On gentle slopes, Chinese silvergrass may form near monocultures, becoming less dominant on steeper slopes [21]. Reduced light and other resources in the center of a patch causes center shoots to die, resulting in the formation of a 'fairy ring' of surviving peripheral shoots [58,96].

Raunkiaer [88] **life form:**
Hemicryptophyte
Geophyte

SEASONAL DEVELOPMENT:
Information pertaining to Chinese silvergrass's North American phenology is limited. It is a warm-season grass [37,84]. One nursery publication indicated that 'Gracillimus', a Chinese silvergrass cultivar, flowers in October in Portland, Oregon [29]. Floras from the northeastern United States [65] and North and South Carolina indicate that Chinese silvergrass flowers from September through November [87]. One invasive species manual from the Southeast indicates Chinese silvergrass flowers from August to November and produces seed from September to January [72].

In Japanese grasslands, Chinese silvergrass begins growing in April [78,118] or early May [80,118] and continues through August [51,103,118], or in some locations, into November [57,78]. In the warmer regions of Japan, shoots emerge between June and November [58]. One publication from Japan indicated that Chinese silvergrass flowers from

September to October [33]. In Japan, Chinese silvergrass plants occurring at high latitudes or elevations may flower as much as 2 months earlier than those at lower latitudes and elevations (Adati 1958 cited in [96]). Chinese silvergrass undergoes end-of-season shoot senescence [57], and in some locations, culms become yellow and begin to wither in September [118]. Shoots developing late in the season may survive the winter [57].

Chinese silvergrass may undergo seasonal changes in its rhizome carbohydrate reserves. In Japan, carbohydrate content in Chinese silvergrass rhizomes was depleted in June when new shoots were developing [46] but was restored in the fall after plants flowered [45,46].

REGENERATION PROCESSES:

- **Pollination and breeding system**
- **Seed production**
- **Seed dispersal**
- **Seed banking**
- **Germination**
- **Seedling establishment and plant growth**
- **Vegetative regeneration**

Chinese silvergrass spreads vegetatively by rhizomes and also by seed (73, review by [96]). In established populations of Chinese silvergrass, very little reproduction occurs from seed [21]. An invasive species manual from the southeastern United States indicated that some cultivars are assumed to be mostly sterile [72].

Pollination and breeding system: Chinese silvergrass is wind pollinated and may be self-incompatible (review by [96], Nishiwaki 1992 cited in [58]); however, an invasive plant guide from New England indicated that many Chinese silvergrass cultivars may self-seed [70]. Seed set percentage may depend on Chinese silvergrass density and distance between plants (review by [96]). One variety of Chinese silvergrass from Taiwan may reproduce by apomixis, while another variety is considered an outcrosser [8].

Seed production: Based on a study from Japan, seed production of individual Chinese silvergrass plants ranged from 64 to 1,051 seeds [33]. In Japanese grasslands, Chinese silvergrass produced 535 [35] to 8,000 seeds/m² (Nishiwaki and others 1996 cited in [96]) and 40,000 to 140,000 seeds/m² in warm areas with high levels of precipitation (Ogato and Nagatoma 1971 cited in [96]). The average weight of Chinese silvergrass seed ranges from 0.87 [79] to 0.96 mg/seed [33].

Seed dispersal: Chinese silvergrass seed is dispersed by wind [21,28,33,70,79,84,85].

Seed banking: In Japan, Chinese silvergrass forms a soil seed bank, but densities may vary depending on the plant community and season. In a Chinese silvergrass-dominated grassland, 80% of the Chinese silvergrass seeds collected from the soil seed bank were viable. The average number of buried Chinese silvergrass seeds in a 3 × 3 × 0.3-foot (1 × 1 × 0.1 m) plot was 875 in the spring and 340 in the summer. In grasslands dominated by other species, the average number of buried Chinese silvergrass seeds in the same size plot was 1,933 seeds in the spring and 1,980 seeds in the summer. In both Chinese silvergrass and Korean lawngrass (*Zoysia japonica*) grasslands, Chinese silvergrass soil seed bank density was greatest in the first 0.8 inch (2 cm) of soil and declined sharply in samples collected from deeper depths. Chinese silvergrass viable seed density was 10 times greater in the Korean lawngrass stand than in stands dominated by Chinese silvergrass [35].

