SPECIES: Pueraria montana var. lobata

INTRODUCTORY

SPECIES: Pueraria montana var. lobata

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FEIS ABBREVIATION:
PUEMONL

SYNONYMS:
Pueraria lobata (Willd.) Ohwi. [18,67]

NRCS PLANT CODE [59]:
PUMOL

COMMON NAMES:
kudzu

TAXONOMY:
There are several species of *Pueraria* throughout the world that are variously referred to as "kudzu" [34]. The currently accepted scientific name for the species of kudzu that has become widely established throughout the southeastern United States is *Pueraria montana* (Lour.) Merr. var. *lobata* (Willd.) Maesen & S. Almeida (Fabaceae) [25,63,68]. Throughout this summary, the common name "kudzu" refers to the above species.

LIFE FORM:
Vine

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
Kudzu is designated as a "noxious weed" in Kansas and Pennsylvania, and a "terrestrial noxious weed" in Florida. West Virginia classifies kudzu as "noxious weed but with crop value: permit may be issued for cultivation", and Oregon cites it as "noxious weed of known economic importance which occurs in small enough infestations to make eradication/containment possible; or is not known to occur, but is present in neighboring states" [60]. For more information see Invaders Database or Plants Database.

DISTRIBUTION AND OCCURRENCE

SPECIES: Pueraria montana var. lobata

GENERAL DISTRIBUTION:
Kudzu originated in China and was brought to the United States from Japan in the late 1800s [34,66]. It is distributed throughout much of the eastern United States and is most common in the South. It occurs from Nebraska, Illinois, New York, and Massachusetts south to Florida and Texas. Kudzu also occurs in Hawaii [2,15,19,20,23,24,25,38,45,49,50,53,59]. Estimated kudzu cover in the Southeast is 7 million acres (2.8 million hectares), with the most extensive infestations in Mississippi, Alabama, and Georgia [51]. The Plants database provides a distributional map of kudzu.

Kudzu has periodically been reported in areas disjunct from the above description, but has not become established in any of these areas as of this writing (2002) [66]. It has recently been discovered near Portland, Oregon, and efforts to eradicate the population are underway [54].

The following biogeographic classification systems are presented as a guide to demonstrate where kudzu could potentially be found. Because the ecology of kudzu in North America has not been extensively studied, precise distribution information is lacking. Therefore these lists are somewhat speculative and may not be exhaustive or complete.

ECOSYSTEMS [17]:
FRES12 Longleaf-slash pine
FRES13 Loblolly-shortleaf pine
FRES14 Oak-pine
FRES15 Oak-hickory
FRES16 Oak-gum-cypress
FRES17 Elm-ash-cottonwood
FRES18 Maple-beech-birch
FRES39 Prairie
FRES41 Wet grasslands

STATES:

AL	AR	CT	DE	FL

GA	HI	IL	IN	KS
KY	LA	MD	MA	MS
MO	NE	NJ	NY	NC
OH	PA	SC	TN	TX
VA	WV	DC		

BLM PHYSIOGRAPHIC REGIONS [1]:
None

KUCHLER [27] PLANT ASSOCIATIONS:
K073 Northern cordgrass prairie
K074 Bluestem prairie
K077 Bluestem-sacahuista prairie
K078 Southern cordgrass prairie
K079 Palmetto prairie
K080 Marl everglades
K082 Mosaic of K074 and K100
K083 Cedar glades
K088 Fayette prairie
K089 Black Belt
K090 Live oak-sea oats
K100 Oak-hickory forest
K102 Beech-maple forest
K103 Mixed mesophytic forest
K104 Appalachian oak forest
K106 Northern hardwoods
K108 Northern hardwoods-spruce forest
K109 Transition between K104 and K106
K110 Northeastern oak-pine forest
K111 Oak-hickory-pine
K112 Southern mixed forest
K113 Southern floodplain forest
K114 Pocosin
K115 Sand pine scrub

