Ashes (Oleaceae: *Fraxinus*) in Kentucky, including the three white ashes, with notes on plans for conservation in response to the Emerald Ash Borer. Julian Campbell, October 2011.

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Abstract. An account of the wild and cultivated ashes in Kentucky is presented, together with maps and notes on their distribution and ecology. Geographic patterns in ash distribution, including historical data, are summarized in relation to natural regions of the state, indicating a general association between ash abundance within forests and base-rich soils. The key for identification of taxa is based partly on Nesom's (2010) recent revision of *Fraxinus americana*, sensu lato, but with additional observations on vegetative characters. In herbaria, there is a decline in the percentage of flowering or fruiting collections identified as the three segregates of traditional *americana*: from the diploid *americana* (ca. 60% in Kentucky), to the reportedly tetraploid *smallii* (10-20%), to the hexaploid *biltmoreana* (1-5%). However, leaf samples analyzed by flow cytometry (in cooperation with R. Olsen, National Arboretum) indicate that typical *smallii* from Kentucky and elsewhere is hexaploid. In recent years, green ash and blue ash have produced more frequent seed than white ashes, in general, with large crops often at intervals of 2 years. Given the impending devastation from Emerald Ash Borer, a scheme is outlined for rapid collection of germplasm, including digging of seedlings. Such collection would allow organized sampling for analysis of genetic differences, for various experimental uses, and for some initial efforts to conserve diversity if EAB persists to reduce the new cohort of trees after the initial epidemic. Existing institutional plans are briefly reviewed.

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A paper (or chapter) with the above theme will be completed in 2012. The materials below will be used in this effort, and are being distributed at this time (EAB meeting in Wooster Ohio, 12-13 October 2011), in order to exchange with other interested people and foster collaboration.

Appendix A. Global key to sections of genus *Fraxinus.*
Developed mostly from Wallander (2008).
Appendix B. Global key to species of *Fraxinus* Section *Fraxinus*.
Appendix C. Key to taxa of *Fraxinus* in the Ohio Valley, native and cultivated.
Appendix D. Notes on taxa of *Fraxinus* in the Ohio Valley, with emphasis on Kentucky.
Including tables of characters, maps and recent data on ploidy level from some Kentucky collections.
Appendix E. Diagrams summarizing habitats for taxa of *Fraxinus* in east-central states.
Including gradients of xeric versus hydric conditions, mature mesic forest versus open land, base-rich versus strongly acid soils, and potential dynamic patterns within mesic-submesic woods on base-rich soils.
Bibliography.

Appendix A. Global key to sections of genus *Fraxinus*

This is adapted from Wallander (2008), with additional notes from Nesom (2010a-f) and the author's work at US.

1a. Inflorescence emerging with the leaves on current year's shoots from terminal buds; flowers with 4 free white petals or apetalous, always with calyx; hermaphrodites or androdioecious..... *Ornus* (15 species in Old World).

1b. Inflorescence emerging from lateral buds on previous year's shoot, before or at the same time as the leaves emerge from terminal buds; flowers with 2-4 united petals or apetalous, with or without calyx; hermaphrodites, polygamous or dioecious

2a. Stems quadrangular, with narrow wings on vigorous shoots; flowers mostly bisexual, with 2 united petals or without petals. *Dipetalae* (3 species in New World: *anomala*, *dipetala*, *quadrangulata*). [Note also similarity in some characters to *F. sogdiana* of central Asia, the most eastern segregate of the *angustifolia* complex; a coll. of *sogdiana* at US has long curling hairs at petiole bases, distinct petiolules, and bluish-blackish leaflets.]

2b. Stems terete or slightly quadrangular, without any wings; flowers uni- or bisexual, with 4 united petals or without petals

3a. Corolla with 4 united petals; trichomes on leaflet bases and rachises scaly-branched and reddish, in marked contrast to the more distal long white hairs under leaflets [?] .....One unplaced species, *F. cuspidata* (New World). [This is a highly variable but distinct species with dimorphic leaves, 1-9 leaflets; inclusion of the trichome character is tentative, based only on a coll. at US (*Palmer 30928*); see Nesom (2010d).]

3b. Corolla without petals; trichomes not as above, usually without two such distinct types on leaflet base and rachis versus general leaflet surface [?].

4a. Shrubs or small trees; leaf rachis winged; leaflets 1-9, mostly small, ca. 1-5 × 0.5-1.5 cm [?]; flowers with calyx; polygamous

5a. Few-flowered cymose panicles; samaras ca. 1.5-2.5 cm long .....*Pauciflorae* (5 species in New World: *dubia*, *goodingii*, *greggii*, *purpusii*, *rufescens*; not including *pauciflora*)

5b. Many-flowered dense cymose panicles (ca. 0.5-1.5 cm wide); samaras ca. 3-5 cm long .....*Sciadanthus* (2 species in Old World)

4b. Mostly large trees; leaf rachis not winged; leaflets 3-13, small or large, ca. 3-15 × 1-7 cm; flowers with or without calyx; polygamous or dioecious

6a. Flowers without calyx or with small and/or deciduous calyx, polygamous (or dioecious with rudimentary stamens in female flowers of mandshurica); seed cavity of samara [usually somewhat] flattened; terminal bud scales somewhat foliar [?]; leaflets usually 7-13, sessile or on petiolules up to 3-5 mm long, usually serrate .....*Fraxinus* (4 species in Old World, 1 in New)

6b. Flowers with calyx, strictly dioecious; seed cavity of samara terete; terminal bud scales more entire; leaflets usually 5-9, on petiolules ca. 3-15 mm long, usually serrulate to subentire.....*Melioides* (10 species in New World)

Appendix B. Global key to species of Section Fraxinus

This is adapted from Sargent (1922), Little (1952), Wei & Green (1996), Wallander (2008), Nesom (2010a-f) and miscellaneous other observations. Section Fraxinus has: no corolla; leaflets sessile or subsessile with petiolules up to ca. 3 mm (versus ca. 3-10 mm in Mel.); blades (2.5-)5-14(-20) × (1-)2-5 cm; panicles lax, 5-20 cm [see also Melioides].

1a. Calyx present (ca. 1.5 mm long) and persistent at base of fruit; samara 3-6 cm long, the wing contracted near summit of seed, much narrower to obscure along seed; petioles on flowering shoots abruptly swollen at base ("clasping the shoot"); buds reddish brown .....*F. platypoda* (sensu lato)
[Some authors have included *F. spaethiana* of Japan, but that has distinctively papillose lower leaf surfaces and may be recognized as a separate species, perhaps closer to sect. Melioides (Wallander 2008). Perhaps also this couplet should lead to *chiisanensis* of South Korea, but that taxon has flowers intermediate in morphology between *mandshurica* and *chinensis*, plus a terete seed cavity; also its chemistry suggests sect. Melioides, as reviewed by Wallender (2008). Other provisional notes: small calyx present on bisexual flowers, campanulate, ca. 1.5 mm long; no corolla; samara not twisted, the wing contracted near summit of seed; leaf bases lack tuft of hairs across rachis; branchlets puberulent or glabrous; fruit (?-) 4-6 × 0.7-1 cm; panicles 12-15 cm long; trees largely dioecious, but with a few bisexual flowers (polygamodioecious).]

1b. Calyx deciduous or absent; samara (2.5-)3-4(-4.5) cm long, the wing broadly decurrent to base of seed; petioles not abruptly swollen at base; buds reddish brown or black

2a. Twigs not notably swollen out at junction with petioles; leaf scars suborbicular; base of lower leaflet surface with tuft of dense rusty hairs along midrib, extending onto rachis; terminal bud pointed [?]

3a. Calyx usually formed (sometimes absent) but deciduous; samaras flat; twigs terete or nearly so; terminal buds separated by short internode above adjacent lateral buds; leaflets usually sessile, often sharply serrate; trees with frequent bisexual flowers as well as unisexual flowers.....*F. nigra*

3b. Calyx absent; samara twisted; branchlets nearly 4-angled; leaflets usually subsessile, serrulate; trees largely male or female (dioecious), but with a few bisexual flowers (polygamodioecious) that have rudimentary stamens .....*F. mandshurica*

2b. Twigs swollen out at junction with petioles (forming "raised platform"); leaf-scars more or less semicircular; base of lower leaflet surface without tuft of hairs extending onto rachis; terminal bud rounded [?]

4a. Terminal bud pale brown [and smaller?]; leaves often in whorls of 3 at summit of vigorous shoots; inflorescence racemose, ca. 5 cm long; trees usually with both male and bisexual flowers (androdioecious); samaras often twisted [at least in *sogdiana*?] .....*F. angustifolia* (sensu lato, including *oxyphylla*, *sogdiana* and other segregates)

4b. Terminal bud black [ca. 5-10 mm long]; leaves strictly opposite; inflorescence paniculate [as generally found in genus], ca. 10-20 cm long; trees usually just male or female (dioecious), sometimes with both male and female flowers, rarely if ever with bisexual flowers [?]; samaras flat ..... *F. excelsior*

Appendix C. Key to taxa of ash (*Fraxinus*) in the Ohio Valley, native and cultivated.

This is a work in progress (as keys often are but rarely admitted), with several tentative characters that need to be tested [usually provided with bracketed notes or question marks]. Feedback is sought from all interested people—perhaps consensus can eventually be reached. A much shorter, succinct version of this key will be developed after further testing.

1a. Twigs quadrangular, with sharp narrow wings on young vigorous twigs, but blunter on older or slow-growing twigs; leaf scars on distinct raised pedestals (confluent with stem angles, most evident on 1 year old twigs); young petiole bases (often also rachises and young twigs) partly covered with long repeatedly curling hairs; buds blackish but largely covered with light brownish to grayish granular glands and hairs, without broad glands; leaflets usually 7-11, declining in size from medial to terminal, drying to bluish- or blackish-green on both sides; flowers mostly bisexual, with calyx (without petals); all trees producing ovules and pollen; samaras wings decurrent with no narrowing to the base, obtuse at apex, length/width usually 4-4.5, usually not falling until the spring. .....Section *Dipetalae*: *F. quadrangulata*, the blue ash (native)

1b. Twigs terete or slightly quadrangular, without any wings; leaf scars on distinct pedestals or not; buds blackish or partly covered with broad (embedded or sessile cup-shaped) reddish-brown glands, without general covering of hairs; young petiole bases (also rachises and young twigs) glabrous, with short hairs or long curling hairs; leaflets usually 5-9 in native trees (7-13 in *nigra* and some cultivated trees), the terminal one sometimes as large or larger than adjacent pair, drying bluish-green, olive or brownish above, often paler to whitish below; flowers uni- or bisexual, with or without calyx (without petals); most trees producing pollen with virtually no ovules, or producing ovules with virtually no pollen; samaras with or without distinct narrowing at base, obtuse or acute at apex, length/width usually 5-7, usually falling during the autumn.

2a. Flowers without calyx or with small and/or deciduous calyx, polygamous (or virtually dioecious but with rudimentary stamens in female flowes); samaras with length/width usually 5-6, the wing decurrent to base, the seed cavity [usually somewhat] flattened; terminal buds usually acuminate, blackish and covered with few or no brownish glands; leaflets usually 7-13, the terminal one usually smaller than adjacent pair [?], sessile or on petiolules up to 3-5 mm long, usually serrate, largely glabrous except along midrib, the hairs long-curling and yellowish to brownish towards base, with or without whitish hairs distally, densely tufted at base, sometimes extending onto rachis; young twigs usually yellowish-green to yellowish- or grayish-brown when dried, sometimes slightly 4-angled..... Section *Fraxinus*

3a. Petiole bases strongly swollen (about doubled), about as thick as twigs; leaflets with glaucous waxy lower surfaces; samaras usually 40-60 × 7-10 mm; calyx present at least in bisexual flowers..... *F. platypoda* (sensu lato). [This largely Chinese taxon has been combined by some authors with the largely Japanese *F. spaethiana*, which has larger leaflets with smooth (versus densely hairy) petiole bases, and more pointed samaras. One or both taxa are reported in a few North American Arboreta, and may be expected rarely in cultivation or for research.]

3b. Petiole bases slightly swollen (about 50%), less thick than twigs; leaflets with distinctly glaucous waxy surface, samaras usually 25-45 × 5-9 mm; calyx present or absent in bisexual flowers.