Vertical soil distribution of Chinese silvergrass seed in Japanese grasslands in 8 plots (10 ×10 × 10 cm²) [35]					
Depth (cm)	0-2	2-4	4-6	6-8	8-10
Average number of	48	5	5	4	8

Chinese silvergrass seeds					

In Japan, soil samples (3 feet² × 4 inches deep (1 m² × 10 cm)) were taken from three grasslands with average Chinese silvergrass cover of 34.0%, 69.0%, and 76.5%. Grasslands contained an average of 220, 630, and 600 viable Chinese silvergrass seeds/plot, respectively. Samples of the same size collected from a shrubland with 18.7% Chinese silvergrass cover contained an average of 30 viable seeds per sample [111].

The density of viable Chinese silvergrass seed in the soils of various forest communities in southwestern Japan ranged from 0 to 2,238 seeds/0.4 m² plot at a depth of 4 inches (10 cm) and was generally higher in samples collected in fall rather than spring [79].

It is unclear how long Chinese silvergrass seeds stay viable in the soil. In the laboratory, Chinese silvergrass can be stored for at least 1 year without an appreciable loss of viability; the storage method is not critical. However, older seed may have a lower germination rate [9].

Germination: Germination testing indicates that Chinese silvergrass seed may have little dormancy and has a high germination capacity over a wide range of environmental conditions. In several greenhouse and laboratory studies, Chinese silvergrass seed began germinating within 6 days [84], and up to 69% to 100% of its seed germinated in 10 to 25 days [2,4,10,84]. In a laboratory, Chinese silvergrass seed germinated at temperatures from 59 to 90 F° (15-30 °C); optimum temperature was near 77 °F (25 °C). Chinese silvergrass seed germinated in a wide range of pH conditions, ranging from 4.3 to 8.5 [4]. One invasive species manual from the southeastern United States indicated that Chinese silvergrass seed viability may be variable [72].

Seedling establishment and plant growth: Information pertaining to seedling establishment and growth of Chinese silvergrass is limited. Broadcasting Chinese silvergrass seed onto the soil surface produced 15.5 seedlings/m² on average. Chinese silvergrass seedlings emerged within 10 days of being sown but "many" seedlings died from desiccation during the warm, dry conditions that occurred 3 to 4 weeks after sowing [10]. Seedling growth may be inhibited by high (≥8.5) or low (≤4.0) pH, resulting in reduced dry weight [4]. One literature review suggested that in "extremely" acidic soil, Chinese silvergrass may not reproduce by seed [96].

A review of Japanese literature indicated that average aboveground dry matter biomass of Chinese silvergrass ranges from 1.8 t/ha to 21.8 t/ha, although the latter is considered exceptionally high. Warmer climates of Japan may produce higher yields. More research is needed to determine how climate may influence Chinese silvergrass growth [96]. Chinese silvergrass seedlings, grown from seed collected from wild populations in the eastern United States, had an average shoot biomass of 0.08 ounce (2.3 g) and an average height of 17.9 inches (45.4 cm) 15 weeks after seed was planted [71].

Vegetative regeneration: Chinese silvergrass regenerates by sprouting from the rhizomes and by tillering. Rhizomes may aid the recovery of Chinese silvergrass if it is top-killed [35]. Researchers in Japan determined that individual Chinese silvergrass rhizomes survive for at least 3 years; mortality tends to increase for older rhizomes [45]. Under cultivation, however, 5-year-old Chinese silvergrass rhizomes were more productive than rhizomes that were either 1 or 9 years old [9]. Average fresh weight of Chinese silvergrass rhizomes 0 to 7 years old ranged from 7.92 to 31.55 g/0.25 m² and was greatest for rhizomes 1 to 3 years old [45]. Chinese silvergrass annual rhizome production has been estimated to be from 1.3 t/ha to 1.8 t/ha (review [96]). Others have estimated Chinese silvergrass's combined annual rhizome and root production to equal approximately 20% to 25% of its total underground biomass [45]. In a 3-year study of Chinese silvergrass in Japan, tillering occurred 2 to 3 times/year between June and November [57].

