# Glechoma hederacea



# INTRODUCTORY






AUTHORSHIP AND CITATION:
Waggy, Melissa A. 2009. Glechoma hederacea. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [ 2010, January 29].

FEIS ABBREVIATION:
GLEHED

NRCS PLANT CODE [112]:
GLHE2

COMMON NAMES:
ground-ivy
cat's foot
creeping Charlie
creeping Jenny
gill-over-the-ground
ground ivy
groundivy

TAXONOMY:
The scientific name of ground-ivy is *Glechoma hederacea* L. (Lamiaceae) [31,49,55,97,107,118]. It is common to see the scientific genus name spelled *Glecoma* in some systematic and other literature, especially in floras associated with the western United States [20,35,44,45]. The generic name was not consistently spelled by Linnaeus, and the 2 spellings have been used concurrently [1,118].

One variety, *Glechoma hederacea* L. var. *micrantha* Moric., is recognized by a few systmetists (e.g.[97,107]), but some consider it a synonym for *G. hederacea* L. [55,131].

SYNONYMS:
*Glecoma hederacea* L. [20,35,44,45]
*Nepeta hederacea* Trevis. [76]

LIFE FORM:
Forb

FEDERAL LEGAL STATUS:
None

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

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# DISTRIBUTION AND OCCURRENCE

SPECIES: Glechoma hederacea

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A review by Hutchings and Price [51] is cited throughout this literature summary. While many of their inferences and conclusions are based on research, the authors also provide information based on personal observations.

GENERAL DISTRIBUTION:
Ground-ivy is a nonnative species that occurs throughout most of North America north of Mexico. Native to Eurasia [31,44,49,51], this species was introduced to North America by early settlers [72,76]. In the United States, it occurs in all states except Nevada, Arizona, and New Mexico. In Canada, ground-ivy has been found in all provinces but has not spread north into the territories [55]. Most information documenting the occurrence of ground-ivy in North America comes from studies in deciduous forests in the eastern United States [69,70,82,86,109,119], suggesting that ground-ivy may be more common in that region. Specific distributional information on the variety is lacking; however, regional floras indicate that *G. hederacea* var. *micrantha* may occur both east and west of the Mississippi River [35,131]. NatureServe provides a distributional map for ground-ivy and its associated variety in the United States and Canada.

Likely brought by settlers to North America for its medicinal properties and other uses [51,72,76], ground-ivy was typically grown in small garden plots (Rafinesque 1811, as cited in [72]). It was first reported in the northeastern United States in 1672 [122]. Since its introduction, ground-ivy has escaped cultivation and spread to a variety of native plant communities. Although it is unclear by what means or how fast it spread throughout North America, there are reports of this species in Indiana from 1856 [98] and from Colorado as early as 1906 [96], suggesting its westerly introduction and/or migration did not occur recently.

HABITAT TYPES AND PLANT COMMUNITIES:
In North America, habitat types and specific plant community associations for ground-ivy are difficult to describe

accurately because specific survey information is lacking. Gaps exist in the understanding of ground-ivy's ecological characteristics, specifically its invasiveness in North America. Therefore, ground-ivy may occur in plant communities other than those discussed here and listed in the Fire Regime Table.

Ground-ivy occurs in deciduous and riparian forests in the eastern and central portions of the United States [11,47,56,70,86,95,119] and in parts of Canada [77]. In Massachusetts, ground-ivy was a common understory component of a riparian forest dominated by silver maple (*Acer saccharinum*) mixed with lesser amounts of eastern cottonwood (*Populus deltoides*) [56]. Ground-ivy was a minor understory component in a Pennsylvania forest community dominated by silver maple and sycamore (*Platanus occidentalis)* [119]. In New Hampshire, ground-ivy was observed after a prescribed fire in an eastern white pine (*Pinus strobus*)/mixed hardwood forest characterized by red oak (*Quercus rubra*) and red maple (*Acer rubrum*) [95]. In Ohio, ground-ivy occurred in upland and floodplain forests associated with headwater streams on the western glaciated Allegheny Plateau, but it was more common in the floodplain. At the time of the study, upland forests in the area were characterized by a mixed-oak (*Quercus* spp.) and hickory (*Carya* spp.) overstory with American beech (*Fagus grandifoli*a) and sugar maple (*Acer saccharum*) in the understory. Low-lying areas were generally associated with vernal pools characterized by a red maple, buttonbush (*Cephalanthus occidentalis)*, and green ash (*Fraxinus pennsylvanica*) overstory [47]. In Indiana, trace amounts of ground-ivy were found in the interior of a fragmented forest dominated by sugar maple and American beech that was surrounded by croplands [11]. In a fragmented riparian forest along the Assiniboine River in Canada, ground-ivy occurred with green ash, boxelder (*Acer negundo*), and basswood (*Tilia americana*)[77].

Ground-ivy can also occur in more open plant communities. It was a common component in an early successional eastern redcedar glade (*Juniperus virginiana*) in Tennessee characterized by a widowscross-pitcher's stitchwort (*Sedum pulchellum-Minuartia patula*) plant community, and was an occasional component in older portions of the glade, growing with prairie fleabane (*Erigeron strigosus* var. *strigosus*) [82]. In a tallgrass prairie restoration site on a previously cultivated field in Illinois, ground-ivy established in an area dominated by native and nonnative grasses including quackgrass (*Elymus repens*), Canada wildrye (*Elymus canadensis*), and switchgrass (*Panicum virgatum*) [48]. In a wildlife refuge in central New York, ground-ivy was found in a managed semi-native grassland transitioning to shrubland, characterized by gray dogwood (*Cornus racemosa*), common buckthorn (*Rhamnus cathartica*), Allegheny blackberry (*Rubus allegheniensis*), red-osier dogwood (*Cornus sericea)*, Morrow's honeysuckle (*Lonicera morrowii*), and goldenrods (*Solidago* spp.). Poison ivy (*Toxicodendron radican*s) and black swallow-wort (*Cynanchum louiseae*) were also common at this site [90]. Throughout its range, ground-ivy is frequently associated with human development such as roadsides [35,87,94], fallow fields [81], pasture fringes [11,35], and other disturbed sites [21,31,107,131]; and it readily invades lawns and gardens [28,42,45,60,87,107].

