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Cottonwoods of the Midwest: A Community Profile

by Wilma Mitchell, Jean O'Neil, and Antisa Webb

PURPOSE: This profile was prepared to assist researchers at the U.S. Army Engineer District, Omaha and the U.S. Army Engineer Research and Development Center (ERDC) in preparing a community-based index model for the cottonwood (*Populus* spp.) community. The profile will also supply requirements and suggestions for restoration initiatives on the Missouri River. The cottonwood community is defined as a plant community dominated by cottonwood trees, with associated plant and animal species, commonly found in floodplains and the next higher elevations. This profile addresses two species of cottonwoods over their range but highlights Midwestern literature, specifically Nebraska and South Dakota. Preparation of the profile was funded as part of a reimbursable project for the Omaha District of the U.S. Army Corps of Engineers and the Community Templates research work unit in the Ecosystem Management and Restoration Research Program (EMRRP). Dr. Wilma A. Mitchell, Dr. L. Jean O'Neil, and Antisa C. Webb, ERDC Environmental Laboratory (EL), Vicksburg, Mississippi, prepared this technical note.

BACKGROUND: In their assessment of ecological communities that have been subjected to severe loss and degradation, Noss et al. (1995) provided literature that describes large percentage losses to the plant communities of many riparian and floodplain systems across the county. Lytle and Merritt (2004) cited numerous studies documenting the decline of the cottonwood community, with reasons largely related to changes in hydrologic flows in the last decades and related changes in groundwater and sediment movement. River regulation may cause declines in cottonwoods through manifestation of water stress and consequent reduced root and leaf structure (Williams and Cooper 2005). Specifically along the Missouri River, cottonwood stands are aging and dying without sufficient recruitment and maturation, leading to a concern for other resources of the river (U.S. Fish and Wildlife Service (USFWS) (2000), such as First Nation cultural elements, the threatened bald eagle (*Haliaeetus leucocephalus*), riparian fauna, and cavity-nesting birds (Shafroth et al. 1995).

Cottonwoods are large, fast-growing, deciduous trees widely adapted to moist, well-drained soils of streams, rivers, and floodplains across the United States and parts of Canada (Harlow et al. 1979) (Figure 1).

Cottonwoods live from 60 to 200 years; some individuals alive today likely co-existed with bison herds that roamed the Great Plains in past centuries (Great Plains Nature Center 2006). Recreations of even earlier vegetation patterns show cottonwoods as a component of the forested and floodplain

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Figure 1. Cottonwoods growing along the Missouri River.

environment (Nelson et al. 1997). Cottonwoods in the Midwest grow abundantly in alluvial floodplains and on upland prairies with adequate sources of moisture (Cooper and Van Haverbeke 1990). In the prairie states, a winding belt of green cottonwood crowns usually indicates the presence of a stream or water course (Harlow et al. 1979).

COTTONWOOD SPECIES: Cottonwoods belong to the same family (Salicaceae) as the willows (*Salix* spp.) and poplars (*Populus* spp.). The most widespread species in the Midwest are the eastern (*P. deltoides deltoides*) and plains cottonwoods (*P. deltoids occidentalis*) (Cooper and Van Haverbeke 1990). Cottonwood species found in the western United States include black cottonwood (*P. balsamifera trichocarpa*) on the west coast, Fremont cottonwood (*P. fremontii*) in the Southwest, and narrowleaf cottonwood (*P. angustifolia*) in western mountain ranges (Preston 1961). Swamp cottonwood (*P. heterophylla*) occurs on the southern coastal plain and in the Mississippi and Ohio River drainages (Johnson 1994). This note focuses on the eastern and plains cottonwoods that predominate in the Midwestern states. Taxonomy is frequently confusing because these species hybridize at overlapping range boundaries. In this profile, plains cottonwood is considered to be a variety because of the treatment in Burns et al. (1990). Common names of eastern cottonwood also include southern cottonwood, Carolina poplar, and eastern poplar (Cooper and Van Haverbeke 1990). Plains cottonwoods are also called Texas cottonwood, river cottonwood, plains poplar, and western cottonwood (Cooper and Van Haverbeke 1990).

PLANT DESCRIPTION: The eastern cottonwood is a large, deciduous tree typically growing 24.4 to 30.5 m (80 to 100 ft) tall (Harlow et al. 1979) and often to over 50 m (164 ft) (Cooper and Van Haverbeke 1990), and up to 1.8 m (6 ft) in diameter at breast height (dbh) (Bechtold et al. 1990). Cottonwoods growing on open sites develop a spreading crown supported by a massive trunk that is often divided near the ground and terminates in an extensive superficial root system (Harlow et al. 1979). In closed stands, the tree has a tall, straight, relatively branch-free bole with a small rounded crown. Plains cottonwoods can grow to approximately 29 m (98 ft) with a dbh up to 2 m (6.5 ft) (Read 1958, Edminster et al. 1977). Cooper and Van Haverbeke (1990) reported that plains cottonwoods are usually single-stemmed with an open crown. Rooting habit of a plains cottonwood tree varies with the soil, from approximately 1.2 m (4 ft) or less in dry soils, to several meters in moist sites.

The deltoid leaves are 7.6 to 15 cm (3 to 6 in.) long and 10 to 12.5 cm (4 to 5 in.) wide with margins that have glandular, rounded to sharp teeth (Harlow et al. 1979). The leaf apex is acute to acuminate, and the base is truncate to chordate. The petiole is 3.8 to 7.6 cm (1.5 to 3 in.) long, glandular, and flattened. Both leaf surfaces are smooth; the dorsal surface is lustrous green, whereas the ventral surface is much paler. The twigs are stout, yellowish-brown, and smooth with lustrous brown, resinous buds approximately 1.9 cm (0.75 in.) long. The bark is light greenish-yellow and smooth on young stems but becomes ash-gray, thick, corky, and deeply furrowed on mature trees. Both male and female flowers are in catkins; the male catkins have bright red stamens (Ellis and Chester 1980). The tiny, light brown seeds are attached to tufts of silky hairs, which aid in wind dispersal and give the plant its common name. Female trees produce enormous quantities of seeds, averaging 159,000 per kg (350,000 per lb) (Harlow et al. 1979).

DISTRIBUTION

Eastern Cottonwood: The native range of eastern cottonwood encompasses most of the eastern United States from the Rocky Mountains to the southern Atlantic coast (Harlow et al. 1979). The range extends from southern Quebec westward into southwestern Manitoba and North Dakota, south to central Texas, and east to northwestern Florida and the lower coastal plain states (Cooper and Van Haverbeke 1990). The distribution covers the area from latitude 28° N to 46° N, with the exception of the higher Appalachians, southern Florida, and the Gulf Coast. Altitude is the primary determiner of the western boundary, which is not well-defined because of the intergradations of eastern and plains cottonwoods in this region.

Plains Cottonwood: Plains cottonwoods occur in a broad band approximately 2400 km (1500 miles) long and 800 km (500 miles) wide, which extends southeasterly from the southern prairie provinces of Canada into the high plains of northern Texas (Cooper and Van Haverbeke 1990). It grows from southern Alberta, central Saskatchewan, and southwestern Manitoba in Canada, south through the Great Plains of North Dakota, South Dakota, Nebraska, Kansas, and western Oklahoma into north central Texas and extreme northeastern New Mexico, and north into Colorado, eastern Wyoming, and eastern Montana (Figure 2). This range spans the longitude from 92° to 115° W and the latitude from 30° to 55° N. The eastern limit is not well-defined because eastern and plains cottonwoods intergrade along this boundary.