SITE CHARACTERISTICS:

Climate: Information pertaining to Chinese silvergrass relationship to climate in North America is limited to 2 localized examples. Chinese silvergrass occurred in a deciduous woodland in Maryland where the regional climate was described as mild temperate and rainy with no distinct dry season; summers were hot and winters mild. The average daily maximum temperature was 67.3 °F (19.6 °C) and average daily minimum temperature was 43 °F (5.9 °C). The warmest month was July and coldest months were January and February. The average total annual rainfall was 45.04

inches (1,144 mm), with the wettest month occurring in August and the driest month in February [95]. Chinese silvergrass occasionally occurred in a longleaf pine ecosystem of the Sandhills region in the southeastern United States that experienced 4 distinct annual seasons. Humid southwestern airflows predominated during late spring and summer, while northwesterly cold fronts alternated with easterly rainy spells during late fall and winter. Fall and spring were the driest seasons. The average winter temperature was 44 °F (6.9 °C), while the average summer temperature was 78.8 °F (26.0 °C). Annual precipitation averaged 47 inches (1,200 mm) of rain plus 3.0 inches (75 mm) of snow [93]. Temperature may influence Chinese silvergrass's elevational distribution (see Elevation).

In Japan, Chinese silvergrass occurs in subarctic, cool-temperate, and warm-temperate climates [83]. It has been reported on sites with annual mean temperatures ranging from 44 °F (6.5 °C) [34,51] to 64.8 °F (18.2 °C) [37,54,57,58,78] and annual mean precipitation ranging from around 47 inches (1,200 mm) [51,78] to 144 inches (3,670 mm) [34,37,54,57,58]. In a 3-year field test across several countries, Chinese silvergrass established and grew on sites where average annual rainfall from April to September ranged from 5.79 inches (147 mm) to 18.1 inches (459 mm) [14].

Tests performed in Europe indicate that Chinese silvergrass hybrids are tolerant of cold, although level of cold tolerance may vary between cultivars. Chinese silvergrass had greater tolerance of frost than other species of *Miscanthus*, which was attributed to lower moisture content in its rhizomes [11]. In field tests in Denmark and Sweden, Chinese silvergrass rhizomes survived winter soil temperatures below 24 °F (-4.5 °C) [14].

Elevation: Chinese silvergrass occurs at elevations <700 feet (200 m) in California [36]. At a National Historic Site in North Carolina, Chinese silvergrass occurred at a low elevations [115]. In Japan, Chinese silvergrass has been reported from 1,000 (400 m) [80] to 5,900 feet (1,800 m) [34,74,110].

A literature review indicated that elevation may influence Chinese silvergrass's growth and development [96]. Hayashi and Hishinuma [34] considered 4,300 feet (1,300 m) to be near the limits of Chinese silvergrass's distribution in Sagadaira, Japan. At this elevation, growth may not be sufficient to form monocultures [34]. Other reports from Japan indicate that Chinese silvergrass occurred at elevations from 5,410 to 5,810 feet (1,650-1,770 m) but dominated only around 5,410 feet (1,650 m). Researchers attributed lower cover of Chinese silvergrass at higher elevations to a reduction in mean annual temperature [74]. In the Philippines, Chinese silvergrass dominated the groundlayer vegetation at elevations from 5,380 to 7,500 feet (1,640-2,300 m). Its dominance declined at lower elevations and in valley grasslands [60].

General habitat: In North America, Chinese silvergrass occurs primarily in anthropogenically altered sites such as previously cultivated fields, vacant lots, yards, gardens, irrigation ditches, along roadsides and railroad tracks, and near old home sites and cemeteries [19,32,36,65,69,70,75,76,87,93,107]. It occasionally occurs in wildlands or on the fringe of wildlands in deciduous woodlands [95], coniferous forests [93], forest clearings [31,99], and in grasslands [17,70,112].

Substrate and pH: In Japan, Chinese silvergrass occurs in most soil textures ([47,54], Jinno and Umeno 1995 cited in [96]). In one study, Chinese silvergrass occurred in mountain grasslands that contained a thick humus layer [118]. Chinese silvergrass grasslands may occur on volcanic ash or volcanic ash-like soil [53,118]. On these sites, large amounts of dead plant material, produced by dying Chinese silvergrass, is incorporated into soil organic matter each year [53,91,92,118].

