



United States Department of Agriculture
Animal and Plant Health Inspection Service

Pathway Assessment: *Geosmithia* sp. and *Pityophthorus juglandis* Blackman movement from the western into the eastern United States



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Executive Summary

We conducted this assessment at the request of the USDA APHIS PPQ Executive Team. Our objectives were to identify potential pathways for the movement of a newly recognized disease of walnut (*Juglans* spp.) and its known vector from the western states to the east; determine any other potential vectors; and identify the risk to the east.

The disease has been named thousand cankers disease (TCD). The causal agent is an unnamed *Geosmithia* sp. and the only known vector is the walnut twig beetle (WTB, *Pityophthorus juglandis* Blackman).

There are multiple walnut species in the west, including California walnut (*J. californica*), Hinds walnut (*J. hindsii*), Arizona walnut (*J. major*), black walnut (*J. nigra*), and English walnut (*J. regia*), each of which can serve as host for the WTB and *Geosmithia* sp. *Juglans californica*, *J. hindsii*, and *J. nigra* are highly susceptible to TCD. *Juglans regia* is susceptible to a lesser degree, and *J. major* (believed to be the original host for the beetle) appears to be quite tolerant. In the east, *J. nigra* and *J. regia* are the primary species considered at risk for infection.

We mapped the current known and suspected distribution of TCD. Confirmed populations are scattered throughout western states (Washington, Oregon, California, Idaho, Utah, and Colorado) and the disease is thought to be widespread. Cooperators from the impacted states believe that WTB and, by association, TCD, may be present wherever susceptible walnut species grow.

Our analysis focuses on TCD entry into the east via natural and human mediated pathways. The most likely pathway for movement is raw wood (logs, burls, stumps, firewood, wood packaging material (WPM)). Other potential pathways include nursery stock, scion wood for grafting, and natural spread. We used a geographic information system (GIS) based approach to characterize the movement of TCD east via these pathways. The approach rate of TCD into the eastern United States is likely to be low but consistent. Specifically, the beetle/pathogen complex is likely to enter the east gradually and in relatively low quantities with each entrance event, as follows:

- Movement of untreated walnut (logs, burls, stumps, firewood) across the country from the west into eastern states appears limited but it does occur and it is rarely documented. Low grade walnut may be utilized in WPM; if bark is attached this could be an important pathway. Raw wood is the most critical pathway.
- Campsites and sawmills in the Great Plains states may facilitate the eastern movement of TCD (Appendix I).
- To date there have been no reports of infected trees in walnut production nurseries; however, if nurseries do become infected, this could become an important pathway.
- Natural spread along riparian corridors is likely to occur.

We considered potential economic and environmental damage that could occur if the vector and pathogen were to become established in the eastern United States. *Juglans nigra* is a valuable timber and nut species in the east; production sectors that face negative impact include timber, furniture, nut and nursery stock. Exports could be affected. Homeowners may face the cost of tree removal. Additionally, because *J. nigra* is a hard mast producer, wildlife may be negatively impacted.

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I. Introduction

A newly recognized fungal canker disease of walnut (*Juglans* spp.) has been identified and may threaten the native range of black walnut (*Juglans nigra* L.) throughout the eastern United States. The causal agent for this disease is an unnamed fungus of the genus *Geosmithia*. The common name for the disease is ‘thousand cankers’ due to the coalescing cankers surrounding multiple beetle entry points on twigs, branches, and main stems. The only known vector is the walnut twig beetle (WTB, *Pityophthorus juglandis* Blackman), a bark beetle native to North America (Arizona, New Mexico, California, and certain areas of Mexico), but other vectors may exist. For example, an Asian ambrosia beetle (*Xyleborinus saxesenii* (Ratz.)) has been collected with WTB from *Geosmithia*-infected *J. nigra* in Colorado).

Thousand cankers disease (TCD) appears has now been found in association with walnut mortality in Washington, Oregon, California, Idaho, Utah, Colorado, and New Mexico (Figure 1) (Alston, 2008; Cranshaw and Tisserat, 2008; Jacobi, 2007; Murray, 2009; Pizzo, 2009a; PIO, 2009; Pscheidt, 2009a; Tisserat et al., 2009; UI, 2009). Susceptible hosts include black walnut (*J. nigra*) (Tisserat et al., 2009), Hinds walnut (*J. hindsii*), California walnut (*J. californica*), and, to a lesser degree, English walnut (*J. regia*) (Seybold et al., 2009).

Juglans nigra is highly valued economically and environmentally, and is highly susceptible to TCD (Tisserat et al., 2009). To date, the walnut twig beetle appears to be very aggressive on *J. nigra* and populations increase rapidly. Where disease is expressed in Colorado, an infested tree may contain tens of thousands of *Geosmithia*-carrying beetles (Cranshaw, 2008). The current eastern distribution range of TCD is the Front Range of Colorado, where the majority of urban black walnut trees have been killed. The native range of black walnut extends west into eastern Kansas and Nebraska. Movement of this insect/pathogen complex further east could threaten native black walnuts, causing environmental damage and negatively impacting black walnut timber, nut, and nursery production.

The disease is scattered throughout western states and reports of walnut mortality are occurring simultaneously in areas that are connected by major highways (Figure 1). This distribution along major commerce routes suggests that movement of thousand cankers disease and its vector may be human-assisted.

Our analysis focuses on TCD entry into the east via natural and human mediated pathways. Factors that could affect subsequent TCD establishment in the east include: 1) the volume of host material shipped east that is infested with WTB carrying the *Geosmithia* sp., 2) the volume of this material that is deposited near a host, 3) the processing time for infested host material from the west, 4) the successful infestation of host trees by WTB, and 5) the successful infection of host trees by the *Geosmithia* sp.

U.S. TCD Distribution

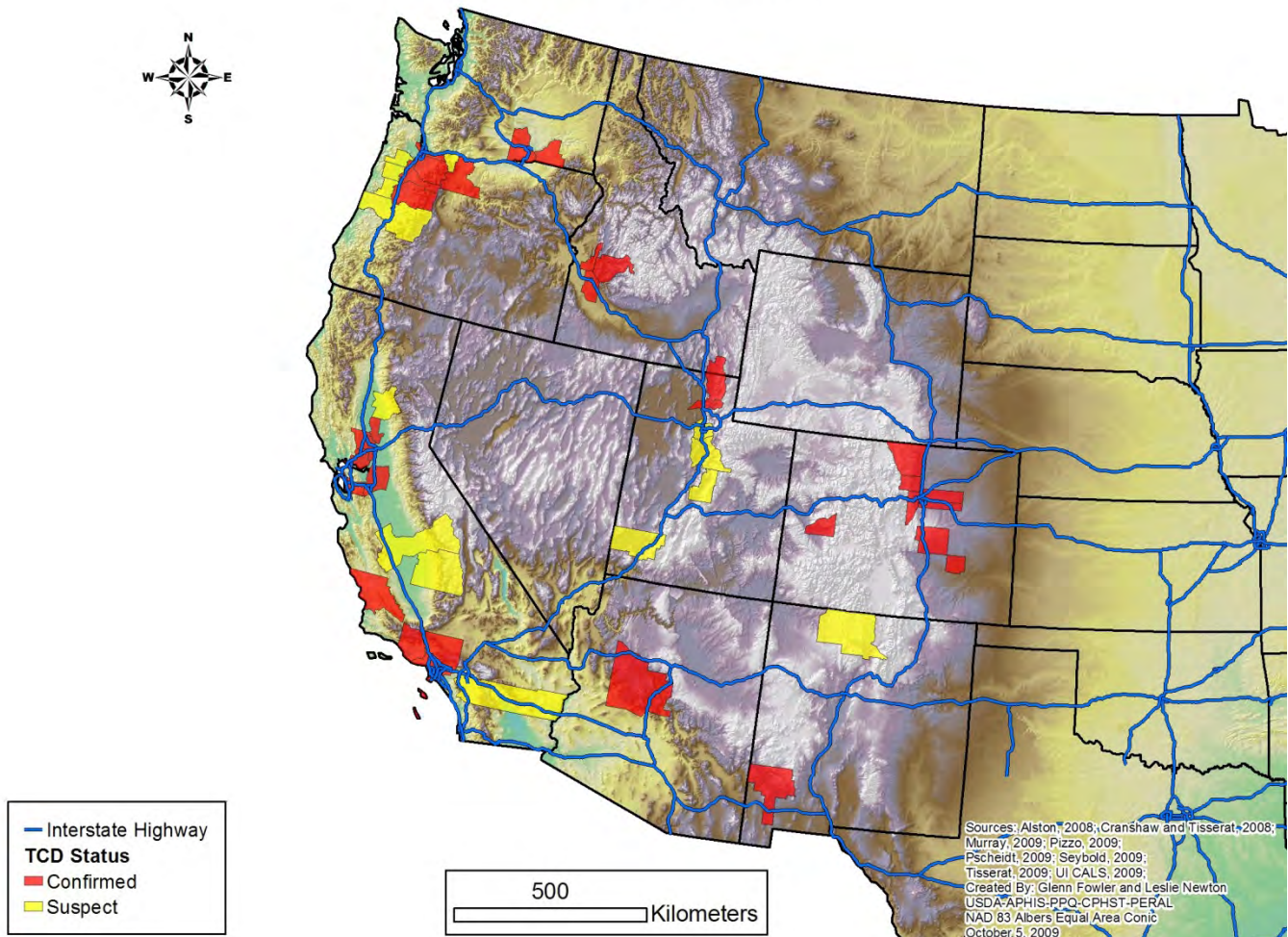


Figure 1. U.S. county distribution of Thousand Cankers Disease (TCD) as of October 6, 2009.

II. History of the walnut twig beetle and thousand cankers disease

The walnut twig beetle (WTB, *Pityophthorus juglandis* Blackman) was originally described in 1928 based on specimens collected in the area of Lone Mountain in Lincoln County, New Mexico (Blackman, 1928); its primary range includes New Mexico, Arizona, and Chihuahua, Mexico. This range coincides largely with the distribution of Arizona walnut (*J. major*), the likely original host for the beetle (Cranshaw and Tisserat, 2008). Museum records and surveys record WTB in California in the 1950s (Graves et al., 2009). Additionally, *P. juglandis* was described from specimens collected in California on *J. nigra* (Bright and Stark, 1973) and *J. californica* (Bright, 1981). These California records indicate that (1) the beetle is not a new introduction to California but probably native and (2) WTB has been present in California on walnut species susceptible to TCD (*J. nigra* and *J. californica*) for over 25 years. The first recording of the beetle in Utah is from 1988 (Clark, 2008).