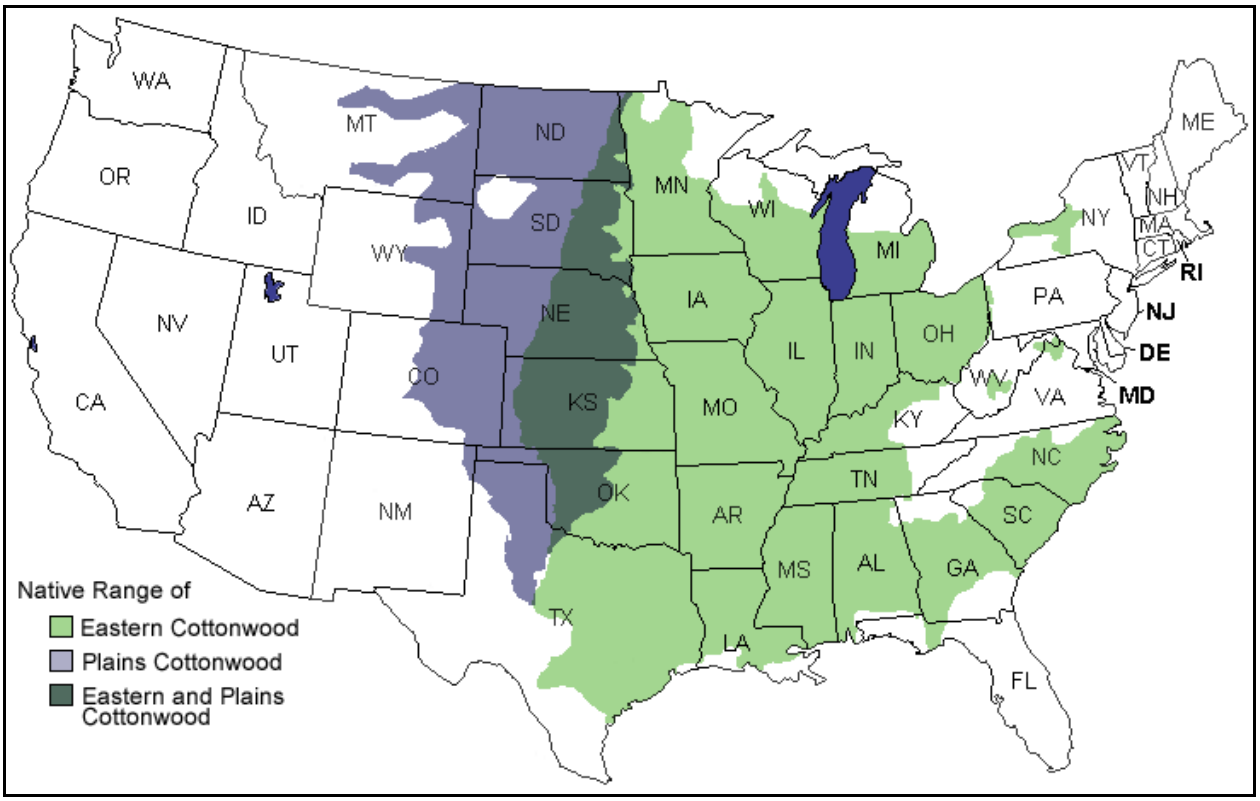

Figure 2. The distributions of eastern cottonwood and plains cottonwood, showing region of overlap along their western and eastern limits.

FUNCTIONS AND USES

Ecological Value: In natural ecosystems, both eastern and plains cottonwoods are an integral component of floodplain and riparian forests (Weaver 1968). They establish on the banks of rivers and are the only vegetative type growing on some eroding shores and may be the only tree species present on prairie landscapes. Cottonwoods are frequently planted as an ornamental to provide quick, but temporary, esthetic and protective effects. Cottonwoods are planted near homes to provide shade on open sites, stabilize soils along stream or ditch banks, and reforest nonproductive sandy fields that contain adequate moisture. Plains cottonwoods are planted in the Great Plains as a major tree component of windbreaks and shelterbelts (Cooper and Van Haverbeke 1990). A wind barrier 12 to 15 m (40 to 50 ft) tall can be produced in 15 to 20 years on stream lowlands and on deep, sandy, sub-irrigated lands. Eastern cottonwoods are well suited for revegetating disturbed riparian sites and have been used extensively in the reclamation of strip-mined lands in the East (Brothers 1988, Muncy 1989). Plains cottonwoods have been used to reestablish woody plants on mine spoils of the northern High Plains (Bjugstad 1977).

Branches, twigs, and leaves that fall from riparian woody species are a source of carbon and other nutrients to the soil and water (Malanson 1993); trees and their roots capture sediment and may help alter hydrologic processes. As a component of the floodplain forest, cottonwoods provide habitat for many species of birds to roost, nest, and feed in the branches and bole. Because of their ability to transpire, cottonwoods have been examined for their use in phytoremediation (Vose et al. 2000).

Commercial Uses: Eastern cottonwood is a valuable timber species that is highly suitable for plantation management for commercial purposes (Funck et al. 1981, Krinard and Johnson 1984). Primary wood products include lumber, veneer, plywood, excelsior, fiberboard, saw-timber, and pulpwood; finished wood products include pallets, furniture, and food containers (Taylor 2001). Eastern cottonwood has been used in rural Iowa to rehabilitate and construct timber bridges in recent years (Lee and Ritter 1997). Plains cottonwood is not considered to be as commercially valuable as eastern cottonwood. Plains species are used for pallets, rough construction lumber, interior parts of furniture, excelsior, crating, and pulpwood, which produce a very high-grade gloss paper (Cooper and Van Haverbeke 1990). Other uses include livestock roughage and fiber and reconstituted wood products.

Wildlife Benefits

Eastern Cottonwood. Both eastern and plains cottonwood are important to the wildlife species of their native ranges. Eastern cottonwood provides many benefits for wildlife species, including shelter for large mammals, browse in early successional stages for herbivores, food and pole-size trees for dam construction by beavers (*Castor canadensis*), and nesting sites for large raptors, such as the bald eagle (Figure 3) (Cooper and Van Haverbeke 1990). Bald eagles using the Missouri River main stem system depend on adjacent cottonwood forests for both nesting and wintering habitat (USFWS 2000). In the eastern United States, the Indiana bat (*Myotis sodalis*) sometimes uses large cottonwoods for nursery colonies (Brady 1983). In the Southeast, cottonwood plantations provide excellent habitat for a variety of recreationally important species such as the white-tailed deer (*Odocoileus virgianus*) and eastern cottontails (*Sylvilagus floridanus*) throughout the year and brood habitat for wild turkey (*Meleagris gallopavo*) and northern bobwhite (*Colinus virgianus*) in the spring (Wesley et al. 1981). In the northern Great Plains, eastern cottonwoods are a component

Figure 3. Cottonwoods provide nesting sites for large raptors such as the bald eagle.

of riparian forest and moist woodlands that may provide up to 50 percent of deer (*Odocoileus* spp.) habitat and 70 percent of sharp-tailed grouse (*Tympanuchus phasianellus*) habitat (Taylor 2001). Field mice (*Peromyscus* spp.), rabbits (*Sylvilagus* spp.), deer and domestic livestock (Bull and Munz 1943, Johnson 1965) eat the bark and leaves of cottonwood seedlings and saplings.

Plains Cottonwood. Plains cottonwood is particularly important for wildlife on the Great Plains. Plains cottonwood bottomlands provide the only natural habitat for eastern fox squirrels (*Sciurus niger*), which use the stands for nesting and foraging (Yeager 1959). Cottonwood stands provide habitat for 82 percent of bird species breeding in northeastern Colorado (Segelquist et al. 1993). Species using cottonwood bottomlands in the Midwest include the sharp-tailed grouse (Swenson 1985), Swainson's hawk (*Buteo swainsoni*) (Gilmer and Stewart 1984), Lewis' woodpecker (*Melanerpes lewis*) (Hadow 1973), wild turkey (Miller et al. 1991), and golden eagle (*Aquila chrysaetos*) (Phillips and Beske 1990). Beavers use the wood of plains cottonwood for food and dam and lodge building materials (Hansen et al. 1994). In Montana, plains cottonwood is an important source of food for porcupines (*Erethizon dorsatum*) (Hendricks and Allard 1988) and browse for mule deer (*O. hemionus*) (Martinka 1968). Domestic livestock also use cottonwood communities for forage and shade in summer and for thermal cover in winter (Bjugstad and Girard 1984).