Great Britain's vegetation classification system provides detailed information about ground-ivy's associated plant communities in that region [91,92,93]. Although this classification system is specific to Great Britain, it may help to infer what types of plant communities ground-ivy might prefer in its introduced range. In Great Britain ground-ivy is associated with numerous woodland, grassland, and maritime-influenced plant communities [91,92,93]. Ground-ivy typically comprises 20% or less of the vegetation cover in woodlands dominated by oak (*Quercus* spp.), beech (*Fagus* spp.), alder (*Alnus* spp.), willow (*Salix* spp.), birch (*Betula* spp.), and hawthorn (*Crataegus* spp.). It is a common associate of the ash-maple (*Fraxinus* spp.-*Acer* spp.) plant community in the *Primula vulgaris-Glechoma hederacea* sub-community where it can comprise 41% to 60% of the vegetation cover. It comprises 20% or less of the vegetation cover in scrublands associated with blackberry (*Rubus* spp.) and up to 40% of the vegetation cover in a bracken fern (*Pteridium aquilium*) dominated community [91]. Ground-ivy is an occasional component in mesic grassland communities characterized by sheep fescue (*Festuca ovina*) and colonial bentgrass (*Agrostis capillaris*) [92]. It is a minor component in fireweed (*Chamerion angustifolium*) dominated communities in damp, fertile soils on disturbed, often burned ground associated with woodlands, heaths, and human activities (e.g., train tracks, recreational sites, roads). In maritime-influenced plant communities, it can comprise 1% to 20% of the vegetation cover in a few sand dune communities and communities dominated by stinging nettle (*Urtica dioica*) [93].

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# BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Glechoma hederacea



GENERAL BOTANICAL CHARACTERISTICS:



**Botanical description:** This description provides characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [31,35,45,49,62,87,97,107,131]).

Aboveground description: Ground-ivy is a low-growing perennial herb that spreads by branched horizontal stolons that root at their nodes. It is clonal and forms patches or carpet-like mats [51]. Plant height varies from about 2 to 24 inches (5-60 cm) [31,44,51,87,102]. Stolons often grow to over 7 feet (2 m) in length [51]. Individual ramets are produced annually at the stolon nodes and develop from overwintering structures that can be 2-leaved ramets or 8- to 10-leaved rosettes [51]. In colder climates, like Sweden, overwintering structures can be 2-leaved stolon fragments with auxiliary rosettes situated in the leaf axil [103,126].

Ramets have 2 erect petioles and may or may not produce flowers [52,103,124]. Petioles arise from the stolon nodes and bear cordate-reniform leaves that average about 0.4 to 1.2 inches long (~1-3 cm) [46,51,79,123] and can reach over 3 inches long (8 cm) [51]. Plants are often pubescent but can be nearly glabrous [49,51,62,97]. In Great Britain [91], the northeastern United States [113], and the Carolinas [87], ground-ivy is reported to be evergreen. Flowerstalks can be erect or ascending and may not always produce flowers [51]. The inflorescence is a 2- to 6-flowered cyme [51,108,130]. The fruit is a nutlet [30,124,125,130] containing one 1.9 × 1.1 mm seed [51,108].

Belowground description: Ground-ivy has fine, fibrous, shallow roots that develop at the stolon nodes [5,29,31,51,108,113]. Several authors describe superficial rhizomes [16,31,113].

Stand structure: Although ground-ivy can form large patches, it typically does not dominate the vegetation where it occurs in Great Britain [51]. In southern Sweden, however, it occasionally forms extensive monocultures covering over 1,000 feet² (100 m²), and has been observed growing in patches covering over 10,000 feet² (1,000 m²) [124]. Stand structure is not well described for ground-ivy populations in North America.

Other: Rice [89] suggested that ground-ivy may have allelopathic properties. In the laboratory, leaf and root extracts of ground-ivy had both inhibitory and stimulative effects on germination and growth of radish (*Raphanus sativus*) and cheatgrass (*Bromus tectorum*) [89]. However, allelopathy in ground-ivy has not been studied in the field.

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

SEASONAL DEVELOPMENT:
In Great Britain, overwintering structures of ground-ivy begin to grow in the spring [103]. In general, 2-leaved ramets grow vegetatively, while rosettes typically elongate and produce vertical, flowering branches (Clapham and others 1962, as cited in [103]). This vertical growth typically occurs between March and June in conjunction with flowering [6]. During the flowering phase, the upright branches depend on the root system associated with the original rosettes for soil resources [103]. Flowering times for a portion of ground-ivy's range are given in the table below.

| Reported flowering periods for ground-ivy by geographic area | |
|---|---|
| Area | Reported flowering period |
| North America | |
| California | March-May [79] |
| Carolinas | flowers March-June; fruits May-July [87] |
| Florida | spring-fall [131] |
| Georgia (DeKalb County) | mid-February-mid-March [27] |
| Illinois | April-July [78] |
| Kansas | April-May [3] |
| Kentucky | April-June [40] |
| Texas | April-June [19] |
| West Virginia | April-July [107] |
| Adirondacks | May-June [61] |
| Blue Ridge Province | March-June [129] |
| Great Plains | April-June [35] |
| Intermountain West | April-June [16] |
| New England | early May-early July [97] |
| Northeast | April-June [31] |
| Pacific Northwest | April-June [46] |
| Canada (Manitoba) | September-November [77] |
| Other Countries | |
| China | May [130] |
| Czech Republic | May-June [59] |
| Great Britain | March-August [51,76,103]; occasionally year-round [67] |
| Japan | April-May [26] |
| southern Sweden | May-July [124,125] |

After flowering, ground-ivy's upright branches continue to grow. These branches become structurally weak and bend to the ground, where they root and spread horizontally (see Vegetative regeneration) [103,124,125]. The original rosette may continue to produce stolons and ramets [6,103]. A study in Great Britain found that the density of ramets declined throughout the fall due to frost, and all cohorts typically died by year end. The ramet population of the following year emerged primarily in the fall and had low mortality during winter [103]. In regions near the Czech Republic, annual stolons usually fragment by early spring [59] and in Sweden, stolon connections between ramets typically decay after the growing season, making it difficult to distinguish whether 2 or more ramets belong to the same clone [124,125,127].

REGENERATION PROCESSES:

- **Pollination and breeding system**
- **Seed production**
- **Seed dispersal**
- **Seed banking**
- **Germination**

- **Seedling establishment**
- **Growth**
- **Vegetative regeneration**

Unless otherwise stated, information pertaining to ground-ivy's regenerative processes is primarily limited to research from its native range. However, because these experiments were typically conducted in controlled laboratory settings, information regarding regenerative processes is likely applicable to most regions in which ground-ivy occurs.

