Coronilla varia

INTRODUCTORY

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FEIS ABBREVIATION:
CORVAR

NRCS PLANT CODE [148]:
SEVA4

COMMON NAMES:
crownvetch
crown vetch
purple crownvetch

TAXONOMY:

The scientific name of crownvetch is *Coronilla varia* L. (Fabaceae) [66].

There are at least 3 common crownvetch cultivars: 'Penngift', 'Chemung', and 'Emerald'. These cultivars are essentially ecotypes that developed with 20 or more years of natural selection at different sites [92].

SYNONYMS:
Securigera varia [60,78,141,159]

LIFE FORM:
Forb

DISTRIBUTION AND OCCURRENCE

SPECIES: Coronilla varia

GENERAL DISTRIBUTION:
Crownvetch is a nonnative species found throughout the contiguous United States and southern Canada [8,96,139,160,169]. Crownvetch also occurs in Hawaii [155] but does not occur in Alaska [148]. Most reports indicate that crownvetch is native to Eurasia [8,96,160,169], and it may also be native to northern Africa [46,139]. Although crownvetch is widely distributed in North America, it is most common in areas near sites where it was planted [155]. In the northern and central parts of the United States, crownvetch is most common [92] and can be invasive (see Impacts). For a map of crownvetch's North American distribution, see Plants Database.

Introduction: In the reviewed literature, the earliest report of crownvetch in the United States occurred in 1869 in New York. As of 1872, this population near the Hudson River was described as "thoroughly established and naturalized, spreading in open spaces of the wood" [163]. In 1874, crownvetch was "well naturalized" in fields in the Pine Plains region of Dutchess County, New York [57]. Reviews report that crownvetch was available commercially in the United States by 1890 [92,120].

After 1935, when crownvetch plants were found covering over 10 acres (4 ha) of very poor quality soils in Pennsylvania, research into crownvetch as an erosion control and revegetation plant began. By the 1950s, crownvetch was planted extensively in North America [139]. The crownvetch population in Pennsylvania developed from a single plant that emerged in an alfalfa field planted in 1905 [39]. Crownvetch persisted in soils with "fertility levels so low that only poverty grass would normally survive" [162]. Crownvetch was commonly used to revegetate roadside cuts, mining sites, and railroad embankments. It was also planted as an ornamental and used as a cover crop or as green fertilizer [8,35,67,109,119,132,159,160]. By the 1960s, crownvetch was abundant in the eastern United States [60]. Although widely planted to control erosion, in some areas crownvetch has only camouflaged erosion (Grover and Harper-Lore 2001 personal communications cited in [139], review by [147]). For more information, see Other Uses.

On abandoned mine sites, crownvetch was commonly recommended for revegetation [152], and throughout the Appalachian coal region, crownvetch was seeded on mine sites [73,137]. In 1977, the US federal government established guidelines that required establishment of 70% perennial ground cover on abandoned mine sites. Crownvetch provided rapid perennial cover and was used extensively [58]. In some areas, crownvetch has escaped from the revegetation site and is growing in adjacent native vegetation. On an 18-year-old coal surface-mined site in southeastern Kentucky, crownvetch was "adapting to the point of becoming naturalized". In the mid 1960s, crownvetch was used to revegetate coal spoils, but in 1984, researchers described crownvetch as "especially aggressive" in the area and found plants in adjacent vegetation excluding native plants. Although seeding crownvetch on coal spoils provided

rapid cover as required by federal and state reclamation laws, dense crownvetch growth may limit establishment of native herbs, shrubs, and trees [137].

Local distribution changes: Escaped and invasive crownvetch populations are common in the Midwest and occur sporadically in surrounding areas, but in other areas escapees are rare [133,155] or restricted to disturbed sites [27,65,126]. Although not known to escape and persist throughout its nonnative range, reviews indicate rapid spread by seed [22,121], and long-distance seed dispersal by deer is likely (see Seed dispersal).

In the Midwest and eastern United States, studies have documented crownvetch spread. In Pennsylvania, crownvetch was seeded on highway slopes at more than 100 sites in 30 counties. Even with years of below normal precipitation, crownvetch cover was dense on 75% of seeded slopes within 2 years [92]. Within ten years of seeding a 10-foot (3-m) length of roadside in Indiana, crownvetch spread to occupy a 75-foot (23 m) length of roadside [46]. In Boone County, Iowa, a crownvetch patch increased in size from 32,900 ft² (3,060 m²) in 2004 to 39,100 ft² (3,630 m²) in 2005, through the establishment of new patches and growth of existing patches [84]. During surveys conducted along railroads in St. Louis, Missouri, crownvetch colony was found in 1971 but was not found in earlier surveys that began in 1954 [97]. As of 2002, crownvetch was invading and/or disrupting native plant communities in more than 10 Missouri counties [95]. In 2003, crownvetch occurred on 4 sites and 0.4 acres (0.2 ha) of Michigan's Ottawa National Forest [145]. Two years later, crownvetch occurred on 14 sites and 11 acres (4.5 ha) of the Forest [143]. Crownvetch occurred in oak openings in northwestern Ohio by 1928. In a 1978 survey of the same study area, crownvetch was found fewer than 5 times [28]. Crownvetch was absent from Ohio's Athens State Forest flora in 1957, but in 2005 it occurred in disturbed areas of the Forest [45]. As of 2001, Ohio's Department of Natural Resources considered crownvetch well established in the state (Windus and Kromer 2001 cited in [61]). On cut slopes in West Virginia, crownvetch spread beyond seeded areas on at least 2 sites. On one site, crownvetch spread 33 feet (10 m) outside of the planting area within 6 years of seeding. On an "extremely harsh" site, crownvetch spread to double the size of the seeded area. Vegetation adjacent to these sites was not described [100].

HABITAT TYPES AND PLANT COMMUNITIES:
In its native range, crown vetch occurs in meadows, grasslands, savannas, and disturbed areas ([21], review by [158]). Similar habitats are occupied by crownvetch in North America.

Although crownvetch was reported in pine (*Pinus* spp.) forests in the western United States [24,52], it is unlikely that crownvetch is restricted to pine forests in the West. In revegetation guides for the Intermountain West, crownvetch reportedly grows well in big sagebrush (*Artemisia tridentata*), mountain shrubland, aspen (*Populus tremuloides*), and pinyon-juniper (*Pinus-Juniperus* spp.) vegetation types [56,101].

Crownvetch often occurs in tallgrass prairies and upland vegetation in the central and Midwestern United States ([44], review by [38]). Based on a survey of Wisconsin's natural area and botanical experts, crownvetch is most common in grasslands but also occurs in barren and forested communities [107].

Grasslands and savannas are also habitat for crownvetch in the eastern United States. In Pennsylvania, crownvetch commonly occurs in xeric limestone prairies dominated by sideoats grama (*Bouteloua curtipendula*) [79]. In Evansburg State Park, crownvetch occurs in old fields, roadside vegetation, and utility corridors, and researchers determined that the distribution of crownvetch was related more to disturbances than site conditions [70]. In the Wallops Island region of Virginia, crownvetch occurs in lawns and other disturbed sites, on secondary dunes with saltmeadow cordgrass (*Spartina patens*), and in meadows dominated by bushy bluestem (*Andropogon glomeratus*) and little bluestem (*Schizachyrium scoparium*) [72]. In Great Falls Park, Virginia, crownvetch occurs in open-canopy pignut hickory-oak-white ash (*Carya glabra-Quercus* spp.*-Fraxinus americana)* woodlands [125]. In the Land Between the Lakes National Recreation Area in Kentucky, crownvetch occurs in warm season grasslands dominated by big bluestem (*A. gerardii*), switchgrass (*Panicum virgatum*), and little bluestem [136].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Coronilla varia

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GENERAL BOTANICAL CHARACTERISTICS:

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., [35,41,74,105,155,160]).

Aboveground description: Crownvetch is a mostly hairless, perennial forb with weak spreading stems from a short branching caudex [8,41,105,109,155]. Crownvetch lacks tendrils that are characteristic of true vetches (*Vicia* spp.) [139]. In flower, crownvetch plants may be 3 or more feet (1 m) tall, but plants are generally just 1 foot (0.3 m) tall in their vegetative state [8,162]. Crownvetch produces trailing stems that may reach 6 feet (2 m) long [139] and often appears as a heavy mat of stems [3]. Crownvetch is often described as "long-lived" [56,162], but precise life expectancy was rarely reported. One report indicates that crownvetch plants live up to 20 years [31]. Another report indicates that crownvetch has survived in the same location for over 50 years [3].

Crownvetch has odd-pinnate compound leaves that are 2 to 6 inches (4-16 cm) long. Leaves have 7 to 25 leaflets that measure 0.4 to 1 inch (1-3 cm) long [8,49,67,133]. In the winter, crownvetch's basal, and sometimes upper, leaves remain green [129]. Crownvetch produces pea-like flowers in a spreading umbel that resembles a crown [49,155]. Individual flowers are 9 to 12 mm long, have 10 stamens, and are white-pink to rose colored [8,109,160]. Umbels contain 6 to 25 flowers [8]. Pubescence, flower color, and leaflet size and shape can vary considerably [41].

Crownvetch generally produces seeds in a slender, linear, jointed pod [49,155]. Pods may reach 2 inches (6 cm) long and have up to 12 joints. Each joint contains a single seed [8,35,105,133]. Pods are described as indehiscent by Stubbendieck and Conard [133], but Stevens and Monsen report that pods break open when dry [129]. Crownvetch seeds are cylindrical and measure 3 to 4 mm by 1 to 1.2 mm [7,133].