HABITAT CHARACTERISTICS

Climatic Conditions: Both eastern and plains cottonwood are subject to considerable variation in climatic conditions throughout their ranges.

Eastern cottonwood. Eastern cottonwood grows in climates with temperatures as high as 46 °C (115 °F) and as low as -45 °C (-50 °F); average January temperatures vary from 8 °C (46 °F) to -10 °C (14 °F) (Cooper and Van Haverbeke 1990). Eastern cottonwood occurs in areas with less than 100 to more than 200 consecutive frost-free days per year. Rainfall varies from more than 140 cm (55 in.) in the southern part of the range to less than 38 cm (15 in.) in the northwest. Rainfall requirements are meaningless in the driest parts of its range because most moisture is derived from streams. In the lower Mississippi Valley, more than one-third of the rainfall occurs during the growing season after a full subsoil recharge during the winter and sometimes after flooding. Although moisture is usually inadequate for optimum growth by the latter part of the growing season, eastern cottonwood is tolerant to drought (Dickmann and Stuart 1983, Gebre and Kuhns 1991).

Eastern cottonwood has been classed as moderately tolerant to waterlogged soils (Hosner and Boyce 1962, Hook 1984). It tolerates periodic flooding from January through April, but mortality and growth depend on the number of events per year, season of year, flooding duration and depth, and age class (Green 1947, Hosner 1958, Hook 1984, McKevlin 1992). A study using cuttings found that cottonwood survived less than 16 days of complete submergence (Hosner 1958), and roots died when soaked for more than one month (Hosner and Boyce 1962).

Plains cottonwood. Plains cottonwood grows in the Great Plains region, which is characterized as subhumid to semiarid, with extremes and rapid fluctuations in temperature, unpredictable and limited precipitation, frequent and cyclic droughts, and strong persistent winds (Bates 1935). Maximum temperatures range from 38 °C (100 °F) to 46 °C (115 °F) throughout the region, with

minimum temperatures of -46 °C (-50 °F) in the north to -18 °C (0 °F) in the south (Thornthwaite 1941). Average January temperatures vary from 4 °C (40 °F) in the south to -15 °C (5 °F) in the north, and the frost-free period varies from 100 days in the north to 220 days in the south. Average annual rainfall ranges from about 25 cm (10 in.) in the northern and western Great Plains to about 76 cm (30 in.) in the southeastern part of the range; about 75 percent of the annual precipitation occurs during the growing season. Drought periods of 35 to 60 consecutive days occur annually, and periods of 60 to 70 days without rainfall occur once in 10 years. Drought periods of 90 to 120 days have occasionally been recorded in the northern and southern plains, respectively. Drought hazard is greatest in autumn and winter in the northern plains and in winter in the southern plains, where snowfall is less. High-velocity winds occur in all seasons but are strongest and most persistent during winter and early spring.

Soils and Topography: Cottonwoods are typically found along bodies of water or associated with upland areas containing a high water table.

Eastern cottonwood. This species occurs at elevations of 78 to 1981 m (255 to 6500 ft) (Bell 1974, Bellah and Hulbert 1974). It is usually found as a well-formed tree at elevations up to 4.6 to 6.1 m (15 to 20 ft) above the average level of streams (Putnam et al. 1960). Eastern cottonwood grows primarily on the moist alluvial soils of floodplains and bottomlands (Wilson 1970, Myers and Buchman 1984, Powell 1988). In the lower Mississippi River Valley, the best sites are in the batture (the alluvial land between the river and levee), where the species grows on the front land ridges, the high land or banks of present or former stream courses, well-drained flats, and the terrain between low ridges (Putnam et al. 1960). On slopes, cottonwood grows on the lower levels that remain moist throughout the growing season. It is also found in ravines (Bjugstad and Girard 1984), along disturbed streams (Hupp 1992), and in low areas of sandy uplands with a high water table (Wilson 1970). Although eastern cottonwood survives on deep, infertile sands and clays, it grows best on moist, well-drained, fine sandy or silt loams (Baker and Broadfoot 1979). Most cottonwood sites are in soils of the orders Entisols and Inceptisols (Cooper and Van Haverbeke 1990). The best sites are characterized by the absence of mottles in the upper 46 cm (18 in.), water tables from 60 to 180 cm (24 to 72 in.), bulk density of less than 1.4 g/cm3 (0.8 oz/in.3), pH of 5.5 to 7.5, and more than 2 percent organic matter.

Plains cottonwood. This species typically grows between elevations of about 300 m (1,000 ft) near its eastern limit to about 1830 m (6000 ft) in the Rocky Mountains (Cooper and Van Haverbeke 1990). It has been found as high as 2743 m (9000 ft) in Wyoming (Dittberner and Olson 1983). Plains cottonwood grows along most rivers and streams that flow through the loessial soils of the Great Plains on sites that are 2.4 to 3.7 m (8 to 12 ft) above the water table (Albertson and Weaver 1945). This species is common in homogenous stands on river sandbars and overflow land in the bends of large rivers and is also found in the beds of intermittent streams. Plains cottonwood occurs on small sandbars in the river beds or large bends where stream flow is greatly retarded during high water; it is also found next to springs that flow long enough to form ponds (Read 1958, Keammerer et al. 1975). Plains cottonwood grows on sandy soils (Johnson et al. 1976) or well-drained soils with a high water table to supply year-round moisture (Albertson and Weaver 1945). It is found in Entisols along alluvial streams, and in Mollisols, Alfisols, and Inceptisols of stream terraces, drainage ways, bottomlands, and subirrigated valleys. It will also grow on level subirrigated uplands with deep, sandy soils. Plains cottonwood grows best on deep, rich, well-drained loams. However,

moisture availability appears to be more significant to plains cottonwood than soil texture or fertility (Read 1958).

Hydrology: Establishment of cottonwoods is highly dependent on stream hydrology (Rood et al. 2003), such that cottonwoods may be considered an indicator of natural stream systems. Both surface water flows and groundwater are important; for example, Harner and Stanford (2003) found higher productivity in cottonwoods growing in stream reaches where groundwater was rejoining surface water; a higher water table and increased level of nutrients were considered responsible. River configuration and flows determine when and where moist and bare substrate will occur, which is necessary for cottonwood recruitment (Larson and Borman 2001).

The wetland indicator is Facultative for cottonwood in the North Plains (Region 4[1]) and the Central Plains (Region 5[2]) (USFWS 1988). This shows that cottonwood species are equally likely to occur in wetlands and non-wetlands (i.e., the estimated probability is 34 to 66 percent). In the North Central states (Region 3[3]), cottonwood is classed as Facultative Plus, indicating that it is more frequently found in wetlands than in uplands.

PLANT ASSOCIATES: Both eastern and plains cottonwoods are associated with a wide variety of other plants. This section describes plant associates of the two profiled species, and then focuses in to the northern floodplain forest, then closer to the Missouri River in Nebraska and South Dakota.