Ground-ivy reproduces primarily by vegetative means [103,125]. Although seedling establishment is likely rare in many habitats ([103], Grimes and others 1988 as cited in [51]), considerable quantities of resources are allocated to flower and seed production [51,103,125].

**Pollination and breeding system:** Ground-ivy is gynodioecious and clones are classified as either hermaphroditic or female (male-sterile flowers) [124,125]. Clones bearing only male-sterile flowers are thought to be more common in the United States than hermaphroditic types [16,46,107]. Occasionally the same clone will produce both hermaphroditic and male-sterile flowers [127]. Hermaphroditic plants produce more flowers, and the flowers are larger than those produced on female clones [124].

Hermaphroditic flowers on ground-ivy are protandrous and typically considered self-compatible when artificially pollinated [124,125], but self-compatibility is questionable in wild populations [3,30,124]. Cross pollination occurs between flowers on hermaphroditic clones and flowers on female clones [124,125]. Visitation from an insect is likely necessary for natural pollination to occur, even if hermaphroditic flowers are self-compatible [51,124]. In the northeastern United States, honeybees were the principal nectar feeders at ground-ivy [104]. In Sweden, the most frequent pollinators observed on ground-ivy were bumblebees, but honeybees, syrphids, beetles, and ants were also occasionally reported. For female plants, pollination rates and subsequent fruit and seed set were negatively correlated with increased distance to pollen source. Mean pollen dispersal distance for ground-ivy was estimated at 19 feet (5.9 m) when based on fruit set and 17 feet (5.3 m) when based on seed set. Pollination may not occur in female clones if the distance to a pollen source (i.e., hermaphroditic clone) is greater than about 330 feet (100 m) [124].

Sex-expression of a clone may not be entirely genetically based; environmental conditions or resource availability may influence its expression. In Europe, 8 purportedly female clones, which had already initiated flowering, were transferred to a greenhouse. Within 3 weeks, 4 of the clones produced "considerable numbers" of hermaphroditic flowers (Price 1991, as cited in [51]).

**Seed production:** Populations of ground-ivy produce "large quantities" of viable seeds [51,124]. Each flower produces up to 4 seeds [51]. Seed production may be influenced by plant sex or pollen availability [103,124]. In England, ramets on female clones growing in a grassland produced significantly fewer ($P<0.01$) flowers than ramets on hermaphroditic clones at the same site. Additionally, a greater proportion of hermaphroditic ramets produced seed compared to female ramets [103]. In Sweden, the number of flowers produced per ramet in a wild population of ground-ivy was similar for both sexes (~12 flowers/ramet) but seed set was significantly lower ($P<0.001$) in female clones (6.1%) than in hermaphroditic clones (44%). Seed set may be lower in female clones, due to limited pollen availability [124].

**Seed dispersal:** Ground-ivy seeds are dispersed primarily by gravity [8,77,124,125] and may be further distributed by ants and other animals ([8], Grime and others 1988 as cited in [115]). As the fruit matures, the calyx bends down and the seeds fall to the ground near the parent plant [124,125]. No additional information is given regarding dispersal by ants or other animals. However, Grime and others [36] note that seeds of ground-ivy lack surface appendages or hairs that would aid in dispersal.

**Seed banking:** Research pertaining to ground-ivy's seed bank longevity, density, and vertical distribution in the soil differs in methods, location, and emphasis, making it difficult to derive specific inferences from. Some ground-ivy seeds apparently go through a period of physiological dormancy before they germinate (review by [4]), suggesting potential for at least short-term persistence in the soil seed bank (see Germination). Additional research is necessary to

understand ground-ivy's seed banking potential in North America.

As of 2009, only two studies were found from North America that included seed banking information for ground-ivy. Using a seedling emergence method, ground-ivy was found in both the aboveground vegetation and the soil seed bank in an abandoned cultivated field undergoing restoration; however, researchers did not indicate to what extent ground-ivy was present in either stratum or report the estimated age of the seed [68]. Although ground-ivy was present in the aboveground vegetation in a Pennsylvania forest, it failed to germinate from core samples collected from the top 4 inches (10 cm) of soil from the site [66].

Available English language literature from Europe suggests ground-ivy's longevity in the soil seed bank may be highly variable; however, many studies failed to report to what extent ground-ivy occurred in the existing vegetation, making it difficult to draw conclusions about ground-ivy seed bank longevity. A review of seed bank literature in northwestern Europe [111] cites several studies suggesting that ground-ivy has only a transient soil seed bank (seeds persist for less than 1 year). A 20-year study on soil seed banking potential of weeds in a cultivated field in England found that ground-ivy seeds failed to germinate after the first 4 years of the study; however, continuous cultivation and herbicide treatments in this field may have influenced ground-ivy's persistence, seed dispersal, and seed longevity [13]. Other evidence indicates that ground-ivy seeds may remain viable in the soil for longer periods under some conditions. Researchers in Russia found viable ground-ivy seed buried at soil depths from 1.6 to 2.4 inches (4-6 cm) in a spruce plantation that was approximately 40 years old (Petrov and Palkina 1983, as cited in [51]). In an arable field in the United Kingdom, researchers found viable ground-ivy seeds at soil depths from 0 to 4.7 inches (0-12 cm) about 19 years after cultivation had ceased (Stag 1996, as cited in [51]). In 1963, excavation of a 460-year old monastery site uncovered viable ground-ivy seeds at soil depths between 21 and 29 inches (52-73 cm). The monastery and its associated buildings were gone by the mid-1500s but the land continued to be cultivated until 1935, suggesting that the ground-ivy seed found on this site is a remnant of recent cultivation activities rather than persistent in the soil for 460 years [80].

Reports on ground-ivy seed bank densities and the vertical distribution of its seeds in the soil are variable. A literature review on seed banks in northwestern Europe cites several reports on soil seed bank densities for ground-ivy. Seed densities ranged from 0 to 281 seeds/m² for various soil depths. However, the review did not report to what extent ground-ivy occurred in the aboveground vegetation, making it difficult to infer to what extent existing vegetation influenced seed banking. Additionally, different methodologies were used among studies, making comparison of the data difficult [111]. In a laboratory in Estonia, 17 ground-ivy seedlings emerged from a 4-inch³ (~63 cm³) soil core collected at a depth of about 2 to 4 inches (5-10 cm) from an early-successional (20- to 25-year-old) forest clearcut [132]. Stag (1996, as cited in [51]) determined that ground-ivy seed densities were greatest in the late summer, especially in the top 2 inches (5 cm) of soil.