Available information indicates that Chinese silvergrass prefers moist but not saturated soils. A nursery publication from Oregon stated that the cultivar 'Gracillimus' tolerates wet soil but prefers well-drained soil [29]. One study from Japan claimed that Chinese silvergrass does not grow well where the A horizon is shallow and the amount of moisture in the soil is relatively low [51]. Soil moisture content in Chinese silvergrass-dominated riparian communities in Japan ranged from 14% to 25% (Jinno and Umeno 1995 cited in [96]). In another Chinese silvergrass grassland in Japan, moisture content for the A, B, and C horizons ranged from 46% to 52% [34]. In the Philippines, Chinese silvergrass occurred near a bog but did not readily invade areas that were inundated with water for part or all of the year [21]. In a pine forest in the Philippines, Chinese silvergrass occurred on moist "protected" sites [60]. Chinese silvergrass hybrids are being developed to improve drought tolerance [13].

Chinese silvergrass occurs in a wide range of soil acidities. In Japan, Chinese silvergrass grasslands have soil pH from 3.8 [52,53] to 6.5 [26,34,52,53,100]; however, seedling establishment may be inhibited on sites with very low or high pH (see Seedling establishment and plant growth). Soils in Chinese silvergrass grasslands may be slightly more acidic in the B and C horizons than in the A horizon [34]. On sites where Chinese silvergrass distribution was scattered, soil pH ranged from 2.7 to 6.8 [2]. In eastern Asia, Chinese silvergrass excretes citric acid, allowing it to grow in acidic soils containing high concentrations of aluminum [52]. In Japan, Chinese silvergrass is a dominant species in acidic volcanic ash soils [118]. Landscapers from Portland, Oregon, recommend that Chinese silvergrass cultivars be planted in slightly acidic soil, preferably enriched with organic material [29].

SUCCESSIONAL STATUS:

Shade tolerance: Available evidence at the time of this publication (2010) indicates that Chinese silvergrass grows in full sun but tolerates at least some shade. An invasive species guide from Massachusetts stated that Chinese silvergrass grows in full sun [66]. Landscapers in the Portland, Oregon, recommend that Chinese silvergrass cultivars be planted in full sun to slight shade [29]. One invasive species publication from the southeastern United States stated that Chinese silvergrass is shade tolerant [72]. In southeastern Kentucky, Chinese silvergrass is commonly found in secondary Cumberland Plateau woodlands [68]. In Japan, Chinese silvergrass was the second most dominant species on a site shaded by a 49-foot (15 m) tall Japanese-cedar (*Cryptomeria japonica*). The maximum light intensity at that site was 67% (even at the most unshaded time of the season) compared to a sunny site that was not shaded [59]. In a pine forest in the Philippines, Chinese silvergrass cover was unaffected by canopy cover [60].

Potential successional stages: In Japan, Chinese silvergrass-dominated grasslands are typically considered seral stages in secondary succession [83] that eventually transition to forests [25,26,35,51,78,80,83] or Korean lawngrass-dominated grasslands (Itow 1962 cited in [96]). In the absence of fire, Chinese silvergrass grasslands have converted to forest within 20 [26] to 100 [25] years.

In Japan, Chinese silvergrass establishes during early stages of secondary succession [85] in young tree plantations [37] or forest clearcuts [45]. Chinese silvergrass may also establish in grasslands shortly after pioneering short-grass species begin to decline [83]. Chinese silvergrass also establishes during the initial stages of primary succession [33] or during early secondary succession on volcanic sites [100]. Once established, Chinese silvergrass grasslands may persist for several decades or even for a century before transitioning to other communities (Sakanoue 2001 cited in [96]).

Available evidence suggests that successional changes in Chinese silvergrass may be influenced by habitat and resource availability. In Japan, the relative dominance of Chinese silvergrass in plant communities increased faster on ridge and slope habitats compared to valley habitat, leading researchers to speculate that resource availability in different habitat types and/or topographical features may influence Chinese silvergrass's growth and its subsequent successional patterns [85]. In Chinese silvergrass grasslands in the Philippines, dense shade from Chinese silvergrass leaves may prevent later-successional species from establishing [21], particularly pine seedlings [60]. Researchers in Japan speculated that seasonal changes in light availability in Chinese silvergrass grasslands may influence the establishment and subsequent growth of tree seedlings [103]. On abandoned ski slopes in Japan, tree seedlings established better in patches of Chinese silvergrass than in patches of other native and nonnative grasses, leading Tsuyuzaki [106] to speculate that Chinese silvergrass grasslands may facilitate successional transitions toward forest. In the Philippines, Chinese silvergrass surrounding bogs may eventually dominate the bogs if standing water is drained [21].