Eastern Cottonwood: Eastern cottonwood occurs as a dominant or co-dominant component of floodplain and bottomland hardwood forests (Curtis 1959, Hosner and Minckler 1960, Myers and Buchman 1984). Throughout its range, it grows in pure stands as on the alluvial soils in the Mississippi Valley (Harlow et al. 1979), but more frequently occurs in mixed stands with a wide variety of other trees and shrubs (Bell 1974). It is a principal species in riverfront forests in the eastern United States (Meadows and Nowacki 1996) and is the key species in the forest cover type Cottonwood (Society of American Foresters Type 63) (Eyre 1980). Eastern cottonwood is an associate in the following forest types: Black ash-American elm-red maple[4] (Type 39), bur oak (Type 42), river birch-sycamore (Type 61), silver maple-American elm (Type 62), sweetgum-willow oak (Type 92), sycamore-sweetgum-American elm (Type 94), and black willow (Type 95). The shrub components of eastern cottonwood forests are chiefly hardwood seedlings until the canopy closes and shades out the less-tolerant younger plants and shrub species. Common and frequently abundant woody vines in floodplain forests include grape, bittersweet, greenbrier, poison ivy, Virginia creeper, and virgin's bower (Weaver 1968). Major tree, shrub, and vine associates of eastern cottonwood are listed in Table A1. Forbs and graminoids may be understory components of the more open forests. The most common of these are provided in Table A2.

Plains Cottonwood: Although plains cottonwood grows in homogenous stands, it is frequently an associate in three forest cover types: Bur oak (Type 42), Cottonwood (Type 63), and Cottonwood-willow (Type 235) (Eyre 1980). Black willow and peachleaf willow are the most common tree

[1] Eastern Montana, North Dakota, South Dakota, eastern Wyoming.
[2] Eastern Colorado, Nebraska, Kansas.
[3] Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Wisconsin.
[4] Scientific names of most species are provided in Tables A1 and A2.

associates (Read 1958). Other associates on the more productive sites include American elm, slippery elm, hackberry, boxelder, green ash, red mulberry, black walnut, American sycamore, eastern redcedar, and silver maple (Ware and Smith 1939, Albertson and Weaver 1945, Read 1958). Trees, shrubs, and vines associated with plains cottonwood are listed in Table A1. In cottonwood stands of the western plains, shrubs are largely replaced by graminoids and forbs (Albertson and Weaver 1945). Plains cottonwood communities contain a greater diversity of herbaceous plants because of the more open sites on which this species occurs. Common species include sand dropseed, buffalograss, sunflowers, lambs-quarters, and Russian thistle. A more complete listing of graminoid and forb associates is provided in Table A2.

Northern Floodplain Forest: Kuchler (1975) mapped and defined the northern floodplain forest as occurring from Montana east to Minnesota, south to eastern Colorado and northern Oklahoma, and extending to southern Illinois and Missouri. This forest type (K098) occurs on the lower terraces and floodplains of the Mississippi, Missouri, Platte, Kansas, and Ohio Rivers. The northern floodplain forest is dominated by elm-ash-cottonwood species, which corresponds closely to the forest types SAF 63 (cottonwood), SAF 95 (black willow), and SAF 235 (cottonwood-willow and silver maple-American elm). In the K098 classification, the dominant tree species are eastern cottonwood, black willow, and American elm (Kuchler 1964). Other tree species present include boxelder, red maple, silver maple, river birch, hackberry, white ash, green ash, honey locust, black walnut, and sycamore in the south, plains cottonwood in the west, and peachleaf willow, sandbar willow, and slippery elm. Streamside stands in North Dakota include bur oak, American basswood, green ash, American elm, boxelder, quaking aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*) (Wikum and Wali 1974). Typical vines in the northern floodplain forest are American bittersweet, virgin's bower, Virginia creeper, poison ivy, and bristly greenbrier (*Smilax hispida*) (Kuchler 1964).

Nebraska Cottonwood Communities: The three main forest types (after Garrison et al. (1977)) of Nebraska are elm-ash-cottonwood, oak-hickory, and ponderosa pine. Bottomland hardwoods represent over 1 million acres, 58 percent of the total woodland acreage in Nebraska. These bottomlands fall within the range of the northern floodplain forest (K098). The willow-cottonwood portion of the floodplain forest is especially typical of the Platte and Missouri Rivers (Weaver 1968). It extends over low sandy banks, sandbars, and abandoned channels. The floodplain community reaches its best development along the larger streams in the southeastern part of Nebraska; the trees are much larger, and fewer of the less tolerant species are found because of the dense shade. Secondary species include white ash, chokecherry, Kentucky coffeetree, Ohio buckeye, hackberry, and American sycamore. Common shrubs of the floodplain forest that extend beyond its margin and intermingle with coarse grasses include roughleaf dogwood, Indigo bush, wolfberry, coralberry, smooth sumac, American plum, American elder, and wild gooseberry.

SUCCESSION PATTERNS: Eastern cottonwood is shade intolerant (Dickmann and Stuart 1983). It is a pioneer species that typically establishes on the freshly exposed alluvium of sandbars, streambanks, and other floodplain sites (Bjugstad and Girard 1984, Bradley and Smith 1986, Hupp 1992). Establishment and dominance may occur after sandbar willows have stabilized the site (Wilson 1970); willows have abundant fibrous roots that catch and retain the silts and clays carried by floodwaters (Weaver 1960). Succession is characterized by the growth of boxelder, American elm, slippery elm, green ash, and black walnut, which in turn may be replaced by basswood with the

elms remaining as co-dominants (Aikman 1927). In northern floodplain forests, willows are usually closest to the water's edge, with cottonwoods, elms, boxelder, and ashes farther from the water (Weaver 1960). Successive community types in riparian areas along the Yellowstone River in Montana are bare sandbars, willow thickets, cottonwood forests, green ash forests, and grasslands (Boggs 1984). On the Little Missouri River in western North Dakota, cottonwoods occur in a series of even-aged stands corresponding to channel migration events (Everitt 1968).

Plains cottonwood, willow, and boxelder represent an early succession stage on floodplains in Nebraska (Albertson and Weaver 1945). The plains cottonwood-willow type converts to the plains cottonwood-green ash type in North Dakota (Johnson et al. 1976) and succeeds to the green ash-western snowberry community if left undisturbed (Girard et al. 1989). The number of associated tree species decreases westward until only the early successional species (namely cottonwood and willow) remain; in much of the western Great Plains the climax native bottomland community is now shrubland or grassland rather than forest (Hefley 1937, Lindauer 1983).

Since the 1800s, fire suppression and decreased flow variability have allowed invasives such as Russian olive and trees from the eastern Plains, especially green ash and eastern redcedar, to become established in western bottomlands where shade-tolerant species were formerly absent (Olson and Knopf 1986, Johnson 1992, Shafroth et al. 1995).

INVASIVE SPECIES: Both eastern and plains cottonwood communities include invasive species. These may be either introduced or native plants that grow abundantly, frequently on sites that have been altered. For example, Russian olive and saltcedar are introduced species that have invaded riparian woodlands dominated by cottonwoods and willows across the Great Plains and southwestern United States (Taylor 2001). Invasive species often do not provide the same functions as the native species although consequences of invasives are not always clear (Zouhar 2005). Introduced species are considered detrimental to native communities as they have displaced native vegetation, increased water demand, increased fire frequency, and allowed soil erosion at sites of invasion (Shafroth et al. 1995, Larmer 1998). Eradication, when possible, or some degree of control of invasive species is costly. Invasive species that may be found associated with cottonwoods in Nebraska and the Great Plains are indicated in Tables A1 and A2.

NATURAL REGENERATION AND RECRUITMENT

Sexual Reproduction: Cottonwood species regenerate both sexually and vegetatively. Cottonwood is dioecious with a sex ratio of about 1 to 1 (Farmer 1964). According to geographic location, plants flower 1 to 2 weeks before leaf initiation (Braatne et al. 1996) in early to late spring (February through May) (Dickmann and Stuart 1983, Braatne et al. 1996). Flowering may vary by as much as a month among trees in a stand (Farmer 1966).

Seed production and dispersal. Seeds develop in capsules with three to four valves on short stalks of long catkins. From 30 to 60 seeds are produced in each capsule. The minimum seed-bearing age of plains cottonwood is about 10 years (Schreiner 1974), whereas seed production of eastern cottonwood begins at 5 to 10 years and increases rapidly as trees age and enlarge in size (Cooper and Van Haverbeke 1990). At 10 to 15 years of age, trees annually produce large seed crops (25 to 28 million seeds per tree per year) (Braatne et al. 1996). Estimates of annual seed production of a single open-grown tree have been as high as 48 million seeds (Bessey 1904).