Number of ground-ivy seeds germinating from soils collected in East Sussex, United Kingdom in 1992 (Stag 1996, as cited in [51]).

| Depth (cm) | Density of seeds/m² | | | |
|---|---|---|---|---|
| | April | August | November | February |
| 0-4 | 24 | 80 | 12 | 21 |
| 4-8 | 5 | 60 | 3 | 13 |
| 8-12 | 6 | 52 | 3 | 7 |

Available evidence suggests that seed bank densities for ground-ivy may be site specific and influenced by localized environmental factors, making them difficult to characterize. Factors that may influence ground-ivy seed occurrence and densities include abundance of ground-ivy in the aboveground vegetation, frequency of flooding [114], soil acidity, shade, land management practices [120], and age of seed [80]. However, the presence and abundance of ground-ivy in the aboveground vegetation may not correspond to its presence and abundance in the soil seed bank [66,114].

**Germination:** Studies from Europe indicate that a portion of ground-ivy seeds germinate when fresh [36,51]; others

seem to require a period of dormancy prior to germination ([36], review by [4]). A laboratory experiment determined that approximately 23% of freshly collected seeds from ground-ivy germinated in 9 days and 45% germinated overall. Ground-ivy seeds continued to germinate in light and shade treatments after extended periods of alternating temperature and light, but failed to germinate in the dark [36]. Another study observed an inhibitory effect of darkness on the germination of ground-ivy seed. Germination of ground-ivy seeds stored at 68 °F (20 °C) for 10 days was 84% in light compared to 8% in the dark. However, a high percentage of seeds placed in the dark germinated (84%) after being transferred to unshaded conditions, suggesting that buried seed can remain viable in the soil until conditions become favorable for germination. Shade may also influence germination of ground-ivy seed. Simulated canopy shade (increased percentage of far-red light) reduced germination of ground-ivy seeds to 52%, but germination increased to 80% when the seeds were transferred to unshaded conditions (C.P.D. Birch, unpublished data, as cited in [51]).

**Seedling establishment:** Hutchings and Price [51] report that when wetted, ground-ivy seeds become enveloped in a disc of mucilage about 0.39 inches (1 cm) in diameter that fixes them to the substrate. After the cotyledons emerge, the first true leaves of a ramet develop in approximately 1 week. An illustration depicting the stages of germination and early seedling development for ground-ivy is available in Hutchings and Price [51].

**Growth**: Literature pertaining to ground-ivy's growth is limited to information derived in its native range. Primary stolons develop from the axillary buds at the base of each ramet [52], and growth occurs through rapid stolon extension and additional ramet production [51]. In a greenhouse, stolon extension rate ranged from 0.75 to 1.1 inches/day (1.9 and 2.9 cm/day), and ramets were produced at a rate of approximately 2/week [5]. However, ground-ivy does not typically flower in greenhouse conditions [52,102], suggesting that its growth rate may be slower in wild populations where some energy is allocated to flowering.

A greenhouse study on ground-ivy growth determined that maintenance of stolon connections in ground-ivy was advantageous to growth and ramet survival [100]. However, another greenhouse study found that fragmented ground-ivy stolons can develop into physiologically independent units capable of continued growth [7]. Growth on fragmented stolons was associated with a smaller ramet size but greater ramet density than on intact stolons [100]; however, ramet production on fragmented stolons may be limited if fewer than 5 rooted ramets remain [7].

Greenhouse studies in England found that ground-ivy's morphology was highly plastic in response to resource availability. When compared to plants grown in unshaded, nutrient-rich environments, plants grown where light and nutrients were limited had decreased stolon branching, leaf area, and ramet production [99,100,102,128] and increased internode and petiole length [99,100,101,102,128].

Interspecific competition for resources may also influence ground-ivy growth. In the greenhouse, ground-ivy's morphology changed in response to competition from perennial ryegrass (*Lolium perenne*) for soil resources and light. Plants grown with uncut perennial ryegrass exhibited decreased ramet production, stolon branching, and secondary stolon production, and increased internode and petiole length, when compared to ground-ivy plants grown without competition [85]. On an experimental site in Germany, DaBler and others [18] observed that leaf area ratio (total leaf area per total dry mass per shoot) of ground-ivy increased in response to increased competition for light when grown with species common to Central European semi-natural grasslands.

Ground-ivy may be more productive in heterogeneous growing conditions (patchy nutrient distribution) when compared to homogenous conditions (uniform nutrient distribution) [6,51]. In the greenhouse, Birch and Hutchings [6] reported that the overall biomass of ground-ivy grown in heterogeneous nutrient conditions was over 2.5 times greater than biomass of plants grown in homogeneous habitats providing the same quantity of nutrients. Eighty percent of ground-ivy's root biomass was concentrated at nodes associated with localized patches of nutrient-rich soil (peat-based potting compost), suggesting that nutrient heterogeneity may influence root establishment and growth in ground-ivy. Roots also developed earlier and grew longer in plots with heterogeneous soil resources compared to those with homogeneous soil resources [6]. Ramets developing on localized sites with fewer resources seldom sprouted roots at the node. In another greenhouse experiment, Farley and Fritter [24] reported that specific root length (m/g root dry weight) of ground-ivy was greater in patchy nutrient enriched soils compared to patches of unenriched soils, although the difference was not significant. Root length density (km of root/$m^3$) was more likely to increase in medium to large patches of enriched soil versus smaller patches [24]. Clones rooted in heterogeneous soils may translocate resources

from older to newer ramets. This allows ramets in nutrient-rich patches to transport resources to ramets established in less favorable growing conditions, thereby increasing their chances for survival [101].

**Vegetative regeneration:** Ground-ivy is a clonal species and has a great capacity to regenerate vegetatively. Upright branches become structurally weak, bend to a horizontal position, and start to develop roots and rosette buds at some of the nodes. Under suitable conditions, these buds give rise to horizontal stolons and ramets [103,125]. Additionally, fragmented stolons can develop into physiologically independent units capable of continued growth [7].