For descriptions of the morphological similarities and differences between the 3 most common crownvetch cultivars: 'Penngift', 'Chemung', and 'Emerald', see [92].

Belowground description: Anecdotal reports about crownvetch's underground growth are common, but details and measurements are generally lacking. Crownvetch produces both roots and rhizomes. The taproot is deep and multibranched (review by [120]). Rhizomes are strong and fleshy and may grow to 10 feet (3 m) or longer (reviews by

[119,120,139]). From the lower surface, rhizomes produce roots and from the upper surface, shoots (review by [22]). In a cemetery near Cincinnati, Ohio, crownvetch roots occurred more than 6.5 feet (2 m) deep in heavy clay soils [39]. On cut slopes with moist, loose soil and "ample" phosphorus in West Virginia, an 8-month-old crownvetch plant produced roots over 6 feet (2 m) long. On a steep, dry slope, 47- to 77-day-old crownvetch seedlings had 3- to 6-inch-long (8-16 cm) taproots. Within 100 days, most grass seedlings on the site had died, while crownvetch established well [100].

Raunkiaer [106] **life form:**
Chamaephyte
Hemicryptophyte

SEASONAL DEVELOPMENT:
Crownvetch flowers are possible from May to September throughout its US range [8,41,89,105,169]. In the northeastern United States, crownvetch flowering is "profuse" for a 6-week period in May and June (review by [83]). However, crownvetch flowers and produces seed throughout the growing season. Often both newly opened flowers and mature fruits occur on the same plant [84]. In the winter, at least the basal crownvetch leaves remain green (review by [129]).

Based on 2 years of study, total available root carbohydrates decreased from about 18% in late April to seasonal lows of 12% or 13% as vegetative growth was produced [77]. During field studies conducted near Blacksburg, Virginia, researchers found that the total nonstructural carbohydrates of crownvetch plants were generally highest in the fall (October and November) and lowest in summer (July and August), regardless of frequent or infrequent clipping [167].

REGENERATION PROCESSES:
Crownvetch reproduces by seed and rhizomes. Rhizome spread and sprouting are important to crownvetch growth and persistence (see Vegetative regeneration).

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

Pollination and breeding system: Crownvetch flowers are perfect [160] and almost "entirely dependent upon insects for pollination" [3]. In controlled experiments, seed production ranged from 0.007 to 0.190 seeds/selfed flower [47]. In the field, honeybees are the primary crownvetch pollinators, even though crownvetch is not a good nectar source. In a 90-acre (36-ha) study area in Pennsylvania, seed set increased with increasing bee abundance. When researchers provided 4 bee colonies, crownvetch set 17.8 seeds/flower head, and with 18 bee colonies, crownvetch set 24.6 seeds/flower head [2]. When insects were excluded from crownvetch plants in the field, no seed was produced [3].

Seed production: Crownvetch typically produces seed in its 2nd year of growth (Bender personal observation cited in [11]), and seeds typically mature 6 to 10 weeks after flower pollination. Generally, seed production is low, and high precipitation, low light, and/or low temperatures may reduce production. Seed production of 75 to 175 lb/acre is common, although 400 lb/acre has been reported [92]. Seed production may be limited by pollinators. When bee hives were located near a crownvetch population in Pennsylvania, production averaged 16.4 metric tons of air dry seed/ha [1].

Seed maturation and production can vary with growing conditions. In a year with above-average growing season precipitation, production averaged 257 kg/ha, and in a year with slightly below-average growing season precipitation,

production averaged 530 kg/ha [1]. In years with abundant moisture, crownvetch often produces a "flush" of vegetative growth, which shades developing seed pods and delays or limits seed development and maturation [92,111]. On low fertility, droughty soils, vegetative growth rarely interferes with seed development and maturity [111]. In a field study, crownvetch plants that were covered by screens with bees inside produced lighter and fewer seeds than plants in the open. The researcher considered reduced light beneath the screens the likely reason for reduced production [3]. Low night temperatures in late summer or early fall can "retard seed maturation" [92].

Seed dispersal: Generally, crownvetch seed falls near the parent plant, but deer and likely other animals contribute to long-distance seed dispersal. As seeds mature, pods break, and seeds fall [92]. Crownvetch seeds are not adapted for wind dispersal [102]. In the Great Plains, crownvetch is "usually found close to where it was originally planted, as it does not readily migrate" [133]. In other areas, however, crownvetch populations occur miles away from a seed source (review by [119]). In Gila County, Arizona, a crownvetch population grew on a roadside cut, but a single plant also occurred in a ponderosa pine (*Pinus ponderosa*) forest 738 feet (225 m) from the small roadside population [52]. Studies in the northeastern United States indicate that crownvetch seed can be dispersed by deer. Four crownvetch seeds germinated from white-tailed deer feces collected from mixed-deciduous forests in central New York [98]. In southern Connecticut, 6 crownvetch seeds germinated from white-tailed deer feces. During this study, the median maximum distance travelled by white-tailed deer was 1,860 feet (568 m)/day. In 4% of observations, deer traveled over 6,500 feet (2,000 m) in 24 hours [164].

Seed banking: Reports on the persistence of crownvetch seed in the soil vary, and experimental seed bank studies are generally lacking. Grover (2001) indicates that crownvetch is capable of producing a large soil seed bank (personal communication cited in [139]). A review reports that crownvetch seed may be viable for 15 years or more [22]. However, during studies in calcareous grasslands in Germany's middle Swabian Alb, crownvetch seeds were typically viable for less than 2 years in the soil [102]. Up to 25% of seed produced by crownvetch is hard and requires scarification before it will germinate. Likely hard seeds contribute most to the seed bank. Additional information about hard crownvetch seeds is presented in the Germination section below.

Storage studies indicate that crownvetch seed in an area with minimal temperature and humidity fluctuations remains viable for 11 to 15 years (review by [64]). After 8 years of storage in an open warehouse in Sanpete County, Utah, stored crownvetch seed germinated better (70%) than freshly collected seed (41%) ($P<0.05$). Seeds stored for more than 8 years failed to germinate. Temperature extremes in the open warehouse ranged from -29.9 °C to 38.3 °C over a 25-year period [128].

In Iowa, no crownvetch seedlings emerged from soil samples collected from established crownvetch patches [84,85]. Crownvetch also failed to emerge from soil samples collected from a constructed wetland along the Delaware River near Trenton, New Jersey, although crownvetch occurred in the aboveground vegetation [80]. However, up to 384 crownvetch seedlings emerged from soil samples taken from a roadside in Campbell County, Kentucky, where crownvetch was dominant. Crownvetch emergence was lower from soil samples taken beneath staghorn sumac (*Rhus typhina*) clumps than from samples collected outside staghorn sumac clumps [86].

Germination: Generally, crownvetch seed germination is best when seeds are scarified and shallowly buried in moist, nonsaline, warm soils (air temperatures 68-77 °F (20-25 °C)). The percentage of crownvetch seed that is hard or impermeable to water varies. Reports indicate that 20% [111] to 80% of seed is hard [1]. Once scarified, crownvetch seed germination percentages are usually high (85-90%) [40,111].

In his review of species that produce water-impermeable seeds, Rolston [110] indicated that hard seed coats can be broken down or punctured naturally by fire or digestive tract passage. In the laboratory, 29% of unscarified crownvetch seeds germinated. When seeds were kept in 190 °F (90 °C) water for 4 hours, germination was 42%, and when mechanically scarified, germination was 63%. Regardless of the method, germination was significantly greater for scarified than unscarified seeds ($P<0.05$) [26]. Researchers found that most hard crownvetch seeds had to be pierced to a depth of at least 98 µm before they absorbed water and germinated [91]. In other controlled experiments, very short-duration heating softened crownvetch seeds, but heating for more than 1 minute killed many seeds. Hard seeds heated to 190 °F (85 °C) or 210 °F (100 °C) in less than 1 minute beneath heat lamps germinated twice as well as untreated seeds. About 60% of hard seeds rotted when heating occurred over a 2-minute period. Oven heat treatments

of 210 °F (100 °C) or 260 °F(125 °C) resulted in "nearly complete (seed) death" [13]. Experiments conducted on hard seeds of 2 crownvetch cultivars suggested that abrupt changes in temperature produced greater germination than long exposure to high temperatures. Germination of hard seeds increased after 5 seconds in boiling water, and for seeds that were still hard after this treatment, germination was increased by a second boiling water treatment (<30 seconds). After 2 short-duration boiling water treatments, crownvetch seed germination was greater than after a single long-duration boiling water treatment [33].

Based on 2 studies, shallow burial in nonsaline soils is best for crownvetch seed germination. In the greenhouse, crownvetch emergence was significantly greater from 2-inch (4-cm) depths than from the soil surface or 3-inch (8-cm) depths (P<0.05) [85]. A Utah forage and conservation planting guide recommends seeding crownvetch in the fall at 0.25 to 0.5 inch (0.5-1 cm) deep [56]. Another guide recommends a seeding depth of 0.5 cm or less (review by [129]). According to a review [147], frost heaving can force crownvetch seeds into the soil. In soils with a salt content of 5 g/kg, crownvetch seed germination was delayed, and germination percentages were "markedly" decreased compared to seeds in nonsaline conditions [82].