SAF COVER TYPES [12]:
17 Pin cherry
19 Gray birch-red maple
21 Eastern white pine
22 White pine-hemlock
23 Eastern hemlock
25 Sugar maple-beech-yellow birch
26 Sugar maple-basswood
27 Sugar maple
28 Black cherry-maple
33 Red spruce-balsam fir
37 Northern white-cedar
39 Black ash-American elm-red maple
40 Post oak-blackjack oak
42 Bur oak
43 Bear oak
44 Chestnut oak
45 Pitch pine
46 Eastern redcedar
50 Black locust

51 White pine-chestnut oak
52 White oak-black oak-northern red oak
53 White oak
55 Northern red oak
57 Yellow-poplar
58 Yellow-poplar-eastern hemlock
59 Yellow-poplar-white oak-northern red oak
60 Beech-sugar maple
61 River birch-sycamore
62 Silver maple-American elm
63 Cottonwood
64 Sassafras-persimmon
65 Pin oak-sweetgum
69 Sand pine
70 Longleaf pine
71 Longleaf pine-scrub oak
72 Southern scrub oak
73 Southern redcedar
74 Cabbage palmetto
75 Shortleaf pine
76 Shortleaf pine-oak
78 Virginia pine-oak
79 Virginia pine
80 Loblolly pine-shortleaf pine
81 Loblolly pine
82 Loblolly pine-hardwood
83 Longleaf pine-slash pine
84 Slash pine
85 Slash pine-hardwood
87 Sweetgum-yellow-poplar
88 Willow oak-water oak-diamondleaf (laurel) oak
89 Live oak
91 Swamp chestnut oak-cherrybark oak
92 Sweetgum-willow oak
93 Sugarberry-American elm-green ash
94 Sycamore-sweetgum-American elm
95 Black willow
96 Overcup oak-water hickory
97 Atlantic white-cedar
98 Pond pine
100 Pondcypress
101 Baldcypress
102 Baldcypress-tupelo
103 Water tupelo-swamp tupelo
104 Sweetbay-swamp tupelo-redbay
108 Red maple
109 Hawthorn
110 Black oak
111 South Florida slash pine

SRM (RANGELAND) COVER TYPES [47]:
601 Bluestem prairie
711 Bluestem-sacahuista prairie
726 Cordgrass
731 Cross timbers-Oklahoma
801 Savanna
802 Missouri prairie
803 Missouri glades
804 Tall fescue
805 Riparian

806 Gulf Coast salt marsh
807 Gulf Coast fresh marsh
808 Sand pine scrub
809 Mixed hardwood and pine
810 Longleaf pine-turkey oak hills
811 South Florida flatwoods
812 North Florida flatwoods
813 Cutthroat seeps
814 Cabbage palm flatwoods
815 Upland hardwood hammocks
817 Oak hammocks
818 Florida salt marsh
819 Freshwater marsh and ponds
821 Pitcher plant bogs
822 Slough

HABITAT TYPES AND PLANT COMMUNITIES:
Kudzu is most invasive in the Southeast. Factors that determine occurrence and invasiveness are most likely climate, light availability, and previous local establishment. The particular local native plant community probably has little influence on kudzu distribution and invasiveness. Even core areas of otherwise undisturbed, insular forest habitat can eventually succumb, as invading kudzu slowly advances from established populations along a forest perimeter. Any southeastern plant communities in the vicinity of an existing kudzu population -- from pine plantations to mixed hardwoods -- are likely to be at risk of invasion.

Kudzu is not a climax dominant or indicator species in habitat type classifications. However, due to its ability to achieve and maintain dominance on many sites where it occurs, kudzu might be considered the de facto climax dominant on these sites, regardless of site potential.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Pueraria montana var. lobata

GENERAL BOTANICAL CHARACTERISTICS:
Kudzu is a climbing or trailing, herbaceous to semiwoody, nonnative, deciduous, perennial vine or liana. The compound leaves are 2 to 8 inches (5-20 cm) long [37,45]. Flowers are 0.8 to 1 inch (2-2.5 cm) long and are borne on 4- to 8-inch-long (10-20 cm) axillary racemes [37]. Seeds are produced in 1.6- to 2-inch (4-5 cm) long pods [37,45].