SITE CHARACTERISTICS:

Ground-ivy is a species of temperate latitudes (review by [51]). It was classified as a Eurasian boreo-temperate species but may now be considered circumpolar boreo-temperate since its introduction and spread to other parts of the world [49,50,51,83]. While its distribution has typically been restricted to the temperate regions of the northern hemisphere, its introduction to New Zealand [50,51] suggests its distribution may be expanding.

A few floras from the western United States report ground-ivy's elevational range. In California this species occurs below 2,625 feet (800 m) [44], while in Utah ground-ivy occurs from about 4,600 to 5,200 feet (1,400-1,590 m). In Colorado, it has been reported growing from 5,000 to 6,000 feet (~1,525-1,825 m) [41]. Ground-ivy was found in a mid-elevation mixed oak (*Quercus* spp.) forest between approximately 1,970 and 4,920 feet (600-1500 m) in the southern Appalachian Mountains [38]. British references indicate that ground-ivy is primarily a species of the valleys and foothills of temperate Europe [51]. It occurs from sea level in England, Scotland, and Wales to about 1,150 feet (350 m), and up to 5,250 feet (1,600 m) in the Alps [50,51].

In North America, ground-ivy is frequently associated with riparian habitats [3,35,47,56,73,78,86,116,118,119,123]. It also occurs in thickets [16,35,40,79,86,107,118], moist woods [16,31,46,70,79], wetlands [34], and forest edges [11,118]. In Ohio, ground-ivy was a characteristic ground flora component in a riparian forest, maintaining approximately 0.6% of the mean ground cover during the spring. It maintained a higher percentage of groundcover in a floodplain than in the adjacent upland (see table below) [47].

In Great Britain, ground-ivy occurs in hedgerows [36], grasslands [51], fens [33,91], and on scree slopes [53]. It grows on a wide range of slopes and aspects in Britain and is common on south-facing slopes but most abundant on unshaded north-facing slopes and on sites with a "moderate to high" percentage of bare ground (review by [51]).

Ground-ivy readily invades sites associated with anthropogenic disturbance and human activities, such as roadsides [3,35,40,87,97,118], housing developments [97], prairie restoration sites [48,90], cultivated pastures [3,35], fallow fields [81], pasture edges [11], "waste ground" [107,118], and lawns [3,35,45,118]. In Canada, ground-ivy was considerably more abundant in fragmented riparian forest associated with urban land use and disturbance than in undisturbed sites farther from urban areas [77]. In Sweden, ground-ivy ramets were observed in 1 plot in a highly managed "semi-natural" grassland [54].

Although ground-ivy has variable light requirements, it is more often associated with shaded habitats in North America such as woodlands, riparian forests [16,31,46,47,56,70,73,79,86,113,119], and thickets [16,35,40,79,107,118]. In a floodplain along the Potomac River in Maryland, ground-ivy cover was significantly greater in the more heavily shaded forested sites (50% to 75% ground-ivy cover) than in the forested site with increased light penetration (trace of ground-ivy cover) [86]. Ground-ivy can grow in full sunlight [2,59,113], especially on disturbed sites or where human activity has altered the natural vegetation (e.g., roadsides, pastures, lawns) [51], but it likely prefers some degree of shade even on these types of sites [51,105,110]. Ground-ivy has been found in prairies and grasslands undergoing restoration in Illinois and central New York [48,90].

In Great Britain, ground-ivy is associated with light gradients ranging from open to shaded [2] but is typically a plant of shaded or patchily shaded habitats (review by [51]). It is also associated with grassland communities in Great Britain, suggesting that increased light does not preclude ground-ivy from establishing [51].

Across its introduced range in North America, ground-ivy appears to prefer moist, but not saturated, soils associated with riparian areas, floodplains, wetlands, and moist woods [16,31,34,46,47,70,79]. Throughout most of the United

States, this species is ranked as a facultative upland species; usually occurring in non-wetland habitat but occasionally found in wetlands (estimated 1% to 33% probability of occurrence in a wetland) [34,112]. In a Pennsylvania wetland, ground-ivy was strongly associated with wetlands that retained seasonal surface water, but was not strongly associated with permanently flooded wetlands or those with high groundwater [34]. Along the Potomac River in Maryland, researchers found that while ground-ivy was common in the floodplain, its frequency decreased with increased proximity to the water's edge [86]. In Great Britain, ground-ivy occurs as a minor component in fens [91] but may be locally abundant on some sites [33]. In France, ground-ivy did not occur in a meadow where summer groundwater was less than about 16 inches (40 cm) below the surface. It did occur on sites where groundwater was deeper than 16 inches and it was most abundant on sites where summer groundwater levels were 3.3 feet (1 m) or greater below the surface. In that same meadow, ground-ivy was found in areas that flooded between 1 and 3 months a year but was absent from sites experiencing more frequent flooding [114].

Information pertaining to soil characteristics associated with ground-ivy in North America is limited. Ground-ivy was found in loamy-skeletal, mixed mesic soils at one site in the southern Appalachian Mountain region [38]. A floodplain study in Massachusetts found ground-ivy to be a common understory component where soils were predominantly sandy loams with a pH ranging from 4.5 to 8.0 [56]. Ground-ivy grew in coarse soil associated with a constructed wetland in New Jersey [69]. In Ohio, several substrate parameters were reported for a floodplain and adjacent upland where ground-ivy occurred [47]:

Mean values of environmental variables (SE) for landforms along a first order stream at Johnson Woods State Nature Preserve, Ohio [47].

| Variable | Floodplain | Upland |
|---|---|---|
| Distance from stream (m) | *8.65(1.12) | 26.44 (1.28) |
| Elevation from stream (m) | *0.35(0.06) | 2.66 (0.21) |
| pH | *5.11(0.07) | 4.59 (0.04) |
| Organic matter (%) | *4.96(0.30) | 3.38 (0.10) |
| A horizon thickness (cm) | 10.25 (0.59) | 9.22 (0.42) |
| Sand (%) | *26.70 (0.70) | 22.93 (0.48) |
| Silt (%) | *39.86 (1.29) | 51.35 (0.53) |
| Clay (%) | *33.45 (1.24) | 25.73 (0.50) |
| ground-ivy cover (%) - early spring | 0.55% | 0.20% |
| ground-ivy cover (%) - late spring | 0.60% | 0.04% |

*Values of measured environmental variable are significantly different (P<0.001) between floodplain and upland sites

Ground-ivy substrate requirements have been studied extensively in parts of its native range. Regional floras from Great Britain indicate that ground-ivy prefers damp, heavy, fertile and calcareous soils with a pH range from 5.5 to 7.5 but occurs in soils with a pH as low as 4.0 (review by [51]). In that region, it often grows on fine-textured soils and heavy clays ([91], Landolt 1977 as cited in [51]). In central Estonia, ground-ivy seedlings emerged from soils with a pH of 5.5 [132]. In England, ground-ivy seed germinated in brown earth soils with a basic pH [120]. It has also been reported that ground-ivy does not grow in strongly acidic soils and is intolerant of saline conditions (Landolt 1977, as cited in [51]). In central Belgium and Great Britain, ground-ivy tolerates heavily compacted soils associated with disturbed areas [32,91]. Others have found that ground-ivy may only become abundant where there is an adequate supply of phosphate, nitrate, and calcium in the soil (review by [51]).