4a. Leaf scars not on distinct pedestal (0-1 mm high), suborbicular (not consistent??); leaflets usually 5-20 × 2-5 cm; base of lower leaflet surface with tuft of dense rusty hairs along midrib, extending onto rachis.

5a. Calyx usually formed (sometimes absent) but deciduous; samaras flat; twigs terete or nearly so; terminal buds [blackish "corky-ridged" W] separated by 2-5 mm internode from adjacent lateral buds; trees with frequent bisexual flowers as well as unisexual flowers. ??young branches corky?? (Maryland Flora) ..... *F. nigra*, the black ash; native, but perhaps extinct in northern Kentucky

5b. Calyx absent; samara twisted; twigs nearly 4-angled; terminal buds not clearly separated from adjacent buds (internode < 2 mm); trees largely male or female, but with a few bisexual flowers that have rudimentary stamens ..... *F. mandshurica*, the Mandshurican ash (cultivated)

4b. Leaf-scars on distinct pedestals (the twig swollen out ca. 2 mm at junction with petiole), semicircular to suborbicular (??); leaflets usually 3-12 × 1.5-3 cm; base of lower leaflet surface without tuft of hairs extending onto rachis.

6a. Buds blackish but partly covered with brownish glands or hairs, terminal ones usually 3-5 mm long; leaves often in whorls of 3 at summit of vigorous shoots; inflorescence racemose, ca. 5 cm long; trees usually with both male and bisexual flowers (androdioecious); samaras often twisted (sogdiana)? ..... *F. angustifolia* (sensu lato, includes *oxycarpa*, *sogdiana*); to be expected in cultivation

6b. Buds deep black with little or no brownish glands or hairs (except at margins of scales), terminal ones usually 5-10 mm long; leaves strictly opposite; inflorescence paniculate [as generally found in genus], ca. 10-20 cm long; trees usually just male or female (dioecious), sometimes with both male and female flowers, rarely if ever with bisexual flowers (?); samaras flat ..... *F. excelsior*, the "English Ash" (but widespread in Europe); occasionally cultivated

2b. Flowers with calyx, strictly dioecious; samaras with length/width usually 6-7, distinctly narrowed with little or no wing at base, the seed cavity terete; terminal buds usually acute, often blackish but proximally (at least on more exposed scales) to completely covered with reddish-brown glands (of varied shade, sometimes orange, golden or purplish); leaflets usually 5-9, the terminal one usually as large or larger than adjacent pair (?), on petiolules 3-15 mm long, serrulate to subentire on flowering shoots, largely glabrous to densely hairy, the hairs whitish, short and straight to long and slightly curling but not in distinct tufts at base; young twigs usually pale olive-greenish to brownish or purplish when dried, terete.... Section *Melioides*

6a. Leaflets not distinctly bicolored, without white waxy minute papillose reticulation on lower surface, upper surface darker than lower but both usually deep green to (especially in herbaria) dull dark, brownish or reddish green, usually turning yellowish or orange-brown in fall (with minute pale yellowish-brown glands clearly evident, hairs if present slightly yellowish to reddish), sessile or petiolulate, with varied shape and serration, often relatively thin [?]; bud scars with little or no notch, almost parallel to surface of twig, often subopposite****; twigs not greenish or purplish in

second year, soon becoming corky in later years and often olive- to reddish-brown**** [?]; styles green [?]****; wing of samaras decurrent to ca. 20-100% below apex of body, gradually widened, usually acute at apex, the bodies (and mature seeds) greatly elongated, with l/w ca. 6-12 .....*F. pennsylvanica* (sensu lato)

7a. Leaflets mostly 7.5-11× 2.5-5 cm, usually with obtuse to acute bases; pubescence largely absent or widespread on fresh twigs and leaves; samaras mostly 25-50 (60) × 4-8 (11) mm, the wing decurrent to ca. 20-50% below apex of body, the bodies mostly 15-22 × 1-2 mm.

8a. Leaflets with petiolules only 0-2 mm, numbering mostly 5-7 (and generally smaller), usually with distinct serration (the teeth ca. 0.5-1 mm deep), usually glabrous over most surfaces; buds ca. 50-100% as wide as leaf scar; samaras mostly 25-37 mm long, with relatively broad blunt shape, often spathulate-oblanceolate, the wings with more prominent veins [and perhaps up to 11 mm wide]..... *F. campestris* Britt., the western green ash; including "Marshall's Seedless" (from Utah) and similar cultivars (native from Great Plains to Rocky Mountains but widely planted in eastern states); this taxon may also include *F. pennsylvanica* var. *austinii* Fern. with more hairy leaves and broad short samaras

8b. Leaflets with distinct petiolules 1-12 mm long, numbering mostly 7-9, usually entire to undulate or with weak serration (the teeth ca. 0-0.5 mm deep), glabrous or pubescent; buds ca. 30-50% as wide as leaf scars; samaras mostly 34-46 mm long, linear-lanceolate, the wings with obscure veins.

9a. Fresh twigs, rachises and lower leaflets surfaces largely glabrous, except along midrib on lower leaflet surfaces; leaflets often weakly serrated; samaras mostly 25-45 mm long ..... *F. lanceolata* (= *F. pennsylvanica* var. *subintegerrima*), the eastern green ash

9b. Fresh twigs, rachises and lower leaflets surfaces sparsely to densely pubescent; leaflets usually subentire; samaras mostly 40-50 mm long ..... *F. pennsylvanica* (var. *pen*.) the red ash

7b. Leaflets mostly 9-15 × 3.5-7 cm, usually rounded at base; pubescence usually dense on fresh twigs, petioles and rachises, often also on lower leaflet surfaces; samaras mostly 40-70 (75)× 6-11 (12) mm, the wing decurrent to ca. 50-100% below apex of body, the bodies mostly 18-30 × 3-4.5 mm.
..... *F. profunda* (= *F. pen*. var. *profunda*), the pumpkin ash

6b. Leaflets distinctly bicolored, with white waxy minute papillose reticulation covering lower surface, at least between veinlets [view with at least ×40; however, in shade leaves it appears that the waxy covering is generally less pronounced and often absent from veins]*, usually plain green to (especially in herbaria) olive or bluish above, usually turning golden yellow, pinkish, reddish or purplish in fall (with minute pale yellowish-brown glands somewhat obscured by wax, the hairs, if present, usually whitish), usually more rounded at base to distinct petiolules 3-15 mm long and apruptly acuminate at apex, entire to crenulate, firm to subcoriaceous; bud scars sometimes with deep notch, usually [?] angled out from surface of twig (20-30 ^{o} versus 10-20°) and strictly opposite****; twig surface in second

year greenish to purplish, with waxy exfoliation, bark remaining smooth for many years and strictly gray to black**** [?]; styles red to purple [?]****; wing of samara decurrent to ca. 10-30% below apex of body, usually blunt to retuse at apex, the bodies (and mature seeds) moderately elongated, with l/w ca. 4-5.5 ..... *F. americana* (sensu lato)

10a. Petiole bases deeply notched (ca. 30-50%) around buds, the margins sharp; twigs and petioles glabrous; lower leaflet surfaces with hairs usually restricted to midrib and proximal parts of primary veins but sometimes more widespread and occasionally dense**; leaflets usually plain yellowish-green above, often folded up in sun [?]; mature samaras mostly 25-32 × 3-5 mm***, the bodies mostly 6-11× 1.5-2.5 mm .....*F. americana* (sensu stricto), the northern white ash

10b. Petiole bases truncate to slightly notched (ca. 0-20%) around buds, the margins blunt; twigs and leaves virtually glabrous to densely whitish-pubescent, lower leaflet surfaces with hairs usually dense along veins, often widespread over lower leaflet surfaces, sometimes thin to glabrous**; leaflets usually somewhat bluish-green above, usually not folding up [?]; mature samaras mostly 33-54 × 5-8 mm***, the bodies mostly 10-15 × 2-4 mm.

11a. Fresh twigs, petioles and rachises usually glabrous, sometimes irregularly and thinly hairy especially in distal parts of rachis; samaras up to 44 mm long, mostly 5-7 mm wide. .....*F. smallii* (= *F. americana* var. *subcoriacea*), the southern white ash

11b. Fresh twigs, petioles and rachises usually covered with dense minute hairs, sometimes moderately dense to sparse but still uniform; samaras up to 54 mm long, mostly 6-8 mm wide ..... *F. biltmoreana* (= *F. americana* var. *biltmoreana*), the hairy white ash

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* The white waxy papillose reticulation can be a problematic character. It is generally not apparent in seedlings a few years old (Talor 1972). It may also be less developed in the shade, and it may be less apparent after hotter drying. Although hybrids between *pennsylvanica* group and *americana* group are apparently rare in the wild, they probably do exist; Taylor (1973) found one in her 3 year study. Hybrids have been produced artificially; see also J. Koch (pers. comm.). Some cultivars are suggestive of hybrid origin: “Rosehill” has clear white-wax reticulation between ultimate veinlets but the veinlets are relatively wide and remain bright green when dried; the cultivar “Cimarron” also deserves attention. Nesom (2010d) indicated that *F. pauciflora* has the papillose character, as in the *americana* group, but in collections of *pauciflora* seen so far this character is less clear than in americana. The work of Wallander (2008) and Nesom may still allow for potential reticulate evolution within the *caroliniana-pauciflora* complex, which appears to have diverged early in the radiation of section Melioides.

** Pubescence of lower leaf surfaces varies too much across ranges of whole species to be a reliable character by itself. But within Ky. typical americana is mostly smooth except on larger veins (rarely if ever with dense hairs across the surface), while smallii and biltmoreana usually have widespread hairs, often dense across the surface. Within typical americana, pubescence may be generally denser in states to the west and south of Ky. Within smallii, pubescence may be less in states to west (and perhaps south) of Ky.

*** Nesom (2010e) noted that unusually large samaras do occur in otherwise typical *americana*, especially from cooler Appalachian regions to New England (also west to Ohio and Indiana).
**** From Taylor (1972), based only on typical *americana* versus typical *pennsylvanica*; she found that bud-scar and twig characters were most distinctive in shoots growing at ca. 3-6 cm per year.

Table 1a. All potentially recognized species in *Fraxinus* Section *Melioides*.
This listing adopts a 'moderately splitting approach' in their taxonomy. These are arranged in approximate phylogeographic order. Taxa in shaded boxes are detailed in Table 1b. Hybridization between the white and green groups is not proven, but it has been suggested that *biltmoreana* and *pauciflora* are partly derived from hybrids between the groups, as reviewed by Nesom (2010e). See also Wallander (2008), whose suggested phylogeny did not show a clear separation between these groups. The names below are provisional in some cases, and note that: [1] *velutina* includes *papillosa* according to Nesom (2010f); [2] *albicans* includes *texensis*; [3] *latifolia* includes *oregonica*; [4] *lanceolata* includes *subintegerrima*; [5] *profunda* includes *tomentosa*; [6] *caroliniana* has often been defined to include *cubensis* and *pauciflora* (Nesom 2010d).

GROUPS OF ASHES	**POTENTIAL SPECIES WITH THEIR RANGES AND MAXIMUM HEIGHTS, ARRANGED FROM NORTHWESTERN TAXA (left) TO SOUTHEASTERN TAXA (right).**								
WHITE ASHES			***?papillosa*** [1] **Az., e Mexico** **12 m?**	***albicans*** [2] **Texas** **15 m**	***americana*** **e US, Can.** **30+ m**	***smallii*** **e-se US** **20+ m**	***biltmoreana*** **e-se US** **35 m**	***pauciflora*** [6] **Ga., Fla.** **12 m**	
GREEN (or RED) ASHES	***latifolia*** [3] **Wa. Or. Ca.** **24 m**	***coriacea*** **SW desert** **9 m**	***velutina*** [1] **SW canyons** **12 m**	***berlandieriana*** **Texas-e Mex.** **18 m**	***lanceolata*** [4] **c-eUS, Can.** **18 m**	***pennsylvanica*** **eUS, Canada** **25 m**	***profunda*** [5] **e-se US** **35+ m**	***caroliniana*** [6] **se US coast** **12 m**	***cubensis*** [6] **s Fla., Cuba** **10 m**
NEAR BASAL BRANCH			***uhdei*** **Mex.-Hond.** **12 m?**						

Table 1b. Summary of apparent differences between white ashes and green ashes native to Kentucky.
See Table 1a for broader phylogeographic context. See text for further notes (including reports of chromosome numbers) and taxonomic key (Appendix 1) for details of identification.