Warm temperatures (up to 75 °F (24 °C)) and increased available moisture generally increase crownvetch seed germination. In controlled conditions, increasing temperatures typically lead to increased germination of scarified crownvetch seed. Germination was about 20% at 54/43 °F (12/6 °C), 60% at 59/50 °F (15/10 °C), and 80% at 75/64 °F (24/18 °C) day/night temperature regimes [48]. In soil samples collected from a highway road cut, crownvetch seedling emergence was 57%, 10%, and almost 0% from samples with moisture tensions of -1/3, -3, and -6 bars, respectively. After 3 or 4 days of monitoring, total emergence was greater at 70 °F (21 °C) than at 82 °F (28 °C), regardless of moisture levels [168].

Seedling establishment and plant growth: In the first 1 to 2 years after seeding, crownvetch establishment and growth are limited, but 3 to 4 years after establishment, crownvetch can form dense stands (reviews by [83,127]). Site conditions including winter temperatures, soils, moisture availability, and associated vegetation affect crownvetch establishment and productivity.

Two reviews report that crownvetch establishes and spreads well from seed [22,121], but a review from the Great Plains reports that crownvetch is often "found close to where it was originally planted" and does "not seed well" [133]. An Intermountain revegetation guide also rated crownvetch establishment and spread from seed as "poor" [101].

Slow emergence, growth, and establishment are often reported for 1st-year crownvetch seedlings (reviews by [47,83,111,129]). Six- to seven-week-old crownvetch seedlings had an average relative growth rate of 0.117 g/g/day in sand with nutrients added [29]. While crownvetch may completely cover a site within 2 or 3 years of seeding (review by [83]), in the western United States it typically takes 3 to 4 years to flower (review by [127]). In a garden, crownvetch completely covered an area by its 2nd growing season, but aboveground growth was slow in the 1st several weeks after seeding when roots were developing [39].

Temperature and soils: Crownvetch seedlings are sensitive to cold temperatures, soil acidity, and soil compaction. Seedlings emerging after July will not likely survive the winter [92]. Crownvetch seedlings less than 4 inches (10 cm) tall at the time of the first killing frost rarely survive (Woodruff and Blaser 1970 as cited in [100]). Acidic and/or compacted soils can limit crownvetch seedling establishment and growth [40,111]. Soon after seeding in West Virginia, crownvetch cover averaged 70% on mechanically scarified slopes and 32% on compacted slopes. By 18 months after seeding, however, crownvetch cover was 95% to 100% on both slopes [100].

Low moisture levels at the seedling stage will likely reduce crownvetch establishment. Crownvetch establishment was poor in a cleared forest along a utility right-of-way near Tobemory, Ontario. Crownvetch established on only half of the seeded plots, and cover averaged only 0.15% at the end of the 1st growing season. Summer drought was blamed for poor establishment [17]. In the revegetation of Lesser Slave Lake Basin in central Alberta, crownvetch establishment was best in low areas between the sand dunes and poorest on sand dune crests [81]. For more information on crownvetch seedling and plant growth as related to soil characteristics, see Soils.

Associated vegetation: Crownvetch seedling establishment is best on open sites lacking other vegetation [92]. When

crownvetch was seeded in a 10-year-old switchgrass (*Panicum virgatum*) stand near Ames, Iowa, establishment was low and averaged 0.9% in July after the 1st seeding and 7% in August after a 2nd seeding. Crownvetch was seeded at a rate of 171 seeds/m² [12]. The mechanisms by which crownvetch establishment is limited in intact, undisturbed vegetation were not discussed in the available literature (2010), but researchers showed that initial establishment is not limited by shading. Crownvetch seedlings survived 1 month of receiving just 1% to 2% incident radiation beneath an oat (*Avena* spp.) canopy (Buxton and Wedin 1970 cited in [100]).

Vegetative regeneration: Crownvetch produces extensive vegetative growth from multibranched rhizomes (reviews by [121,162]) and is capable of regenerating from stem and rhizome fragments [85]. Once established, crownvetch plants can form a dense mat of vegetation that "gradually chokes out" other vegetation [162]. A review reports that crownvetch rhizomes can reach 10 feet (3 m) long, and a single plant may cover 750 to 1,100 feet² (70-100 m²) in 4 years (review by [119]). On a cut slope in West Virginia, an 8-month-old crownvetch plant had rhizomes over 7 feet (2 m) long that supported 87 stems. On this site, soils were moist, loose, and had "ample" phosphorus [100]. Field observations made in central Bohemia, Czech Republic, indicated that within a year, vegetative offspring rarely occurred more than 1.5 feet (0.5 m) from the parent crownvetch plant [103].

Photo © Mandy Tu

Increased vegetative growth can limit crownvetch seed production. When crownvetch produces abundant vegetative growth as seed is maturing, seed pods are shaded, seed development and maturity are delayed, and seed production is ultimately reduced. This is most common in high moisture years or areas [111].

In some areas, crownvetch persistence and spread is heavily dependent on vegetative regeneration. In Iowa, no crownvetch seedlings emerged from soil collected in crownvetch patches, but all 0.8- to 4-inch-long (2-10 cm) stem fragments with a node produced new growth. Aboveground stem segments that received water only once a week produced new growth but died within 3 weeks. Stem sections without nodes did not produce new growth but were green after a month in well-watered pots [84,85]. The researcher concluded that in this area, crownvetch persistence and spread were due to vegetative growth and regeneration [85].

SITE CHARACTERISTICS:
Throughout its North American range, crownvetch is most common in disturbed areas including fields, former dwellings, roadsides, rights-of-way, and stream banks [7,89,105,113,119,133,166,169]. For a discussion of areas where crownvetch is invasive, see Impacts.

Climate: Crownvetch tolerates a wide range of climates in North America. Reviews report that crownvetch grows well in USDA hardiness zones 3 to 7 [123] and tolerates "long" periods of drought, precipitation of up to 65 inches (1,650 mm)/year, and temperatures as cold as -27 °F (-33 °C) [139]. Revegetation guides for the Intermountain West suggest that crownvetch grows well on sites receiving at least 21 inches (530 mm) of annual precipitation and thrives on sites receiving more than 30 inches (760 mm) of annual precipitation [56,129]. Although tolerant of many climate regimes and present nearly throughout the United States, crownvetch introductions were not very successful in central Alaska, Palo Alto, California, southern Georgia, or Florida. Crownvetch establishment failed on saline shorelines, and plants were winter-killed in central Alaska [92]. For information on the cold tolerance of crownvetch seedlings, see Temperature and soils.

Elevation: Only in Nevada and parts of California are elevation ranges reported for crownvetch. In Nevada, crownvetch occupies a narrow elevational range of 4,500 to 4,600 feet (1,400 m) [67]. In California's Butte and Nevada counties, crownvetch populations were reported at 2,341 feet (714 m) and 7,100 feet (2,160 m), respectively [24].

Soils: Crownvetch establishes and persists on sands, loams, clays, and gravelly and rocky soils (reviews by [83,139,147]). Although crownvetch has "excellent" drought tolerance [83] and in several areas occurs in dry rocky soils ([24], review by [123]), plants are unlikely to persist on sites with less than 15% very fine sand, silt, and/or clay [147]. Highly compacted soils can also limit crownvetch establishment and growth [111]. Moderately acidic and low fertility soils are tolerated [83], but saline and poorly drained soils are not [92,139]. In soils with a salt content of 5 g/kg, crownvetch germination was delayed and reduced as compared to seeds in nonsaline soils [82].

Moisture: Although tolerant of both moist and dry climates [31], crownvetch requires well drained soils [92]. Crownvetch rarely grows well or survives long in poorly drained soils [56,92]. Along the shores of Cave Run Lake in northeastern Kentucky, crownvetch was absent from mud flats but did occur on frequently and infrequently flooded shorelines. Mud flats occurred below the summer pool shoreline, frequently flooded sites were up to 7.9 feet (2.4 m) above summer shoreline, and infrequently flooded sites occurred at 7.9 to 24 feet (2.4-7.3 m) above summer shoreline [87]. During field surveys in Pennsylvania, crownvetch was absent from areas with evidence of soil mottling or water pooling [93].

pH and fertility: Crownvetch may grow best on neutral or alkaline soils [56,59] but also establishes on acidic soils (pH 5) and spreads vegetatively into highly acidic soils [152]. In Europe, crownvetch often occurs on calcareous soils [59], and in Utah, crownvetch grows well in calcareous soils [56]. In a revegetation guide for eastern coal mine spoils, Vogel [152] reported that crownvetch seedling establishment was best on soils with a pH of 5.5 or greater, but established plants usually spread into soils with a pH of 4.5 or less. Crownvetch stand development was considered a "failure" 2 to 4 years after seeding a strip mine spoil with a pH of 4.5 [111]. One to two years after seeding in Davis County, southeastern Iowa, crownvetch cover was greatest (7%) in moderately acidic (5.2-5.9 pH) soils. Crownvetch plants were largest in acidic (4.8-5.4 pH) silt loams. Plant size and cover (2%) were lowest on acidic (5.4-6.2 pH) soils with the shallowest top soil layer [14].

Low fertility soils are tolerated, but crownvetch growth is improved on fertile soils (Barnes and others 1995 cited in [31]). Based on field and greenhouse studies conducted in Pennsylvania, researchers concluded that rapid seedling growth and persistence of crownvetch occurs on soils with good or excellent drainage, high levels of phosphorus, potassium, calcium, and magnesium, and pH levels of 6.5 to 7. In the greenhouse, crownvetch failed to establish in coal mine soils with a pH of 2.8. Seedlings in soils with a pH of 6.3 to 7.7 and high calcium content (1,900-4,800 kg/ha) were larger than those in soils with lower pH and calcium content. In the field, dense crownvetch stands occurred on soils with pH ranging from 4.6 to 7.7 [93].