SUCCESSIONAL STATUS:
Detailed information about ground-ivy's successional patterns in its native and nonnative ranges is lacking; however, available data suggests it can adapt to a variety of light regimes and establishes well on disturbed sites.

**Shade tolerance**: Several morphological adaptations may allow ground-ivy to thrive in shade (see Growth). In the

United States, ground-ivy has been commonly reported growing in the shade of forests [40,47,56,70,86,119] and thickets [45,94,107,118], and a few studies indicate that ground-ivy may have a preference for shade [38,86]. In a riparian forest in Maryland, frequency of ground-ivy was greatest on the site with the lowest light levels [86]. Ground-ivy made up about 0.7% of the vegetation cover in a 50- to 100-year-old oak (*Quercus* spp.) forest in the southern Appalachian Mountains of Virginia that had not been managed for the past 15 to 25 years [38]. A study in England determined that frequency of ground-ivy increased significantly ($P<0.05$) over a 30-year period after tree harvesting was reduced [15]. In Great Britain, ground-ivy can establish under the dense shade of dog's mercury (*Mercurialis perennis*) [91].

While ground-ivy may be shade tolerant, its distribution does not appear to be age-sensitive or restricted to older forests [115]. In North America, ground-ivy can grow in full sunlight [113], and in Great Britain it is found growing in habitats in nearly full sun [51]. Ground-ivy's ability to establish and dominate on sites of variable light availability suggests that there may be factors besides shade that influence this species' ability to establish at various successional stages.

Increased shade may limit growth and reproduction of ground-ivy. In a laboratory, increases in the percentage of far-red light, typically associated with canopy shading, may decrease germination in ground-ivy (C.P.D. Birch, unpublished data, as cited in [51]). In the United Kingdom, researchers found that more flowers develop on clones growing on open sites; however, seed set was greatest in shaded habitats (review by [51]). Some researchers in England have observed the total elimination of ground-ivy with increasing canopy cover. Ground-ivy ceased to persist in a thinned woodland 3 years after thinning operations had been completed, suggesting that increased canopy cover may have inhibited its growth [2].

**Establishment and persistence on disturbed sites**: Several attributes make ground-ivy an effective invader of disturbed sites. Successful establishment of ground-ivy on disturbed sites may be facilitated through rapid stoloniferous growth and subsequent ramet production if a clone is nearby [6]. In a laboratory setting, fragmented stolons with a sufficient root system rapidly developed into physiologically autonomous segments, a characteristic that might enable ground-ivy to exploit disturbed habitats [7]. Ground-ivy has the ability to adapt morphologically to changes in the environment (e.g., light, nutrients) [99,102], giving it an advantage in variable conditions typically associated with disturbance. Its ability to produce greater mass under heterogeneous growing conditions [6] (see Growth) may make it a strong competitor on disturbed sites. Ground-ivy can also establish and grow in heavily compacted soils [32,91], which are often associated with disturbed sites.

Information pertaining to ground-ivy's persistence and density following disturbance is limited. Ground-ivy occurred in 1 or more hurricane impacted plots in a deciduous forest in North Carolina 4 years after the hurricane [109]. In another region of North Carolina, ground-ivy was found in a deciduous urban riparian forest invaded by English ivy (*Hedera helix*) that experienced intense recreational pressure [116]. In New York, ground-ivy was a dominant species in a fallow field where cultivation had ceased for approximately 20 years but mowing continued [81]. It was commonly found in portions of the floodplain on the Potomac River that were greater than 3.3 feet (1 m) from the water's edge [86]. Ground-ivy established in a recently planted tallgrass prairie restoration site in Illinois that had been previously cultivated [48].

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# FIRE EFFECTS AND MANAGEMENT

SPECIES: Glechoma hederacea

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FIRE EFFECTS:

**Immediate fire effect on plant:** Ground-ivy is likely damaged by fire because its stolons are on the soil surface;

however, to what extent is unclear. Chapman and Crow [14] reported that hemicryptophytes generally respond favorably to burning, but species having rhizomes in the litter or those without rhizomes are damaged more easily and recover more slowly [14]. In a greenhouse study, defoliation of ground-ivy resulted in significantly lower biomass production and subsequent stolon death [84], suggesting that leaf destruction, typically a consequence of fire, may be detrimental to its survival.

**Postfire regeneration strategy** [106]:
Surface rhizome and/or a chamaephytic root crown in organic soil or on soil surface
Ground residual colonizer (on site, initial community)
Secondary colonizer (on- or off-site seed sources)

**Fire adaptations and plant response to fire:** As of this writing (2009), information pertaining to ground-ivy's response to fire is very limited. Ground-ivy can establish on open disturbed sites (see Successional Status), suggesting that if seed is available, establishment in a burned area might occur. However, ground-ivy's primary mechanism for seed dispersal is gravity (see Seed dispersal), so establishment from offsite seed sources would be unlikely unless animals aid seed dispersal ([8], Grime and others 1988 as cited in [115]). It is unclear how well ground-ivy plants tolerate heat or to what extent ground-ivy can sprout vegetatively after fire [14].

Two studies report the presence of ground-ivy after fire [90,95]. In central New York, ground-ivy occurred in a grassland where rotational mowing and prescribed fire were used for at least 10 years to control invasive shrubs. Two plots where ground-ivy occurred were treated with an additional 2-year cycle of mechanical treatments and low-intensity prescribed fire. Three months after the 2-year treatment cycle, ground-ivy had greater cover than before these treatments [90]. See Fire Management Considerations and Physical or mechanical control for details. Researchers found a trace of ground-ivy in an eastern white pine/mixed hardwood forest in New Hampshire prior to and shortly after a low-intensity spring prescribed burn [95]. It was unclear whether the occurrence of ground-ivy could be attributed to vegetative sprouting or seed germination in either of these reports.