SUMMARY OF APPARENT DIFFERENCES BETWEEN WHITE ASHES AND GREEN ASHES OF THE OHIO VALLEY (with moderately 'splitting' taxonomy)			
TAXA OF GREEN ASHES VERSUS WHITE ASHES	**GENERALLY LESS HAIRY; relatively small leaflets; relatively small seeds; reportedly all diploids; less tolerant of seasonal droughts and full sun.**	**GENERALLY INTERMEDIATE OR MIXED CHARACTERS; reportedly diploids (most/all *pennsylvanica*), tetraploids or hexaploids (*smallii*); habitats tend to be intermediate.**	**GENERALLY MORE HAIRY; relatively large leaflets; relatively large seeds; reportedly all hexaploids; more tolerant of seasonal droughts and full sun.**
WHITE ASHES: Leaflets with white-waxy papillose lower surfaces, tend to have broader shape, often red-purplish in fall. Fruits with less decurrent wings. Habitats not hydric.	***F. americana* (in strict sense, excluding larger fruits)** **bud scars deeply notched (with sharp petiole edges)** **largely glabrous twigs and leaves; sometimes hairy across lower surfaces** **fruits ca. 25-32 × 3-5 mm**	***F. smallii* or similar (= *ame*. var. *subcoriacea*)** **bud scars un-notched/shallow (needs more assessment)** **leaflets hairy to glabrate; rachises and twigs usually not hairy (rarely thin/short hairs)** **fruits ca. 33-44 × 5-7 mm**	***F. biltmoreana* (= *ame*. var. *biltmoreana*)** **bud scars clearly un-notched (with blunt petiole edges)** **densely hairy twigs and leaves (or lower surfaces sometimes less dense)** **fruits ca. 33-54 × 6-8 mm**
GREEN ASHES: Leaflets not white-waxy papillose below, tend to be narrower, yellowish in fall. Fruits with more decurrent wings. Habitats usually somewhat hydric.	***F. lanceolata* (= *pen*. var. *subintegerrima*); typical of base-rich riparian zones** **bud scars un-notched** **largely glabrous leaves and twigs; uniform in stands** **fruits ca. 25-40 × 4-7 mm**	***F. pennsylvanica* (in strict sense); usually on subhydric sites, summer-dry** **bud scars un-notched** **leaves hairy, often twigs also; highly variable (Taylor 1972)** **fruits ca. 40-50 × 5-10 mm**	***F. profunda* (= *pen*. var. *profunda*); more winter-wet, but also summer-dry** **buds scars un-notched** **leaves hairy, usually twigs also but variable** **fruits ca. 40-70 × 6-11 mm**

Appendix D. Notes on taxa of *Fraxinus* in the Ohio Valley, with emphasis on Kentucky; including selected maps. Species are in the taxonomic order that is supported by phylogenetic keys above.

1. *F. quadrangulata* Michx.
This highly distinct species of ash (Wallender 2008) occurs on calcareous soils across east-central states, with some more or less disjunct sections in its range (Little 1971; USDA 2010). Its flowers are perfect, in contrast to other eastern species, which are largely dioecious. A blue dye was made from its bark in olden times, but no analysis of the chemistry has been published. Horses often nibble the bark in woodland pastures of the Bluegrass region, but generally refrain from complete consumption of the cambium. Initial experiments with the Emerald Ash Borer in Ohio have shown that *quadrangulata* may be the only eastern ash with some significant resistance to this pest (D. Herms, pers. comm.).

2. *F. nigra* Marsh.
Short (1828), Gray (1878-86) and others reported this northeastern tree from Ky. during 1770-1860 (Gleason 1952, Campbell 1989, Medley 1993). But only one coll. has been located, and it is not clear if this was from a wild or cultivated tree: J.S. Terrill, 7 Sep 1893, from "Lexington" in FAYE (KY). *F. nigra* still occurs within 5-50 miles of the state line in s. Ind., s. Ohio (where discovered recently by D. Boone on a seeping base of Indian Hill in Hamilton Co.), and w. Va (Deam 1940, Braun 1961, Little 1971, Harmon et al. 2006). Based on general ecological trends in the sequence of ash species along the xeric to mesic to hydric gradient [Fig. 3 and poster], one might expect the 'niche' for *nigra* to be available in Kentucky. An ordination of forest composition within the central Bluegrass showed that there is an unusual gap in ash distributions between *americana* and *pennsylvanica* (Campbell 1980; unpublished). This gap would be centered in damper swales and seeps of the region, where farming and especially grazing by livestock has generally devasted native vegetation. Several other plant species typically associated with *nigra* or associated fen-land further north have also disappeared from the region since settlement (e.g. *Anemone canadensis, Angelica atropurpurea, Caltha palustris, Hasteola suaveolens*).

F. nigra is closely related to, and sometimes confused with, the European *F. excelsior* L. (Wallender 2008), which is sometimes cultivated in northeastern states but rarely if ever escapes (Fernald 1950, Gleason & Cronquist 1991, Weakley 2010). Both species have short flattened samaras, no calyx, sessile leaflets and blackish buds. Leaflets of *excelsior* are less hairy at their bases (versus densely covered with rusty hairs at junctions with rachis); terminal buds are usually deeper black, more rounded and adjacent to the upper pair of lateral buds (versus distinctly separated); twigs are slightly 4-angled (versus terete), and petiole bases are raised (versus flush with twigs), leaving more or less semicircular scars (versus suborbicular). Both species are diploids (2n = 46), but hybrids have not been reported. The more closely related East Asian species, *F. mandschurica* Ruprecht, has also been planted in cooler regions of North America, including selected cultivars and hybrids with *nigra*.

3. *F. mandschurica* Rupr.
This northeast Asian species is cultivated at a few arboreta or for research in North America. The closest trees to Ky. may be associated with ongoing experiments in northern Ohio (D. Herms, pers. comm.).

4. *F. excelsior* L.

This European species is occasionally grown as an ornamental, including cultivars with unusually bright yellow twigs, which contrast sharply with the jet black buds. It is used locally as street tree in Cincinnatti (D. Boone, pers. comm.).

5. *F. pennsylvanica* Marsh. (sensu lato)
This can be defined as a largely diploid species (2n = 46) that ranges widely across eastern North America and into the Great Plains. Its leaves vary much in size, shape, serration, pubescence, and length of petiolules, but the taxonomic significance remains uncertain (Gleason & Cronquist 1991, Nesom 2010c). The following four taxa have often been combined under *pennsylvanica*, but some degree of recognition is warranted. The original species names are given here, pending a modern analysis of variation in the complex. The appropriate level of recognition—form/race, variety, or subspecies—remains uncertain, and the nomenclature deserves deeper investigation.

5a. *F. campestris* Britt. (? = *F. pennsylvanica* var. *austinii* Fern.)
This 'western green ash' includes the cultivar from Utah known as "Marshall's Seedless" and other cultivars. As confirmed by this author's recent review of collections from across North America, *campestris* is native from the Great Plains to the Rocky Mountains but also widely planted in eastern states. It may also be reasonable to include *F. pennsylvanica* var. *austinii* Fern., a largely mid-western tree which has hairier leaves and relatively broad short samaras (Fernald 1950). According to Britton (1908, North American Trees 799, fig. 726) the general range of campestris is: "Montana to Manitoba, Wyoming and Kansas." Gleason (1952) stated under *pennsylvanica*: "Plants with subsessile lateral leaflets; sometimes pubescent as in our first variety [var. *pennsylvanica*]; sometimes glabrous like the second, occur frequently to the w. of our range [ne US and adjacent Canada] and have been observed as far e. as Mich. and Ont. They have been described as *F. campestris* Britt., but probably scarcely deserve segregation." Fernald (1950) did not mention *campestris* but appears to have treated some trees that are at least transition to it under *F. pennsylvanica* var. *austinii* Fern.: "Banks of streams, Que., to Sask. and Mont., s. to N.S., N.E., Va., O., Ill. and Ia. Passing into... Var. *subintegerrima*..."

The origin of Marshall Seedless was noted by Santamour & McArdle (1983): "Cole Nurs. Co., Painesville, Ohio, Fall 1955 Trade List, p. 7—handsome, shapely tree with extremely dark green glossy foliage, entirely free of seed. Porter-Walton Co., Salt Lake City, Utah, Garden Book No. 46 (1946), p. 56, offered male green ash propagated from 'non-seed-bearing trees.' Some of this material was purchased by Marshall Nurs., Arlington, Nebraska, who, in several undated listings offered 'Seedless Ash.' Cole Nurs. Co. purchased plants from Marshall, and were the first to use the cultivar name. Because of its origin as 'trees' in Utah, this cultivar name may actually apply to several genotypes."

Cultivars from western states, especially Marshall's Seedless, have been widely planted in developed areas of eastern states within the past 50 years but tend to grow poorly in southeastern states (Stoutamire & McArdle 1983; Gilman & Watson 1993). Leaflets of trees like Marshall's Seedless clearly differ from *lanceolata* of east-central states in their shorter petiolules (0-2 mm versus 1-12 mm) and deeper serration (ca. 0.5-1 mm versus 0-0.5 mm); also, they tend to be fewer (mostly 5-7 versus 7-9), smaller and often broader in shape. Their occasional samaras tend to be shorter (mostly 2.6-3.7 cm versus 3.4-4.6 cm), broader/blunter (often spathulate-oblanceolate versus linear-lanceolate) and more prominently veined. Seedlings in urban areas sometimes appear partly derived from these planted trees. Marshall's Seedless can also be confused with species of section *Fraxinus*, which generally have subsessile leaflets.

5b. *F. lanceolata* Borkh. (= *F. pennsylvanica* var. *subintegerrima* Vahl.)
Trees mapped here with largely glabrous leaves and twigs are much more common than hairy ones in Ky., especially in riparian zones and associated sloughs. Open dots mapped here indicate colls. of the species, but with uncertain assignment to variety.

5c. *F. pennsylvanica* Marsh. (sensu stricto)
These relatively hairy plants extend less into the Great Plains than var. *subintegerrima*, and less onto the southeastern Coastal Plain (Fernald 1950, Steyermark 1963, Radford et al. 1964). Within Ky. they tend to occur on sites with more seasonal drying, including streamheads on limestone and drier terraces on sandy alluvium. Mapping here is somewhat provisional, pending more detailed assessment; pubescence may vary continuously (from glabrous to tomentose) is often overlooked in field and herbarium. Lower leaf surfaces are often pale due to hairs, causing misidentification as *americana*. Sargent (1922) noted that the wood is "light brown, with thick lighter brown sapwood streaked with yellow"(versus whitish in *americana*). Fernald (1950) noted: "inner face of outer bark of branches red or cinnamon-color when fresh." But Taylor (1972) considered *pennsylvanica* to lack reddish or purplish coloration in young twigs.

5d. *F. profunda* (Bush) Bush (= *F. pennsylvanica* var. *profunda* (Bush) Sudw.; *F. tomentosa* Michx. f.)
This hexaploid (2n = 138) is widely distributed over eastern states, but concentrated in more permanent wetlands and with a fragmented range similar to that of *Populus heterophylla* (Little 1971; USDA 2010). In addition to being locally frequent in swamps of the lower Ohio Valley, there are scattered populations on base-rich soils further upstream. *F. profunda* has often been confused with *pennsylvanica* or *americana* (sensu lato), but hybridization has not been demonstrated (Nesom 2010a). It has larger fruits (mostly 40-70 × 6-11 mm versus 20-45 × 4-8 mm), and larger leaflets (mostly 9-15 × 3.5-7 cm versus 7.5-11 × 2.5-5 cm), usually with more rounded bases and longer petiolules. Young twigs, rachises and leaflets are tomentose (versus glabrous to tomentose).