Kudzu exhibits a strong diurnal pattern in leaflet orientation, enabling plants to adjust the intensity of incident radiation upon exposed leaflets by altering their axial position relative to the sun. This trait results in comparatively reduced leaf temperatures and transpirational water loss during periods of intense mid-day summer sunlight, and may improve plant water-use efficiency [14,64]. This trait may also improve light penetration in kudzu-dominated tree canopies, enhancing the specie's ability to maintain high leaf areas. High leaf area in arboreal kudzu maximizes photosynthesis and enhances kudzu's ability to compete for light [64].

Kudzu accumulates and maintains substantial carbon reserves in large woody, tuberous roots. Roots can grow to 12 feet (3.6 meters) long in sandy soils and can weigh up to several hundred pounds [33]. Because of its large and deeply growing taproot, kudzu can withstand substantial periods of drought [66]. Deep roots also enable kudzu to maintain relatively high xylem water potentials throughout the hottest part of the day [64].

Kudzu is considered a semiwoody perennial because it exhibits 2 strategies for overwintering. The trailing, prostrate stems found in open areas die back to the root crown following the 1st frost. Stems that climb vertically, such as those invading a forest edge, often overwinter in the canopy. Overwintering vines develop thick bark, accumulate annual rings of vascular tissue, and can attain $\geq$ 0.8-inch (2 cm) stem diameters [44,57]. North American kudzu apparently produces overwintering stems only

on vigorous, climbing plants, but in Japan kudzu produces overwintering stems even on prostrate plants [57].

Growth habit: Vines climb by twining the stem around a support such as the bole of a tree [6]. Spread of kudzu through forested areas may be accelerated by other vines such as Japanese honeysuckle (*Lonicera japonica*), since kudzu can more easily twine around smaller diameter vines than around bare tree trunks [33,35].

RAUNKIAER [46] LIFE FORM:
Chamaephyte
Phanerophyte

REGENERATION PROCESSES:
Asexual regeneration:
Kudzu commonly spreads by sending down roots from nearly every node along stems that contact soil. Rooting usually occurs every few feet along horizontal stems, and new root crowns develop at these nodes. New ramets develop the following spring, with new tendrils radiating in all directions from newly established root crowns [33,39,44].

Breeding system: No information

Pollination: No information

Seed production: Kudzu plants do not usually flower until their 3rd year [3]. Kudzu rarely flowers on prostrate vines and seeds are only produced on climbing vines [11,33,39]. Generally, a cluster of seedpods produces only 1 or 2 viable seeds [11]. Seed production is substantially limited in North America, especially in areas outside the Southeast [19,20,51].

Seed dispersal: No information

Seed banking:
Seeds require scarification before they germinate. Although information on seed longevity is lacking, seed banks can apparently develop [11,33,39].

Germination:
Seeds are unable to germinate until the seedcoats are rendered water permeable. Dormancy may be broken by physical scarification of seeds. Prolonged exposure to warm summer temperatures may promote germination by increasing seedcoat permeability, but detailed information is lacking [55,56].

Seedling establishment/growth: Kudzu reportedly sets seed infrequently in North America [51,66]. It is speculated that kudzu seedlings are far less competitive than asexually established ramets, and may be of minor concern regarding invasiveness [64]. The ecology of kudzu sexual reproduction in North America is little studied and more research is needed in this area.

Vines can grow up to 1 foot (30 cm) per day and 33 to 99 feet (10-30 m) in a growing season [37,45].

SITE CHARACTERISTICS:
Kudzu is typically found in open, disturbed areas such as abandoned fields, roadsides, and forest edges [14,61]. Spread is most rapid in open areas, and is slowed as kudzu encounters the shade of a forest edge [44]. Kudzu monocultures typically contain thousands of individual plants per acre [33].

Kudzu is most prolific in areas where winters are mild (40 to 60 degrees Fahrenheit (4-16 °C)), summer temperatures rise above 80 degrees Fahrenheit (27 °C), the growing season is long, and annual precipitation is > 40 inches (1,000 mm) [51,66]. Kudzu thrives in areas that experience abundant sunny weather during the growing season. Growth rates up to 3 times greater have been demonstrated on sunny days, compared to overcast conditions. Photosynthesis is not inhibited by high temperatures until 86 to 95 degrees Fahrenheit (30-35 °C) [64].