Although crownvetch growth may be best on fertile and moist but well drained sites, sources indicate decent growth and persistence on dry, low fertility sites as well. During droughts on dry, low fertility soils in West Virginia, crownvetch grew "vigorously" [111]. In Pennsylvania, researchers recognized crownvetch as a potentially useful plant for the revegetation of harsh sites, when it occurred "at fertility levels so low that only poverty grass would normally survive" [162].

SUCCESSIONAL STATUS:
Crownvetch is an early- to mid-seral species that is moderately shade tolerant. In many areas, crownvetch is restricted to disturbed sites, although grazing and mowing may decrease its abundance.

Studies in its native range indicate that crownvetch occurs in early- and mid-seral stages of secondary succession. Crownvetch may appear earlier when succession begins on bare ground than when succession begins with field abandonment. During the succession of bare sites created during road construction in eastern Bohemia in the Czech Republic, crownvetch occurred with low cover in the first 2 years. Crownvetch dominated the site in years 3 to 5, decreased in year 6, and was rare in year 7 [71]. In another successional study of 16 seres in the Czech Republic, crownvetch was most common after 10 years of succession. Seres began as bare ground resulting from human-caused disturbances and covered up to 76 years of vegetation development [104]. In old field succession in the Bohemian Karst Protected Region of Czech Republic, crownvetch was more common on fields abandoned 30 to 60 years earlier than on those abandoned 6 to 20 years earlier [9]. In Germany, crownvetch was common in old meadows (>30 years abandoned) but not in pioneer communities or early-seral fields (1-4 years abandoned) [124].

Shade tolerance: In most reviews, crownvetch is described as preferring full sun but tolerating partial shade (reviews by [22,123,129]). However, Lorenz and others [83] suggest that crownvetch has "poor" shade tolerance, and Weber and Wittmann [159] indicate that crownvetch thrives in shaded conditions.

Field experiments and observations indicate that crownvetch does tolerate some shading, but long-term persistence in partial or full shade was rarely evaluated. In West Virginia, crownvetch was seeded with black locust (*Robinia pseudoacacia*). Two years after seeding, crownvetch cover was nearly 100%. Four years after seeding, black locust produced a nearly closed canopy, but cover of crownvetch was not "diminished" [111]. In a field study, normal light level reductions of 60% or more were required to reduce crownvetch growth (review by [100]). In established crownvetch stands in Pennsylvania, total herbage yield of crownvetch was significantly lower (P<0.05) in shaded than unshaded plots. In areas shaded 58% to 78% for 2 years from late July to late September, crownvetch yield was 6.7 to 8.8 mg/ha and in unshaded areas was 8.6 to 10.0 mg/ha [20]. During experiments conducted near Blacksburg, Virginia, crownvetch plants dropped leaflets when subjected to "prolonged" shading [167].

Disturbances: Crownvetch is often found on disturbed sites. During surveys of state forests, parks, recreation areas, and wildlife refuges from Oklahoma to Maryland, crownvetch was most common or restricted to disturbed sites that included roads, trails, ditches, utility corridors, parking areas, and abandoned fields [10,45,50,65,70,126]. In Pennsylvania, a single crownvetch plant appeared in 1905 in an alfalfa field and persisted in the field even with repeated plowing and cultivation [39].

Grazing: Several reviews indicate that crownvetch is reduced or eliminated by grazing [120,133,152]. Three seasons of continuous grazing "deteriorates" crownvetch stands [120], and stands established on coal mine spoils can be "weakened or lost if overgrazed" [152]. In north-central Romania, researchers compared continuously grazed and ungrazed feather grass (*Stipa* spp.) stands. Crownvetch was characteristic of sites that were ungrazed for 29 to 57 years. Grazed sites were used by both sheep and cattle from spring to fall [30]. In field experiments conducted near Blacksburg, Virginia, clipping at 7- and 14-day intervals for 2 growing seasons reduced crownvetch cover from 90% to 10% [167]. In the Bohemian Karst Protected Region of Czech Republic, crownvetch biomass increased on sites mowed once and sites mowed repeatedly [9], but Vogel [152] indicates in a revegetation guide that crownvetch stands can be "weakened or lost" if cut more than 1 time/year for hay making.

Field observations and studies in Indiana indicate that soil compaction and not biomass removal limits crownvetch growth on grazed sites. Crownvetch successfully invaded adjacent ungrazed tall fescue (*Schedonorus phoenix*) stands but failed to invade adjacent grazed tall fescue stands. In crownvetch-mixed grass stands that were grazed for 3 years, crownvetch plants were thin, "lacked vigor", and failed to spread. In stands that were mowed and baled for hay, crownvetch plants had "excellent vigor of growth and spreading qualities" [46].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Coronilla varia

FIRE EFFECTS:
Immediate fire effect on plant: Established crownvetch plants are likely only top-killed by fire ([42], review by [121]).

Postfire regeneration strategy [130]:
Rhizomatous herb, rhizome in soil
Ground residual colonizer (on site, initial community)
Secondary colonizer (on- or off-site seed sources)

Fire adaptations and plant response to fire: Crownvetch likely sprouts from its rhizomes or deep taproot (reviews by [119,120,139]) following fire, and germination of hard seeds may be stimulated by low-severity fire (McGuigan 2002 personal communication cited in [139]). In a review, Tu [139] indicated poor fire spread in crownvetch stands and that fire rarely burns into the center of dense patches. In the available literature (2010), fire studies in habitats invaded by crownvetch were rare.

Two sources suggest that crownvetch persists on burned sites. During attempts to restore tallgrass prairie on Iowa's Walnut Creek National Wildlife Refuge, prescribed fire has not controlled crownvetch (Shutte personal communication cited in [37]), and in tallgrass prairie at the Konza Prairie Biological Station in northeastern Kansas, crownvetch occurred on sites burned every 10 years [42].

While fire is a natural method of scarifying the hard seeds of several species [110] and may serve to scarify crownvetch seed (McGuigan 2002 personal communication cited in [139]), controlled studies suggest that germination is only increased by very short duration heating [13,33]. Oven heat treatments of 210 °F (100 °C) or 260 °F (125 °C) resulted in "nearly complete (seed) death". Heating seeds under a lamp from 99 °F (37 °C) to 190 °F (85 °C) or 210 °F (100 °C) in 1 minute, though, doubled hard seed germination percentages. When the heating process was completed over a 2-minute period, 60% of hard seeds were killed [13]. Experiments conducted on hard seeds of two crownvetch cultivars suggested that abrupt temperature changes resulted in greater germination than did long exposure to high temperatures. Germination of hard seeds increased after 5 seconds in boiling water, and for seeds that were still hard after this treatment, germination was increased by a second boiling water treatment (<30 seconds) [33].

FUELS AND FIRE REGIMES:
Fuel characteristics of crownvetch were only noted in a few references. Crownvetch generally remains green in very dry conditions [40] when most associated grasses are "drought-browned" [39]. Fire spread may be limited by dense patches of crownvetch in invaded habitats, although no studies have documented this. In a review, Tu [139] reported that fire spreads poorly in crownvetch-dominated stands and often fails to burn into the center of dense patches. Fire studies on sites with dense crownvetch populations are needed.

See the Fire Regime Table for more information on the fire regimes in communities that may include crownvetch.

FIRE MANAGEMENT CONSIDERATIONS:
Potential for postfire establishment and spread: Because crownvetch is widely distributed, common on disturbed sites, and fire may scarify hard seeds, crownvetch is likely to occur in early postfire succession.

Preventing postfire establishment and spread: Preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. This may be accomplished through early detection and eradication, careful monitoring and follow-up, and limiting dispersal of invasive plant seed into burned areas. General recommendations for preventing postfire establishment and spread of invasive plants include:

- Incorporate cost of weed prevention and management into fire rehabilitation plans
- Acquire restoration funding
- Include weed prevention education in fire training
- Minimize soil disturbance and vegetation removal during fire suppression and rehabilitation activities
- Minimize the use of retardants that may alter soil nutrient availability, such as those containing nitrogen and phosphorus
- Avoid areas dominated by high priority invasive plants when locating firelines, monitoring camps, staging areas, and helibases
- Clean equipment and vehicles prior to entering burned areas
- Regulate or prevent human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation
- Monitor burned areas and areas of significant disturbance or traffic from management activity
- Detect weeds early and eradicate before vegetative spread and/or seed dispersal
- Eradicate small patches and contain or control large infestations within or adjacent to the burned area
- Reestablish vegetation on bare ground as soon as possible
- Avoid use of fertilizers in postfire rehabilitation and restoration
- Use only certified weed-free seed mixes when revegetation is necessary

For more detailed information on these topics see the following publications: [6,15,36,146].

Use of prescribed fire as a control agent: Successful control of crownvetch with fire alone has not been documented in the literature (2010), but several sources indicate that fire may be useful in an integrated crownvetch control program. A review suggests that late-spring prescribed fire can provide some crownvetch control [151], but details were lacking. In another review, Tu [139] suggested that late-spring fires may help to control crownvetch if associated vegetation is stimulated by the fire. Although fire alone will not likely eliminate crownvetch from a site, it may slow its spread [139].