Black walnut decline was first observed in Utah and Oregon (Willamette Valley) in the early 1990s, and attributed at that time to environmental stress (Murray, 2008b; Pscheidt, 2009b). Cankers were noted on

declining black walnut in Utah in 1992 but no tests were performed to determine the pathogen (Murray, 2008b). Walnut decline continued in Oregon and Utah and WTB was first implicated (Utah) in 1998 (Alston, 2008; 2007); specimens of WTB were collected from black walnut in Utah (Clark, 2008; Murray, 2008b) and Oregon (LeBonte, 2008; Pscheidt, 2009b). In 2001, widespread mortality of *J. nigra* was reported in the Espanola Valley of New Mexico and WTB was recovered from declining trees. In Colorado, mortality of *J. nigra* was first reported in Colorado Springs in 2003 and WTB was recovered from declining trees (Cranshaw and Tisserat, 2008). Walnut decline and mortality continued (and continues) to spread through the Willamette Valley of Oregon, the Front Range of Colorado, Utah, and into southwestern Idaho, with WTB consistently collected from the dying trees (Pscheidt and Shaw, 2008; Cranshaw and Tisserat, 2008; Murray, 2008b; UI, 2009).

The pathogenic connection to the *Geosmithia* sp. was not suspected until 2006 (Tisserat, 2008a). In the fall of 2007, a previously unknown *Geosmithia* fungus (see biology below) was consistently isolated from branch and twig cankers surrounding WTB galleries and directly from the beetles in Colorado (Tisserat, 2008a). In 2008, this *Geosmithia* sp. was isolated from declining walnuts (*J. nigra*, *J. hindsii*, *J. regia*) in Oregon (Pscheidt and Shaw, 2008), Utah, New Mexico, Colorado, and Idaho (Tisserat, 2008b).

More recently, TCD has been reported on dying walnuts in several counties in California (Garvey, 2009; Graves et al., 2009). Scientists from UCA-Davis noted walnut twig beetles (summer 2008) on declining and dying trees; they sent samples to Colorado State where the fungus was isolated on *J. californica*, *J. hindsii* and *J. regia* (Leslie, 2009; Seybold and Leslie, 2009). In California, the beetles appear to attack trees under stress from age, mistletoe, blackline disease, or crown gall (Leslie, 2009). Although *J. regia* trees in the National Clonal Germplasm Repository contain beetles and are showing symptoms, the disease is not widespread in orchards thus far (Leslie, 2009). Similarly, in Oregon, mortality is less severe compared to disease expression in Colorado; factors such as older trees with thicker bark, differences in climate, possible differences in *Geosmithia* sp. virulence may enable trees in California and Oregon to tolerate low levels of TCD for longer periods of time (Leslie, 2009). The beetle/disease complex is thought to be widespread throughout California (Leslie, 2009; Seybold, 2009b).

Infestation (and by association, infection) levels of walnut orchards in California are estimated to be 5-10% . Infested material is more likely to be *J. californica*, *J. hindsii*, or *J. hindsii* x *J. nigra*. Very little *J. regia* is infested, but rootstock (including 'Paradox' *J. hindsii* x *J. regia*) appears capable of becoming infested. Roadside plantings of *J. hindsii* are more likely to be infested, at 30-40% (Seybold, 2009c).

Research on thousand cankers disease is continuing at Colorado State University (Ned Tisserat and Whitney Cranshaw), the University of California at Davis (Steven Seybold), and Oregon State University (Jay Pscheidt). Studies are focused on the biology and ecology of this *Geosmithia* sp. and the walnut twig beetle, host range, host responses, lures, epidemiology, controls, and other factors. Walnut breeders from a nonprofit organization in Utah and Idaho, where the disease is prevalent on black and English walnuts, are utilizing the natural spread of the insect-mediated canker disease through their plantings as a screening process so they can select trees for TCD resistance as well as other desirable qualities (Ford, 2009). Walnut breeders at UC-Davis and scientists at the National Germplasm Clonal Repository (NCGR) in California are also looking at gene conservation and resistance (Leslie, 2009).

In a recent survey of the northwestern edge of the native distribution of *J. nigra* (the Missouri River Valley in South Dakota, Nebraska, and Iowa), researchers found no evidence of *P. juglandis* or *Geosmithia* infection in native *J. nigra* growing along riparian corridors (Seybold, 2009a).

III. Biology and ecology of thousand cankers disease

A. Causal agent: *Geosmithia* sp.

The unnamed *Geosmithia* species (Ascomycota: Hypocreales) recently linked to the development of TCD belongs to a genus of dry-spored anamorphic fungi that predominate in galleries built by phloem-feeding bark beetles and other subcortical insects (Kolarik et al., 2007). To date this species has been found only on *Juglans* species. The only known vector is the walnut twig beetle, *Pityophthorus juglandis* (Tisserat et al., 2009).

In the early stages of walnut decline, the *Geosmithia* sp. produces small, roughly circular to oblong diffuse-type cankers in twigs, branches, and the trunk. These cankers develop around the galleries of the walnut twig beetle and are usually not visible until a thin layer of the outer bark is removed. Even when leaf wilting is present, branches with numerous beetle galleries and cankers often show no outward appearance of bark damage except for the small beetle entrance holes making detection difficult. The cankers surrounding the beetle galleries in thicker-barked branches or the trunk are often initially restricted to the first three layers of the cork cambium (Utley et al., 2009) and do not extend into the vascular cambium. With time the cankers expand in the phloem and outer bark, becoming more diffuse and causing a dark brown to black maceration of the tissues. Cambial discoloration occurs only after extensive bark colonization by the fungus. In the advanced stages of decline, beetle galleries and associated cankers often occur every 2 to 5 cm in the bark. Eventually, the cankers coalesce and girdle twigs and branches, resulting in dieback (Tisserat et al., 2009).

The *Geosmithia* sp. is not systemic (Cranshaw and Tisserat, 2009). While it is possible for fungal spores surrounding beetle galleries to be moved by wind or water (Kolarik et al., 2008), the pathogen appears to require a vector to establish well and produce the multiple, coalescing cankers required to kill a tree. Presumably, relatively high populations of WTB are required before TCD could cause severe decline or mortality.

The origin of this newly recognized *Geosmithia* species is uncertain. High genetic diversity has been found among the *Geosmithia* isolates from walnut in the western United States. The variability was not correlated with geographic sites or hosts from which isolates were collected (Freeland et al., 2009), suggesting that the species is native or has been here for a long time. However, records of WTB on susceptible walnut species in California (*J. californica* and *J. nigra*) for over 25 years do raise the question as to why the trees are now suffering decline and mortality from TCD.

To date, this *Geosmithia* sp. has not been recorded in the eastern United States and, to our knowledge, no surveys have been conducted.

B. Known vector: Walnut twig beetle, *Pityophthorus juglandis* Blackman

The causal agent for TCD has been consistently recovered from the walnut twig beetle (WTB; *Pityophthorus juglandis*), a minute (1.5-1.9 mm) bark beetle which introduces the fungus into trees during gallery formation (Tisserat et al., 2009). The WTB carries the *Geosmithia* conidia on its elytra (wing covers) (Seybold et al., 2009).

On *J. nigra* in Colorado (Cranshaw and Tisserat, 2008; Cranshaw, 2008), the beetles tend to colonize the base of twigs in rough areas of bark; the underside of branches is preferred and typically on the warmer side of the tree. Very large branches and even the trunk can be colonized. Winter is spent, possibly exclusively, in the adult state sheltered within cavities excavated in the bark of the trunk. Adults resume activity by late April and most fly to branches to mate and initiate new tunnels for egg galleries; some may remain in the trunk and expand overwintering tunnels. Larval development takes 6-8 weeks to complete. There are generally two overlapping generations per season in Colorado. Adult beetles can be observed flying from mid-April to late October in Boulder.

Recent studies conducted on *J. hindsii* in California have produced the following observations: The brood galleries of the walnut twig beetle, frequently associated with the unnamed *Geosmithia* species, occur on branches 1.5 cm (6/8 inch) or greater. Male beetles colonize newly cut branches in 4-9 days and are joined quickly by 1 to 2 females. Brood galleries are then created. Both sexes contribute to an aggregation pheromone that attracts both sexes to infested branches (Seybold et al., 2009).

Early records relating to WTB do not indicate any significant effects on ecosystems within its native range (Arizona, New Mexico, California). However, it clearly has expanded both its host range and its geographic range into Colorado, Utah, Idaho, Oregon and Washington. Regardless of whether or not the *Geosmithia* sp. was always associated with the beetle, scientists working closely with TCD in western states seem to agree that at this point in time, WTB and the pathogen are now consistently in association.

The *Geosmithia* sp. appears to require high vector populations in order to kill its host. Bark beetle populations often fluctuate and a few species (< 1%) undergo broad scale outbreaks, but 'tree killers' in North America usually attack conifers and are mostly concentrated within *Dendroctonus*, *Ips*, and *Scolytus*. For populations to breach the stand-level eruptive thresholds, a 'perfect storm' combination of host availability and suitability, beetle population density, weather, and escape from natural enemies is required (Raffa et al., 2008). Conifer twig beetles (*Pityophthorus* spp., *Pityogenes* spp., *Pityotrichus* spp.) reached eruptive populations on piñon and other pines in New Mexico between 2000 and 2004 in association with *Ips* spp.; twig beetles do the most damage to trees on dry rocky slopes, overcrowded stands, heavily infected with dwarf mistletoe, injured by construction activities, or transplanted (Sandoval, 2008). Tree-killing bark beetles are rarely associated with angiosperms (hardwoods); reasons include 1) a hypersensitive (induced) response of hardwood phloem to the invasion of fungi introduced by attacking beetles and 2) physiological costs incurred by scolytids attacking angiosperm phloem are greater than nutritive benefits (Ohmart, 1989). In Colorado, the unusually high populations of WTB on planted *J. nigra* and the rapid decline and mortality from TCD could be associated with tree stress from a variety of factors. Any defense mechanisms against insects and pathogens are diminished under stress.

C. Host range

Host species for WTB and the *Geosmithia* sp. include both native and introduced walnut species. Native hosts (Figure 2) include California walnut (*J. californica*), Hinds walnut (*J. hindsii*), black walnut (*J. nigra*), Arizona walnut (*J. major*) and, possibly, little walnut (*J. microcarpa*). English walnut (*Juglans regia*) is an introduced host and other introduced ornamental walnuts may serve as hosts.

Susceptibility (the lack of inherent defenses against damage by the WTB and TCD) varies (Table 1). *Juglans californica*, *J. hindsii*, and *J. nigra* are susceptible to TCD, suffering damage and ultimately death. *Juglans regia* is susceptible. *Juglans major* appears resistant, tolerating both the WTB and the pathogen with little damage. *Juglans microcarpa* has tested positive for canker development in *Geosmithia* sp. pathogenicity trials, but we have no reports that WTB or the pathogen have been field collected from *J. microcarpa*. This species is important because it could serve as a natural bridge for the movement of TCD on native hosts.