Kudzu grows on a variety of soil types [51,66], but performs best on deep, well-drained, loamy soils [61]. Because kudzu is a nitrogen-fixing plant, it is likely to be competitive on nitrogen-deficient sites [33].

SUCCESSIONAL STATUS:
Kudzu is generally considered shade intolerant. A study at the University of Maryland showed that kudzu had the highest light requirement of 5 native and 3 exotic vine species of the Southeast, and establishment appears to be greatly inhibited under shaded, forest floor conditions [6]. While growth is slowed under shaded conditions, kudzu does have some ability to tolerate low irradiance levels [13,16]. This trait enables kudzu to maintain a competitively high leaf area index within a forest canopy, and to grow through several canopy layers before overtopping overstory trees [13].

Although kudzu is typically found in disturbed habitats, it can invade along edges of forested areas, enveloping, suppressing, and eventually killing mature trees. Kudzu monocultures can arrest successional development of native plant communities. Although kudzu has been established in North America for nearly a century, there are no published reports as of this writing (2002) that document long-term successional patterns in kudzu-dominated communities. Because kudzu spreads largely by asexual means in North America, populations are generally localized [44].

SEASONAL DEVELOPMENT:
Seasonal development varies with latitude and altitude. Leaf emergence occurs in late spring [13]. Shoot biomass and leaf area index peak near the end of June in the Georgia Piedmont. Stem elongation and leaf production are continuous throughout the growing season, but production varies with conditions [64]. Flowering occurs from late July through September, depending on location [13,14,37]. Seeds mature in fall [11,37,45]. Foliage is generally killed by the 1st fall frost, and plants are dormant until spring [66].

FIRE ECOLOGY

SPECIES: Pueraria montana var. lobata

FIRE ECOLOGY OR ADAPTATIONS:
Fire adaptations: Kudzu escapes fire damage by maintaining perennating root crowns beneath the soil surface [43]. Kudzu stems and foliage are likely to resist fire damage during the growing season because they typically maintain high water content. Even during drought when nearby plants may be susceptible to fire due to desiccation, kudzu's deep taproot allows the plant to maintain a relatively high water content [64,66].

Soil heating as a result of fire may promote seed germination by scarifying the seedcoat, allowing water to penetrate into the seed [33,39,55,56]. In addition, dry kudzu litter can provide substantial fuel for dormant-season surface fires, perhaps providing a positive feedback in promoting seed germination. More research is needed to help understand the role of fire in promoting kudzu seed germination and postfire seedling establishment.

Fire regimes:
Because kudzu tends to be more opportunistic than predictable in its occurrence, it is difficult to ascribe particular fire regimes to it. To the extent that abundant, moist, green kudzu foliage can inhibit fire, kudzu may alter historic fire regimes by lengthening fire return intervals. Conversely, substantial fuel loading from dense mats of kudzu litter may enhance dormant-season fire potential. Additionally, the presence of kudzu in forest canopies may provide ladder fuels that enhance the likelihood of crown fires, particularly in areas where frequent surface fires may otherwise maintain seral pine or oak dominants. As kudzu invades shrub and forest communities, increases in standing and ground-layer fuels from dead woody plants that have succumbed to invasion could also increase fire intensity and severity. These scenarios are speculative. However, if kudzu continues as an important presence on the landscape, more research is need to determine how kudzu affects the fire ecology of native communities and ecosystems.

The following table lists fire return intervals for communities or ecosystems throughout North America where kudzu may occur. This list is meant as a guideline to illustrate historic fire regimes and is not to be interpreted as a strict description of fire regimes for kudzu.