Seed dispersal follows flowering by about 2 months in southern populations and by a shorter period in the North (Farmer 1966). Seed dispersal and germination occur in late spring to early- or mid-summer, typically coinciding with decreasing water flow levels (May through August) (Farmer and Bonner 1967, Braatne et al. 1996). The dispersal pattern results in abundant deposits of seeds along watercourses as spring floodwaters recede (Schreiner 1974). Seeds are dispersed by both water and wind. Seeds carried on the wind may land only several hundred feet away from the parent tree, whereas seeds falling into water may be carried long distances before deposition on sandbars and riverbanks.

Germination and survival. There is no seed dormancy in eastern and plains cottonwoods (White 1979). Seeds are highly viable at dispersal and remain viable for 1 to 2 weeks (Braatne et al. 1996). Seed viability for plains cottonwood has been reported at almost 100 percent during the first 5 days after dispersal if seeds are kept moist (Read 1958), but seeds lose viability rapidly in the absence of a suitable germination site (Farmer and Bonner 1967). Germination occurs as soon as seeds are deposited on a suitable site (Read 1958, Bradley and Smith 1986, Segelquist et al. 1993). An ideal site for germination is the moist silt, sand, or gravel along river and stream floodplains that is exposed to full sunlight (DeBell 1990). After deposition on such a site, eastern cottonwood typically germinates within 8 to 24 hr (Moss 1938, Noble 1979), and plains cottonwood will germinate within 48 hr (Engstrom 1948, Chong et al. 1988). The germination rate is high and has been known to exceed 90 percent for eastern cottonwood (Van Haverbeke 2002) and 98 percent for plains cottonwood (Schreiner 1974). Successful germination and good early growth of cottonwood are optimal within the temperature range of 27 to 32 °C (80.6 to 89.6 °F) and at < 5-atm moisture stress (Farmer and Bonner 1967).

Suitable sites occur naturally as a result of disturbance, i.e., spring flooding (Read 1958). Receding floodwaters leave freshly deposited, exposed alluvium; seed germination along prairie river floodplains may occur exclusively on these alluvial sites (Wilson 1970, Johnson et al. 1976). Since young seedlings do not compete well in shade, exposed soil is essential (Putnam 1951, Johnson et al. 1976), and moisture is critical during germination and seedling development (Cooper and Van Haverbeke 1990).

The probability of an individual cottonwood establishing and growing to maturity is very low (Shafroth et al. 1995). With the brief period of viability, many sites are not suitable for germination; mortality is extremely high on sites that are not ideal, and substantial mortality occurs even among seedlings germinating on ideal sites. Therefore, the coincidence of seed viability, receding flood flows, and suitable sites is such that germination may occur only once every 2 to 10 years (Larson and Borman 2001). Along the Milk River, Alberta, conditions for recruitment leading up to long-term survival occur on an average of once in 5 years (Bradley and Smith 1986).

The meandering nature of streams and rivers is important for the germination and survival of cottonwoods (Friedman et al. 1997). The sandbars created by erosion and subsequent deposition of eroded material provide seed beds with favorable germination conditions. Newly created point bars are bare and likely moist. As a meander continues to move with time, the sandbar becomes further removed from frequent flooding, thus enhancing seedling survival. Channel narrowing and flood deposition and erosion are also important hydrologic dynamics in germination and survival of seedlings. Channel narrowing typically occurs after one to several years when peak flows are lower

than normal, and the stream concentrates in one part of its normal bed. Thus the stream deepens the narrower bed, and cottonwood stands often establish on the benches left after narrowing. Flood deposition and erosion occur along most streams but are especially important for cottonwood establishment where lateral channel movement is constrained by a narrow valley (Scott et al. 1996). The channel is not moving, so the only locations safe from scouring are those at high elevations. Only the greatest flows produce bare, moist substrate at these high elevations. This dynamic may initiate channel narrowing in that an unusually large flood will enlarge the channel, then leave moist benches on which cottonwood can establish.

Establishment. Growth of young seedlings is rapid (Kennedy 1985). Although initial stem development is slow, the growth rate rapidly accelerates after the first 3 weeks (Baker and Blackmon 1977). Seedlings can extend taproots 30.5 to 40.6 cm (12 to 16 in.) and lateral roots 61 cm (24 in.) by the end of the first growing season (Ware and Penfound 1949). These roots serve as anchorage during floods and help to ensure a water supply during dry periods. Most of the roots are in the uppermost, aerated layer of soil and are nearer the surface in clay soils than in loams (Cooper and Van Haverbeke 1990). After siltation, roots develop on the covered portion of the stem.

Young seedlings are susceptible to several adverse factors, including heavy rains, very hot sunshine, and damping-off fungi (Cooper and Van Haverbeke 1990). Once established, eastern cottonwood seedlings may suffer damage from flooding. Hosner and Minckler (1963) found that 8 days of inundation weakened all seedlings, while 16 days resulted in mortality. However, seedlings can survive if flooded less than 50 percent of the growing season (Myers and Buchman 1984). Seedlings will establish near the edges of river channels, but long-term survival is greater at higher elevations above the stream channel (Friedman et al. 1997).

Establishment of cottonwoods, especially on the Great Plains, is dependent upon moisture availability (Albertson and Weaver 1945, Cooper and Van Haverbeke 1990). Seedling mortality is most often drought-induced, when root growth cannot keep up with the dropping water table (Rood et al. 2003). Cool, moist conditions in the first growing season enhance seedling survival, as do high flows in the fall, but scouring by winter ice flows is a threat to cottonwood seedlings. For successful establishment, the elevation of the seedbed must be high enough to avoid flash flows and ice scouring but low enough to avoid drought.

Growth and development. Eastern cottonwood is the fastest growing native tree in North America (Dickmann and Stuart 1983, Kennedy 1985). It increases 1.7 to 2.54 cm (0.7 to 1 in.) in diameter and 1.5 m (5 ft) in height annually up to 10 to 15 years of age and grows at only a slightly slower rate up to 30 to 35 years of age (Bull and Munz 1943). In the fertile Mississippi Valley, it can reach 36.6 m (120 ft) in height and 50.8 cm (20 in.) dbh by 35 years (Bull and Munz 1943, Ware and Penfound 1949). Plains cottonwood is the fastest growing native species on the Great Plains; it grows most rapidly in the first 25 to 30 years when it can reach 15.2 m (50 to 75 ft) in height and 61 to 91.4 cm (24 to 36 in.) dbh (Geyer 1981). It usually attains maximum development in 40 to 50 years (Scott 1928, Sudworth 1934).

Both eastern and plains cottonwood are highly intolerant of shade and require full sunlight for maximum growth (Scott 1928, Cooper and Van Haverbeke 1990). Eastern cottonwood is more intolerant of shade than any of its associates except willow. Although the two frequently seed in together, pure stands of one or the other are the general rule after the first few years. Willow

survives on the wetter sites, while cottonwood survives on the slightly higher, drier sites. Its faster growth allows cottonwood to crowd out the willow except on sites where prolonged deep flooding drowns the cottonwood component of the stand.

Establishment and subsequent dominance of cottonwoods and willows under natural conditions require the following attributes: (a) large, dependable seed crops; (b) effective dispersion by wind and water to optimal germination sites; (c) rapid germination; (d) rapid root and shoot growth sufficient to withstand flooding, drought, and sedimentation; (e) tolerance of low soil fertility; and (f) the ability of cottonwoods and willows to reproduce vegetatively (Johnson 1994). These pioneer species modify the riverbed environment suitable for early successional species into relatively stable surfaces favorable for recruitment of later successional species.