In Japan and the Philippines, most Chinese silvergrass grasslands are artificially maintained as "subclimax" communities by mowing, grazing, and burning [21,25,26,35,46,78,80,82,83], with 2 exceptions. On volcanic soils, Chinese silvergrass dominated "subclimax" grasslands under "natural" conditions [118]. Chinese silvergrass grasslands occurring at high elevations above the tree line may persist in late succession without human intervention [83].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Miscanthus sinensis

- FIRE EFFECTS
- FUELS AND FIRE REGIMES
- FIRE MANAGEMENT CONSIDERATIONS

FIRE EFFECTS:

- **Immediate fire effect on plant**
- **Postfire regeneration strategy**
- **Fire adaptations and plant response to fire**

Immediate fire effect on plant: Several studies from Japan suggest that Chinese silvergrass is generally top-killed by fire [28,35,46,47]; however, its rhizomes typically survive (see Fire adaptations). In experimental plots, 0% to 83% of Chinese silvergrass culms were top-killed by spring and early summer prescribed fire [46]. Spring fire may have less immediate impact on Chinese silvergrass than summer fire, particularly in areas where it does not fully emerge until May. Fire temperature may influence the percent of Chinese silvergrass culms top-killed by fire (see Plant response to fire).

Postfire regeneration strategy [97]:
Rhizomatous herb, rhizome in soil
Tussock graminoid

Fire adaptations and plant response to fire:

Fire adaptations: Chinese silvergrass survives fire primarily because of its ability to sprout from rhizomes [28,35,46,47] and tillering [46,47], but it may also establish from seed after fire [28]. One study from Japan indicated that when aboveground culms of Chinese silvergrass are destroyed by fire or mowing, regeneration occurs primarily from rhizomes rather than from seed [35]. Chinese silvergrass regenerated from both rhizomes and seeds in a Japanese red pine forest after a March prescribed fire; however, postfire regeneration was substantially greater from rhizomes (average 0.62 rhizome sprout/m²) than from seed (average 0.02 seedling/m²) [28].

Plant response to fire: Information available as of 2010 suggests Chinese silvergrass responds favorably to fire. One invasive plant publication from the southeastern United States indicated that Chinese silvergrass establishes and spreads easily , particularly after burning [72]. In Japan, Chinese silvergrass grasslands are maintained with regular annual burning [26,46,80,92]. A regression model developed for pine forests and grasslands in the Philippines indicated that Chinese silvergrass's importance tended to increase with time since fire. In a pine forest, Chinese silvergrass dominated the ground vegetation, which had not burned for over 5 years; however, Kowal [60] speculated that that if fire continued to be excluded, most of the pine forest and adjacent grassland would eventually be replaced by montane forest species.

Studies from Japan suggest that fire may increase tillering [46,47], accelerate leaf emergence, and increase photosynthetic rates [47] in Chinese silvergrass. Fujita [20] observed increased chlorophyll content in Chinese silvergrass after fire and attributed it to postfire increases in soil nitrogen. A survey from the Philippines suggested that fire facilitates Chinese silvergrass growth by "opening up the vegetation and restoring ashes to the ground" [21]. One review indicated that charred residues of Chinese silvergrass contribute to the accumulation of humus on some sites in Japan [96].

Fire may damage Chinese silvergrass culms (see Immediate fire effect on plant), but plants typically recover quickly by tillering and sprouting from rhizomes. In a Chinese silvergrass grassland burned in April or May (when Chinese

silvergrass's rhizome starch reserves are high and culms are not fully emerged (see Seasonal Development)), tillering was 2 to 4 times greater in burned plots than in the unburned plot. By fall of the same year, Chinese silvergrass abundance (based on height, dry weight, or culm number) on burned plots was nearly equal to that on the unburned plot [46,47]. In plots burned in June of that same year, Chinese silvergrass recovery was slower, but by the next growing season, the number of Chinese silvergrass culms exceeded those observed in plots burned in April or May [46].