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
maple-beech-birch	*Acer-Fagus-Betula*	> 1000
silver maple-American elm	*A. saccharinum-Ulmus americana*	< 35 to 200
sugar maple	*A. saccharum*	> 1000
sugar maple-basswood	*A. saccharum-Tilia americana*	> 1000 [62]
bluestem prairie	*Andropogon gerardii* var. *gerardii-Schizachyrium scoparium*	< 10 [26,41]
bluestem-Sacahuista prairie	*A. littoralis-Spartina spartinae*	< 10 [41]
mangrove	*Avicennia nitida-Rhizophora mangle*	35-200 [40]

sugarberry-America elm-green ash	*Celtis laevigata-Ulmus americana-Fraxinus pennsylvanica*	< 35 to 200
Atlantic white-cedar	*Chamaecyparis thyoides*	35 to > 200 [62]
northern cordgrass prairie	*Distichlis spicata-Spartina* spp.	1-3 [41]
beech-sugar maple	*Fagus* spp.-*Acer saccharum*	> 1000
black ash	*Fraxinus nigra*	< 35 to 200
yellow-poplar	*Liriodendron tulipifera*	< 35 [62]
Everglades	*Mariscus jamaicensis*	< 10
melaleuca	*Melaleuca quinquenervia*	< 35 to 200 [40]
shortleaf pine	*Pinus echinata*	2-15
shortleaf pine-oak	*P. echinata-Quercus* spp.	< 10
slash pine	*P. elliottii*	3-8
slash pine-hardwood	*P. elliottii*-variable	< 35
sand pine	*P. elliottii* var. *elliottii*	25-45 [62]
South Florida slash pine	*P. elliottii* var. *densa*	1-5 [16,40]
longleaf-slash pine	*P. palustris-P. elliottii*	1-4 [40,62]
longleaf pine-scrub oak	*P. palustris-Quercus* spp.	6-10 [62]
pitch pine	*P. rigida*	6-25 [5,22]
pocosin	*P. serotina*	3-8
pond pine	*P. serotina*	3-8
eastern white pine	*P. strobus*	35-200
eastern white pine-eastern hemlock	*P. strobus-Tsuga canadensis*	35-200
eastern white pine-northern red oak-red maple	*P. strobus-Quercus rubra-Acer rubrum*	35-200
loblolly pine	*P. taeda*	3-8
loblolly-shortleaf pine	*P. taeda-P. echinata*	10 to < 35
Virginia pine	*P. virginiana*	10 to < 35
Virginia pine-oak	*P. virginiana-Quercus* spp.	10 to < 35
sycamore-sweetgum-American elm	*Platanus occidentalis-Liquidambar styraciflua-Ulmus americana*	< 35 to 200 [62]
eastern cottonwood	*Populus deltoides*	< 35 to 200 [41]
black cherry-sugar maple	*Prunus serotina-Acer saccharum*	> 1000
oak-hickory	*Quercus-Carya* spp.	< 35
northeastern oak-pine	*Quercus-Pinus* spp.	10 to < 35 [62]
oak-gum-cypress	*Quercus-Nyssa*-spp.-*Taxodium distichum*	35 to > 200 [40]
southeastern oak-pine	*Quercus-Pinus* spp.	< 10
white oak-black oak-northern red oak	*Q. alba-Q. velutina-Q. rubra*	< 35
bear oak	*Q. ilicifolia*	< 35 >
bur oak	*Q. macrocarpa*	< 10 [62]
oak savanna	*Q. macrocarpa/Andropogon gerardii-Schizachyrium scoparium*	2-14 [41,62]
chestnut oak	*Q. prinus*	3-8
northern red oak	*Q. rubra*	10 to < 35
post oak-blackjack oak	*Q. stellata-Q. marilandica*	< 10
black oak	*Q. velutina*	< 35

live oak	*Q. virginiana*	10 to< 100 [62]
cabbage palmetto-slash pine	*Sabal palmetto-Pinus elliottii*	< 10 [40,62]
Fayette prairie	*Schizachyrium scoparium-Buchloe dactyloides*	< 10
southern cordgrass prairie	*Spartina alterniflora*	1-3 [41]
baldcypress	*Taxodium distichum* var. *distichum*	100 to > 300
pondcypress	*T. distichum* var. *nutans*	< 35 [40]
eastern hemlock-yellow birch	*Tsuga canadensis-Betula alleghaniensis*	> 200 [62]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [9,62]

FIRE EFFECTS

SPECIES: Pueraria montana var. lobata

IMMEDIATE FIRE EFFECT ON PLANT:
Dormant-season fire top-kills live, overwintering, canopy-draped vines [43], and can also kill root crowns of small, newly established plants [33].