Two important native species within the family Juglandaceae have been exposed to the *Geosmithia* sp. in pathogenicity tests (Utley et al., 2009). These preliminary tests demonstrated that butternut (*Juglans cinerea*) and pecan (*Carya illinoensis*) did not develop cankers and appear to be resistant (or entirely immune) to the pathogen.

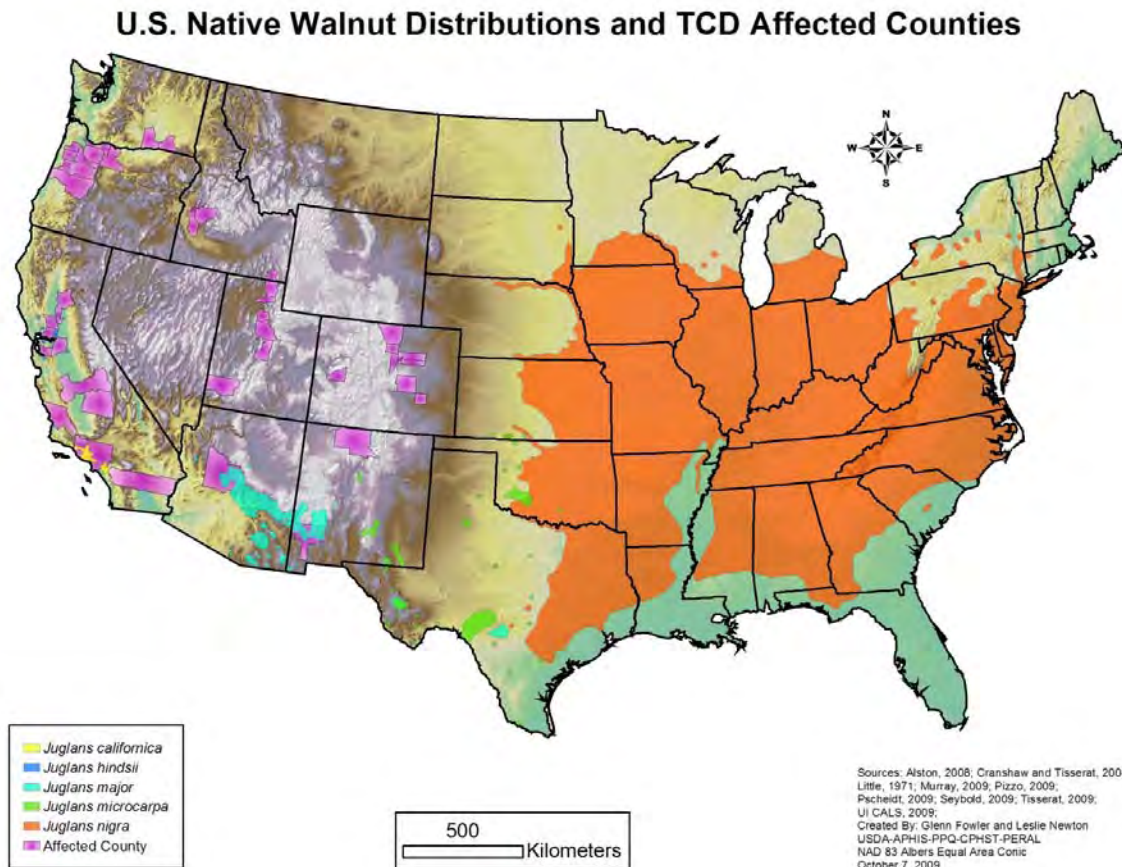


Figure 2. Distribution of U.S. native walnut species and TCD affected counties.

Table 1. Susceptibility of selected species within Juglandaceae to TCD.

Species	Status/Distribution	Uses	Susceptibility
<i>Juglans californica</i> (California walnut)	Native / Natural range restricted to southern California	Native tree	Susceptible (Utley et al., 2009)
<i>J. cinerea</i> (butternut)	Native / Natural range throughout NE U.S. and into Southern Appalachian region	Nuts, ornamental, timber	Nil (preliminary) (Utley et al., 2009)
<i>J. hindsii</i> (Hinds walnut or northern California walnut)	Native / Natural range from northern CA into OR	Timber, rootstock for English walnut (<i>J. regia</i>)	Susceptible (Utley et al., 2009)
<i>J. major</i> (Arizona walnut)	Native / Natural range AZ, NM, Mexico (Chihuahua)	Native tree	Resistant (tolerant)
<i>J. mandshurica</i> (Manshurian walnut)	Exotic	Ornamental	Susceptible (Utley et al., 2009)
<i>J. microcarpa</i> (little walnut)	Native / Natural range restricted to scattered populations in NM, TX, OK and KS	Ornamental, nuts (not commercial), rootstock in TX for non-native <i>Juglans</i> species	Susceptible (Utley et al., 2009)
<i>J. nigra</i> (black walnut)	Native / Natural range extends throughout eastern U.S. and into Kansas and Nebraska; planted throughout U.S.	Timber, nut and ornamental tree; used as rootstock for English walnut grafts	Highly susceptible (Tisserat et al., 2009; Utley et al., 2009)
<i>J. regia</i> (English walnut)	Exotic / Planted in commercial groves throughout U.S., particularly in CA (264,517 acres) and OR (1,460 acres)	Nut production – 99% of U.S. production of walnuts from CA English walnuts	Susceptible (Lauterback, 2007; Seybold and Leslie, 2009; Ford, 2009)
<i>Carya illinoensis</i> (pecan)	Native / Natural range through the central U.S.; widely planted throughout U.S.	Nut production; ornamental	Nil (preliminary) (Utley et al., 2009)

D. Establishment and spread potential

More information on the biology of the WTB and *Geosmithia* sp. is needed in order to accurately predict the potential geographic range of TCD. However, USDA plant hardiness zones may provide some clues regarding its potential distribution. The USDA plant hardiness zones represent the extreme annual minimum temperatures in 10° Fahrenheit thermal bands, e.g. zone 2 = -50°F to -40°F. They are often used in horticulture and risk assessments to determine where an organism could establish (Cathey, 1990; Magarey et al., 2009; USDA-APHIS, 2000).

The current county distribution of TCD primarily includes USDA plant hardiness zones 4 to 10 (a small area in the upper elevations of Larimer County, Colorado was zone 3) (Figure 3). This indicates that TCD may be able to occur throughout most of the United States, wherever suitable host material is found.

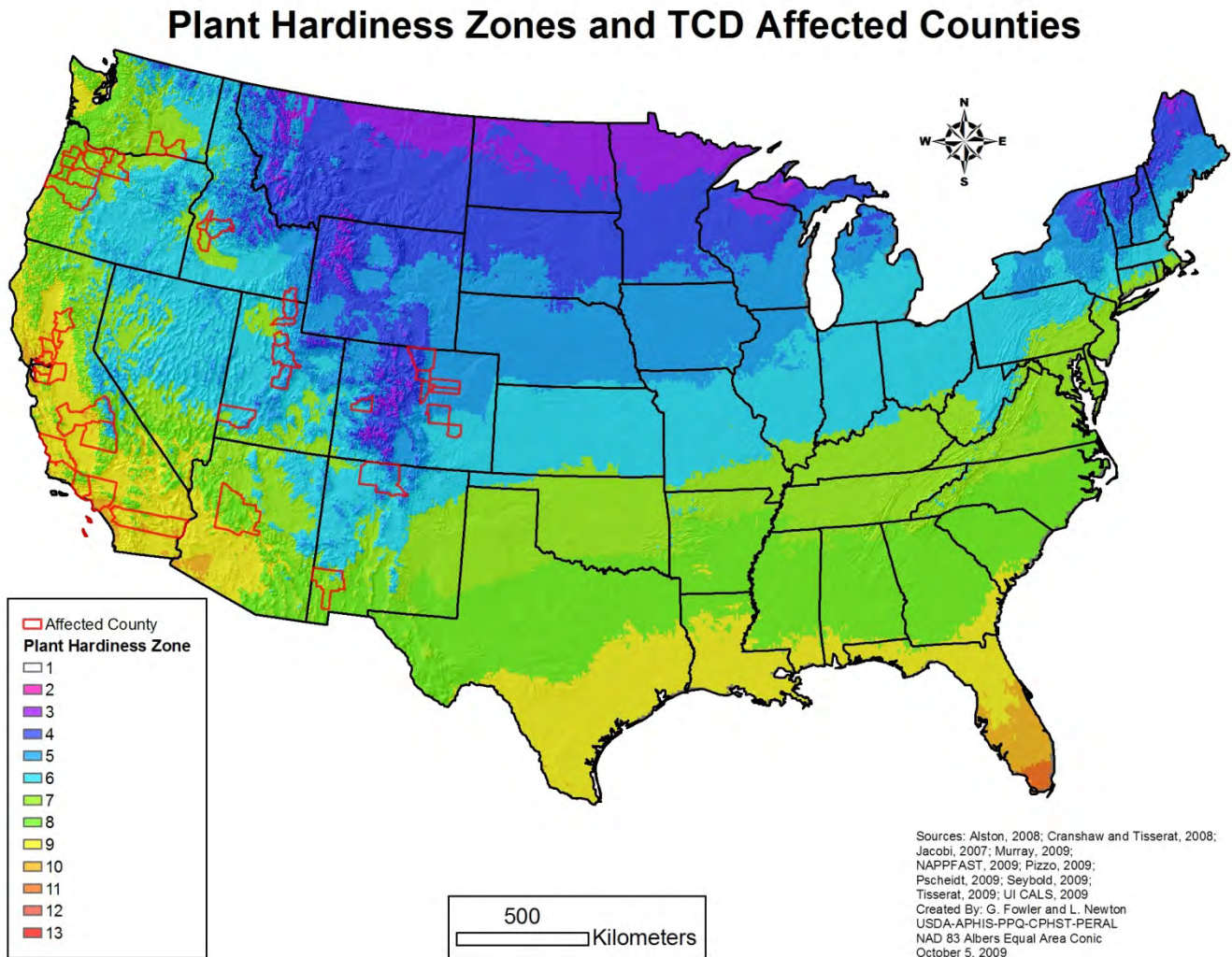


Figure 3. Plant hardiness zones and counties affected by TCD.

Host trees occur throughout much of the United States, both naturally (Figure 2) and planted (not mapped). The eastern distribution of *Juglans nigra*, based on Forest Inventory Analysis (FIA) data is shown in Figure 4 below. We note that *J. nigra* extends further west than is shown in these maps. Pioneers carried *J. nigra* westward and not only has it been planted widely in western states (as is evidenced by the occurrence of TCD on *J. nigra* in seven western states), but it has naturalized in a number of counties in the Great Plains States (NRCS, 2009).