FUELS AND FIRE REGIMES:
**Fuels:** As of 2009, information pertaining to ground-ivy's fuel properties and potential to alter fire behavior or fire regimes is lacking.

**Fire regimes:** As of 2009, information describing fire regimes associated with ground-ivy is limited and it is unknown whether invasive populations of ground-ivy can alter fire regimes. Available literature suggests that in North America, ground-ivy is most common in moist deciduous forests, eastern white pine/mixed hardwood forests, and riparian areas in the northeastern, Great Lakes, and southern Appalachian Mountain regions of the United States (see Habitat Types and Plant Communities). Deciduous forests and pine/mixed hardwood forests in this region typically have long fire-return intervals that have been estimated from several hundred to greater than 1,000 years and can be of stand-replacement, mixed-severity, or surface types. Although stand-replacing disturbances are more often caused by natural events other than fire (e.g., hurricanes, ice storms) in these areas, fire has likely played a role in shaping the structure and composition of the vegetation [134]. The historical role of fire in riparian communities is unclear. Riparian vegetation in the United States is often dominated by hardwoods and/or conifers with a dense shrub layer [65,134]. For theses communities, fire typically has longer intervals and is less severe, especially in moister forest types [23]; however, in some cases it can be frequent [134]. See the Fire Regime Table for more detail on fire regimes in plant communities where ground-ivy may occur.

FIRE MANAGEMENT CONSIDERATIONS:
The limited information on ground-ivy's postfire response suggests that fire may damage it but may not control it. Fire will likely damage ground-ivy stolons, meristem tissue, and shallow roots, but this species' ability to establish on open disturbed sites (see Successional Status) suggests that fire might create favorable conditions for ground-ivy establishment and/or spread.

In central New York, researchers combined mechanical and fire treatments to control invasive shrubs in a grassland that had been treated with rotational mowing and prescribed fire for at least 10 years. In 2001, prior to treatment, 2

plots chosen for low-intensity prescribed fire had little (2.8% of vegetation cover) or no ground-ivy. After alternating treatments of mowing/cutting and prescribed fire over a 2-year period, ground-ivy cover increased on both plots to 5.3% and 11.4% respectively. A third plot, that was mowed but not burned, experienced a similar increase (from 0% to 12.5% of the vegetation cover) in ground-ivy cover. Ground-ivy also increased on an untreated control plot but to a lesser degree (from 1.1% to 2.3%) [90]. Ground-ivy's ability to persist and increase on treated plots suggests that neither mowing alone, nor the combination of burning and mowing/cutting, adversely impacted its survival.

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# MANAGEMENT CONSIDERATIONS

SPECIES: Glechoma hederacea

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IMPORTANCE TO WILDLIFE AND LIVESTOCK:
In its native range, many invertebrates utilize ground-ivy for forage; a comprehensive list of species is given by Hutchings and Price [51]. In Great Britain, bank voles utilize ground-ivy as a food source [121]. A study in Germany determined that ground-ivy was commonly used as a nesting material for European Starlings [37]. European wild boars eat the leaves of ground-ivy (Janda 1954, as cited in [9]), and in the United States, it is considered a potential food source for introduced boars in the Smokey Mountains [9].

**Palatability/nutritional value:** It appears that ground-ivy is palatable for the few animals identified above, but nothing has been reported on its importance as forage.

Ground-ivy is thought to be toxic to livestock [22,25,40,51], especially horses [17,76], and to some species of rodents [51].

**Cover value:** No information is available on this topic.

OTHER USES:
In the past, ground-ivy was used for various medicinal purposes and in place of hops for brewing beer and ale [3,40,51,76,108]. Today, this plant may still be cultivated and used as an herbal remedy for various ailments.

IMPACTS AND CONTROL:
**Impacts:** Although ground-ivy is found throughout much of North America, north of Mexico, no specific information was available as of this writing (2009) regarding its impacts on native plant communities and ecological processes across this range. The lack of data pertaining to ground-ivy's impacts suggests that it may be less invasive and widespread than other invasive species that have been well documented. However, ground-ivy's ability to exploit heterogeneous resources [6,51], allelopathic potential [89], ability to regenerate vegetatively [7,103,125], and its early bloom time may provide opportunity for it to spread into native plant communities. The shade-tolerant nature of ground-ivy makes it problematic because it can invade under a forest canopy (see Shade tolerance)

A few regional weed publications and floras have reported on ground-ivy invasiveness. In Connecticut, distribution of ground-ivy is banned because of its invasive potential [112]. In Virginia, ground-ivy is ranked as a "moderately invasive species" in mesic, partly sunny to shaded habitats. Species ranked as moderately invasive may have a minor influence on ecosystem processes, alter plant community composition, and affect community structure. Usually some type of disturbance is necessary for these species to establish, and they may dominate the understory layer [117]. In Kentucky, ground-ivy is considered a "significant threat" that may have the capacity to invade natural plant communities associated with disturbance [57]. Ground-ivy is ranked as a Category B invasive plant in Missouri. Species in this category are occasional invaders of native plant communities in Missouri or are invasive in other states with similar habitats, but with generally low levels of impact [75]. In the upper midwestern United States, ground-ivy

is categorized as a lesser invader in forests and woodlands and "is generally not a threat to established native plant communities except along woodland edges" [17]. In the Intermountain West area of the United States ground-ivy is described as "too aggressive for most areas" [46]. In Canada, ground-ivy is considered a potential threat to native habitats and is listed as a species of concern [12], and in Nova Scotia, it can be "almost impossible to eradicate" around sites associated with human habitation [94].

Ground-ivy's greatest impact may be to lawns and turfgrass [3,35,43,45,60,74,118] where it can form dense mats that eliminate desirable vegetation [17,105]. In Ohio, ground-ivy was reported to "grow like mad" in home lawns [28]. It disrupts turf uniformity and is difficult to control in these environments [60]. While reports suggest ground-ivy can grow in full sunlight, some turf care professionals report that it usually prefers shaded turf [105]. Ground-ivy has become such a nuisance to the turf management industry that research has been launched to evaluate different control methods for ground-ivy [60].