Fire may be used to accomplish specific management goals or may be used as part of an integrated management plan. Although the fire conditions necessary to scarify hard crownvetch seed are largely unknown, when these conditions are understood, fire could be used to stimulate seed bank germination (McGuigan 2002 personal communication cited in [139]). In invaded areas, fire may also be used to remove litter, increase herbicide coverage, and expose crownvetch seedlings and sprouts for follow-up treatments (review by [119]). In northwestern Illinois, researchers found that available soil nitrogen was higher inside than outside crownvetch patches even 1 year after treating crownvetch with herbicide. Based on these findings, researchers speculated that removal of crownvetch litter mechanically or by burning could reduce nitrogen inputs from crownvetch litter, restoring the nitrogen-limited environment that existed before the invasion of crownvetch. Absence of the litter barrier may also improve the germination success of associated species [134].

Altered fuel characteristics: Some sources indicate that fire spread is limited in dense crownvetch patches (review by [139]), which even in very dry conditions remain green [39,40]. This suggests that fire spread may be reduced in habitats heavily invaded by crownvetch. See Fuels for details.

MANAGEMENT CONSIDERATIONS

SPECIES: Coronilla varia

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:
Although its seeds and foliage may be poisonous to nonruminants [41,133], elk, deer, most classes of livestock, and rabbits feed on crownvetch. Crownvetch is considered high quality livestock, deer, and elk forage, and in the winter, these large mammals paw through the snow to feed on crownvetch. Ground-nesting birds, meadow voles, and rabbits utilize crownvetch as cover (reviews by [129,139,147]).

Livestock: Reviews indicate that crownvetch is good, palatable livestock forage [129,139,147] but contains nitroglycosides that are toxic to horses (review by [123]). Sheep consume crownvetch leaves but typically avoid stems, and cattle may avoid crownvetch in early spring when foliage is less palatable (review by [120]). In Pennsylvania, Hereford steers gained 1.5 to 2 lbs/head/day on crownvetch pasture [92].

Deer: Along an Interstate in central Pennsylvania, researchers found white-tailed deer abundance increased in late fall and winter in crownvetch-dominated vegetation. Other vegetation in the study area included cultivated fields and mixed-deciduous forest with conifer clumps [19].

Small mammals: Studies indicate that crownvetch can be important meadow vole cover but may not be important forage. In a commercial crownvetch field in Centre County, Pennsylvania, 4 of 5 meadow vole brood nests occurred in dense crownvetch patches (94% cover) [117]. In this same area, meadow voles did not consume crownvetch when presented with other foods [63], and when provided only crownvetch and water, meadow voles died within 3 days (Jones 1978 cited in [63]). In newly planted apple orchards in New York, meadow vole population densities were high in plots where crownvetch was the ground cover. Researchers observed meadow voles feeding on crownvetch leaves, and long crownvetch stems allowed meadow voles to climb inside the mesh guards installed to protect tree trunks. Cumulative tree mortality over a 4-year period was much higher in plots with crownvetch cover than in plots with different or lacking ground cover [94].

Insects: Crownvetch flowers are visited by butterflies and moths in North America. During surveys of Pennsylvania's Allegheny Portage Railroad National Historic Site and Johnstown Flood National Memorial, butterflies feeding on crownvetch made up 7% of 200 feeding observations. Crownvetch was utilized by 2 butterfly species [68]. In southern New Jersey, crownvetch was a food source for orange sulfur butterflies in mid-winter and was also a "reliable" summer food [112]. In the early 1990s, researchers found *Coleophora colutella* on crownvetch plants on Cape Cod. This European moth was likely introduced with imported plant material. Early surveys indicated that this moth was using only crownvetch as a host, but in Europe, the moth uses several legume hosts [53]. For more information, see the discussion on crownvetch's impacts on insects.

OTHER USES:
The use of crownvetch to revegetate and control erosion on abandoned mine sites and roadside cuts has likely facilitated its wide distribution in North America. Crownvetch has recently been used as a cover crop in the United States. In Virginia, crownvetch was used in conjunction with biological control agents to control Canada thistle (*Cirsium arvense*) populations. Aboveground biomass of Canada thistle was reduced by 69% when tall fescue and crownvetch were seeded in an area where the tortoise beetle (*Cassida rubiginosa*) was established [4]. Canada thistle

reductions were greater on defoliation plots that had been seeded with crownvetch and tall fescue than on plots with defoliation alone [5].

Although used as a cover crop and for erosion control, some studies suggest that crownvetch may persist indefinitely on these sites, may not provide good erosion control, and may not provide useful cover. In 1990, crownvetch was seeded on a coal mine site in Wise County, Virginia, and remained on the sites at least 11 years after seeding [31]. The Natural Resources Conservation Service described crownvetch as a "useful but overused erosion control plant". While crownvetch has partially stabilized rocky, steep slopes in the eastern United States, rills and gullies often occur beneath the crownvetch canopy. On dry sites, seeding switchgrass with crownvetch provided better slope stabilization than seeding crownvetch alone (review by [147]). In apple orchards in New York, long crownvetch stems allowed meadow voles to climb over the mesh guards installed to protect tree seedlings. Tree mortality was much higher in plots with a ground cover of crownvetch than on plots lacking a ground cover or with another species as ground cover [94].

IMPACTS:
Descriptions of crownvetch's weedy behavior range from "minor" [34] to "highly invasive" [144]. Crownvetch is often, but not exclusively, described as weedy and problematic in the Midwestern and eastern United States. Although considered aggressive in some North American locations [42,107,144], in many areas, crownvetch is restricted to disturbed sites and considered a minor threat to native vegetation [25,27,32,34,70,126,150]. Whether or not crownvetch is more invasive in the Midwest and eastern United States because of site conditions, more plantings, and/or greater time since first introductions is unknown. Oregon's Native Plant Society found crownvetch in the Willamette Valley in 2008 and suggested that crownvetch may be in the lag phase of colonization but may, in time, develop into a "high impact" species capable of modifying native habitats and/or altering ecological functions and processes [99].

Although more common in the eastern and Midwestern United States, descriptions of crownvetch's aggressive growth habit and potential to negatively impact native vegetation occur nearly throughout crownvetch's nonnative North American range. At the Konza Prairie Biological Station in Kansas, crownvetch is "aggressively invading" tallgrass prairie [42] and is considered "a serious management threat to prairies and savannas" (review by [121]). In a survey of plant and natural area experts in Wisconsin, crownvetch ranked 12th when 66 nonnative invasive plants were evaluated for their impacts on native plant communities [107]. The Eastern Region of the Forest Service ranks crownvetch as "highly invasive" [144]. As of 2001, crownvetch was considered a "significant" threat in Tennessee [135] and as of 2008, was considered a severe threat in Kentucky [69].

Introduction and spread: In some cases, where crownvetch has been used in revegetation it has displaced native plants. In a restoration handbook for the West, researchers cautioned that crownvetch is "very competitive" and often dominates revegetated sites to the exclusion of other vegetation [129]. Colorado systematists indicated that crownvetch produces dense cover rapidly and "thrives in shade" [159]. As of 2002 in Missouri, crownvetch had invaded and/or disrupted native plant communities in more than 10 counties [95]. In Michigan, crownvetch was heavily promoted as a rapidly growing ground cover good for erosion control. Crownvetch populations spread extensively along roadsides, waterways, and fields in that state [154]. For more about crownvetch spread, see Local distribution changes.

In several areas, crownvetch populations persist as monocultures. In Pennsylvania, crownvetch likely arrived as a contaminant in alfalfa seed. It was discovered in an alfalfa field in the early 1900s, and 60 years later a dense crownvetch stand remained in the field. Except for a few sumac shrubs (*Rhus* spp.), few other species had established in the crownvetch stand [92]. Crownvetch was used for revegetation throughout the Appalachian coal region [137]. In southeastern Kentucky, it was used to revegetate a coal mine site where, 24 years later, observers described crownvetch growth as "especially aggressive". Crownvetch spread from the original planting area into adjacent vegetation. While crownvetch has persisted on harsh and continually disturbed sites, it did not persist on Lee Canyon ski slopes in southern Nevada. Crownvetch was seeded on the slopes between 1970 and 1980 but was not found in a 1999 survey of ski runs and adjacent forests [138].

Displacement of native vegetation is the most commonly described impact in crownvetch-invaded habitats, but delayed succession and reduced reproduction were also reported. Crownvetch may limit the development of some native plants by increasing available nutrients ([134], review by [158]) or through allelopathy [90,131]. However, nutrient increases

were not directly measured on invaded sites, and results from allelopathy studies are mixed. In some areas, crownvetch invasions may reduce insect diversity.

Impacts on vegetation:

Native grasses and forbs: Rapid, dense crownvetch growth can displace native plants. Experimental studies and observations suggest that impacts to native vegetation are greatest after crownvetch is established and producing substantial vegetative growth. Crownvetch growth has been described as a dense mat that "gradually chokes out more or less persistent weeds" [162]. Land managers have associated crownvetch spread with the displacement of native plants in prairies in Minnesota's Ottawa Bluffs Preserve (McGuigan 2002 cited in [139]) and in Iowa's Broken Kettle Grasslands and Ames High Prairie Preserve (Moats 2001 cited in [139]). In shale barren communities of the Allegany National Forest in Pennsylvania, crownvetch has excluded native plants from open woodlands (Keech 2002 cited in [139]). In Kentucky's Rolling Fork/Salt River Drainage area, crownvetch was associated with reductions in the abundance of tall warm-season grasses, native forbs, and 2 threatened species: Tennessee gladecress (*Leavenworthia exigua*) and Eggert's sunflower (*Helianthus eggertii*) (Mazyck 2002 cited in [139]). However, when seeded into plots with established vegetation in western Iowa, crownvetch seedling emergence and growth were "uniformly poor". Established vegetation included a bluestem (*Andropogon* spp.) monoculture, a mixture of tallgrass prairie species, and a mixture of tall and shortgrass species [85].