6. *F. americana* L. (sensu lato).
In its broad sense this widespread eastern tree species is highly variable, including a polyploid series, as reviewed by Wallander (2008), Nesom (2010b) and Weakley (2010). Nesom has revived division into three species: diploid *americana* (2n = 46), tetraploid *smallii* (92) and hexaploid *biltmoreana* (138). However, R. Olsen (National Arboretum) has shown that typical *smallii* is hexaploid, based on flow cytometry, and he has not yet located a tetraploid in this group. All three taxa differ from other eastern ashes in their minutely papillose-reticulated, waxy-whitened lower leaf surfaces.

6a. *F. americana* L. (sensu stricto)
This has a relatively northern range, being rare to absent on the southeastern Coastal Plain. It differs from the other two taxa in its generally smaller fruits (mostly 25-32 mm long versus 33-54 mm), deeply notched petiole bases usually wrapped around buds (versus shallow-notched to truncate, the sides no more than level with tops of buds), usually glabrous leaves except along major veins (at least in Ky.), and glabrous twigs (versus glabrous or hairy). Its leaves tend to be smaller, on average, with upper surfaces usually plain yellowish-green (versus bluish) and less glossy. Hybrids have been suspected between the *americana* group and the *pennsylvanica* group, but there is no conclusive evidence from wild populations. Nesom found virtually no indication of hybrids involving these two groups of taxa ('white' and 'greens/red'), based on examination of many herbarium colls. In Ky. confirmed records of *americana*, sensu stricto (mapped as solid symbols), are concentrated in the Bluegrass region and surrounding Knobs; some of the uncertain records mapped here (open dots) may be *smallii* instead. Typical *americana* appears to be much less frequent to virtually unknown in

western regions of Ky. and Tenn., except along larger valleys of the Cumberland Rv. and Tennessee Rv. (Nesom 2010b). Several colls. from central regions were confirmed as diploids by R. Olsen (National Arboretum, pers. comm.), using flow cytometry with leaf samples from the following counties: METC, GREE, TAYL, MARI, BOYL, MERC and JESS (JC, 21 Sep 2011, deposited at NA). Several cultivars of *americana* (sensu stricto) have been distributed, often with selection for deeper reddish or purple fall color. In some cases, cultivars have been misidentified as *pennsylvanica*, including "Cimmaron" (Dirr 1997, Jackson 2003).

6b. *F. smallii* Beadle (= *F. americana* var. *subcoriacea* Sargent)
Mapping here for Ky. is provisional; see also notes under *americana* and *biltmoreana*. *F. smallii* is reported to range widely across eastern states south of the Great Lakes and New England (Nesom 2010b). Compared to *biltmoreana*, it has largely glabrous twigs, petioles and rachises (versus sparsely to densely hairy); fruits are smaller, on average (up to 44 mm long versus 54 mm). In Ky. leaflets are usually pubescent below, relatively large and bluish (like *biltmoreana* but unlike *americana*), but there is much variation in these characters. Initial mapping here is based partly on Nesom's data (triangles), pending further study of variation in the *americana* group. Uncertain records (open dots) are based on colls. without fruits that generally match *smallii* based on leaves and twigs. F. smallii appears to be widespread in Ky., especially in southern regions, where it is more than twice as frequent as typical *americana*. However, fruiting or flowering specimens form a much smaller percentage of colls. (EKY, KY): ca. 10-20% versus 60% of *americana*. Some colls. from south-central regions were identified as hexaploids by R. Olsen (National Arboretum, pers. comm.), using flow cytometry with leaf samples from the following counties: METC, GREE, MARI and BOYL (JC, 21 Sep 2011, deposited at NA). *F. smallii* has been grown at the Arnold Arboretum since 1874, and Sargent (1919) noted under var. *subcoriacea*: "The trees of this variety have grown more rapidly and are handsomer than any of the other American ashes in the collection." However, there is no evidence that cultivars have been developed.

6c. *F. biltmoreana* Beadle (= *F. americana* var. *biltmoreana* (Beadle) J. Wright ex Fern.)
Mapping here is provisional; see notes under *americana* and *smallii*. *F. biltmoreana* occurs widely in eastern states south of the Great Lakes and New England, and may be most frequent on rocky soils in the Ohio Rv. watershed and in the Ridge-and-Valley region (Nesom 2010b). Fresh twigs, petioles and rachises are densely to sparsely hairy; lower leaflet surfaces are usually covered with dense hairs, but in a few colls. hairs are confined to midribs and primary veins. *F. biltmoreana* tends to occur more frequently on relatively dry sites. In Ky. it appears to be about as frequent as *smallii*, based on provisional examination of colls. at KY and EKY. However, flowering or fruiting specimens form only ca. 1-5% of the colls. in those herbaria; compare data noted under *smallii*. Some colls. from central regions were confirmed as hexaploids by R. Olsen (National Arboretum, pers. comm.), using flow cytometry with leaf samples from the following counties: METC, GREE, BOYL and JESS (JC, 21 Sep 2011, deposited at NA). The cultivar "Urbanite" was originally collected in 1966 from Danville, Illinois, and has been widely distributed (Jackson 2003), but under the species name *pennsylvanica*; see trees planted at the Shelby Arboretum (OARDC at Wooster). Probably from this cultivar, *biltmoreana* has been used locally as a street tree in New Albany, Franklin Co., Ohio (D. Boone, pers. comm.).

Figure 1. Distribution of native ashes in Kentucky, based on herbarium specimens and associated reports.
Most of the specimens have been located in herbaria of Kentucky (state universities and Berea College); others have been studied at GH, MO and US. These observed specimens get priority in the mapping below. Supplementary records come from the generally reliable reports of Braun (1942), Little (1971), Clark & Weckman (2008), and especially Nesom (2010e). Less reliable records come from Garman (1913) and other miscellaneous uncertain or unchecked specimen identifications. In the case of *smallii*, most of the data are based on an initial examination of specimens by the author; see notes in text.

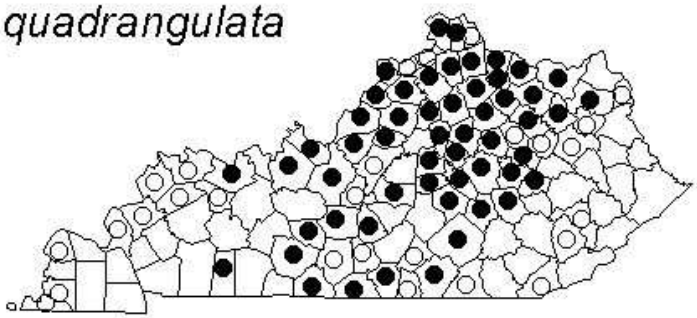
Native Fraxinus in Ky.

● herbarium specimens located

▲ reliable records from literature

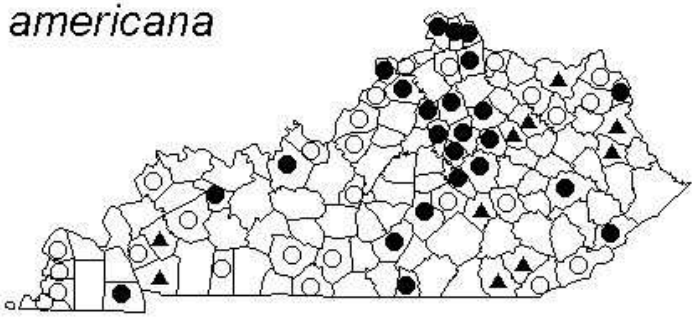
○ less reliable records (see text)

quadrangulata



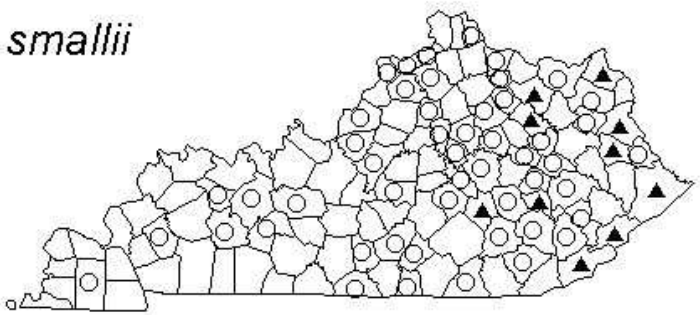
pennsylvanica var. subintegerrima

americana

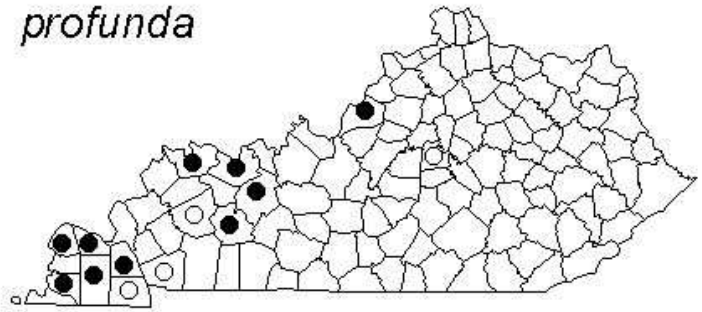


pennsylvanica var. pennsylvanica

smallii



profunda



biltmoreana

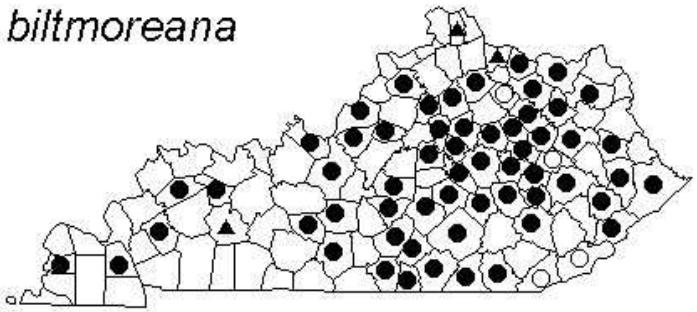


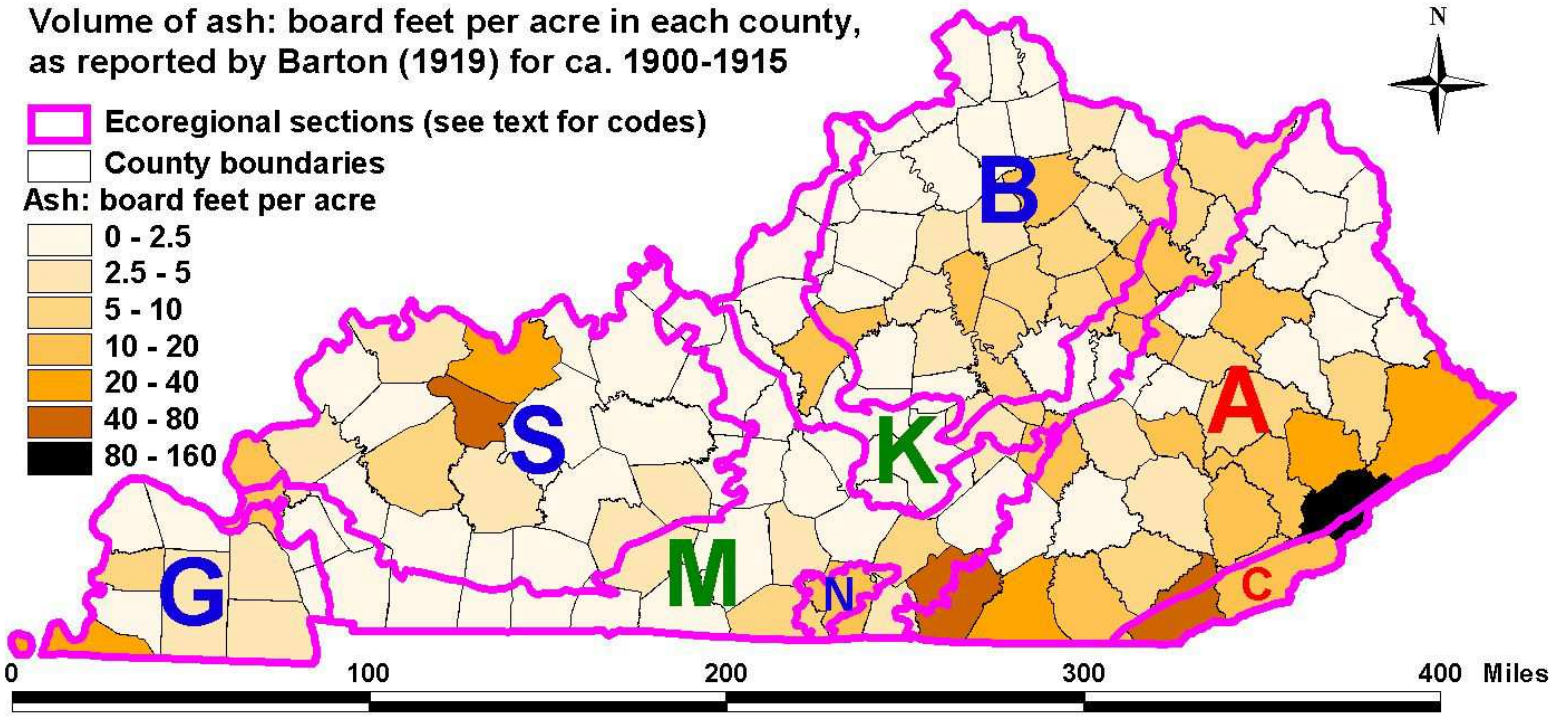
Figure 2. Distribution of ash abundance across counties of Kentucky: 1900-15 versus 2005-10.