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
Green kudzu foliage probably does not burn well due to high water content. Growing season fire may top-kill kudzu foliage if enough combustible fuel is present to carry the burn [3]. Litter from vegetation that has recently succumbed to kudzu competition, especially persistent woody material, could provide substantial fuel. As of this writing (2002), there are no published descriptions of fire effects on kudzu.

PLANT RESPONSE TO FIRE:
Kudzu sprouts from the root crown after fire. It quickly reestablishes following dormant-season fire, in some cases returning to previous levels of dominance by the 2nd postfire growing season [43,44].

There is speculation that the heat pulse from a ground fire may promote kudzu seed germination by increasing seedcoat permeability [33,39,55,56]. Laboratory experiments have demonstrated that seed dormancy may be broken by exposure to high temperatures, which promotes seedcoat scarification and allows permeability to water [55,56]. Information on postfire kudzu seedling establishment is lacking.

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
Because kudzu sprouts rapidly and vigorously after fire, questions concerning susceptibility of foliage and stems to growing season fire may be largely moot. Conditions likely to promote a surface fire of sufficient severity to kill mature, well-developed root crowns, while theoretically possible, have not been documented as of this writing (2002).

FIRE MANAGEMENT CONSIDERATIONS:
Because fire may promote kudzu seed germination, managers should be aware of the potential for emergence of new plants following burning [39]. Young kudzu plants are relatively easy to eradicate because they have not yet developed the extensive taproots of older plants. Miller [33] recommends burning after herbicide treatments to encourage germination of the kudzu seedbank, which can then be eliminated with a follow-up herbicide treatment. Burning as a follow-up to herbicide treatment can also bolster rapid recolonization of the site by native plants by removing litter and increasing light availability [61]. Dense kudzu litter remaining after herbicide treatments has been shown to inhibit germination of the residual native seedbank [43].

Burning may also be used to prepare sites for more efficient herbicide application, and to reveal size and density of root crowns previously hidden under dense litter [11,33]. Burning kudzu prior to other management activities can also reveal uneven terrain and other potential hazards previously hidden by dense mats of vegetation and litter [33].

MANAGEMENT CONSIDERATIONS

SPECIES: Pueraria montana var. lobata

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
Kudzu has potential value as livestock forage [7,65]; however, it is easily overbrowsed, and its utility may not be sustainable [66]. Moreover, while it has been previously cultivated for livestock use and grazing can be an effective control measure (see Biological Control section below), kudzu has been identified as an invasive pest plant throughout the South. It is not recommended for cultivation for any purposes [11,51,61].

Kudzu seeds are a favored food for northern bobwhite, comprising 61.4% of the January and February diet of birds studied on an abandoned agricultural site in the Georgia Piedmont [28].

Palatability/nutritional value: Kudzu has comparable nutritional value to alfalfa (*Medicago sativa*) and Bermuda grass (*Cynodon dactylon*) hays. The following table provides information on nutritional value of kudzu [7]:

Parameters	Leaf	Stem	Root
Crude protein (% of dry matter)	17.5	10.3	8.6
Neutral-detergent Fiber (% of dry matter)	48.1	73.7	39.8
Acid-detergent Fiber (% of dry matter)	38.2	44.0	53.3
Ash (% of dry matter)	8.3	7.9	4.3
Ca (% of dry matter)	0.7	0.1	0.4
Fe (mg kg^{-1})	162.3	156.6	3,600
K (% of dry matter)	1.0	1.0	0.3
Mg (% of dry matter)	0.3	<0.1	0.1

Cover value: No information

OTHER USES:
Kudzu has potential value as livestock feed [7,65].

IMPACTS AND CONTROL:
Impacts:
Kudzu invasion can have severe negative impacts on native plant communities. Because of its rapid growth rate and habit of growing over objects in its path, kudzu can outcompete native plants and quickly dominate habitats where it becomes established [61]. Kudzu infestations are typified by a continuous blanket of monospecific foliage resulting in large-scale alteration of biotic communities [51]. Patches larger than 100 acres (40 ha) now exist in some areas of the South [36]. Plant densities in mature stands may be 1-2 plants per square foot or tens of thousands of plants per acre [11].