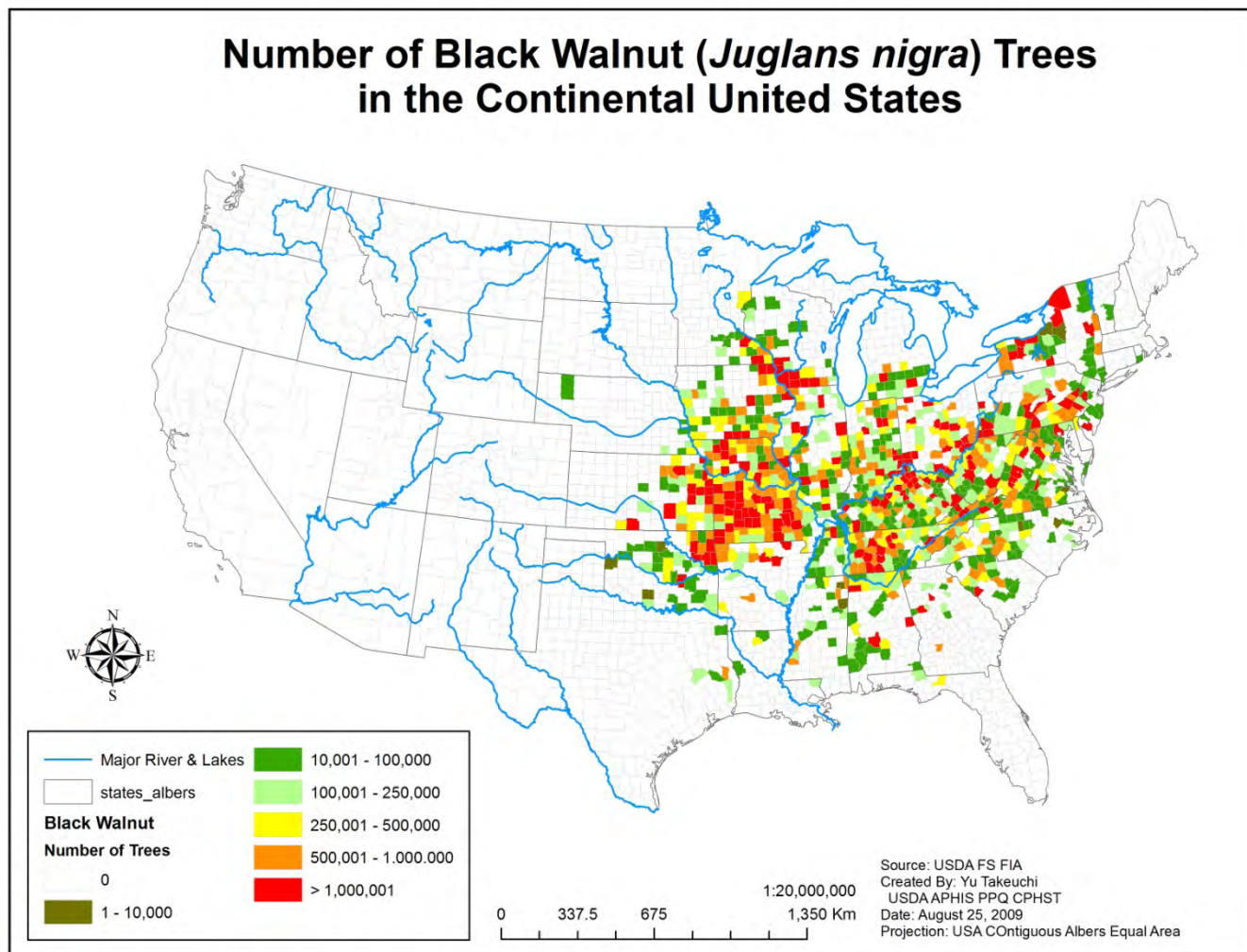


Figure 4. Number of black walnut (*J. nigra*) trees in the United States. Based on FIA data.

E. Potential vectors

There are a number of bark beetles (Coleoptera: Curculionidae: Scolytinae) that have the potential to serve as alternate vectors of *Geosmithia* conidia (Table 2). In the central states and into the east, a likely vector may be *Pityophthorus lautus*, a congener of *P. juglandis* that uses black walnut as a preferred host (Wood, 1982). *Xylosandrus germanus* and *Xyleborinus saxesenii* are widely distributed and polyphagous; *X. saxesenii* is often associated with the WTB and TCD trees in Colorado and is likely to be exposed to the conidia. Also, *X. saxesenii* is often the most common and widely distributed species in traps across the United States and often attacks weakened trees (Rabaglia, 2009).

Two additional species have been found emerging from dead walnut branches in California: *Scobicia declivis* (Coleoptera: Bostrichidae) and *Xylotrechus nauticus* (Coleoptera: Cerambycidae) (Seybold et al., 2009). Although they may possibly carry *Geosmithia* conidia on their bodies, correlation that they are vectoring TCD remains uncertain.

Table 2. Potential vectors that may contribute to the spread of the *Geosmithia* sp.

Species	Information on potential vector
<i>Pityophthorus lautus</i>	Distribution: Northeastern and Midwestern US; MN and Quebec to KS and MS, including at extremes of range ME, MO, and NC (Wood, 1982)
	Hosts: <i>Juglans nigra</i> (Wood, 1982)
	Comment: Not a major pest, but known to attack <i>J. nigra</i> in native range (Wood, 1982)
<i>Xylosandrus germanus</i>	Distribution: In CA and throughout the native range of black walnut in the eastern U.S.; Asia (native); Europe (introduced) (CABI, 2007)
	Hosts: Polyphagous, including <i>J. nigra</i> , <i>Carya illinoensis</i> , and many other hardwoods
	Comment/Associated Fungi: A significant pest of black walnut in the midwestern U.S. and often associated with <i>Fusarium</i> spp. cankers; can attack vigorous trees, especially young trees in plantations (Katovich, 2004); two known <i>Geosmithia</i> species (<i>G. lavendula</i> and <i>G. obscura</i>) have been isolated from the mycangia of a congener, <i>X. mutilatus</i> , in Mississippi (Six et al., 2009)
<i>Xyleborinus saxesenii</i>	Distribution: British Columbia, Ontario; western U.S. and throughout the native range of black walnut (CABI, 2007); North America, Asia, Australia, Europe, and South America (Wood, 1982)
	Hosts: <i>J. regia</i> (Bright and Skidmore, 1997); polyphagous – multiple hardwood species (CABI, 2007)
	Comment/Associated Fungi: Not considered a major walnut pest; beetles favor lower stumps and lower portions of dead and dying trees (Katovich, 2004); vector of <i>Geosmithia</i> in Europe (Kolarik et al., 2008); found on black walnuts with thousand cankers disease in Colorado (Tisserat et al., 2009)
<i>Xyleborus ferrugineus</i>	Distribution: MA south to FL and west to MI and southern CA; Hawaii; Mexico; Central and South America; tropical Africa; Asia; Australia (Solomon, 1995)
	Hosts: <i>Juglans</i> spp., <i>Carya illinoensis</i> ; has a host range of 180+ species worldwide (Katovich, 2004)
	Comment/Associated Fungi: Not considered a major walnut pest; most common attacking stumps and logs on the ground (Katovich, 2004); has a well-known symbiotic relationship with <i>F. solani</i> (Norris and Baker, 1967)
<i>Hypothenemus eruditus</i>	Distribution: From WV to MS (Baker, 1972)
	Hosts: <i>J. nigra</i> (Wood and Bright, 1992); <i>J. regia</i> (Bright and Skidmore, 1997)
	Comment/Associated Fungi: Not known to be a significant pest of walnut; it is capable of carrying <i>Fusarium</i> spp. (Romon et al., 2007)

IV. Pathways of Movement

Potential long-distance dissemination pathways include raw timber (vener quality logs, sawlogs, burls, stumps), firewood, wood packaging material (WPM), nursery stock, scion wood for grafting, nuts, and natural spread.

We queried the USDA APHIS interception database (last queried 10/8/2009) to determine if *Pityophthorus* spp. were intercepted from other countries. Very few interceptions detail species, but within the last 10 years there have been 1015 border interceptions of *Pityophthorus* sp. (reportable/actionable). Almost all (98.3%) were from Mexico. Over half of the intercepted commodities were destined for either California or Texas. Pathways included 'bark, stem, trunk' (indicating raw timber) (12%); wood packaging material (WPM; crating, dunnage, and pallets) (22%); 'wood' (10%); and 'woodware' (2%).

A. Timber (vener logs, sawlogs, burls, stumps)

Raw wood, particularly with the bark intact, often serves as a key pathway for the movement of forest pests. Bark and ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) are commonly intercepted on raw wood. Logs may be infested with insects prior to felling, or may become infested during timber extraction, transport, or while stored in the lumber yard awaiting processing. Likewise, insects within the bark of an infested log, burl, or stump may fly from the original host during transport or while in the lumber yard.

Pityophthorus juglandis has been intercepted in New Zealand at least once in a *Juglans* log from the United States (Brockerhoff et al., 2003). The exact date of the interception and the species of *Juglans* is unknown.

Neither *J. nigra* nor any walnut species is regularly included in timber reports or considered in any federal/state forestry programs in the western states where TCD has been found (ODF, 2009; MacLean et al., 1992; Campbell et al., 2004; Waddell and Bassett, 1997; WWPA, 2009; CFA, 2009; FFSL, 2009; CDF, 2009; ENMRD-NM, 2007). However, black walnut is highly valued with walnut prices ranging from \$200-1,000 per thousand board feet (MBF) stumpage (standing timber) and \$750-1400/MBF if delivered to the mill; veneer quality prices range from \$500-4,000/MFB stumpage and \$800-6,000/MBF if delivered to the mill (ILDNR, 2008).

Data relative to walnut production in the west is scarce. The University of Montana (Morgan, 2009a) conducts a census of northwestern timber processors (large and small) every few years. Eight sawmills (out of all reporting sawmills) in Oregon processed a total of 117 MBF of walnut (species not identified) during CY 2003, all of which came from private lands in Oregon. During the same year all sawmills reporting timber production in Oregon processed 2.7 billion BF of Douglas fir (*Pseudotsuga menziesii*), 358 million BF of hemlock (*Tsuga* spp.), and 153 million BF of red alder (*Alnus rubra*) (Morgan, 2009b).

Western walnut species are prized by woodworkers for the marbled patterns within the wood where logs, stumps, and burls from these trees are traded regularly, albeit on a small scale, by lumber producers and individuals. This wood is called ‘claro walnut’ and is utilized by artisans for production of fireplace mantles, guitars and other musical instruments, gunstocks, sculptures, frames, and furniture. Claro walnut can refer to the native *J. hindsii* or a ‘hybrid’ between *J. hindsii* and *J. nigra*; the term is often used for the wood taken from orchard trees of *J. regia* grafted onto *J. hindsii* or hybrid *J. hindsii* x *J. regia* (‘Paradox’) rootstock. The mix in colors near the graft line, with the light color above and the darker colors below creates unique patterns in the wood. Orchards trees are replaced every 40-70 years and the logs and stumps from these trees sold to various woodworking organizations. Logs from orchard trees may be processed locally, shipped out of country, or simply placed on the open market (TG, 2008; WFRG, 2009; Pizzo, 2009b).