Fire may not favor Chinese silvergrass in all instances. In Japan, a Chinese silvergrass-dominated grassland transitioned to a bicolor lespedeza stand after being burned repeatedly in early spring [35]. In another Chinese silvergrass grassland, Chinese silvergrass persisted on a site that had been burned annually; however, its growth was greater on unburned sites than on burned sites [80].

FUELS AND FIRE REGIMES:

- **Fuels**
- **Fire regimes**

Fuels: Invasive plant publications from southeastern United States indicate that Chinese silvergrass is considered highly flammable and a fire hazard [18,72,99]. A survey from the Philippines suggested that Chinese silvergrass provides abundant "material" for fire [21]. In Japan, annual prescribed fire consumes dead [27,78] Chinese silvergrass culms and litter [25]. Chinese silvergrass litter is typically greatest in May when plant material from the previous growing season has accumulated. Its litter decomposes gradually over the growing season, reaching its lowest abundance in October [34]. In an experimental Chinese silvergrass grassland in Japan, the amount of dried grasses and litter before fire ranged from 330 g/m² to 950 g/m². Prior to burning, the fuel was "pushed down" to resemble early spring conditions and spread out to <20 inches (40 cm) above the soil surface. The fire's spread rate ranged from 0.5 to 4.0 m/minute in fall fires, and from 0.7 to 1.4 m/minute in spring fires [46]. In another Chinese silvergrass grassland in Japan, "fire ran quickly on the soil surface" [92].

In subtropical Asia, Chinese silvergrass is a codominant groundlayer species in Benguet pine forests. During the dry season, cured grasses and pine litter favor the spread of surface fires, which tend to kill pine seedlings and other fire-sensitive vegetation. Pine stands with fires at short intervals (1-3 years) had little pine regeneration (Goldammer 1985 cited in [27]).

Fire regimes: Because little has been described about what types of plant communities are most vulnerable to Chinese silvergrass invasion in North America, it is unclear what fire regimes it is associated with or how it may influence fire regimes in North America. D'Antonio and others [18] speculated that the most "significant" effect of invasion by nonnative grasses in general is the potential of nonnative grasses to increase fire frequency and perhaps intensity because these grasses provide the fine fuels necessary for the initiation and propagation of fire [18]. NatureServe [81] suggested that Chinese silvergrass may alter fire regimes in plant communities it invades but provided no details or examples.

In Japan, Chinese silvergrass grasslands are maintained by annual prescribed fire [25,78,80], suggesting it is adapted to frequent fire. In subtropical Asia, Chinese silvergrass is a codominant groundlayer species in Benguet pine forests where fire may occur every 1 to 3 years; however, it is unclear if these fires are wild or prescribed. In this plant community, fire intensity and severity vary according to fire frequency. Annual fires usually consume dead organic matter including grasses. Where fire is excluded for long periods, wildfires tend to be of "extreme intensity" due to high fuel accumulation. Most fires take place during the dry season from the middle of January until May [27].

As of this writing (2010), detailed information on fire intensity and severity in areas where Chinese silvergrass occurs was limited to prescribed fires used to maintain Chinese silvergrass grasslands in Asia. Average fire temperatures and flame heights were measured for prescribed fires in a Chinese silvergrass grassland in Japan. Average fire temperature was greatest for spring fire, while average flame height was highest for fall fire. A complete list of fire temperatures and flame heights, weather, air temperature, wind spread and direction, fuel load, and rate of spread for individual fires is provided in the publication [47]. In another Chinese silvergrass grassland in Japan, charred plant material and half-

charred plants were scattered over an area that had undergone a prescribed fire [92], suggesting low to moderate fire severity.

See the Fire Regime Table for further information on fire regimes of vegetation communities in which Chinese silvergrass may occur.

FIRE MANAGEMENT CONSIDERATIONS:
In its native range, Chinese silvergrass is well adapted to fire and responds favorably after being burned (see Plant response to fire). In Japan, prescribed fire is used to maintain Chinese silvergrass grasslands by preventing encroachment of native woody species [26,54,78,80] and reducing accumulated litter ([25], review by [96]).