Vegetative Reproduction: Vegetative reproduction occurs by sprouting from stumps and root crowns, by the formation of adventitious shoots on the roots (suckers) (Schier and Campbell 1976, Dickmann and Stuart 1983), and by crown breakage and flood-trained shoots (sprouts from broken limbs covered by sediment) (Braatne et al. 1996). However, the ability to sprout declines with age (Read 1958). Although eastern cottonwood may sprout from the roots and bole after top-kill or damage, the response is weak. Most suckers arise from suppressed buds in the periderm of undisturbed roots after death or injury of aboveground parts (Gom and Rood 1999a). There is disagreement about the ability of eastern cottonwood to sprout from the bole after cutting (Minckler 1958, Dickmann and Stuart 1983). Plains cottonwood does not readily form suckers or stem sprouts (Gom and Rood 1999b), and sprouting is uncommon except in flood-trained shoots (Bradley and Smith 1986, Gom and Rood 1999a, Scott et al. 1997).

Disease Agents: Leaf rusts and stem cankers are the most widespread and damaging diseases (Cooper and Van Haverbeke 1990). Leaf rusts cause premature defoliation of trees that results in decreased growth, weakened trees, and increased susceptibility to infection by other pathogens. Melampsorea leaf rust, caused by *Melampsora medusae*, is a serious disease of plains cottonwood (Morris et al. 1975). Other rusts include Septoria (*Septoria musiva*) leaf spot, *Marssonina brunnea* leaf spot, and Alternaria (*Alternaria tenuis*) leaf and stem blight. The most serious canker is Cytospora (*Cytospora chrysosperma*) canker, which can result in wind breakage at the wound site. Other canker diseases include those caused by *Fusarium solani*, *Phomopsis macrospora*, *Botryodiplodia theobromae*, *Cryptosphaeria populina*, and *Scytinostroma galactinium*.

Insects that are most damaging to plains cottonwood are the defoliators and woodborers (Stein 1976). The defoliators cause loss of vigor, and wood borers reduce the quality of lumber. Some of the more important defoliators include the cottonwood leaf beetle (*Chrysomela scripta*), cottonwood borer (*Plectrodera scalator*), flatheaded woodborer (*Dicera divaricata*), carpenterworm (*Prionoxystus robiniae*), poplar-and-willow borer (*Cryptorhynchus lapathi*), and bronze poplar borer (*Agrilus liragus*).

Human Impacts to Natural Regeneration: Regeneration and recruitment of plains cottonwood have been adversely affected by the construction of dams and reservoirs in the Great Plains region (Rood and Mahoney 1990). Dams installed to capture the peak flow of spring run-off for use in irrigation or power generation have altered water cycle patterns necessary for the natural regeneration of cottonwood (Williams and Cooper 2005). Changes in flood magnitude and frequency, sedimentation rates, and rates of meander migration contribute to the reduction of suitable

recruitment sites (Johnson et al. 1976, Bradley and Smith 1986). The stabilization of flows created by dams alters the flow of sediment, thus resulting in a depletion of sites for cottonwood establishment (Bradley and Smith 1986). Plains cottonwood is adapted for recruitment in high-disturbance environments of meandering river floodplains, in particular on point bars that are flooded periodically and experience rapid sedimentation and lateral migration. Alterations to natural water flow reduce the ability of a river to change course, thus limiting its geographic spread and variation of substrates, which reduces the availability of suitable regeneration sites.

Reduced flows can induce drought stress, which in turn leads to high mortality to seedlings and very old cottonwoods (Rood and Mahoney 1990, Scott et al. 2000). Channel incision associated with sustained flooding can lower channel elevations enough to cause significant stress and resulting stand mortality (Scott et al. 2000). An abrupt reduction in downstream flow is particularly stressful (Crouch 1979, Rood and Heinze-Milne 1989). Natural flow variations give cottonwoods an interval for hardening during which drought tolerance gradually increases, but an abrupt decrease of water eliminates this hardening interval. Artificial flow reductions may also cause the water table to fall more rapidly than normal. Extreme stress or mortality will result from these conditions if maximal root growth is inadequate to maintain contact with the falling water table. If seedlings have just established, the limited root systems may be unable to cope with the sudden change in water availability, and mortality will occur by desiccation. An abrupt water cutoff can be fatal to older, less vigorous trees that are already less drought resistant than middle-aged trees (Albertson and Weaver 1945).

Land modifications impact cottonwood regeneration. Upstream clear-cutting or overgrazing can reduce the ability of the watershed to hold and slowly release water. As a result, seedlings may experience drought or may not be able to germinate because seedbeds have been covered with sediment that encourages growth of plant competitors. Groundwater pumping for agricultural, domestic, or industrial purposes can draw down the permanent water table to create an artificial drought, which may stunt or kill mature trees. Agricultural clearing and direct harvesting of trees also contribute to forest failure (Rood and Mahoney 1990). Livestock grazing has had extensive impacts on riparian areas in the western United States (Malanson 1993). Cottonwood seedlings are preferred forage for cattle, which also trample young plants.

Invasive plants, especially introduced species such as Russian olive and saltcedar, compete successfully with plains cottonwood for establishment (Bradley and Smith 1986) (Figure 4). Russian olive is a small tree native to western Asia (Little 1961) that was planted for windbreaks and wildlife habitat enhancement and has become extensively naturalized throughout the western United States (Christiansen 1963). Lesica and Miles (1999) investigated the invasion of Russian olive into cottonwood forests along the lower Marias River below Tiber Dam in Montana and found that it invades cottonwood stands of all ages. It forms an understory canopy beneath mature cottonwoods, its shade precluding cottonwood recruitment. Therefore, as old cottonwoods die, forests of Russian olive will replace the native riparian forests. Russian olive also competes well with plains cottonwood because it is better adapted to establish under regulated stream flows (Shafroth et al. 1995).

Figure 4. Russian olive competes with cottonwoods for establishment along river banks.

RESTORATION OF COTTONWOOD STANDS: Human impacts have profoundly interfered with the natural establishment and development of cottonwoods in river systems. The decline in cottonwood stands along altered rivers and streams has prompted a concerted effort to manage, conserve, and restore these communities. In the Lower Mississippi valley, bottomland hardwoods have been regenerated in small stands, and cottonwood has been successfully established in plantations to provide timber and wildlife habitat (Johnson 1965, Newling 1990). These efforts have involved manual manipulation of the habitat, either in site preparation or seeding/planting. Cottonwood has also been propagated vegetatively on sites in the Northern Plains for use in windbreaks and farmstead plantings (Morgenson 1992).

Natural Seedfall: Ideally, a means to stimulate natural recovery is preferred for cottonwood restoration for both efficiency and probability of long-term success. However, most projects combine at least some habitat manipulation with natural regeneration. The establishment of plains cottonwood using both aspects has been demonstrated along Boulder Creek, a meandering stream in the Colorado plains that has been dammed and channelized (Friedman et al. 1995). The failure of natural cottonwood reproduction downstream of the dam resulted from the scarcity of bare, moist substrate suitable for seedling establishment. Successful regeneration sites were created by removing sod to lower the surface by an average depth of 16.5 cm (6.5 in.) and irrigating with stream water supplied by pumping through sprinklers. Natural seedfall provided the seeding mechanism, as seeds introduced by planting had no significant effect on increasing the rate of regeneration. Using natural seedfall also eliminated the collection and planting of propagules and helped retain the gene pool of the local cottonwood population. The disturbed, irrigated sites produced a cottonwood seedling density of 10.3 seedlings per square meter, whereas non-irrigated, undisturbed plots (similar to current conditions) had a mean density of only 0.03 seedling per square meter.