Walnut burls and stumps are also utilized in the woodworking trade. Burls are abnormal growths on tree trunks. The intricately patterned wood is utilized for a variety of purposes and is quite valuable. Veneer mills in eastern states are known to pay \$8 per pound for 1,500 to 3,000 pound burls (\$12,000-\$24,000 for the seller) (Hafferty, 2009). Green burls (not dried) with bark intact have been shipped on a small scale from the west coast to veneer mills in the east on a fairly regular basis (Hafferty, 2009).



According to the American Walnut Manufacturers Association, walnut logs are occasionally shipped by rail from either Long Beach or Seattle, to Chicago and then by

truck to one of four possible veneer mills, three in Indiana and one in Ohio (Moltzan, 2009). We contacted these mills and spoke with their representatives (personal communications to L. Newton). Two of these mills receive a few shipments each year. One representative was reluctant to share information, but stated that they receive perhaps three (3) 20-ft. containers (20 logs per container) per year. The other mill shared the following information: The burl business is ‘practically dead’ right now and very few large burls are being shipped. A few years ago (3-4 years) they received 10 trucks a month and the material would sit in the lumber yard until it was processed. Now, they receive less than a truck a month (40,000 lbs. or 15-20 logs per truck) during the cooler months (October to March) and the material is processed very quickly. The walnut is shipped on flatbed trucks from California groves (orchards); they are interested in the wood near and under the graft line. Representatives from the other two mills stated that they do not currently receive any walnut from western states.

Timber harvests in the west often begin in the fall (late September or October) and continue into March (Hafferty, 2009). Because the walnut twig beetle tends to overwinter in the lower bole (trunk) of trees

(Cranshaw, 2008), this seasonal harvest may increase the potential for logs, burls or stumps to transmit *Geosmithia*-carrying beetles. Because beetles emerge from overwintering sites in the spring (Cranshaw, 2008), if mills in the east process logs quickly it may lessen the likelihood of beetle establishment and TCD transmission to nearby walnut trees. Debarking logs or burls prior to shipping may also minimize any potential spread of the walnut twig beetle and TCD. However, walnut bark is said to be notoriously difficult to remove, particularly from burls (Hafferty, 2009).

We mapped veneer mills in the east (Figure 5). The volume of these long distance shipments and consequently the approach rate via this pathway appears to be low.

Based on information from Missouri, sawmills may purchase walnut logs (if the quality and quantity is acceptable) within a 300 mile radius (AmericanWalnut, 2009). We identified plywood, veneer and/or sawmills within 300 miles of TCD affected counties as being at risk for receiving infested timber (Figure 6).

There are 14 mills in Kansas and Nebraska (Figure 6) that could facilitate the introduction of TCD into the eastern range of *J. nigra*. Mills located near riparian systems where walnut trees are often found (Baker, 1999) could pose a greater risk for transmitting the disease eastward. This information can be used to inform surveys and facilitate the early detection of walnut decline in the eastern United States.

Additionally, the movement of raw wood by individuals should not be underestimated; quick searches of the internet resulted in 35+ advertisements for walnut timber (raw logs, burls, stumps) for sale by individuals in multiple states across the west and into the central Great Plains states (Appendix II). These examples represent the frequent, yet undocumented, trade in walnut wood in areas with TCD or vulnerable areas in the Great Plains States.

If TCD should become established in western Kansas, the potential for movement will increase. Kansas has 36,800 acres of black walnut, 64% of which is sawtimber sized (Moser et al., 2006). There are 40 sawmills in Kansas; black walnut sawlog production in 2003 totaled 3 million board feet (Reading and Bruton, 2007). There are 16 operations in the eastern portions of the state that will travel statewide to buy timber, including black walnut; there are an additional 16 out-of-state operations (Arkansas, Illinois, Indiana, Minnesota, Missouri and Nebraska) that are willing to buy timber ('all species' or specifically 'walnut') statewide in Kansas (KFS, 2009).

The actual movement of raw logs from the west into the east, including localized movement to mills in Kansas and Nebraska, and the percentage of infested material likely to move, is unknown. The current volume appears to be low, indicating a low approach rate.

Plywood/Veneer Mills, Hardwood Forests and TCD Affected Counties

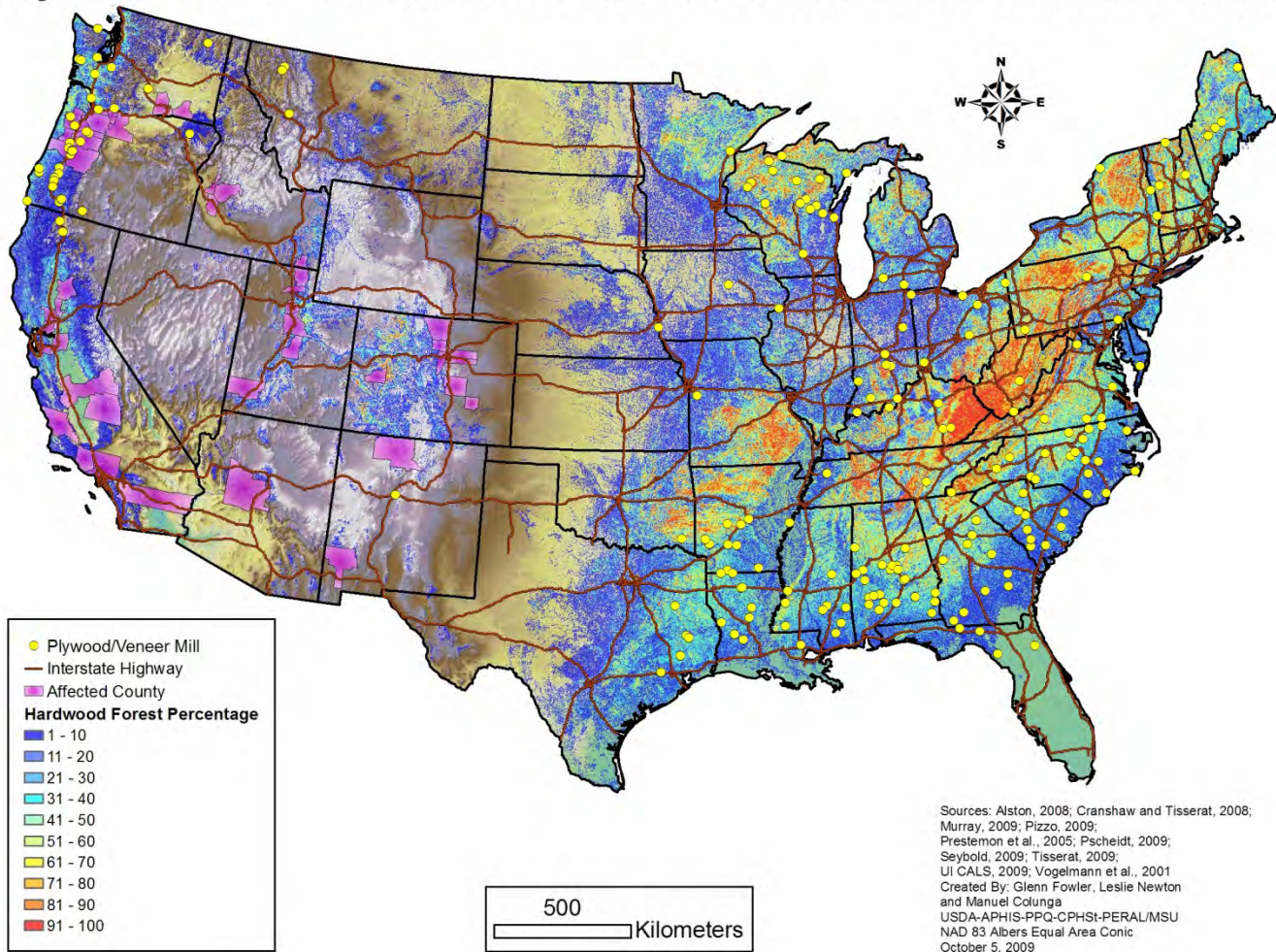


Figure 5. U.S. plywood and veneer mills, hardwood forests and TCD affected counties.

Note: To visualize areas where walnut could occur we used the U.S. hardwood forest GIS layer created by Dr. Manuel Colunga-Garcia (Colunga-Garcia, 2004). To create this layer he queried the national land cover data set, which visualizes forest composition in percentage terms, for all hardwoods plus 50 percent of the mixed forests (Magarey, 2008; Vogelmann, 2001). The NLCD data set was generated at a 30 meter resolution which he resampled to a 900 meter resolution (Colunga-Garcia, 2009). Consequently, tree densities less than 30 meters are not visualized on the map.