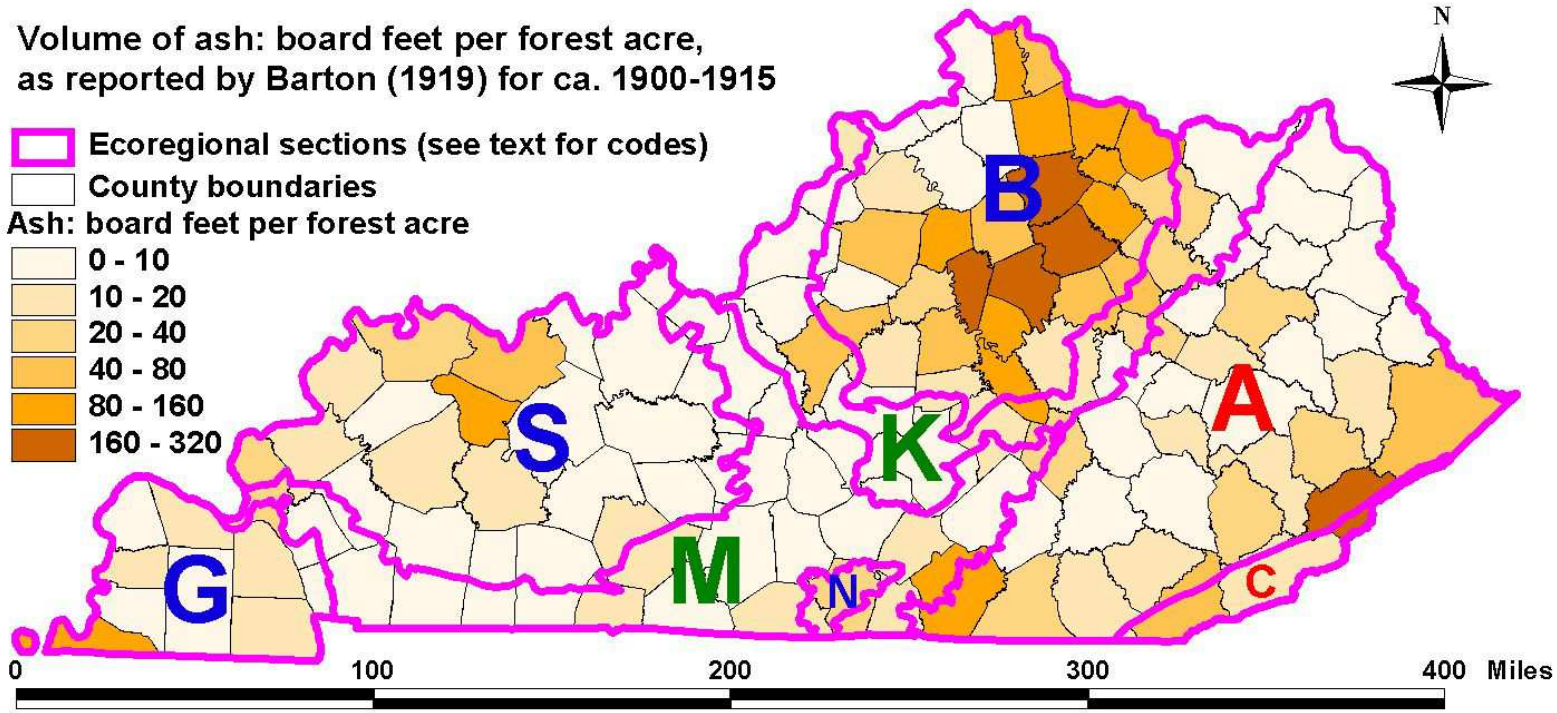
1900-15 data come from Barton (1919), who summarized information collected by government agencies before the war, with little description of sources and methods. These data refer to "merchantable timber" indicating approximate original composition of the forest before settlement. They were presented originally in units of "M" or "1000" board feet, but there is some uncertainty about them. Because McCreary Co. was not established at that time, its data are estimated here as means of the adjacent counties that contributed to its formation: Pulaski, Wayne and Whitley.

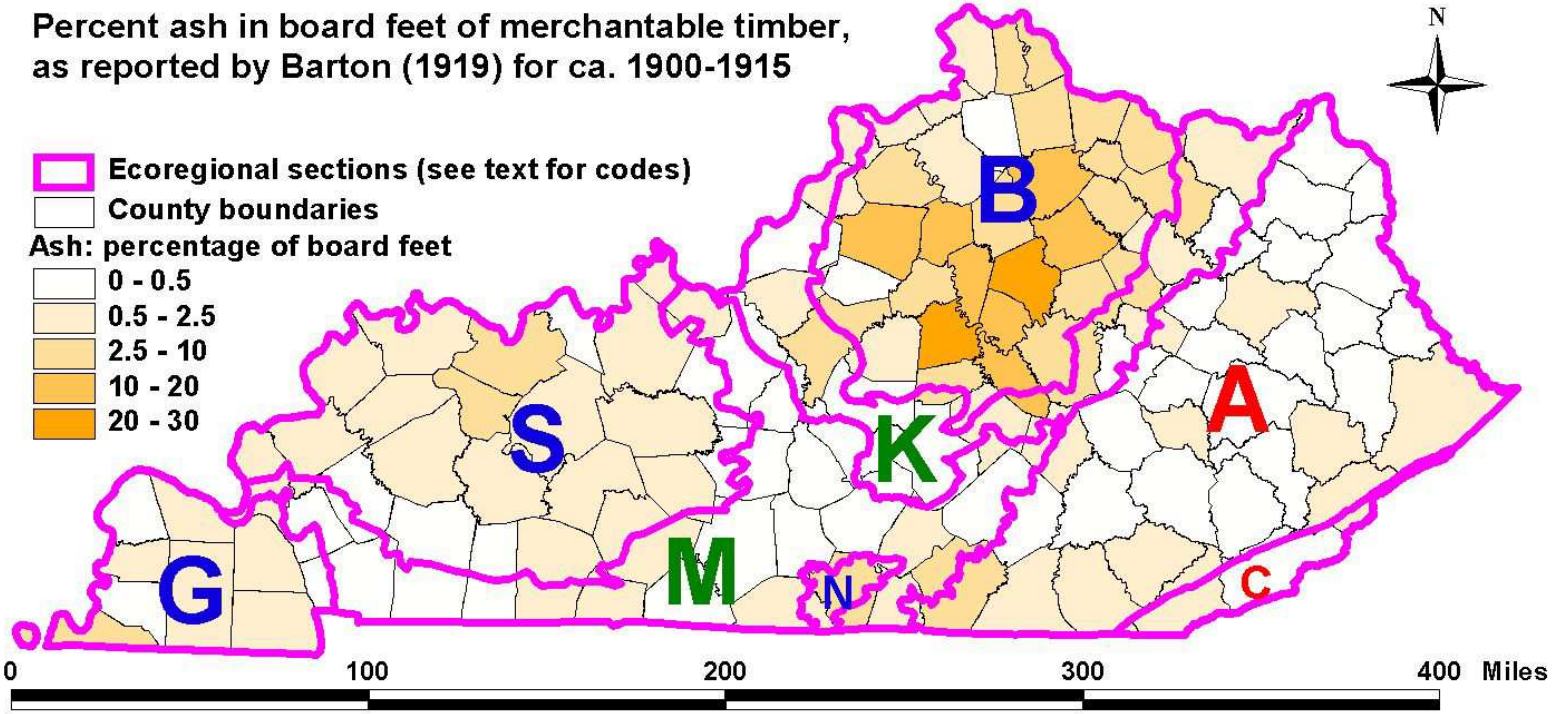
2005-2010 data come from the Forest Inventory Analysis of US Forest Service (using the EVALIDator tool at fia.....). Volumes in cubic feet comprise "all live stems" in all of the defined "forestland" with the full range of stocking. Cubic feet have been converted here to board feet by multiplying × 12.

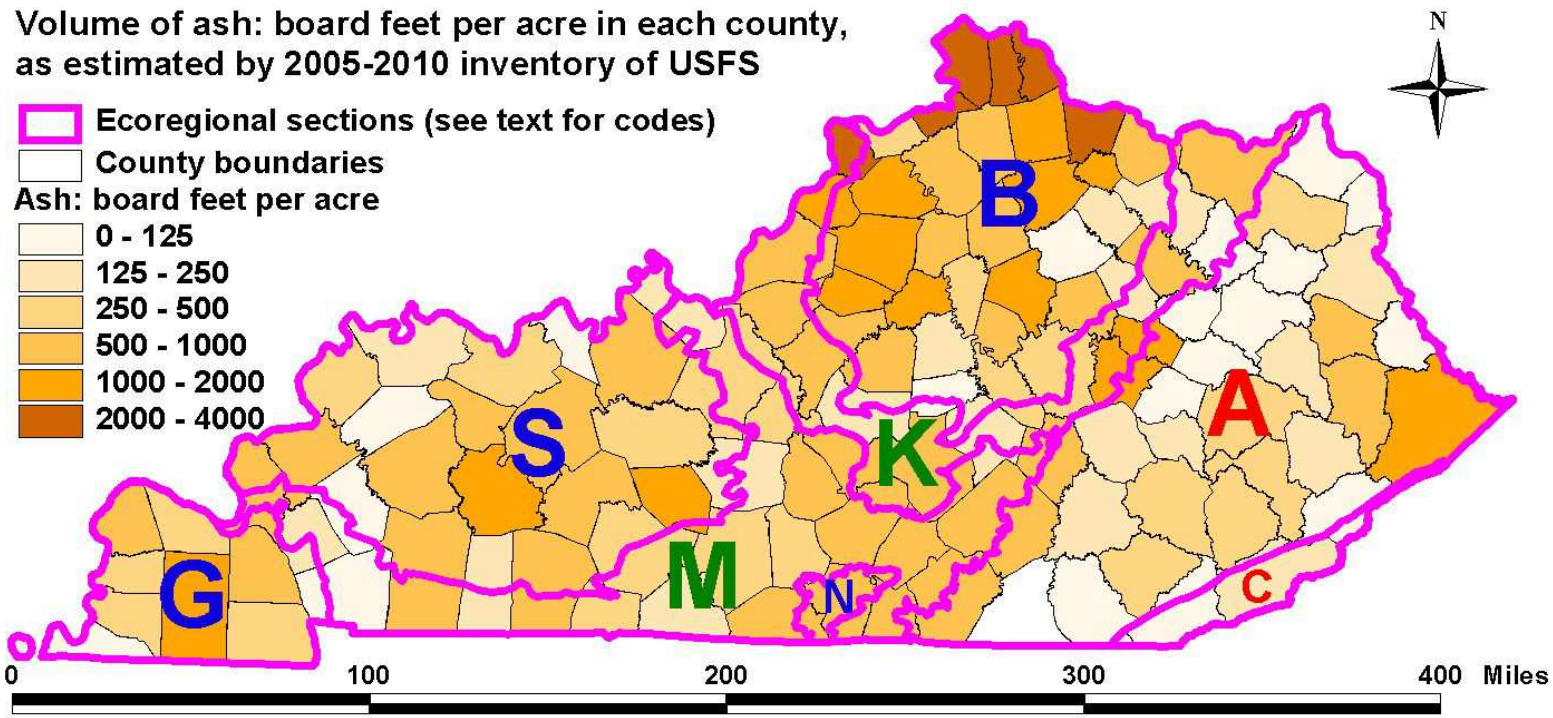
Note that units differ considerably between the two dates; the definition of "board feet" in 1900-1915 appears to have been increased by a factor of × 10 to × 100 from the modern standard—Were cubic feet implied then?—Or did "M" imply one million in some cases? In Appalachian counties at least, much of Barton's information was derived from Holmes & Bradfield (1907), who noted "an average stand of less than 4 M. feet B.M., per acre. A large proportion of the whole area will average less than 1 M. feet B.M. per acre... The virgin forest varies from 7 M. to 10 M. feet per acre, or even more, so it will be seen that throughout the region over half of the timber has been taken off from what is now forest land."