This method may be useful for regenerating cottonwood stands along regulated streams where channel migration and flood disturbance no longer occur (Friedman et al. 1995). To increase seedling yield and decrease cost, it is recommended that selected regeneration sites be high enough to avoid annual scour by water or ice and have grass cover, coarse soil texture, and low organic matter content to minimize herbaceous competition. If an upstream dam and reservoir allowed moderately high flows at designated times but residential and industrial development prevented the use of flows powerful enough to form new bare surfaces, several modifications would help to establish cottonwoods. For example, the site can be artificially disturbed with a backhoe or bulldozer, the area can be flooded before seed dispersal, and high flows destructive to young trees can be prevented during the next few years. Friedman et al. (1995) also provide suggestions for planting cottonwood stands in larger plots. This restoration technique may be suitable for the regeneration of other riparian pioneer species, such as willows, silver maple, and river birch, which produce dependable crops of immediately germinable seeds capable of establishing on a mineral substrate (White 1979).

Cuttings: Cottonwood may be established by cuttings (Dickmann and Stuart 1983, Krinard 1983). The average length of cuttings in the Pacific Northwest and the southern United States is about 50 cm (20 in.), while 20- to 30-cm (8- to 12-in.) cuttings are typical in the northern United States and Canada. Cuttings should be longer where upper soil moisture is limiting (Dickmann and Stuart 1983). Cuttings of 2.4 m (8 ft) or more planted in 1-m-(3-ft-) deep holes have advantages over standard 50-cm (20-in.) cuttings. These advantages include less intensive site preparation, a reduced need for browsing protection, and less intensive weed control (Krinard 1983).

Planting: Whether planting trees by seeding or cuttings, use of native stock is highly recommended, because significant geographic variation exists in growth rate, drought resistance, wood characteristics, and sprouting ability (Cunningham 1975). Site preparation varies with climate and soil type (Lovett and Bolander 2006). Some form of weed control may be necessary. Tillage is not recommended on sandy soils, rough terrain, or any highly erodible soil. Chemical control can be applied to the site in the fall or early spring, and summer fallow is recommended in western Nebraska to conserve fall moisture. Fall tillage is recommended for grassland sites in eastern Nebraska; all sites should be disked before spring planting. Lovett and Bolander (2006) provide guidelines for site preparation, seedling care prior to planting, and planting techniques.

Maintenance: The growth of young seedlings on good sites is rapid; therefore, restoration sites must be kept free of competing vegetation (Carter and White 1971, Kennedy 1985). Sites should be cultivated regularly until the trees are able to shade out most of the herbaceous vegetation (Lovett and Bolander 2006). Preemergent herbicides are effective for weed control, as these chemicals stay in the top 5 cm (2 in.) of soil out of the tree root zone but are readily absorbed by herbaceous roots. Use of the restoration area by wildlife and domestic livestock must be controlled (Dickmann and Stuart 1983). Fencing can be erected to protect seedlings and young trees. Repellents or poisons may be effective for controlling rabbits, mice, and moles if the restoration site is not too large. All losses should be replanted during the first and second years to avoid future wind tunnels.

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APPENDIX A: PLANTS ASSOCIATED WITH EASTERN AND PLAINS COTTONWOODS IN THE MIDWESTERN UNITED STATES

Table A1
Trees, Shrubs, and Vines Associated with Eastern and Plains Cottonwoods in Midwestern States (compiled from Albertson and Weaver 1945, Read 1958, Weaver 1968, Eyre 1980, Cooper and Van Haverbeke 1990, Taylor 2001)

Common Name	Scientific Name	Eastern	Plains	Invasive[1]
Trees				
Boxelder	*Acer negundo*	X	X	
Red maple	*Acer rubrum*	X		
Silver maple	*Acer saccharinum*	X	X	
Ohio buckeye	*Aesculus glabra*	X		
Tree-of-heaven	*Ailanthus altissima*	X		X
Speckled alder	*Alnus rugosa*	X		
Pawpaw	*Asimina triloba*	X		
River birch	*Betula nigra*	X		
American hornbeam	*Carpinus caroliniana*	X		
Water hickory	*Carya aquatica*	X		
Bitternut hickory	*Carya cordiformis*	X	X	
Pignut hickory	*Carya glabra*	X		
Pecan	*Carya illinoensis*	X		
Shellbark hickory	*Carya lacinios*	X		
Shagbark hickory	*Carya ovata*	X		
Mockernut hickory	*Carya tomentosa*	X		
Sugarberry	*Celtis laevigata*	X		
Hackberry	*Celtis occidentalis*	X	X	
Eastern redbud	*Cercis canadensis*	X	X	
Dogwoods	*Cornus spp.*		X	
Roughleaf dogwood	*Cornus drummondii*	X		
Red-osier dogwood	*Cornus sericea*		X	
Hawthorns	*Crataegus spp*	X		
Common persimmon	*Diospyros virginiana*	X		
Russian olive	*Elaeagnus angustifolia*		X	X
Eastern swampprivet	*Forestiera acuminata*	X		
White ash	*Fraxinus americana*	X	X	
Black ash	*Fraxinus nigra*	X		
Green ash	*Fraxinus pennsylvanica*	X	X	
Honey locust	*Gleditsia triacanthos*	X		X
Kentucky coffeetree	*Gymnocladus dioicus*	X	X	
Black walnut	*Juglans nigra*	X	X	
Rocky Mountain juniper	*Juniperus scopulorum*		X	

(Sheet 1 of 4)

[1] Compiled from Stubbendieck, Friisoe, and Bolick 1994; Hoffman and Kearns 1997.

Table A1 (Continued)

Common Name	Scientific Name	Eastern	Plains	Invasive
Trees (cont.)				
Eastern redcedar	*Juniperus virginiana*		X	
Sweetgum	*Liquidambar styraciflua*	X		
Chinaberry tree	*Melia azedarach*	X		
White mulberry	*Morus alba*	X		
Red mulberry	*Morus rubra*	X	X	
Blackgum	*Nyssa sylvatica*	X		
Eastern hophornbeam	*Ostrya virginiana*	x	x	
American sycamore	*Platanus occidentalis*	x	x	
Narrowleaf cottonwood	*Populus angustifolia*		x	
Black cottonwood	*Populus balsamifera*	x	x	
Eastern cottonwood	*Populus deltoides*	x	x	
Bigtooth aspen	*Populus grandidentata*	x		
Plains cottonwood	*Populus sargentii*		x	
American plum	*Prunus americana*		x	
Black cherry	*Prunus serotina*	x	x	
Chokecherry	*Prunus virginiana*		x	x
White oak	*Quercus alba*	x		
Swamp white oak	*Quercus bicolor*	x		
Bur oak	*Quercus macrocarpa*	x	x	
Chinkapin oak	*Quercus muehlenbergii*	x	x	
Cherrybark oak	*Quercus pagoda*	x		
Pin oak	*Quercus palustris*	x		
Willow oak	*Quercus phellos*	x		
Chestnut oak	*Quercus prinus*	x		
Northern red oak	*Quercus rubra*	x	x	
Shumard oak	*Quercus shumardii*	x		
Post oak	*Quercus stellata*	x		
Black oak	*Quercus velutina*	x	x	
Peachleaf willow	*Salix amygdaloides*	x	x	
Pussy willow	*Salix discolor*	x		
Sandbar willow	*Salix exigua*	x	x	
River willow	*Salix fluviatilis*		x	
Black willow	*Salix nigra*	x	x	
Red elderberry	*Sambucus racemosa*	x		
Sassafras	*Sassafras albidum*	x		
Fivestamen tamarisk	*Tamarix chinensis*		x	x
French tamarix	*Tamarix gallica*	x		x
Basswood	*Tilia americana*	x	x	

(Sheet 2 of 4)

Table A1 (Continued)