At-Risk Mills, Hardwood Forests and TCD Affected Counties

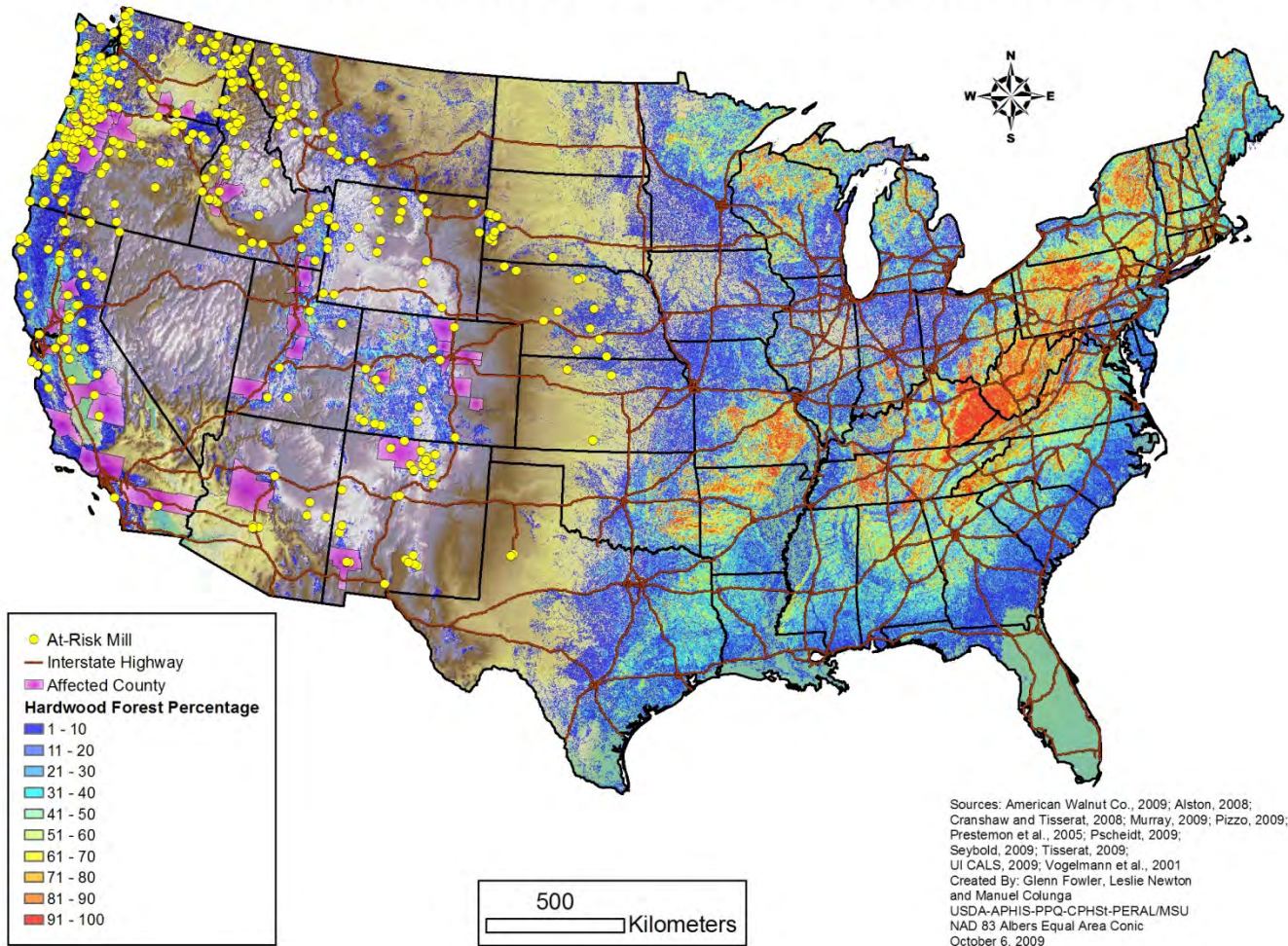


Figure 6. Timber mills within 300 miles of TCD affected counties.

B. Firewood

Firewood is an important pathway for the movement of forest pests, evidenced by the current activities taking place domestically in an effort to prevent the continued spread of the emerald ash borer (*Agrilus planipennis*) (NYSDEC, 2009). Between 9/13/06 and 8/13/09, there were 73 interceptions at California borders of scolytids (often identified only to the genus level) on firewood from other states; the majority were *Ips*, *Dendroctonus*, and 'undefined scolytid', but two were within the genus *Pityophthorus* (CDEA, 2009).

Walnut, including *J. nigra*, is utilized as firewood. There are several characteristics that determine whether or not a walnut tree is valuable for lumber or veneer, including trunk diameter, height, branching, and whether the tree is clear of defects. Urban and yard trees are often grown in open areas, resulting in short boles and numerous branches, and are unattractive to timber mills. Even walnut trees that would appear suitable as lumber or veneer trees are often avoided by timber mills because of the risk that they may contain embedded objects (such as nails, wires, insulators and clothes hooks) which

could damage expensive saw blades and present hazards to sawyers. These trees are often cut for firewood (Owen and Heiligmann, 2002).

Black walnut is ranked a ‘good’ wood for home heating, in the same category as black cherry or red maple, but below the ‘excellent’ ranking of ash, hickory, beech and oak (Donnan, 2009). In its eastern native range, black walnut may comprise 25% of a load of ‘mixed hardwood’ (NVTF, 2009). In western states, walnut (native walnuts or salvaged from orchards) is sold as firewood by dealers, either mixed with other hardwoods or separately (Hafferty, 2009; allseasonsfirewood.com). Most distributors sell dried firewood (at least one season) but it is often available ‘green’ for a lower price. Additionally, the internet (e.g., craigslist.org) lists individuals in high risk areas offering walnut firewood either for sale or free from recently cut trees (Appendix III). Scientists at Colorado State University have seen walnut firewood infested with the WTB and the fungus for sale in Boulder (Jacobi, 2009).

To evaluate the risk posed by this pathway, we assumed a 50 mile (80 kilometer) shipping radius (NYSDEC, 2009) and mapped firewood distributors within this distance of counties affected by TCD (Figure 7) (salesgenie.com, 2009). We then mapped federal, state and private campsites within 250 miles (≈400 kilometers) of the at risk firewood distributors (Figure 8) as probable locations where this wood could be utilized. These distances are based on the results of firewood surveys from Michigan and Colorado and account for a 50 mile firewood customer purchase radius and a 200 mile camper travel radius (Jacobi, 2007; NYSDEC, 2009).

All of the firewood distributors at risk for having infested wood (Figure 7) and the majority of campsites within the 250 mile radius (Figure 8) are located in states west of the Great Plains. There are 99 campgrounds in the Great Plain States that are within the 250 miles radius: 40 in South Dakota, 14 in Nebraska, 4 in Kansas, and 41 in Texas. Most of these are along the Platte and Arkansas Rivers and along major highways. Surveys at these campsites could facilitate early detection of TCD.

The approach rate of TCD into the eastern United States via the firewood pathway appears to be low based on its current distribution, but infested material brought into campsites along riparian areas may facilitate the spread of TCD into the eastern range of *J. nigra*. Additionally, campers are known to carry firewood across country and firewood distributors ship long distances. A survey conducted in Kansas revealed that firewood came into the state from as far away as California and New York (KDA, 2007). A 2006 firewood survey conducted at the Monadnock State Park campground in New Hampshire revealed that 18% of campers outside of New England brought firewood with them, some from as far away as California (NHDR, 2006). Outreach activities and public awareness campaigns similar to those currently used for the emerald ash borer may help mitigate TCD spread.

Firewood Distributors, Hardwood Forests and TCD Affected Counties

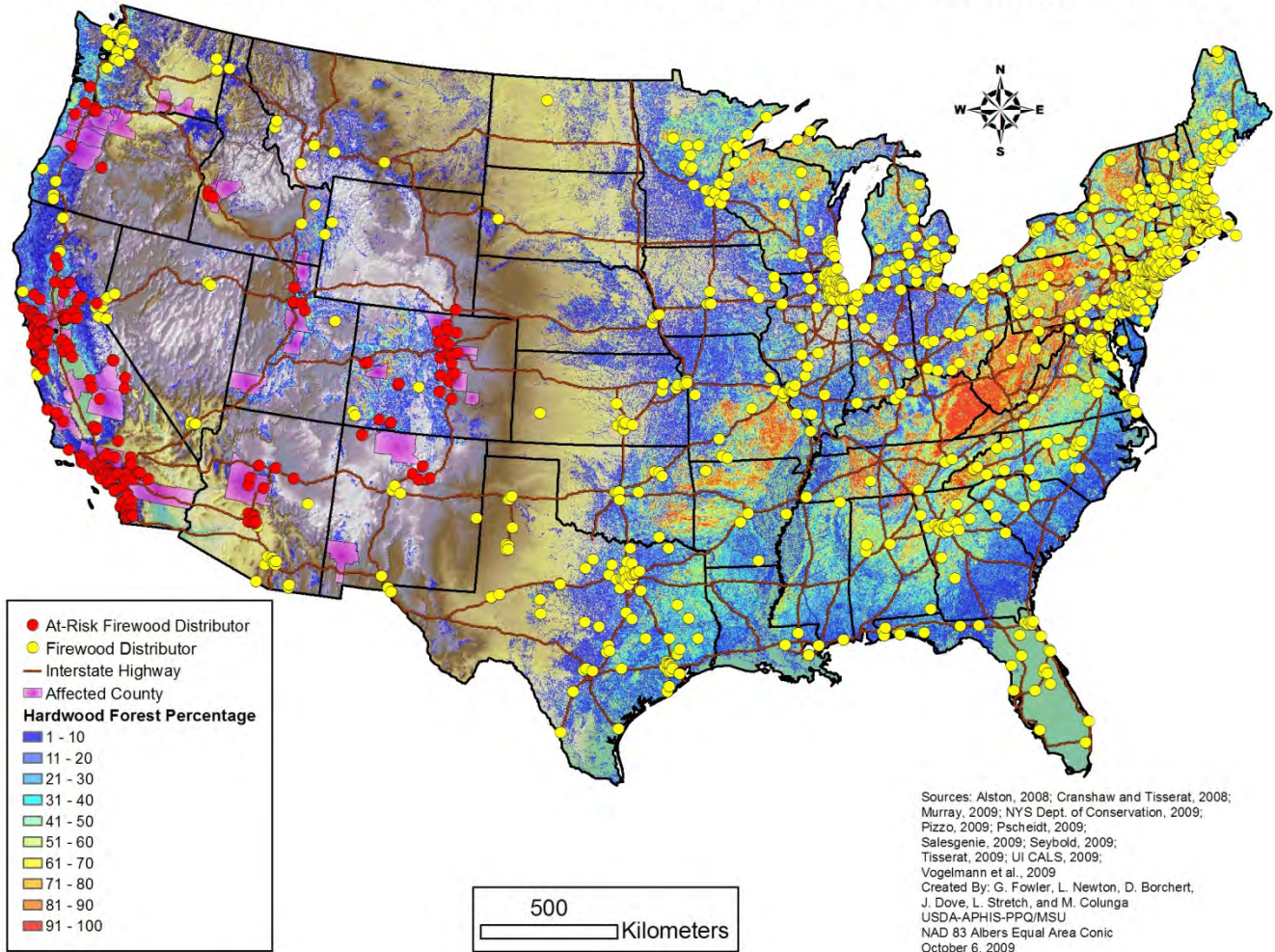


Figure 7. At-risk firewood distributors within 50 miles of TCD affected counties and all U.S. firewood distributors.