In Kentucky, crownvetch occurs in communities with Short's goldenrod (*Solidago shortii*), a federally endangered species. During a field experiment in Robertson County, Short's goldenrod seedlings established and flowering increased by about 3 times in plots where associated vegetation (dominated by crownvetch) was removed. The number of nonflowering Short's goldenrod ramets increased each year associated vegetation was removed, and Short's goldenrod seedlings occurred in 9 of 10 treated plots but not in control plots [156]. In a later vegetation survey of Harrison County, Kentucky, researchers found a Short's goldenrod population in a brush prairie gravel wash community where crownvetch also occurred. Impacts were not evaluated in this study [54].

Crownvetch can limit success in prairie restoration. On the Walnut Creek National Wildlife Refuge in Iowa, crownvetch occupies 1,000 of acres and is considered one of the most problematic species in restoration projects (Shutte personal communication [37]). On a research farm in Monoma County, Iowa, researchers attempted to restore a smooth brome (*Bromus inermis*) pasture to prairie. In 2002, the pasture was herbicide treated, plowed, and planted to prairie species. In 2003, crownvetch was present but only in trace amounts. By May 2005, crownvetch covered 46% of the restoration area, and the project was abandoned. When the project began, crownvetch was restricted to a ditchbank adjacent to the pasture (Wilsey unpublished data cited in [85]).

Woody plants: On some sites, crownvetch may limit shrub and tree seedling recruitment and delay succession. In a revegetation guide for coal mine spoils in the eastern United States, Vogel [152] recommended against planting crownvetch with tree seedlings, and a review reports that crownvetch often shades out shrub and tree seedlings [44].

Crownvetch plantings in Kentucky, Pennsylvania, and Maryland restricted the establishment of woody species. Along a road in Campbell County, Kentucky, crownvetch dominated the understory within and outside 8- to 10-year-old staghorn sumac (*Rhus typhina*) clumps. Researchers found few tree seedlings in the area and suspected crownvetch was limiting tree establishment, because in other succession studies, tree seedlings were often present in 8-year-old staghorn sumac stands [86]. On 51 sites in Pennsylvania and 12 sites in Maryland seeded with crownvetch at least 10 years earlier, woody plant density generally decreased as crownvetch cover increased. On sites with no crownvetch cover, there was 1 woody plant/160 feet² (15 m²). When crownvetch cover was 80%, there was 1 woody plant/1,540 feet ² (143 m²) [115].

On sites in West Virginia and Ontario, however, crownvetch growth did not limit the establishment of woody vegetation. Within 2 years of seeding crownvetch on a roadside in West Virginia, smooth sumac (*Rhus glabra*), sycamore (*Platanus occidentalis*), and sugar maple (*Acer saccharum*) were "naturally encroaching" in dense crownvetch cover [100]. For up to 5 years after crownvetch was seeded on a utility right-of-way near Tobemory, Ontario, tree regeneration was not restricted [17].

Allelopathy: Results from studies designed to uncover crownvetch's allelopathic potential are mixed. Leachate from

crownvetch seeds did not significantly (P<0.05) reduce the germination of a variety of field, forage, turf, weed, flower, and vegetable species, but often seedlings were abnormal. Roots and shoots of seedlings emerging in crownvetch seed leachate were shorter than those of seeds germinated in water [90]. Studies conducted at the Ohio Agricultural Research and Development Center showed that growth of northern red oak (*Quercus rubra*) was inhibited when seedlings were watered with crownvetch foliage extracts (Larson unpublished data cited in [153]). In another study, crownvetch extracts stimulated germination of quackgrass (*Elymus repens*) and crownvetch but inhibited germination of smooth brome and meadow fescue (*Schedonorus pratensis*). Extracts were made from live crownvetch shoots collected from an abandoned field in Argonne, Illinois. An extract made from decomposing crownvetch roots or shoots rarely affected the growth of other plants. Often the extracts from decomposing crownvetch roots stimulated the growth of crownvetch, quackgrass, smooth brome, meadow fescue, and timothy (*Phleum pratense*) [131].

Impacts on insects: Several studies related crownvetch invasions to unbalanced insect herbivory and reduced insect abundance and diversity. In tallgrass prairie at the Konza Prairie Biological Station in northeastern Kansas, total leaf area reductions due to natural enemies and/or abiotic stresses were significantly greater for a native slimflower scurfpea (*Psoralea tenuiflora*) than for crownvetch [42]. When bee populations were compared in "restored" prairies and "weedy" roadsides in Kansas, average bee richness and abundance were significantly (P<0.05) greater in restored than weedy vegetation. Nonnative forbs including crownvetch, sweetclover (*Melilotus* spp.), and common teasel (*Dipsacus fullonum*) covered more than 50% of weedy roadsides. Restored prairies likely provided a greater diversity of insect foods than the roadsides. Before the study, prairie and roadside vegetation was mowed multiple times each year, and roadside vegetation was treated with herbicides. Effects of prior management on bee populations were not discussed [55]. In western Wisconsin and eastern Minnesota, researchers found that Melissa blue butterfly (*Lycaeides melissa melissa*) populations have expanded their range and are using crownvetch as a larval host. This range expansion puts Melissa blue butterfly populations near endangered Karner blue butterfly (*L. m. samuelis*) populations. Although it is unknown whether these species can hybridize and produce viable offspring, hybridization could threaten Karner blue butterfly as a distinct taxon [23].

CONTROL:
Like most nonnative invasive plants, successful control of crownvetch is most likely in the early invasion stages (review by [139]). Because crownvetch is often restricted to disturbed sites and other habitats primarily dominated by nonnative species [32,70], nontarget effects of control may be reduced, but a lack of native plants and seeds may require active revegetation on control sites. Control of biotic invasions is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders [88].

In all cases where invasive species are targeted for control, no matter what method is employed, the potential for other invasive species to fill their void must be considered [16]. In the Lost Mound Unit of the Upper Mississippi River National Wildlife and Fish Refuge in northwestern Illinois, Kentucky bluegrass (*Poa pratensis*) increased dramatically when crownvetch cover was reduced by herbicide treatments. The study area was dominated by little bluestem and sand dropseed (*Sporobolus cryptandrus*) with monoculture patches of crownvetch. One year after herbicide treatments, crownvetch cover was less than 1% on treated sites, significantly less than that of untreated sites (P<0.0001). Available soil nitrogen was significantly (P<0.0001) greater inside than outside crownvetch patches but was not significantly affected by the herbicide treatment. Kentucky bluegrass cover was greater than 50% on treated plots and averaged 14% on control plots. Native species cover was not significantly different on treated and untreated sites. Kentucky bluegrass may have utilized high nutrient levels better than the native species [134].

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

Prevention: It is commonly argued that the most cost-efficient and effective method of managing invasive species is to prevent their establishment and spread by maintaining "healthy" natural communities [88,116] (e.g., avoid road building in wildlands [142]) and by monitoring several times each year [62]. Discontinuing the use of crownvetch in the revegetation of roadsides and mine sites could be key to preventing crownvetch establishment in areas where it does not yet occur (review by [22]).

Managing to maintain the integrity of the native plant community and mitigate the factors enhancing ecosystem invasibility is likely to be more effective than managing solely to control the invader [51]. Weed prevention and

control can be incorporated into many types of management plans, including those for logging and site preparation, grazing allotments, recreation management, research projects, road building and maintenance, and fire management [146]. See the Guide to noxious weed prevention practices [146] for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions.

Cultural control: Seeding or planting native plants in crownvetch stands may provide some control. Grover (2001 personal communication cited in [139]) suggests planting cool-season native grasses, such as switchgrass, into sites invaded by crownvetch or on sites where crownvetch was treated. In tall fescue and crownvetch stands along roadsides in West Virginia, establishment and growth of seeded native species were best when stands were herbicide treated or tilled before seeding [118].

Physical or mechanical control: Small crownvetch populations may be controlled by hand-pulling, digging, or heavy shading by cloth or mulch [44]. For larger crownvetch populations, mowing may be a more useful mechanical control method.

Hand-pulling or digging of crownvetch is time consuming, labor intensive, and requires the removal of all stems, roots, and rhizomes. Sites should be monitored for seedlings and sprouts in successive years (review by [139]). Mowing to control crownvetch spread may be most effective in the late spring or at flower bud stage (reviews by [119,121,123,139,151]), although Henson [47] reported that crownvetch recovery was slow when plants were cut for hay at the full bloom stage. Repeated mowing is necessary (reviews by [119,121,123,139,151]). A review recommends mowing twice a year, first in June and again in late August [22]. Another review suggests that mowing treatments should avoid native or desirable vegetation [123]. While mowing may not be feasible in wildlands, controlling crownvetch in adjacent public use areas may limit its spread into wildlands.

Repeated mowing may be necessary to deplete the carbohydrates stored in crownvetch roots. Immediately following clipping, total available crownvetch root carbohydrates generally decreased but recovered quickly as aboveground stems grew. Researchers found that clipping crownvetch early in the growing season (before 1 June) or late in the growing season (August-October) allowed other "weedy" species to invade crownvetch stands. Clipping also limited seed production [77].