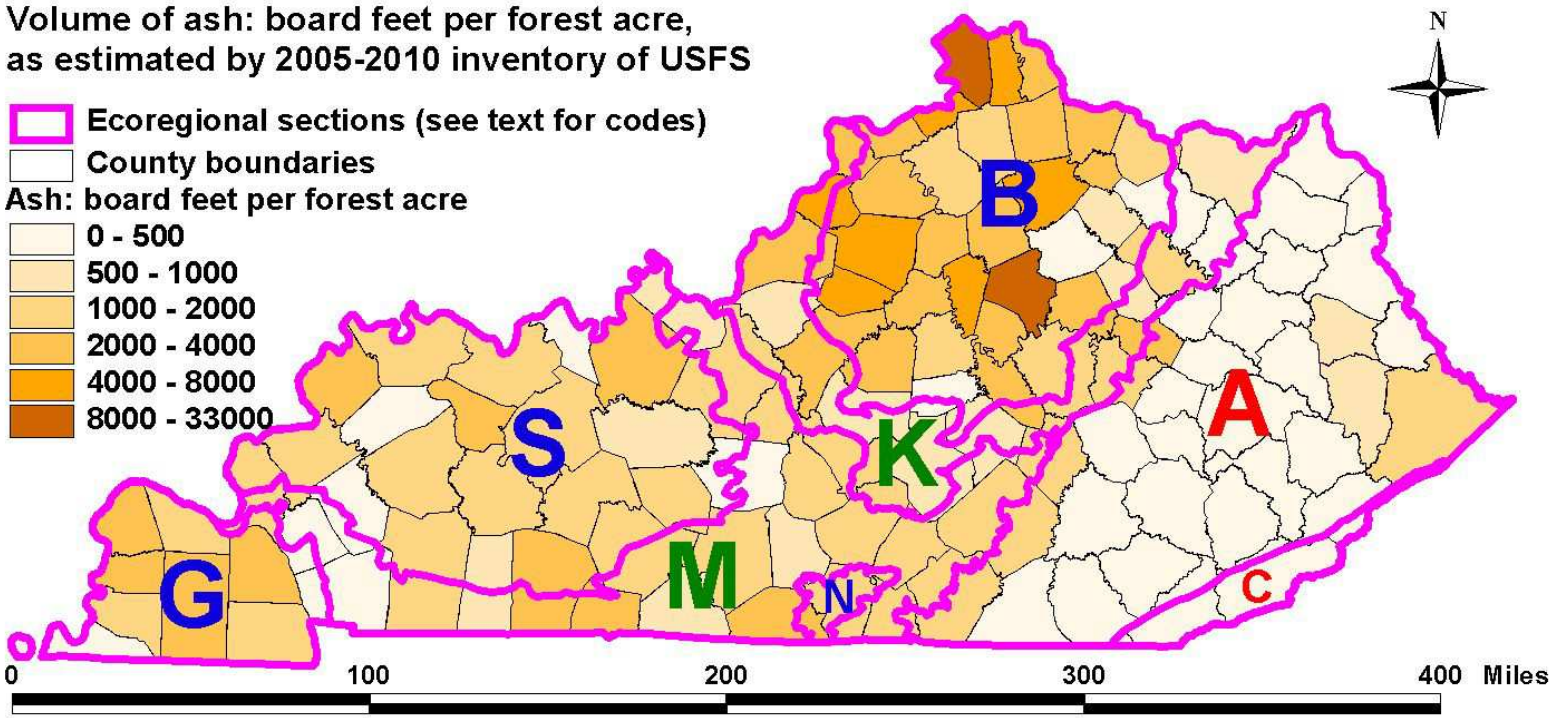
a. Volume per total acre in each county (political boundary).
b. Volume per forest acre in each county; see notes above.
c. Percentage of ash in total volume.
d. Ratio of (ash + elm) versus (hickory + chestnut); see text for discussion

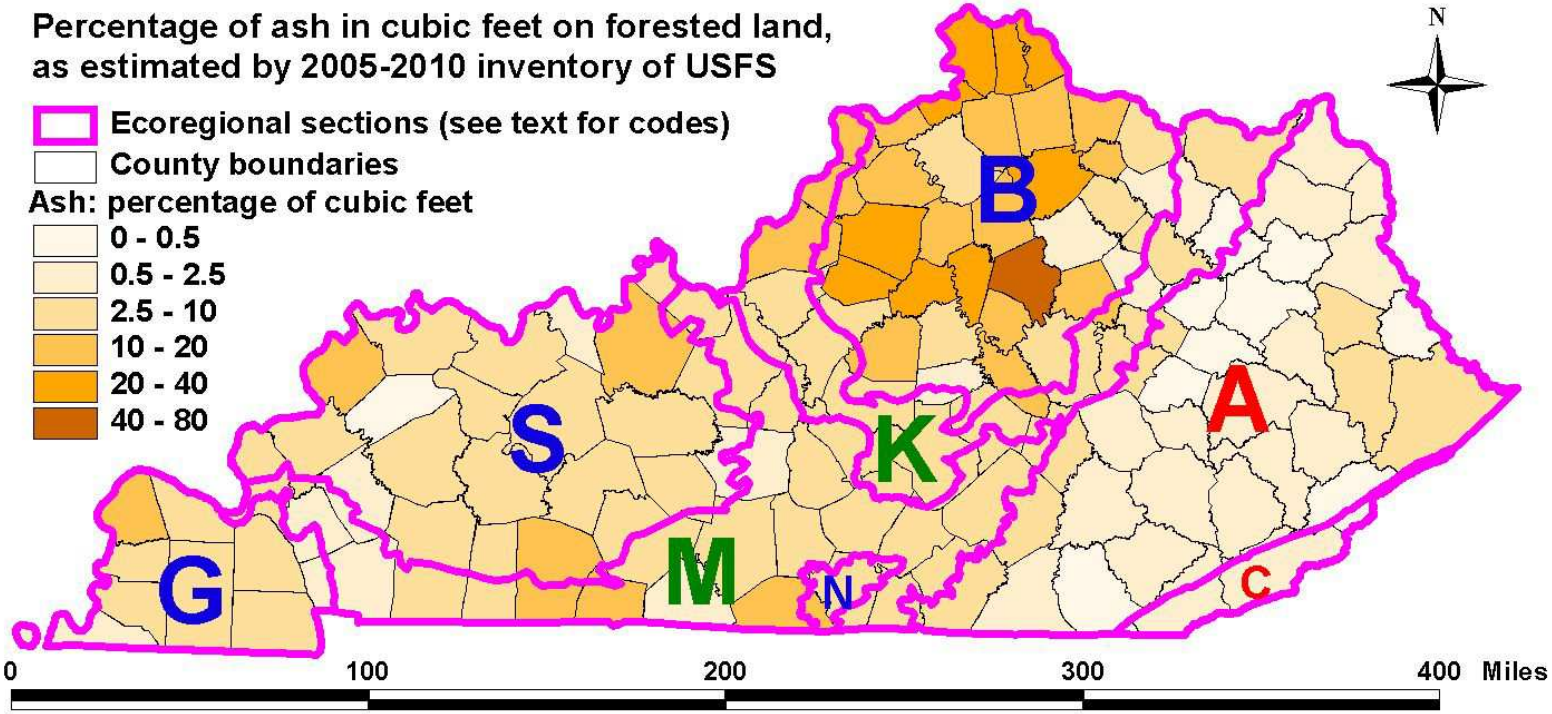

Volume of ash: board feet per acre in each county,
as reported by Barton (1919) for ca. 1900-1915
Ecoregional sections (see text for codes)
County boundaries
Ash: board feet per acre
0 - 2.5
2.5 - 5
5 - 10
10 - 20
20 - 40
40 - 80
80 - 160
N
B
S
K
A
G
M
N
C
0
100
200
300
400 Miles


Volume of ash: board feet per forest acre,
as reported by Barton (1919) for ca. 1900-1915
Ecoregional sections (see text for codes)
County boundaries
Ash: board feet per forest acre
0 - 10
10 - 20
20 - 40
40 - 80
80 - 160
160 - 320
N
B
S
K
A
G
M
N
C
0
100
200
300
400 Miles


Percent ash in board feet of merchantable timber,
as reported by Barton (1919) for ca. 1900-1915
Ecoregional sections (see text for codes)
County boundaries
Ash: percentage of board feet
0 - 0.5
0.5 - 2.5
2.5 - 10
10 - 20
20 - 30
N
B
S
K
A
G
M
N
C
0
100
200
300
400
Miles


Volume of ash: board feet per acre in each county,
as estimated by 2005-2010 inventory of USFS
Ecoregional sections (see text for codes)
County boundaries
Ash: board feet per acre
0 - 125
125 - 250
250 - 500
500 - 1000
1000 - 2000
2000 - 4000
N
B
A
S
K
M
N
G
C
0
100
200
300
400
Miles


Volume of ash: board feet per forest acre,
as estimated by 2005-2010 inventory of USFS
Ecoregional sections (see text for codes)
County boundaries
Ash: board feet per forest acre
0 - 500
500 - 1000
1000 - 2000
2000 - 4000
4000 - 8000
8000 - 33000
N
B
S
K
A
G
M
N
C
0
100
200
300
400 Miles


Percentage of ash in cubic feet on forested land,
as estimated by 2005-2010 inventory of USFS
Ecoregional sections (see text for codes)
County boundaries
Ash: percentage of cubic feet
0 - 0.5
0.5 - 2.5
2.5 - 10
10 - 20
20 - 40
40 - 80
N
B
A
S
K
M
G
N
C
0
100
200
300
400 Miles