At-Risk Camp Sites, Firewood Distributors, Hardwood Forests and TCD Affected Counties

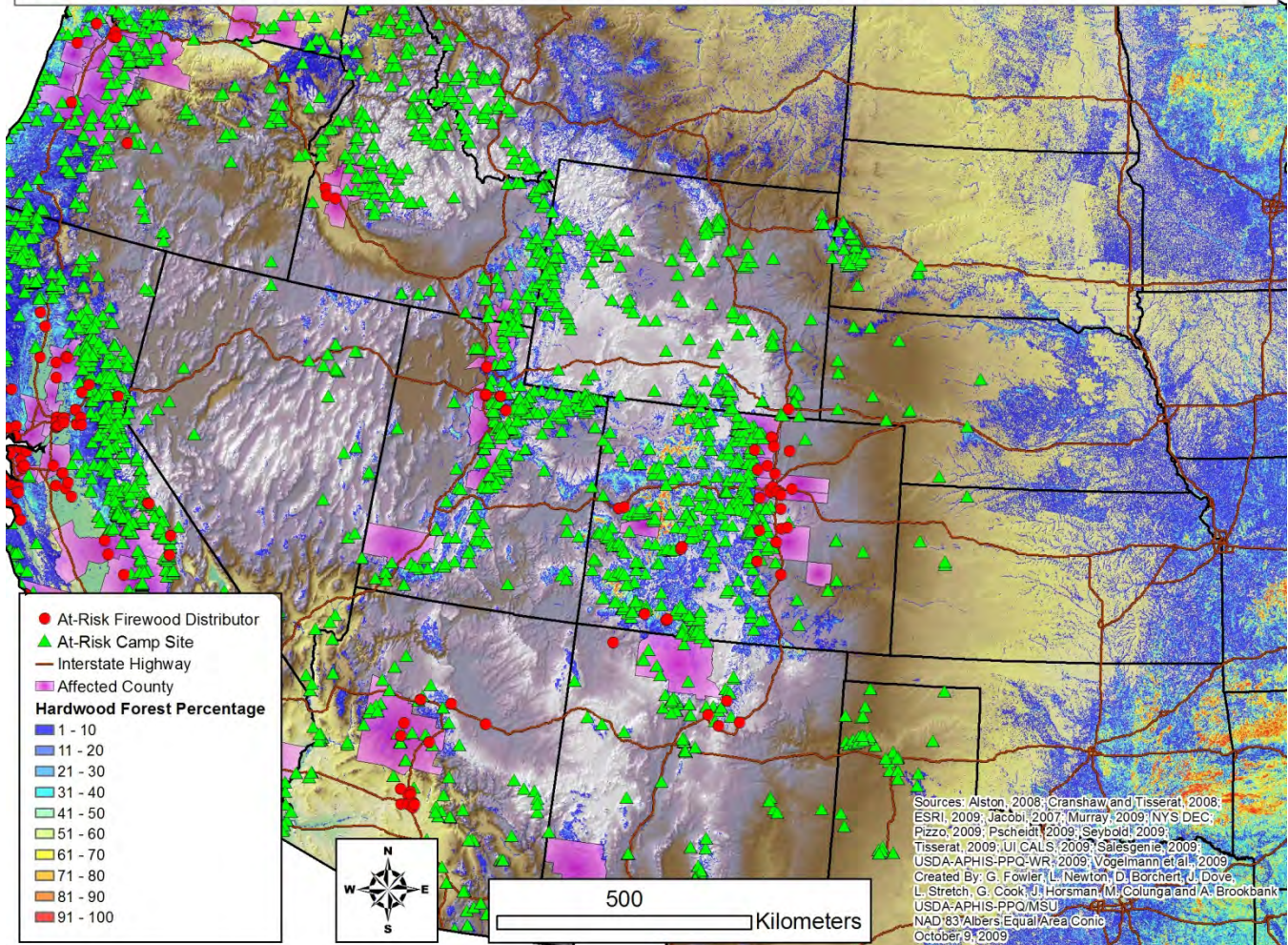


Figure 8. Firewood distributors within 50 miles of TCD affected counties and campsites (federal, state and public) within 200 miles of TCD affected counties and 250 miles of at risk firewood distributors.

C. Wood packaging material

Wood packaging material (WPM; e.g., pallets) is often made of unprocessed raw wood and is a recognized pathway for the movement of exotic bark- and wood-boring beetles (Haack, 2001; Colunga-Garcia et al., 2009). Currently, APHIS regulates the movement of logs, lumber and other unmanufactured wood articles due to the presence of wood pests such as the Asian longhorned beetle (ALB) and the emerald ash borer (EAB) within specific areas of the United States. The spread of these pests is linked to the domestic movement of WPM, which poses a serious threat to U.S. agriculture and forests. APHIS is currently in the process of determining appropriate action specifically related to the domestic movement of WPM (USDA-APHIS, 2009).

WPM accompanies nearly all types of commodities shipped domestically. The National Wooden Pallet Association estimates that 1.2 billion pallets are currently in circulation in the United States, with 93% of all goods moving on those pallets (USDA-APHIS, 2009).

In the manufacturing of WPM, particularly pallets, it is common to use low-grade or scrap wood to reduce costs (Pasek, 2000). Black walnut is valuable as timber, but very low-grade trees or just a few small logs have little value and this material is sometimes diverted to pallet manufacturers (Cassens, 2005). In fact, laminitis in horses is increasingly being caused by black walnut toxicity, from bedding produced in part from pallet plant residues that contain walnut shavings or sawdust, or used walnut pallets converted into mulch (Cassens, 2005).

In order for WPM from at-risk counties to be an effective pathway for TCD, infested walnut with bark attached must be utilized. There are multiple pallet manufacturers present in western counties with TCD, many of which are located in counties with TCD (Figure 9). This pathway could be a means to move TCD throughout the United States. There are numerous pallet manufacturers present within the eastern native range of black walnut. If non-infested material with bark attached were to be moved to counties currently experiencing TCD, risk for further spread could also be realized.

Pallet Manufacturers, Hardwood Forests and TCD Affected Counties

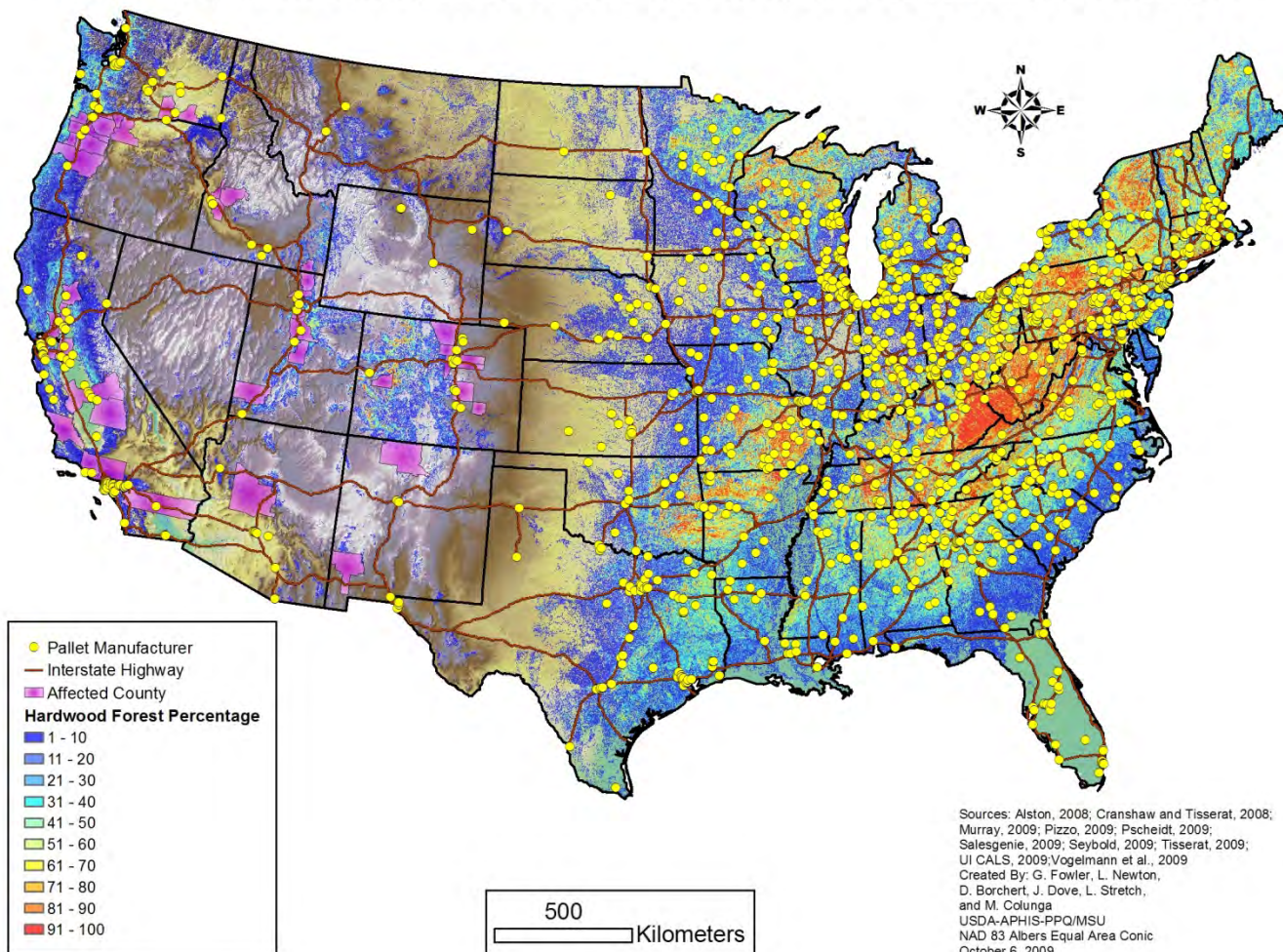


Figure 9. U.S. pallet and skid manufacturers and TCD affected counties.

D. Nursery Stock

To date, there have been no reports of thousand cankers disease infecting nursery stock. However, in pathogenicity tests utilizing 1-year-old *J. nigra*, the *Geosmithia* sp. aggressively colonized the bark and produced cankers (Tisserat et al., 2009). WTB is small (1.5-1.9 mm) and may be attracted to any host material with enough phloem to sustain the beetle. The WTB is often found on branches with diameters as small as 1 cm (Tisserat et al., 2009). Additionally, WTB was collected from a declining three-year-old *J. nigra* tree (3.8 cm diameter) in Utah (Murray, 2008b), indicating that the beetle may be attracted to very young trees.

Based on information from a comprehensive online nursery database, there are at least eighty nurseries throughout the United States that ship walnut host species (PIO, 2009) (Figure 10). Nine of these nurseries are located in counties that have walnut mortality due to TCD (Figure 11). Of these nine, one nursery ships only to western states and another appears to only sell seeds. The other seven nurseries could potentially ship walnut nationally.

It is more cost and time effective for customers in the eastern United States to order walnut trees from nearby suppliers than from nurseries on the west coast (Figure 11). For example, the costs of shipping a 100 lb. package from Dayton, OR as opposed to Afton, VA to Raleigh, NC via UPS ground is \$91 as opposed to \$66; the shipping time required is 5 days as opposed to 1 day (UPS, 2009). Consequently, shipping costs and times may reduce the movement of potentially infected walnut trees into the eastern United States via the nursery pathway.

Based on (1) no reports of infected nursery stock, (2) the limited number of nurseries in TCD affected counties that ship walnut species, and (3) shipping costs and times, we concluded that there currently appears to be a low approach rate of TCD into the Eastern United States via the nursery pathway.

If nursery stock in western states should become infected with TCD, this pathway should be re-examined and more detailed information obtained directly from western nurseries.