Common Name	Scientific Name	Eastern	Plains	Invasive
Trees (cont.)				
American elm	*Ulmus americana*	x	x	
Cedar elm	*Ulmus crassifolia*	x		
Slippery elm	*Ulmus rubra*	x	x	
Rock elm	*Ulmus thomasii*		x	
Shrubs				
Rocky Mountain maple	*Acer glabrum*		x	
Saskatoon serviceberry	*Amelanchier alnifolia*		x	
Indigo bush	*Amorpha fruticosa*	x	x	
Silver sagebrush	*Artemisia c. cana*		x	
Sand sagebrush	*Artemisia filifolia*	x		x
Roughleaf dogwood	*Cornus drummondii*	x		
American hazel	*Corylus americana*		x	
Douglas hawthorn	*Crataegus douglasii*		x	
Burning bush	*Euonymous alata*	x		x
Eastern wahoo	*Euonymous atropurpureus*		x	
Northern spicebush	*Lindera benzoin*	x		
Black tupelo	*Nyssa sylvatica*	x		
Common ninebark	*Physocarpus opulifolius*	x		
American plum	*Prunus americana*	x	x	
Shinnery oak	*Quercus havardii*	x		
Alderleaf buckthorn	*Rhamnus alnifolia*		x	
Smooth sumac	*Rhus glabra*	x	x	x
Skunkbush sumac	*Rhus trilobata*		x	
American black currant	*Ribes americanum*		x	
Golden currant	*Ribes aureum*		x	
Wild gooseberry	*Ribes missouriense*	x		
Smooth rose	*Rosa blanda*		x	
Multiflora rose	*Rosa multiflora*	x		x
Wood's rose	*Rosa woodsii*		x	
Red raspberry	*Rubus idaeus*		x	
American elder	*Sambucus canadensis*	x		
Silver buffaloberry	*Shepherdia argentea*		x	
Western snowberry	*Symphoricarpos occidentalis*	x	x	x
Coralberry	*Symphoricarpos orbiculatus*	x		
Arrowwood	*Viburnum dentatum*	x		
Blackhaw	*Virburnum prunifolium*	x		

(Sheet 3 of 4)

Table A1 (Concluded)

Common Name	Scientific Name	Eastern	Plains	Invasive
Vines				
Peppervine	*Ampelopsis arborea*	x	x	
Hedge bindweed	*Calystegia sepium*		x	x
Trumpet creeper	*Campsis radicans*	x		
Asian bittersweet	*Celastrus orbiculatus*	x		x
Bittersweet	*Celastrus scandens*	x	x	
Western white clematis	*Clematis ligusticifolia*		x	
Virgin's bower	*Clematis virginiana*	x		
Moonseed	*Menispermum canadense*	x		
Virginia creeper	*Parthenocissus quinquefolia*	x	x	
Blackberry	*Rubus spp.*	x		
Greenbriers	*Smilax spp.*	x		
Blue Ridge carrion flower	*Smilax lasioneura*		x	
Poison ivy	*Toxicodendron radicans*	x	x	
Western poison ivy	*Toxicodendron rydbergii*		x	x
Wild grapes	*Vitus spp.*	x		
Riverbank grape	*Vitus riparia*		x	
Frost grape	*Vitus vulpina*		x	

(Sheet 4 of 4)

Table A2
Herbaceous Species Associated with Eastern and Plains Cottonwoods in Midwestern States (compiled from Albertson and Weaver 1945; Read 1958; Weaver 1968; Eyre 1980; Cooper and Van Haverbeke 1990; Taylor 2001)

Common Name	Scientific Name	Eastern	Plains	Invasive
Graminoids				
Creeping bentgrass	*Agrostis stolonifera*		x	x
Big bluestem	*Andropogon g. gerardii*	x		
Blue grama	*Bouteloua gracilis*		x	
Smooth brome	*Bromus inermis*		x	x
Japanese brome	*Bromus japonicus*	x		x
Cheatgrass	*Bromus tectorum*		x	x
Bufflalograss	*Buchloe dactyloides*		x	
Prairie sandreed	*Calamovilfa longifolia*		x	
Assiniboia sedge	*Carex assiniboinensis*		x	
Sedges	*Carex spp.*		x	
Sanddune sandbur	*Cenchrus tribuloides*	x		

(Sheet 1 of 3)

Table A2 (Continued)

Common Name	Scientific Name	Eastern	Plains	Invasive
Graminoids (cont.)				
Bermudagrass	*Cynodon dactylon*	x		
Barnyard grass	*Echinochloa crus-galli*		x	x
Canada wildrye	*Elymus canadensis*	x	x	
Streambank wheatgrass	*Elymus l. psammophilus*	x		
Slender wheatgrass	*Elymus trachycaulus*		x	
Hairy wildrye	*Elymus villosus*		x	
Virginia wildrye	*Elymus virginicus*		x	
Quackgrass	*Elytrigia repens*		x	x
Green muhly	*Muhlenbergia racemosa*		x	x
Switchgrass	*Panicum virgatum*	x		
Western wheatgrass	*Pascopyrum smithii*		x	
Timothy grass	*Phleum pratense*		x	
Common reed	*Phragmites australis*		x	
Kentucky bluegrass	*Poa pratensis*		x	x
Bulrush	*Scirpus spp.*		x	
Indiangrass	*Sorghastrum nutans*	x		
Johnsongrass	*Sorghum halepense*	x		x
Prairie cordgrass	*Spartina pectinata*		x	
Alkali sacaton	*Sporobolus airoides*	x		
Sand dropseed	*Sporobolus cryptandrus*		x	x
Eastern gamagrass	*Tripsacum dactyloides*	x		
Forbs				
Great ragweed	*Ambrosia trifida*	x		x
Wild sarsaparilla	*Aralia nudicaulis*		x	
Louisiana sagewort	*Artemisia ludoviciana*		x	x
Common milkweed	*Asclepias syriaca*		x	x
Smooth aster	*Aster laevis*		x	
American searocket	*Cakile edentula*	x		
Lambsquarters	*Chenopodium album*		x	x
Canada thistle	*Cirsium arvense*		x	x
Poison hemlock	*Conium maculatum*		x	x
Canadian horseweed	*Conyza canadensis*	x		x
Fireweed	*Epilobium angustifolium*		x	
Wild licorice	*Glycyrrhiza lepidota*		x	x

(Sheet 2 of 3)

Table A2 (Concluded)

Common Name	Scientific Name	Eastern	Plains	Invasive
Forbs (cont.)				
Sunflowers	*Helianthus spp.*	x	x	
Common sunflower	*Helianthus annuus*		x	x
Sawtooth sunflower	*Helianthus grosseserratus*		x	x
Jerusalem sunflower	*Helianthus tuberosus*		x	x
Common hop	*Humulus americanus*		x	
Starry Solomon's seal	*Maianthemum stellatum*		x	
White sweetclover	*Melilotus alba*	x	x	
Yellow sweetclover	*Melilotus officinalis*		x	x
Wild mint	*Mentha canadensis*		x	
Heartleaf four o'clock	*Mirabilis nyctaginea*		x	x
American pokeweed	*Phytolacca americana*	x		x
Smooth Solomon's seal	*Polygonatum biflorum*		x	x
Swamp smartweed	*Polygonum amphibium*		x	x
Curly dock	*Rumex crispus*		x	x
Golden dock	*Rumex maritimus*		x	
Russian thistle	*Salsola pestifer*		x	
Prickly Russian thistle	*Salsola tragus*		x	x
Bur cucumber	*Sicyos angulatus*	x		x
Goldenrod	*Solidago spp.*	x		
Moist sowthistle	*Sonchus arvensis uliginosus*		x	x
White panicle aster	*Symphotrichum lanceolatum*		x	
Purple meadowrue	*Thalictrum dasycarpum*		x	
Veiny meadowrue	*Thalictrum venulosum*		x	
Colt's foot	*Tussilago farfara*	x		
California nettle	*Urtica dioica*		x	x
American vetch	*Vicia americana*		x	
Creeping violet	*Viola canadensis rugulosa*		x	
Common cocklebur	*Xanthium strumarium*	x		x

(Sheet 3 of 3)