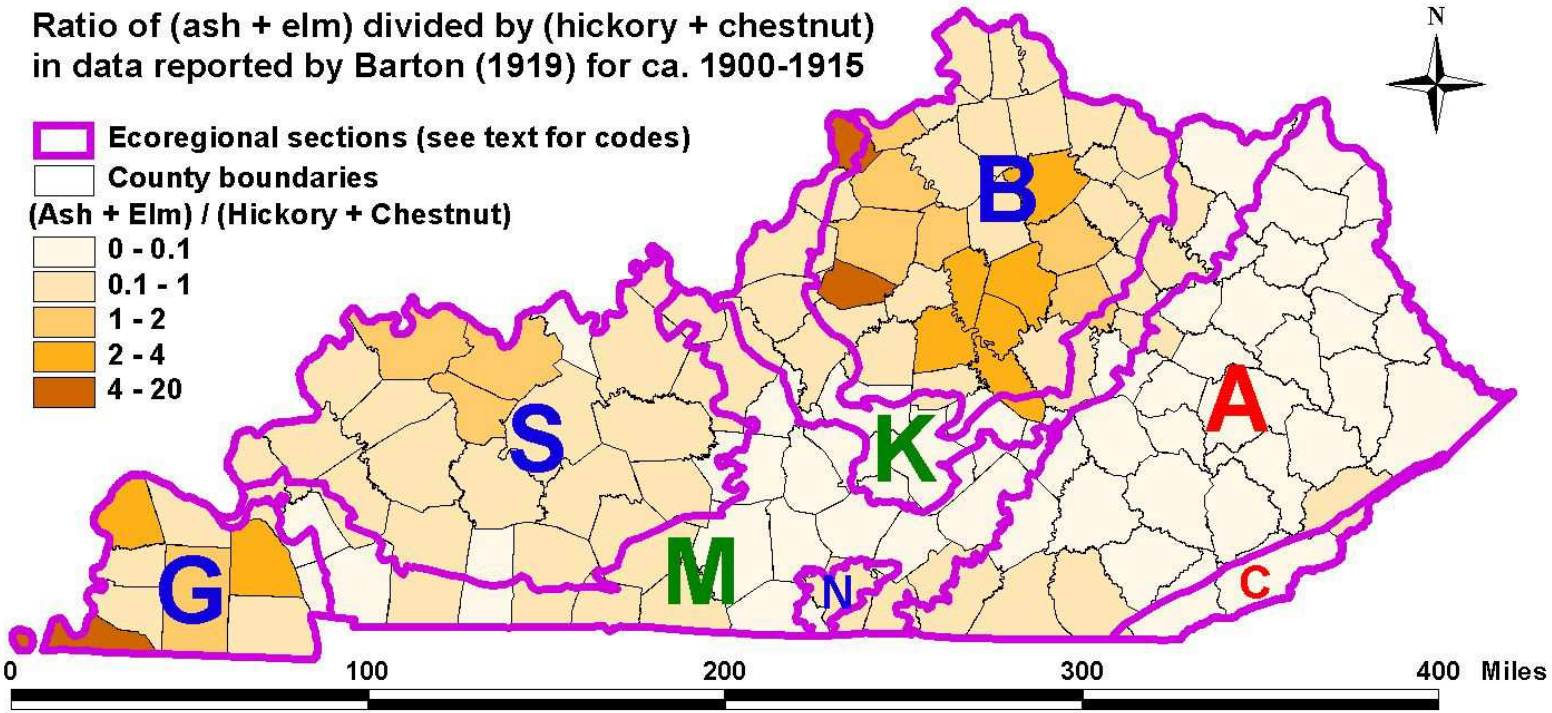
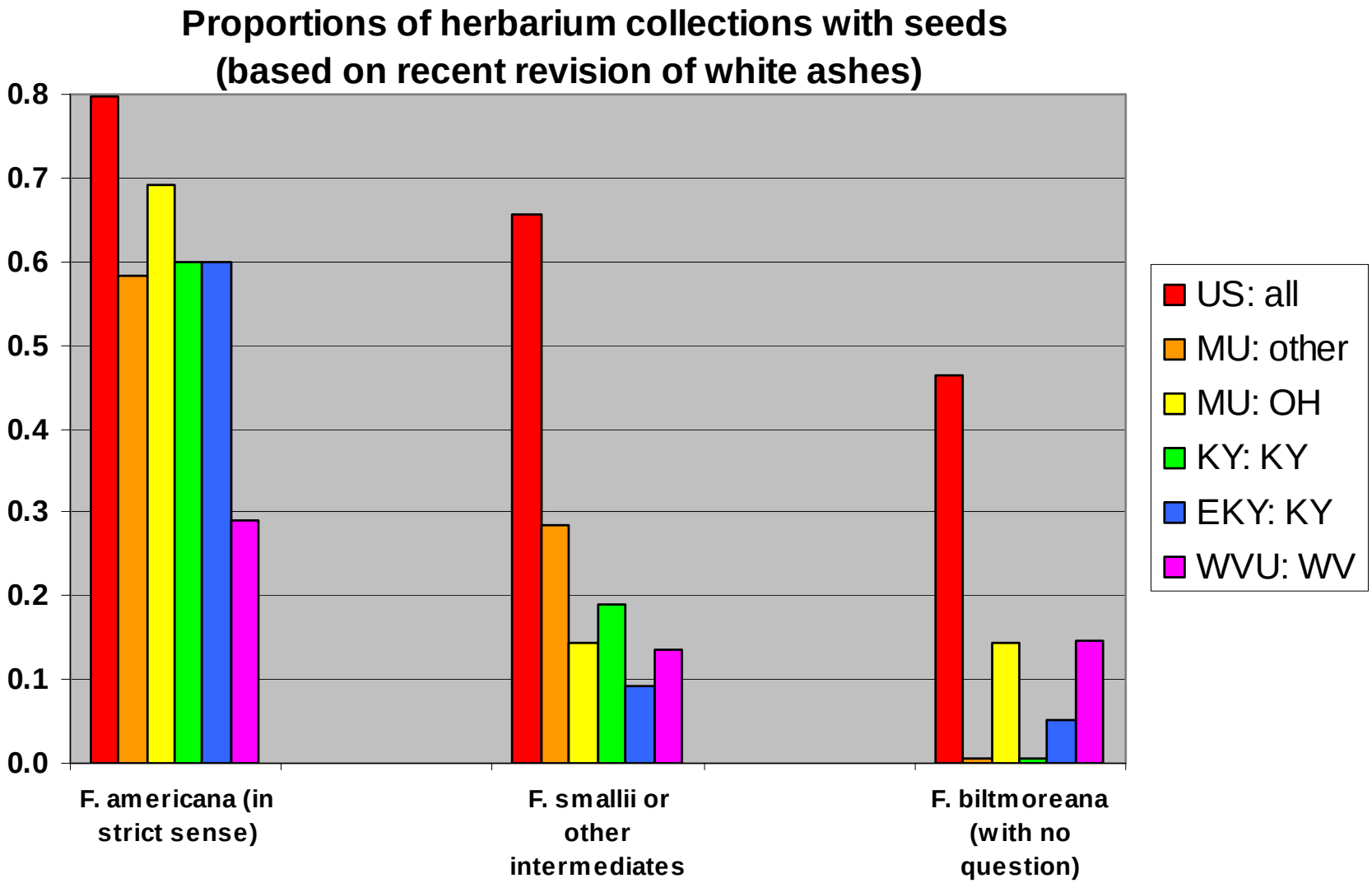

Ratio of (ash + elm) divided by (hickory + chestnut)
in data reported by Barton (1919) for ca. 1900-1915
Ecoregional sections (see text for codes)
County boundaries
(Ash + Elm) / (Hickory + Chestnut)
0 - 0.1
0.1 - 1
1 - 2
2 - 4
4 - 20
N
B
S
K
A
G
M
N
C
0
100
200
300
400 Miles

Figure 4. Proportions of herbarium collections that have seeds in white ashes.
These data are taken from a provisional sorting of collections at herbaria in Kentucky and elsewhere. The legend indicates herbarium source codes (see text), followed by states where collections come from. The '*smallii*' group probably includes some atypical collections of the other two.



Appendix E. Diagrams summarizing habitats for taxa of *Fraxinus* in east-central states.
Including gradients of xeric versus hydric conditions, mature mesic forest versus open land, base-rich versus strongly acid soils, and potential dynamic patterns within mesic-submesic woods on base-rich soils.

Fig. 3a. General relationship of habitat classes to hydrology in eastern to southeastern U.S.A.
Cliffs and other rocky openings occur on the upper side; aquatic openings occur on the lower side. Between these extremes, mesic forest occurs to the left; more open, stressed or disturbed vegetation mostly occurs to the right.

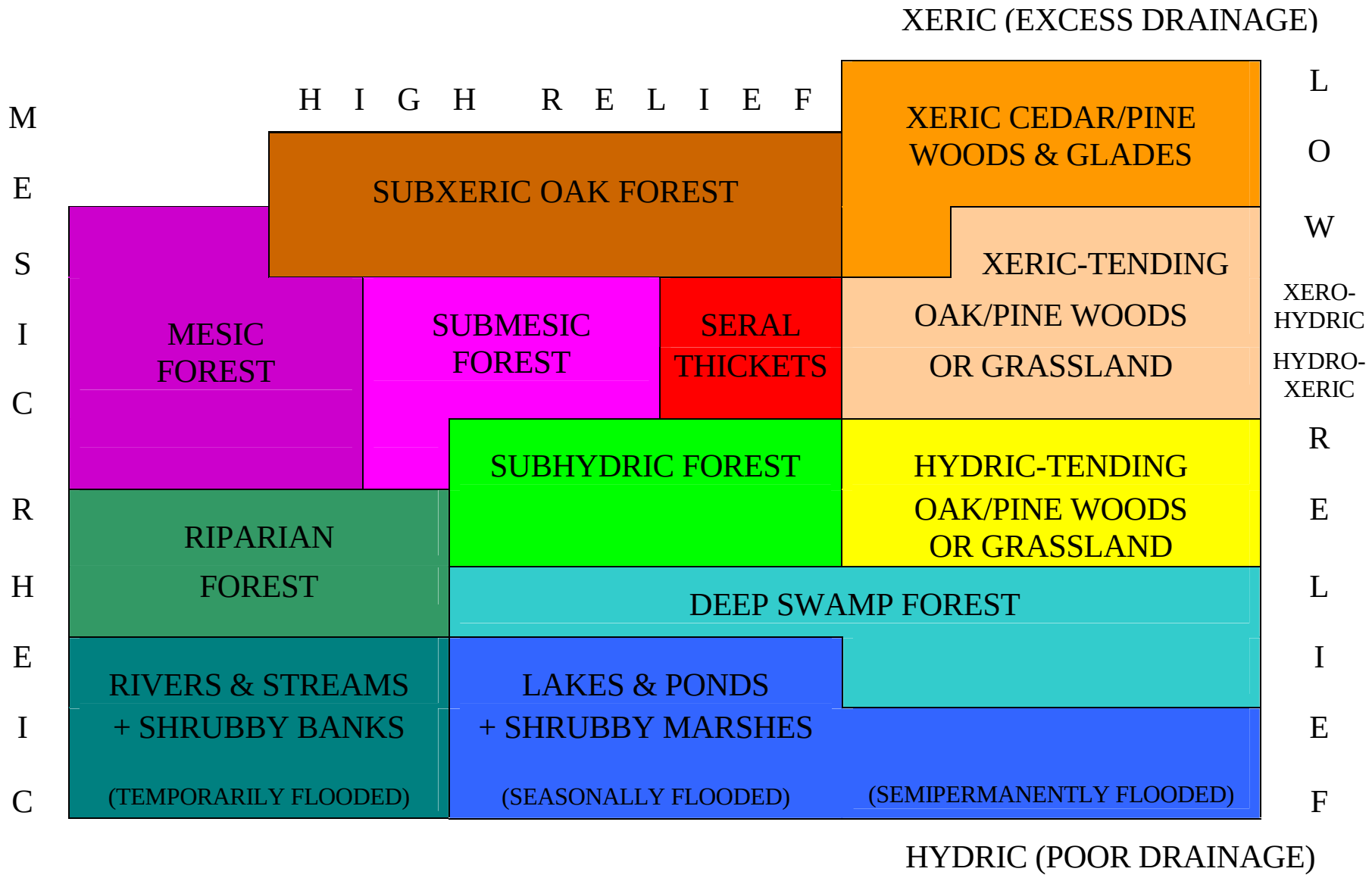


Fig 3b. Overlay of vegetation types (associations) characterized by ash in the National Vegetation Classification (NVC). The primary source for the NVC is NatureServe (2011); see Fig 1a for explanation of the general ecological gradients. Vegetation types are located within their broad ecological classes (boxes with bold outlines); positions within boxes are an approximation based on species composition. Four digit codes refer to "CEGL" numbers for the types in their original descriptions. All types are shown that have *Fraxinus* in their names and which occur in Kentucky or are likely to occur here. Types with underlined numbers have ash as codominant, with no more than two other tree species more common than ash. Bold numbers have ash as the leading leading dominant. The asterisked number (4436) refers to the anomalous 'blue ash-oak woodland' of the Bluegrass region; see notes in text (Braun 1950, Campbell 1989)..

XERIC (EXCESS DRAINAGE)

MESIC

THERMIC

HIGH RELIEF

LOW RELIEF

			6002 3938	4271 **7994**
	8518 4256	8549 2143		
7695 7711 8528	6201 6237 6211	6577 6186 7710	7281	**4436*** .
. .	**7913** 6901	**7806** **6634**	6630 **2427**	4422 .
			7719	8463
little ash		little ash		little ash

XERO-HYDRIC

HYDRO-XERIC

HYDRIC (POOR DRAINAGE)

Fig. 3c. Overlay showing typical position for woody species along ecological gradients in eastern to southeastern U.S.A.
Species codes are first three letter of genus name plus first three letter of species epithet.
Red letters = codes for species associated with strongly acid soils; green = medium acid; blue = circumneutral.