**Control:** Information related to the control of ground-ivy has been derived primarily from the turfgrass maintenance industry but may have some application to wildlands.

Fire: For information on the use of prescribed fire to control ground-ivy see Fire Management Considerations.

Prevention: As of 2009, no information is available on this topic.

Cultural control: The turfgrass industry has suggested that the use of shade-tolerant grasses and other species that are better adapted to shade may deter ground-ivy's spread in turfgrass [105].

Physical or mechanical control: Ground-ivy's ability to regenerate vegetatively (see Vegetative regeneration) makes it hard to control by physical or mechanical means. Turfgrass researchers assert that extensive rooting from stolons would make mechanical control difficult [60,105]. In the midwestern United States, small patches of ground-ivy may be controlled by carefully pulling or raking out the plants when the soil is damp, but great care needs to be taken to remove all roots because stems easily break [17]. In central New York, a grassland managed for control of invasive shrubs experienced little increase or a slight reduction in ground-ivy cover on 3 plots treated with various rotations of brushcutting over a 2-year period. Ground-ivy cover increased more on a control plot than on treated plots (see table below). In another nearby managed grassland, ground-ivy cover increased over a 2-year period from 0% to 12.5% in a plot that was mowed and mulched. Ground-ivy also increased on control plots but to a lesser degree than on the treated plot (from 1.1% to 2.3%) [90]. For more details on this study see Fire Management Considerations.

Percent cover of ground-ivy in plots treated with various rotations of brushcutting over 2-year period at Clark Ridge grassland in New York [90].

| Treatment date | Control | Growing season cut (once/2-yr period) | Growing season cut (twice/2-yr period) | Dormant season cut (once/2-yr period) |
|---|---|---|---|---|
| Prior to 2001 | 1.9 | 2.5 | 5.8 | 3.6 |
| After 2003 | 5.3 | 3.7 | 8.6 | 3.2 |

Biological control: As of 2009, no information is available on this topic; however, herbivory on ground-ivy by invertebrates is common in this plant's native range [51], suggesting that there may be potential for a biological control.

Chemical control: As of this writing (2009), no information was available regarding chemical control of ground-ivy in wildlands. Ground-ivy may be difficult to control chemically in lawns and turfgrass [43,60] but a few publications recommend specific treatments [17,28,42,43,60,105]. Used independently, postemergent herbicide treatment may fail to control ground-ivy because it can quickly reestablish if any ramets or stolons survive [60].

Integrated management: Information pertaining to integrated management techniques for ground-ivy comes from 1

study in central New York where ground-ivy's occurrence was incidental to the study. In a managed grassland (i.e., 10 years of rotational mowing and prescribed fire to control invasive shrubs), ground-ivy increased over a 2-year period on 2 plots treated with a combination of mowing/cutting and low-intensity prescribed fire. Ground-ivy also increased on control plots but to a lesser degree than on treated plots [90]. For more details on this study see Fire Management Considerations and Physical or mechanical control.

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# APPENDIX: FIRE REGIME TABLE

SPECIES: Glechoma hederacea

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The following table provides fire regime information that may be relevant to ground-ivy habitats. Follow the links in the table to documents that provide more detailed information on these fire regimes. If you are interested in fire regimes of plant communities not listed here, see the Expanded FEIS Fire Regime Table.

Fire regime information on vegetation communities in which ground-ivy may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [65], 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.

Great Lakes Northeast Southern Appalachians

**Great Lakes**

- 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 Forested | | | | | |
| Northern hardwood maple-beech-eastern hemlock | Replacement | 60% | >1,000 | | |
| | Mixed | 40% | >1,000 | | |
| Great Lakes floodplain forest | Mixed | 7% | 833 | | |
| | Surface or low | 93% | 61 | | |
| Maple-basswood | Replacement | 33% | ≥1,000 | | |
| | Surface or low | 67% | 500 | | |
| Maple-basswood mesic hardwood forest (Great Lakes) | Replacement | 100% | >1,000 | ≥1,000 | >1,000 |
| Maple-basswood-oak-aspen | Replacement | 4% | 769 | | |
| | Mixed | 7% | 476 | | |

| | | | | | |
|---|---|---|---|---|---|
| | Surface or low | 89% | 35 | | |
| Northern hardwood-eastern hemlock forest (Great Lakes) | Replacement | 99% | >1,000 | | |
| 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**<br>• 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 Forested | | | | | |
| Northern hardwoods (Northeast) | Replacement | 39% | ≥1,000 | | |
| | Mixed | 61% | 650 | | |
| Eastern white pine-northern hardwoods | Replacement | 72% | 475 | | |
| | Surface or low | 28% | >1,000 | | |
| Northern hardwoods-eastern hemlock | Replacement | 50% | ≥1,000 | | |
| | Surface or low | 50% | ≥1,000 | | |
| Northern hardwoods-spruce | Replacement | 100% | ≥1,000 | 400 | >1,000 |
| Appalachian oak forest (dry-mesic) | Replacement | 2% | 625 | 500 | ≥1,000 |
| | Mixed | 6% | 250 | 200 | 500 |
| | Surface or low | 92% | 15 | 7 | 26 |
| Beech-maple | Replacement | 100% | >1,000 | | |
| **Southern Appalachians**<br>• Southern Appalachians Forested | | | | | |
| | | Fire regime characteristics | | | |

| Vegetation Community (Potential Natural Vegetation Group) | Fire severity* | Percent of fires | Mean interval (years) | Minimum interval (years) | Maximum interval (years) |
|---|---|---|---|---|---|
| Southern Appalachians Forested | | | | | |
| Bottomland hardwood forest | Replacement | 25% | 435 | 200 | ≥1,000 |
| | Mixed | 24% | 455 | 150 | 500 |
| | Surface or low | 51% | 210 | 50 | 250 |
| 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 |
| Eastern hemlock-eastern white pine-hardwood | Replacement | 17% | ≥1,000 | 500 | >1,000 |
| | Surface or low | 83% | 210 | 100 | >1,000 |
| Appalachian oak forest (dry-mesic) | Replacement | 6% | 220 | | |
| | Mixed | 15% | 90 | | |
| | Surface or low | 79% | 17 | | |
| Southern Appalachian high-elevation forest | Replacement | 59% | 525 | | |
| | Mixed | 41% | 770 | | |

*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 [39,64].

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