Biological control: Crownvetch has insect predators in North America and may be reduced by livestock grazing. During a 2-year survey of insects in Pennsylvania in the early 1970s, Wheeler [161] collected 125 phytophagous arthropods in crownvetch stands. Differential and redlegged grasshoppers were the most destructive crownvetch pests, but alfalfa plant bugs, potato leaf hoppers, clover stem borers, pollen beetles, and glechiid moths also injured or stressed crownvetch plants [161]. In Kansas, researchers found the striped willow flea beetle using crownvetch as a host plant, suggesting it may be useful as a biological control in areas where crownvetch is invasive. However, the striped willow flea beetle has other known hosts, primarily willows (*Salix* spp.) and cottonwoods (*Populus* spp.) [108]. Several studies indicate that crownvetch abundance is typically lower on grazed than ungrazed sites. Livestock may reduce crownvetch abundance by removing aboveground biomass, compacting soils, or both. For more information, see Grazing.

Biological control of invasive species has a long history that indicates many factors must be considered before using biological controls. Refer to these sources: [149,165] and the Weed control methods handbook [140] for background information and important considerations for developing and implementing biological control programs. Because crownvetch is still planted for erosion control and in pastures, release of a biological control is unlikely (review by [139]).

Chemical control: While herbicides are often effective in gaining initial control of a new invasion or a severe infestation, they rarely provide complete or long-term weed control [18]. See the Weed control methods handbook [140] for considerations on the use of herbicides in natural areas and detailed information on specific chemicals.

For information on herbicides and applications useful for crownvetch control, see [139]. Applying herbicides before crownvetch flowers and before it develops a thick vegetative mat (late April or early May) may be most effective (Walters 2001 personal communication cited in [139]). To kill crownvetch plants, complete coverage of aboveground

material is necessary. Prescribed fire to remove litter may improve herbicide coverage (reviews by [119,121,139]).

Integrated management: An integrated weed management plan for heavily infested crownvetch sites may include cutting or burning a site, treating with an herbicide, then actively revegetating and managing to encourage dense growth of native vegetation (review by [139]).

APPENDIX: FIRE REGIME TABLE

SPECIES: Coronilla varia

The following table provides fire regime information that may be relevant to crownvetch habitats. Follow the links in the table to documents that provide more detailed information on these fire regimes.

Fire regime information on vegetation communities in which crownvetch may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [76], which were developed by local experts using available literature, local data, and/or expert opinion. This table summarizes fire regime characteristics for each plant community listed. The PDF file linked from each plant community name describes the model and synthesizes the knowledge available on vegetation composition, structure, and dynamics in that community. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

Pacific Northwest	California	Southwest	Great Basin
Northern and Central Rockies	Northern Great Plains	Great Lakes	Northeast
South-central US	Southern Appalachians	Southeast	

Pacific Northwest

- Northwest Grassland
- Northwest Shrubland
- Northwest Woodland
- Northwest Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Northwest Grassland					
Bluebunch wheatgrass	Replacement	47%	18	5	20
	Mixed	53%	16	5	20
Idaho fescue grasslands	Replacement	76%	40		
	Mixed	24%	125		

Alpine and subalpine meadows and grasslands	Replacement	68%	350	200	500
	Mixed	32%	750	500	>1,000
Northwest Shrubland					
Wyoming big sagebrush semidesert	Replacement	86%	200	30	200
	Mixed	9%	>1,000	20	
	Surface or low	5%	>1,000	20	
Wyoming sagebrush steppe	Replacement	89%	92	30	120
	Mixed	11%	714	120	
Low sagebrush	Replacement	41%	180		
	Mixed	59%	125		
Mountain big sagebrush (cool sagebrush)	Replacement	100%	20	10	40
Northwest Woodland					
Western juniper (pumice)	Replacement	33%	>1,000		
	Mixed	67%	500		
Oregon white oak-ponderosa pine	Replacement	16%	125	100	300
	Mixed	2%	900	50	
	Surface or low	81%	25	5	30
Pine savannah (ultramafic)	Replacement	7%	200	100	300
	Surface or low	93%	15	10	20
Ponderosa pine	Replacement	5%	200		
	Mixed	17%	60		
	Surface or low	78%	13		
Oregon white oak	Replacement	3%	275		
	Mixed	19%	50		
	Surface or low	78%	12.5		
Northwest Forested					
Ponderosa pine (xeric)	Replacement	37%	130		
	Mixed	48%	100		
	Surface or low	16%	300		
Dry ponderosa pine (mesic)	Replacement	5%	125		
	Mixed	13%	50		
	Surface or low	82%	8		
Mixed conifer	Replacement	4%	400		
	Mixed	29%	50		

(southwestern Oregon)					
	Surface or low	67%	22		
California mixed evergreen (northern California)	Replacement	6%	150	100	200
	Mixed	29%	33	15	50
	Surface or low	64%	15	5	30
Mixed conifer (eastside dry)	Replacement	14%	115	70	200
	Mixed	21%	75	70	175
	Surface or low	64%	25	20	25
Mixed conifer (eastside mesic)	Replacement	35%	200		
	Mixed	47%	150		
	Surface or low	18%	400		
Red fir	Replacement	20%	400	150	400
	Mixed	80%	100	80	130

California

- California Grassland
- California Shrubland
- California Woodland
- California Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
California Grassland					
California grassland	Replacement	100%	2	1	3
California Shrubland					
Chaparral	Replacement	100%	50	30	125
Montane chaparral	Replacement	34%	95		
	Mixed	66%	50		
California Woodland					
California oak woodlands	Replacement	8%	120		
	Mixed	2%	500		
	Surface or low	91%	10		
Ponderosa pine	Replacement	5%	200		
	Mixed	17%	60		

	Surface or low	78%	13		
California Forested					
California mixed evergreen	Replacement	10%	140	65	700
	Mixed	58%	25	10	33
	Surface or low	32%	45	7	
Mixed conifer (North Slopes)	Replacement	5%	250		
	Mixed	7%	200		
	Surface or low	88%	15	10	40
Mixed conifer (South Slopes)	Replacement	4%	200		
	Mixed	16%	50		
	Surface or low	80%	10		
Jeffrey pine	Replacement	9%	250		
	Mixed	17%	130		
	Surface or low	74%	30		

Southwest

- Southwest Grassland
- Southwest Shrubland
- Southwest Woodland
- Southwest Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southwest Grassland					
Desert grassland	Replacement	85%	12		
	Surface or low	15%	67		
Desert grassland with shrubs and trees	Replacement	85%	12		
	Mixed	15%	70		
Shortgrass prairie	Replacement	87%	12	2	35
	Mixed	13%	80		
Shortgrass prairie with shrubs	Replacement	80%	15	2	35
	Mixed	20%	60		
Shortgrass prairie with trees	Replacement	80%	15	2	35
	Mixed	20%	60		
	Replacement	81%	20	3	30

Plains mesa grassland	Mixed	19%	85	3	150
Plains mesa grassland with shrubs or trees	Replacement	76%	20		
	Mixed	24%	65		
Montane and subalpine grasslands	Replacement	55%	18	10	100
	Surface or low	45%	22		
Montane and subalpine grasslands with shrubs or trees	Replacement	30%	70	10	100
	Surface or low	70%	30		
Southwest Shrubland					
Southwestern shrub steppe	Replacement	72%	14	8	15
	Mixed	13%	75	70	80
	Surface or low	15%	69	60	100
Southwestern shrub steppe with trees	Replacement	52%	17	10	25
	Mixed	22%	40	25	50
	Surface or low	25%	35	25	100
Low sagebrush shrubland	Replacement	100%	125	60	150
Mountain sagebrush (cool sage)	Replacement	75%	100		
	Mixed	25%	300		
Gambel oak	Replacement	75%	50		
	Mixed	25%	150		
Mountain-mahogany shrubland	Replacement	73%	75		
	Mixed	27%	200		
Southwest Woodland					
Pinyon-juniper (mixed fire regime)	Replacement	29%	430		
	Mixed	65%	192		
	Surface or low	6%	>1,000		
Pinyon-juniper (rare replacement fire regime)	Replacement	76%	526		
	Mixed	20%	>1,000		
	Surface or low	4%	>1,000		
Ponderosa pine/grassland (Southwest)	Replacement	3%	300		
	Surface or low	97%	10		
Southwest Forested					

Riparian forest with conifers	Replacement	100%	435	300	550
Riparian deciduous woodland	Replacement	50%	110	15	200
	Mixed	20%	275	25	
	Surface or low	30%	180	10	
Ponderosa pine-Gambel oak (southern Rockies and Southwest)	Replacement	8%	300		
	Surface or low	92%	25	10	30
Stable aspen without conifers	Replacement	81%	150	50	300
	Surface or low	19%	650	600	>1,000

Great Basin

- Great Basin Grassland
- Great Basin Shrubland
- Great Basin Woodland
- Great Basin Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Great Basin Grassland					
Great Basin grassland	Replacement	33%	75	40	110
	Mixed	67%	37	20	54
Mountain meadow (mesic to dry)	Replacement	66%	31	15	45
	Mixed	34%	59	30	90
Great Basin Shrubland					
Basin big sagebrush	Replacement	80%	50	10	100
	Mixed	20%	200	50	300
Wyoming big sagebrush semidesert	Replacement	86%	200	30	200
	Mixed	9%	>1,000	20	>1,000
	Surface or low	5%	>1,000	20	>1,000
Wyoming big sagebrush semidesert with trees	Replacement	84%	137	30	200
	Mixed	11%	≥1,000	20	>1,000
	Surface or low	5%	>1,000	20	>1,000
Wyoming sagebrush steppe	Replacement	89%	92	30	120
	Mixed	11%	714	120	