Dark grey background = generally continuous forest. Medium grey = more open woods, often mixed with shrub- or grassland.
Pale grey = zones often dominated by shrubby species: simplified and provisional (steep rocky slopes at upper left).

[a] BETSPP = *Betula lenta* to south; *B. allegheniensis* to north
[b] PINSPP = *Pinus taeda* to south; *P. strobus* to north.
[c] CELSPP = *Celtis laevigata* to south; *C. occidentalis* to north.
[d] QUESPP = *Quercus laurifolia* to south; *Q. palustris* to north.
[f] TILSPP = *Tilia caroliniana* to south; *T. heterophylla* in Appalachians; *T. americana* to north.
[e] ULMSPP = *Ulmus serotina* to south; *U. thomasii* to north.

Fig. 3d-i. Overlays showing typical associates for each species of *Fraxinus*. Shading indicates clusters of associates; darker shading indicates the most common associates. Ratios at lower right show numbers of species associated with base rich soils (1st): versus average soils (2nd): versus strongly acid soils (3rd).

These species are derived primarily from the descriptions of vegetation "associations" by NatureServe (2011); only those species listed as codominant, characteristic or common in the same vegetation as the ashes are shown here. In the case of *biltmoreana*, the information is more tentative, and based on general recent observations of the author, plus miscellaneous earlier reports, from Braun (1950) to Campbell (1980); *smallii* is not shown but appears to be centered between *americana* and *biltmoreana*. Separation of typical *pennsylvanica* versus var. *subintegerrima* (*F. lanceolata*) is also tentative, and based on general observations of the author rather than documented descriptions of vegetation.

					KALLAT ROBSPP RHUARO	PINVIR JUNVIR ULMALA	QUEILI CRNSPP CRNDRU	
	RHOSPP HYDSPP PHISPP	OXYARB CARGLA [e]ULMSPP	QUECOC QUEVEL FRAQUA	VACARB QUEFAL QUESCH	CASPUM CRYAME FRABIL	PINECH ROBPSE GYMDIO	PINRIG QUEMAR GLETRI	QUELAE PRUSPP
TSUCAR HALCAR CLAKEN	MAGSPP QUERUB AESFLA	CASDEN CAROVA ULMRUB	QUEMON QUEALB QUEMUH	CARPALL CARTOM CARCAR	ARASPI SASALB PRUSER	QUEPRI QUESTE QUEMAC	PINPAL CRASPP CRASPP	PINCLA JUNSIL
TSUCAN FAGGRA ACESAC	[a]BETSPP LIRTUL [f]TILSPP	MAGGRA ACERUB* CARCOR	ILEOPA NYSSYL FRAAME	[b]PINSPP JUGCIN JUGNIG	ILEVOM DIOVIR MACPOM	QUEHEM QUENIG ULMCRA	PINSER QUEPHE CRASPP	CYRRAC SABMIN
PLAOCC	BETNIG ACENEG	(FRANIG) ULMAME	QUEPAG QUESHU	PINGLA QUEMIC [c]CELSPP	ILEVER [d]QUESPP QUEBIC	PINELL QUELYR QUETEX	MAGVIR TAXASC GLEAQU	CLIMON SABPAL CHATHY
	ACESAN POPDEL	ACETRI CARILL	LIQSTY FRAPEN	ACEDRU PLAAQU	NYSBIF POPHET FRAPRO	TAXDIS FORACU	NYSAQU FRACAR	
	SALSER SALCAR SALERI	ALNSER SALNIG	CRNFOE	CEPOCC*	DECVER			

Fig. 3d. *Fraxinus quadrangulata*					RHUARO	JUNVIR ULMALA	CRNDRU	
	PHISPP	ULMTHO	FRAQUA	QUESCH	FRABIL	ROBPSE GYMDIO	GLETRI	
CLAKEN	QUERUB AESFLA	CAROVA ULMRUB	QUEMUH	CARCAR	PRUSER	QUEMAC	CRASPP	
ACESAC	TILAME	CARCOR	FRAAME	JUGNIG	MACPOM			
						base-rich ratio 24: 4: 0		

Fig. 3e. *Fraxinus biltmoreana*: tentative (probably includes some *smallii*)					RHUARO	JUNVIR ULMALA	CRNDRU	
		CARGLA ULMSER	QUEVEL FRAQUA	QUEFAL QUESCH	CRYAME FRABIL	ROBPSE GYMDIO	GLETRI	
	QUERUB AESFLA	CAROVA ULMRUB	QUEMON QUEALB QUEMUH	CARTOM CARCAR	SASALB PRUSER	QUESTE QUEMAC		
	LIRTUL TILSPP	ACERUB CARCOR	NYSSYL FRAAME					
						base-rich ratio 18: 15: 1		

Fig. 3f. *Fraxinus americana*: probably includes some *smallii* and *biltmoreana*					RHUARO	JUNVIR ULMALA		
		CARGLA ULMTHO	FRAQUA	QUESCH	FRABIL	ROBPSE GYMDIO	GLETRI	
CLAKEN	QUERUB AESFLA	CAROVA ULMRUB	QUEMON QUEALB QUEMUH	CARCAR	PRUSER	QUEMAC	CRAMOL	
FAGGRA ACESAC	LIRTUL TILAME	ACERUB CARCOR	FRAAME	JUGCIN JUGNIG	MACPOM			
		(FRANIG) ULMAME	QUESHU	CELOCC				
						base-rich ratio 25: 10: 1		

Fig. 3g. *Fraxinus nigra*: excluding more northern associates								
		CAROVA ULMRUB						
TSUCAN	[a]BETSPP LIRTUL TILAME	ACERUB	NYSSYL FRAAME	PINSTR				
		(FRANIG) ULMAME	QUESHU?	CELOCC?	QUEPAL QUEBIC			
		ACETRI	FRAPEN					
						base-rich ratio 8: 7: 3		

Fig. 3h. *F. pennsylvanica*: typical (yellow, orange) and var. *subintegerrima* (greens)								
						QUEMAC		
	TILAME	ACERUB	FRAAME	JUGNIG	MACPOM	ULMCRA		
PLAOCC	BETNIG ACENEG	(FRANIG) ULMAME	QUEPAG QUESHU	QUEMIC CELSPP	QUEPAL QUEBIC	QUELYR QUETEX		
	ACESAN POPDEL	ACETRI CARILL	LIQSTY FRAPEN	ACEDRU PLAAQU	POPHET FRAPRO	TAXDIS FORACU	NYSAQU	
						base-rich ratio 18: 15: 0		

Fig. 3i. *Fraxinus profunda*: often confused with *biltmoreana* on drier sites								
			ILEOPA? NYSSYL?	PINTAE?				
		ULMAME			ILEVER QUEBIC	QUELYR QUETEX	MAGVIR GLEAQU	
		ACETRI	LIQSTY FRAPEN	ACEDRU PLAAQU	NYSBIF POPHET FRAPRO	TAXDIS FORACU		
		ALNSER	CRNFOE	CEPOCC		base-rich ratio 8: 9: 4		

Fig. 3j. *Fraxinus caroliniana*								
							CRAOPA	
		ULMAME					TAXASC	SABPAL
				ACEDRU PLAAQU	NYSBIF FRAPRO	TAXDIS FORACU	NYSAQU FRACAR	
				CEPOCC		base-rich ratio 6: 6: 1		

Table 2a. Approximate separation of mesic-submesic vegetation types and tree species on base-rich soils.
Two gradients are summarized here: mature versus young woods (left versus right), and unpalatable versus palatable species. Only vegetation typical of base-rich soils is included here, as indicated by local abundance of *Acer saccharum* (sensu lato), *Carya cordiformis* (or *illinoenensis*), *Carya ovata* (or *carolinae-septentrionalis*), *Celtis*, *Fraxinus*, *Juglans*, *Quercus muhlenbergii* (or *macrocarpa*), *Q. shumardii*, *Tilia*, *Ulmus*. Excluded is vegetation typical of subxeric-xeric, riparian and subhydric-hydric sites. Numbers are codes in the "CEGL" series of associations that are described by NatureServe (2011); aaaa (non-thorny) and bbbb (thorny) indicate unnamed thickets observed in Kentucky. All associations that occur in Kentucky or in adjacent regions are included here, with a somewhat diffuse boundary but not extending into more distinctive northern or southern floristic regions of eastern North America.

General separation of unpalatable versus palatable trees	**Mature shady woods**: mostly Acer saccharum (s.l.), Aesculus flava, Fagus, Tilia; local Fraxinus, Liriodendron, Q. rubra	**Submature woods:** mostly Quercus spp., Carya spp.; local Acer saccharum (s.l.), Fraxinus, Liriodendron, Ulmus, etc.		**Disturbed/stressed woods:** diverse mix of Quercus spp., Carya spp., Celtis, Fraxinus, Juglans, Liriodendron, Ulmus, etc.; little/no Acer saccharum		**Young thickets and open woods:** mostly Gleditsia, Juglans, Prunus serotina, Robinia pseudoacacia; local Fraxinus, Celtis+	
Predominance of unpalatable over palatable trees		7298 6301 7215 7240	7225 7233 7702	3903 7808 4793 4068	4064	bbbb	
Unpalatable trees tend to be more common	4072 7878 7695 2411	8488 5014 8518 6046	6173 2070 4411 4741	8549 6445 7699 8565	3876 4545	2098 4437 7879	bbbb
Palatable trees tend to be more common	5222 6211 6472 8412	6017 7698 6125 6577	5017 8487 4256 8442	2099 4122 7912 6186	7220 7334	7281 7279 4436	3835
Predominance of palatable over unpalatable trees	8528 7711	5038	7710	aaaa	aaaa	aaaa	

Table 2b-l. Overlays of tree species' occurrences on mesic-submesic vegetation types.
Types are arranged along disturbance-related gradients; see Table 2a for general explanation of the gradients. Numbers are codes for types of NatureServe (2011) that include the subject species as codominant, common or characteristic. Underlining of codes indicates that the species is among the most common three tree taxa; italicizing indicates that the species is only a minor or local associate. This display is a provisional effort to explore the gradients that can be used to test the dynamic theory of Vera (2000); see also Figure... [Poster]..

Fraxinus americana							
	7695		8518				
		6211	6577	4256	6186		
	8528	7711	5038	7710	aaaa	aaaa	

Ulmus and Celtis							
					8565		
					7912	7334	7281
		7711	5038		aaaa	aaaa	

Tilia americana (s.l.)							
	7695	7878	8488		*8565*		
	5222 6472	8412	7698				
	8528	7711		*7710*			

Acer saccharum (s.l.)				*7233*			
	4072 7695	2411	*8488* 6046	6173 4411 4741			
	5222 6472	6211 8412	6017 7698 6125 6577	*5017 8487* 4256 *8442*			
				7710			

Liriodendron, Liquidambar, Platanus				7702			
		2411					
	5222		6125		2099 4122 6186	7220 7334	
				7710			

Fagus grandifolia				*7702*			
	4072	2411	5014	6173			

Quercus: red oaks			7298 6301 7215 7240	7233	7808 4793 4068	4064	
	4072	7878	8488 5014 8518 6046	6173 2070	8549 6445 4699 8565	3876 4545	
			7698 6125	5017 8487 4256 8442	2099 4122 6186		

Quercus: white oaks			7215 7240	7225 7233 7702	3903 7808 4793 4068	4064	
			5014	2070	4699 8565	3876 4545	2098
				5017 8487 *8442*	2099		4436

Aesculus				7225 7702			
	7695				8565		4437
	5222 6472		7698				

Carya: bitternut & pecan					4793		
				4411	6445	Gymno-cladus Juglans	Gleditsia Robinia
					4122 7912	Prunus	Arundinari

Carya: pignuts, shagbarks			6301 7240	7225 7233 7702	3903 7808		
			4741 8518	8488	8549 8565		2098

Discussion—

Outline of scheme for collection of genetic material;

General review of plans for conservation of ashes in Kentucky

Acknowledgements

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