Information pertaining to the use of prescribed fire on Chinese silvergrass infestations outside its native range is lacking. Based on Chinese silvergrass's response to fire in its native range and a few observations from North America [18,72,99], it seems likely that existing populations of Chinese silvergrass would persist and potentially spread after fire, even on sites were Chinese silvergrass was not currently dominant. However, because Chinese silvergrass does not establish readily by seed and many Chinese silvergrass cultivars are thought to be sterile (see Regeneration Processes and Fire adaptations), the ability of Chinese silvergrass to spread onto burns where it did not previously occur may be limited.

Altered fuel characteristics: As of this writing (2010), information pertaining to Chinese silvergrass potential to alter fuel characteristics was lacking. However, grasses and grass-dominated systems in general provide fine fuels necessary for the initiation and propagation of fire [18].

FIRE EFFECTS

Leave this file blank; it is only here to run the bib program. Plans are underway to change the CRS program to match our new file structure.

MANAGEMENT CONSIDERATIONS

SPECIES: Miscanthus sinensis

- FEDERAL LEGAL STATUS
- OTHER STATUS
- IMPORTANCE TO WILDLIFE AND LIVESTOCK
- OTHER USES
- IMPACTS AND CONTROL

FEDERAL LEGAL STATUS:
None

OTHER STATUS:
Information on state-level noxious weed status of plants in the United States is available at Plants Database.

IMPORTANCE TO WILDLIFE AND LIVESTOCK:
One study indicated that reintroduced elk in Kentucky used Chinese silvergrass for forage, primarily in the summer and occasionally in the fall [90]. Based on its palatability to cattle, domestic goats, and domestic sheep, Vermont researchers speculated that Chinese silvergrass could be used as livestock forage in northern temperate regions [5].

In Korea and western Japan, Chinese silvergrass has been used for domestic livestock feed [37,41].

In Korea and Japan, birds use Chinese silvergrass for nesting [41,56]. A literature review gives a detailed description of Chinese silvergrass importance to wildlife in its native range of Japan, including its use by invertebrates [96]. Preliminary studies suggest that grasshoppers may influence the productivity of Chinese silvergrass grasslands [80]; however, in another study grasshoppers had little effect on the primary production of Chinese silvergrass [67].

Palatability and/or nutritional value: A literature review indicates that that Chinese silvergrass may be highly palatable to livestock [96]. In one study, cattle in Japan preferred Chinese silvergrass over other available grasses and herbs [37].

Cover value: No information is available on this topic.

OTHER USES:
In North America, Chinese silvergrass is widely sold as an ornamental grass for landscaping [17,71,72]. In Mississippi, it has been recommended for use as a vegetative hedge [64].

A literature review indicated that in its native range, Chinese silvergrass culms have been used for roof thatching on traditional buildings. It is used to make yellow dye and storage bags for charcoal. In Japan, Chinese silvergrass is used to stabilize easily erodible soils [96] and is planted to revegetate abandoned ski slopes [106].

Because Chinese silvergrass is highly productive and uses nutrients and water efficiently, it has been identified as a potential biomass energy crop [9,49]. Of particular interest is the sterile triploid Chinese silvergrass hybrid *Miscanthus* × *giganteus* [49]. In Europe, Chinese silvergrass has been evaluated as a potential fuel for electricity production [42]. In Korea and western Japan, it has been used for organic fertilizer [37,41].

IMPACTS AND CONTROL:
Impacts: Available evidence suggests that Chinese silvergrass may be invasive in some areas of North America; however, to what degree it impacts native plant communities and ecosystems is unclear. One greenhouse study determined that Chinese silvergrass grows well when planted with switchgrass (*Panicum virgatum*) [71]—a common and "aggressive" grass native to North American tallgrass prairies [38]—suggesting Chinese silvergrass may displace native grasses if it establishes in tallgrass prairies [71]. Based on Chinese silvergrass's popularity as an ornamental grass in the United States and its potential to become invasive in some situations, NatureServe [81] has given Chinese silvergrass an invasive species ranking of medium. Species given this ranking pose a moderate threat to native species and ecological communities [81].