Mountain big sagebrush	Replacement	100%	48	15	100
Mountain big sagebrush with conifers	Replacement	100%	49	15	100
Mountain sagebrush (cool sage)	Replacement	75%	100		
	Mixed	25%	300		
Gambel oak	Replacement	75%	50		
	Mixed	25%	150		
Mountain shrubland with trees	Replacement	22%	105	100	200
	Mixed	78%	29	25	100
Curlleaf mountain-mahogany	Replacement	31%	250	100	500
	Mixed	37%	212	50	
	Surface or low	31%	250	50	
Great Basin Woodland					
Juniper and pinyon-juniper steppe woodland	Replacement	20%	333	100	≥1,000
	Mixed	31%	217	100	≥1,000
	Surface or low	49%	135	100	
Ponderosa pine	Replacement	5%	200		
	Mixed	17%	60		
	Surface or low	78%	13		
Great Basin Forested					
Interior ponderosa pine	Replacement	5%	161		800
	Mixed	10%	80	50	80
	Surface or low	86%	9	8	10
Stable aspen-cottonwood, no conifers	Replacement	31%	96	50	300
	Surface or low	69%	44	20	60
Stable aspen without conifers	Replacement	81%	150	50	300
	Surface or low	19%	650	600	>1,000

Northern and Central Rockies

- Northern and Central Rockies Grassland
- Northern and Central Rockies Shrubland
- Northern and Central Rockies Forested

Vegetation Community (Potential Natural	Fire severity*	Fire regime characteristics			
		Percent of	Mean interval	Minimum interval	Maximum interval

Vegetation Group)		fires	(years)	(years)	(years)
Northern and Central Rockies Grassland					
Northern prairie grassland	Replacement	55%	22	2	40
	Mixed	45%	27	10	50
Mountain grassland	Replacement	60%	20	10	
	Mixed	40%	30		
Northern and Central Rockies Shrubland					
Riparian (Wyoming)	Mixed	100%	100	25	500
Wyoming big sagebrush	Replacement	63%	145	80	240
	Mixed	37%	250		
Basin big sagebrush	Replacement	60%	100	10	150
	Mixed	40%	150		
Low sagebrush shrubland	Replacement	100%	125	60	150
Mountain shrub, nonsagebrush	Replacement	80%	100	20	150
	Mixed	20%	400		
Mountain big sagebrush steppe and shrubland	Replacement	100%	70	30	200
Northern and Central Rockies Forested					
Ponderosa pine (Northern Great Plains)	Replacement	5%	300		
	Mixed	20%	75		
	Surface or low	75%	20	10	40
Ponderosa pine (Northern and Central Rockies)	Replacement	4%	300	100	≥1,000
	Mixed	19%	60	50	200
	Surface or low	77%	15	3	30

Northern Great Plains

- Northern Plains Grassland
- Northern Plains Woodland

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)

Northern Plains Grassland					
Northern mixed-grass prairie	Replacement	67%	15	8	25
	Mixed	33%	30	15	35
Southern mixed-grass prairie	Replacement	100%	9	1	10
Central tallgrass prairie	Replacement	75%	5	3	5
	Mixed	11%	34	1	100
	Surface or low	13%	28	1	50
Northern tallgrass prairie	Replacement	90%	6.5	1	25
	Mixed	9%	63		
	Surface or low	2%	303		
Southern tallgrass prairie (East)	Replacement	96%	4	1	10
	Mixed	1%	277		
	Surface or low	3%	135		
Oak savanna	Replacement	7%	44		
	Mixed	17%	18		
	Surface or low	76%	4		
Northern Plains Woodland					
Oak woodland	Replacement	2%	450		
	Surface or low	98%	7.5		
Northern Great Plains wooded draws and ravines	Replacement	38%	45	30	100
	Mixed	18%	94		
	Surface or low	43%	40	10	
Great Plains floodplain	Replacement	100%	500		

Great Lakes

- Great Lakes Grassland
- Great Lakes Woodland
- Great Lakes Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Great Lakes Grassland					
Mosaic of bluestem prairie	Replacement	79%	5	1	8
	Mixed	2%	260		

and oak-hickory					
	Surface or low	20%	2		33
Great Lakes Woodland					
Northern oak savanna	Replacement	4%	110	50	500
	Mixed	9%	50	15	150
	Surface or low	87%	5	1	20
Great Lakes Forested					
Great Lakes floodplain forest	Mixed	7%	833		
	Surface or low	93%	61		
Great Lakes pine forest, jack pine	Replacement	67%	50		
	Mixed	23%	143		
	Surface or low	10%	333		
Oak-hickory	Replacement	13%	66	1	
	Mixed	11%	77	5	
	Surface or low	76%	11	2	25
Pine-oak	Replacement	19%	357		
	Surface or low	81%	85		
Northeast • Northeast Woodland • Northeast Forested					
Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Northeast Woodland					
Eastern woodland mosaic	Replacement	2%	200	100	300
	Mixed	9%	40	20	60
	Surface or low	89%	4	1	7
Rocky outcrop pine (Northeast)	Replacement	16%	128		
	Mixed	32%	65		
	Surface or low	52%	40		
Oak-pine (eastern dry-xeric)	Replacement	4%	185		
	Mixed	7%	110		
	Surface or low	90%	8		
Northeast Forested					
Appalachian oak forest	Replacement	2%	625	500	≥1,000

(dry-mesic)	Mixed	6%	250	200	500
	Surface or low	92%	15	7	26

South-central US

- South-central US Grassland
- South-central US Shrubland
- South-central US Woodland
- South-central US Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
South-central US Grassland					
Bluestem-sacahuista	Replacement	70%	3.6	1	
	Mixed	30%	7.7	2	
Southern shortgrass or mixed-grass prairie	Replacement	100%	8	1	10
Southern tallgrass prairie	Replacement	91%	5		
	Mixed	9%	50		
Oak savanna	Replacement	3%	100	5	110
	Mixed	5%	60	5	250
	Surface or low	93%	3	1	4
South-central US Shrubland					
Southwestern shrub steppe	Replacement	76%	12		
	Mixed	24%	37		
South-central US Woodland					
Oak-hickory savanna	Replacement	1%	227		
	Surface or low	99%	3.2		
Oak woodland-shrubland-grassland mosaic	Replacement	11%	50		
	Mixed	56%	10		
	Surface or low	33%	17		
Pine bluestem	Replacement	4%	100		
	Surface or low	96%	4		
South-central US Forested					
	Replacement	42%	140		

Southern floodplain	Surface or low	58%	100		
Southern floodplain (rare fire)	Replacement	42%	≥1,000		
	Surface or low	58%	714		

Southern Appalachians

- Southern Appalachians Grassland
- Southern Appalachians Woodland
- Southern Appalachians Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southern Appalachians Grassland					
Bluestem-oak barrens	Replacement	46%	15		
	Mixed	10%	69		
	Surface or low	44%	16		
Eastern prairie-woodland mosaic	Replacement	50%	10		
	Mixed	1%	900		
	Surface or low	50%	10		
Southern Appalachians Woodland					
Appalachian shortleaf pine	Replacement	4%	125		
	Mixed	4%	155		
	Surface or low	92%	6		
Table Mountain-pitch pine	Replacement	5%	100		
	Mixed	3%	160		
	Surface or low	92%	5		
Oak-ash woodland	Replacement	23%	119		
	Mixed	28%	95		
	Surface or low	49%	55		
Southern Appalachians Forested					
Mixed mesophytic hardwood	Replacement	11%	665		
	Mixed	10%	715		
	Surface or low	79%	90		
Appalachian oak-hickory-pine	Replacement	3%	180	30	500
	Mixed	8%	65	15	150
	Surface or low	89%	6	3	10
	Replacement	6%	128	50	100

Oak (eastern dry-xeric)	Mixed	16%	50	20	30
	Surface or low	78%	10	1	10
Appalachian Virginia pine	Replacement	20%	110	25	125
	Mixed	15%	145		
	Surface or low	64%	35	10	40
Appalachian oak forest (dry-mesic)	Replacement	6%	220		
	Mixed	15%	90		
	Surface or low	79%	17		
Southeast • Southeast Grassland • Southeast Woodland • Southeast Forested					
Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southeast Grassland					
Southeast Gulf Coastal Plain Blackland prairie and woodland	Replacement	22%	7		
	Mixed	78%	2.2		
Gulf Coast wet pine savanna	Replacement	2%	165	10	500
	Mixed	1%	500		
	Surface or low	98%	3	1	10
Southeast Woodland					
Longleaf pine/bluestem	Replacement	3%	130		
	Surface or low	97%	4	1	5
Longleaf pine (mesic uplands)	Replacement	3%	110	40	200
	Surface or low	97%	3	1	5
Longleaf pine-Sandhills prairie	Replacement	3%	130	25	500
	Surface or low	97%	4	1	10
Pine rocklands	Mixed	1%	330		
	Surface or low	99%	3	1	5
Southeast Forested					
Sand pine scrub	Replacement	90%	45	10	100
	Mixed	10%	400	60	
	Replacement	4%	200		

Coastal Plain pine-oak-hickory	Mixed	7%	100		
	Surface or low	89%	8		
Southern floodplain	Replacement	7%	900		
	Surface or low	93%	63		

*Fire Severities—
Replacement: Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.
Mixed: Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.
Surface or low: Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [43,75].

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