Spreading kudzu infestations can eliminate forest cover by enveloping trees along margins of wooded areas. Trees of any size may succumb to competition from arboreal kudzu vines, whose prodigious foliage reduces light availability within the canopy. Infested trees, especially shade-intolerant species such as native pines, are weakened from reduced carbon fixation. Additionally, the accumulation of several years' worth of vines draped within tree crowns provides enough downward tension that even large trees can be pulled to the ground. Once kudzu has gained access to the forest canopy, it is capable of spreading more quickly and aggressively throughout a contiguously forested area during subsequent growing seasons [33]. Presence of Japanese honeysuckle and other arboreal vines can exacerbate kudzu invasiveness. Because kudzu climbs by twining, it can ascend and spread into a forest canopy faster and more extensively by utilizing smaller-diameter vines rather than having to twine around larger-diameter tree boles [33,35].

Kudzu has been characterized as "perhaps the largest nonwoody weed problem in forest management in the South" [36]. Kudzu infestation can be costly to commercial timber producers by severely impacting productivity. While eradication treatments can

be expensive, allowing kudzu to continue spreading only increases the acreage impacted and increases the difficulty (and expense) of eradicating older, denser, more intractable infestations [35].

Control: Because kudzu is so invasive, control is best equated with kudzu eradication [32,34]. To ensure complete eradication from a site and prevent reinvasion, every root crown must be killed [34]. Well-established stands may require as long as ten years to eradicate [61].

Kudzu eradication becomes increasingly difficult with increasing age of infestation [32,33,35]. Because kudzu develops large roots that store accumulated starch, older plants may be more resistant to control efforts and require more persistent or intensive management [33]. Vines that have spread vertically into tree canopies are thought to be more vigorous and to sequester starch reserves more rapidly and in greater quantity than prostrate-growing vines [11,33].

Weakening and eventual eradication of kudzu usually requires frequent defoliation by a single or several methods [11]. If managers are limited to a single defoliation treatment per year, it should be conducted in early fall (September in most areas). Kudzu allocates nearly all its resources to stem and foliar growth during the growing season, allocating few resources to root storage until near the end of the growing season. Kudzu recovers from defoliation by allocating root-stored resources to rapidly resume vigorous foliage growth. Defoliation activities conducted during the growing season can help deplete root energy stores and decrease plant vigor. However, fall defoliation is important to reduce resource allocation to roots, and hopefully gain substantial momentum toward eventual eradication [64].

For more information on kudzu control methods, see Mississippi State University Extension Service, Bugwood's Controlling Kudzu in CRP Stands, Controlling Kudzu in Western North Carolina, Southeast Exotic Pest Plant Council, Kudzu in Alabama, and the Virginia Natural Heritage Program websites.

Prevention: No information

Integrated management: No information

Physical/mechanical:
Physical or mechanical methods that destroy kudzu foliage can weaken the plant by simultaneously limiting photosynthesis and depleting root-stored energy reserves. For these methods to be effective, especially when used alone, managers should be prepared to apply them persistently and frequently, often for several years. For old, well-established stands, these methods are likely to be ineffective or require many years of intensive application. They are more likely to be effective when used in combination with herbicides.

The time required for eradication is a function of how long it takes to deplete root energy stores. Small, recently established patches (< 10 years old) can be eliminated by persistent weeding or mowing over a period of several (3-4) years [61]. Frequent mowing or cutting, ideally at 2-week intervals, weakens root crowns and inhibits photosynthesis [51]. Frequent mowing can be efficient and effective as long as all root crowns are in areas that are accessible [44].

Disking or cultivating infestations before and after chemical control efforts weakens plants and enhances herbicide effectiveness [33]. Cultivation may be inappropriate in natural areas or on steep or rocky terrain.

Individual plants may be hand pulled, but the entire root crown must be removed to prevent re-establishment [29]. Root systems of small, initial infestations can be excavated with a Pulaski or similar digging tool. All plant material should be removed from the site and destroyed by burning or bagging [51].