Chinese silvergrass was indentified as one of a dozen invasive plants that land managers in the southern Appalachian states are most concerned about [61], and it is listed as invasive or potentially invasive in 6 southeastern states: Alabama [1], Georgia [22], Kentucky [55], Missouri [73], South Carolina [94], and Tennessee [104]. In Kentucky, Chinese silvergrass is considered a potential threat to whitehair goldenrod (*Solidago albopilosa*), an endemic in the Red River Gorge [114] that is federally listed as threatened [109]. Chinese silvergrass is considered potentially invasive in Connecticut [15] and forms large clumps that may displace native species throughout New England [70]. An invasive plant guide from the upper Great Lakes states indicates that Chinese silvergrass is a minor invader in wildlands, particularly grasslands [17]. In its native range, Chinese silvergrass is considered a weed on disturbed sites [89] and in tree plantations, where it suppresses planted saplings if not controlled [37].

In addition to displacing native plants, Chinese silvergrass may have other ecological impacts. Chinese silvergrass litter decomposes slowly (Matumura and others 1986 [96]), which may slow the return of nutrients to the soil, particularly in the absence of fire [96]. NatureServe [81] suggested that Chinese silvergrass may alter fire regimes in plant communities where it invades but gave no examples of this occurring.

Chinese silvergrass hybrids are being developed that produce high yields [9,12] and are tolerant to cold [11] or drought [13]. Introduction of these hybrids to North America could potentially increase Chinese silvergrass's spread.

Control: As of this writing (2010), information pertaining to Chinese silvergrass control in North America was limited to a few generalizations made regarding the use of physical or chemical controls. Researchers in Japan have had some success at controlling Chinese silvergrass through the use of livestock grazing (see Biological control).

Fire: For information on the use of prescribed fire to control this species, see Fire Management Considerations.

Prevention: Because Chinese silvergrass spreads vegetatively, it is best not to plant it adjacent to wildland areas. Sterile varieties are being developed to reduce its spread [9], but vegetative reproduction will likely be possible from these populations.

Cultural control: No information is available on this topic.

Physical or mechanical control: An Internet publication from the Mid-Atlantic states indicated that Chinese silvergrass may be controlled by hand-pulling seedlings and shallow-rooted plants. Swearingen and others [99] recommended that larger plants be dug out, including the entire root system, to prevent vegetative sprouting, and cautioned that mowing Chinese silvergrass may spread plants into new areas. An invasive plant guide from the upper Great Lakes states suggested manual or mechanical removal of Chinese silvergrass but provided no details on these methods [17].

In Japan, mowing is the most common practice used to control Chinese silvergrass in plantations [37]. One literature review indicated that mowing Chinese silvergrass grasslands 3 times/year decreased Chinese silvergrass's annual biomass production from 7.1 to 0.75 t/ha and reduced its height from 33 inches (85 cm) to 15 inches (38 cm) [96]; however, the source of this information was unclear.

Biological control: Widespread use of Chinese silvergrass as an ornamental makes it unlikely that a biological control will be developed for this species. Additionally, many ornamental plants, particularly Chinese silvergrass, are chosen because they have few biological enemies [101].

Studies from Japan indicate that Chinese silvergrass may have a low tolerance to livestock grazing ([37,113], review by [96]). In Japan, livestock preferred newly developing leaves of Chinese silvergrass, which have high photosynthetic capacity and contain high concentrations of nitrogen. Chinese silvergrass generally declines and vegetation dominance shifts to other species when livestock graze it (review by [96]). On a tree plantation in Japan, 4 years of livestock grazing reduced the average size of Chinese silvergrass plants. After the initial grazing season (190 days), the proportion of undefoliated Chinese silvergrass clumps and shoots "rapidly" decreased, leaving approximately 20% of clumps and 10% of shoots intact. Researchers concluded that cattle grazing could potentially control Chinese silvergrass in tree plantations but recommended further study to determine optimum grazing intensity [37].

Chemical control: One invasive plant publication suggested that periodic spot spraying with glyphosate beginning in spring—when the new shoots are 4 to 6 inches (10-15 cm) tall—until fall when the plants flower, may control Chinese silvergrass [31]. An invasive plant publication from the upper Great Lakes states indicated that a fall or late spring application of glyphosate controlled Chinese silvergrass [99]. The Tennessee Exotic Pest Plant Council [104] recommended a combination of imazapyr and glyphosate treatments in the fall for Chinese silvergrass control. Continued spot treatments may be necessary to kill new rhizome sprouts [31,104].

Integrated management: No information is available on this topic.

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