Fire: See Fire Management Considerations.

Biological:
Intensive grazing can be an effective control measure, where appropriate. Young infestations (< 25 years old) are easier to control with grazing than older stands that have developed very large roots. Steady aboveground herbivory will gradually deplete root energy reserves, inhibit accumulation of new carbon stores by suppressing the amount of photosynthetic tissue, and prevent foliage from spreading into previously uninfested areas. Grazing kudzu infestations for 1 to 2 years prior to herbicide application can help to weaken plants, potentially making chemical control efforts more effective [33,34].

Chemical:
Where appropriate, herbicides may be the most effective means of eradicating kudzu, whether used alone or in combination with other methods. Below is a list of herbicides that have been tested and judged effective for controlling kudzu in North America, as well as a brief discussion of important considerations regarding their use. This is not intended as an exhaustive review of chemical control methods. For more information regarding appropriate use of herbicides against invasive plant species in natural areas, see The Nature Conservancy's Weed Control Methods Handbook. For more information specific to

herbicide use against kudzu, see Kudzu Eradication and Management, Bugwood's Controlling Kudzu in CRP Stands, Southeast Exotic Pest Plant Council, or the Kudzu in Alabama website.

Chemical	Considerations
picloram [8,10,32,35]	Perhaps the most (overall) effective chemical tested against kudzu [32,35,48]. Specific to broadleaf species; generally does not harm grasses [58]. May be mobile in soil solution and can leach into nearby surface water [31,58].
clopyralid [29,48]	More selective than picloram. Has little effect on members of the mustard family (Brassicaceae) and several other groups of broad-leaf plants, as well as grasses and other monocots. Chemically similar to picloram. Has a shorter half-life, but is more water soluble and has lower soil adsorption capacity [58].
fluroxypyr [48]	
triclopyr [29,35,48]	Effective against arboreally established kudzu when applied to vines and foliage around the base of affected trees [35].
metsulfuron	
hexazinone [29]	
methyl 2- benzoate [10]	
tebuthiuron	
picloram + 2,4-D [32,35]	
glyphosate [51,61]	Nonselective. "Cut-stump" method may be used to reduce mortality of neighboring native plants. For details see Southeast Exotic Pest Plant Council. Low toxicity to animals and relatively immobile in soil. Glyphosate itself may be the least potentially harmful of the above chemicals to the environment, although many surfactants or other adjuvants in some formulations are toxic [58].

Single applications of herbicides can reduce kudzu foliage by up to 2 orders of magnitude. However, continued spot treatment is usually required for several years for complete eradication due to recalcitrant root crowns and substantial root-sequestered carbon reserves that enable kudzu to resprout. Diligent monitoring and follow-up treatments may be required for 10 or more years on some sites [33,42]. Regrowth from surviving root crowns may often be delayed until 2 years after herbicide treatment, with no signs of survival during the 1st growing season. Several years of post-treatment monitoring and retreatment may be needed to ensure 100% mortality [33,48].

In general, herbicides are most effective against kudzu when applied after late May [32], although triclopyr was effective against tree-draped vines when applied in spring prior to the appearance of new growth [35]. Herbicides such as those listed above are likely to be most effective when applied near the end of the growing season when plants are translocating stem and foliar nutrients to root systems for dormant season storage [61]. Dormant-season herbicide application appears to be ineffective in controlling kudzu [48].

Higher herbicide application rates may be required for effective control on clayey or rocky soils or when infestations are older than 10 years [30,33,35]. Kudzu populations growing in a prostrate form, compared with plants growing vertically, are thought to be less vigorous and may be controlled using lower application rates [33,48].

Cultural:
Planting grass in the fall following herbicide treatment has been recommended in order to stabilize soil and to provide competition against weakened kudzu plants and other weed species that may be present. Grasses are not injured by some herbicides that can kill kudzu (e.g., picloram or clopyralid) [33].

Planting competing vegetation that provides shade to treated sites, such as dense plantings of pine seedlings, can improve the effectiveness of repeated herbicide treatments [21], potentially reducing treatment duration.

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