Walnut Shipping Nurseries, Hardwood Forests and TCD Affected Counties

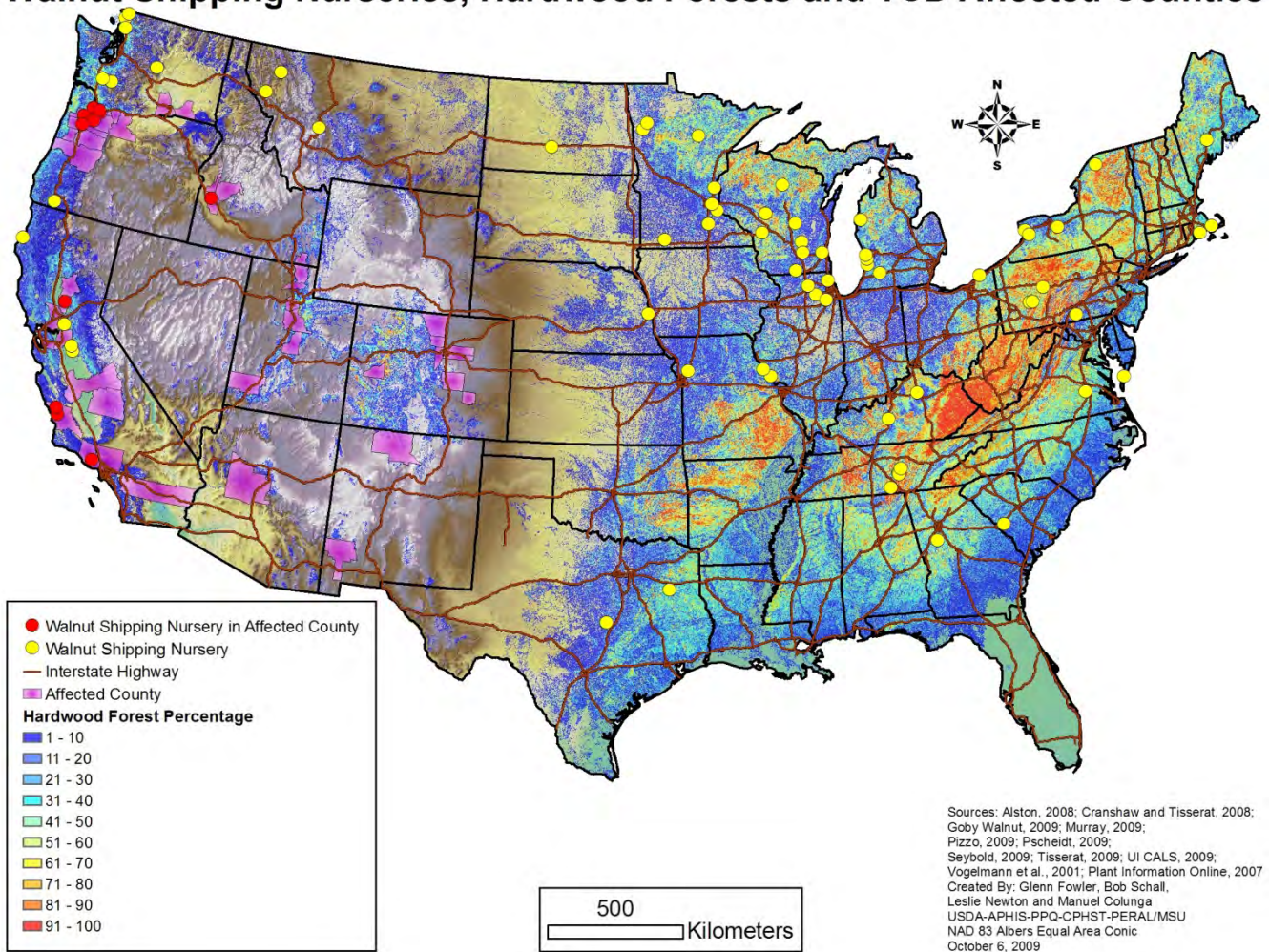


Figure 10. U.S. distribution of nurseries that ship walnut species and counties affected by TCD.

Walnut Shipping Nurseries, Hardwood Forests and TCD Affected Counties

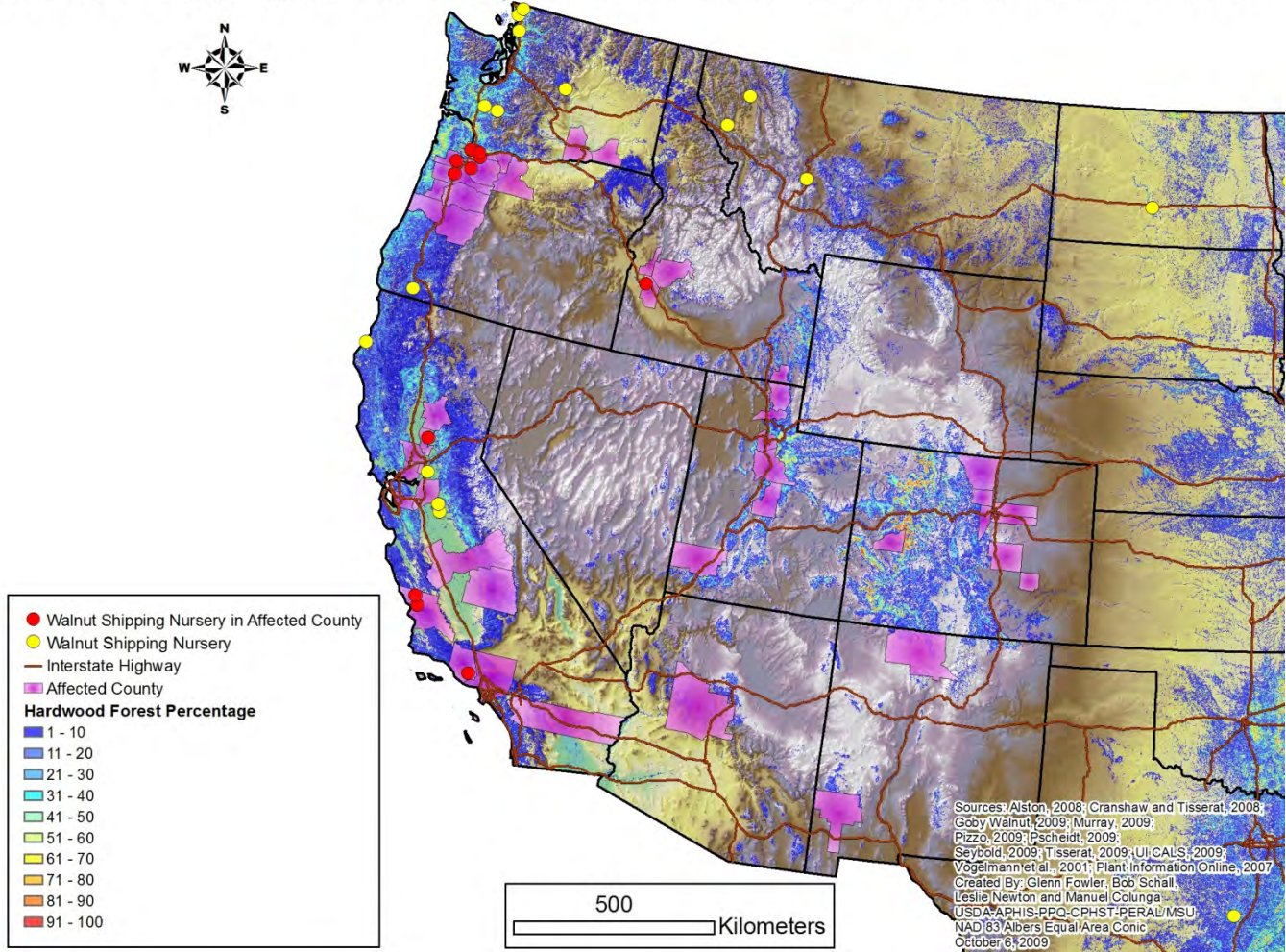


Figure 11. Nurseries that ship walnut species located in TCD affected counties.

E. Scion wood for grafting

For nut production, *Juglans regia* (English walnut) scion wood (cuttings from branch tips) is commonly grafted onto seedling rootstocks. Growers graft the cuttings onto their own rootstock or purchase grafted trees. Typically, nurseries graft seedling rootstocks at the beginning of the second-leaf stage and sell them the following fall (McGranahan, 2002).

Tree breeding operations and individuals interested in cloning superior genotypes utilize bud wood or scion wood to graft onto rootstock. Breeding and selection programs for *J. nigra* are centered at the University of Missouri-Columbia and at Purdue University in West Lafayette, IN (NCGR, 2001). Another example of a walnut breeding facility is IPPFB (a nonprofit organization, ‘Improving Perennial Plants for Food and Bioenergy’) in Richmond, Utah and Dayton, Ohio (Murray, 2008a). The National Clonal Germplasm Repository for walnut species is located in Davis, California. Scion wood is sent from the repository to other breeding facilities and researchers, but scientists in California and Utah are well aware of the potential threat to the east from the movement of infected walnut and have essentially

not shipped walnut scion material for almost two years; the very small amounts that were shipped overseas were checked very carefully to ensure healthy material (Leslie, 2009).

The risk of transmitting TCD via this pathway appears to be low given the awareness of TCD among western walnut breeding operations. However, as with other potential pathways for the movement of TCD, undocumented trade and movement by individuals may increase the risk. There are websites that enable individuals to trade scion wood from various tree species, including walnut (NNGA, 2009). The quantities of material, frequency of trade, and distances shipped are unknown. Outreach activities and education of individuals through growers associations should help garner awareness on the potential spread of the disease through this pathway.

F. Nuts

At this time, nuts are not considered as a likely pathway given that (1) thousand cankers disease is not systemic (Cranshaw and Tisserat, 2009) or a seed-borne pest, and (2) the phloem-feeding vector is unlikely to be attracted to walnuts or walnut husks.

G. Natural Spread

Geosmithia spores surrounding beetle galleries can be moved by wind and water (Kolarik et al., 2008), but thousand cankers disease has been found in western states only in association with walnut twig beetle galleries. This suggests that this pathogen requires a vector to effectively inoculate and establish in a new host tree, but if moved into a different climate with greater access to host material, it may behave differently.

The Great Plains States often serve as a natural barrier for the natural spread of forest pests because of limited host material in the western areas (Figure 12). Although this may help to slow the natural spread of the WTB and TCD into the east, it is important to consider that walnut (native or naturalized) often grows in riparian areas (Baker, 1999). The Platte and Arkansas rivers (Figure 13) could serve as corridors out of Colorado for TCD. Walnut is also planted at homesteads in the plains, which could assist natural spread.

The WTB is estimated to fly one to two miles (NPAG-Archives, 2008). The U.S. west to east wind currents could facilitate longer distance flight and aid its movement east, particularly given its small size.

Given the limited flight distance of WTB and the limited host material in the western areas of the Great Plains States, the approach rate of TCD through natural spread appears to be low. However, surveys along riparian areas in the plains and where walnut is planted may assist in the early detection of TCD and help mitigate its spread east.

Hardwood Forests and TCD Affected Counties

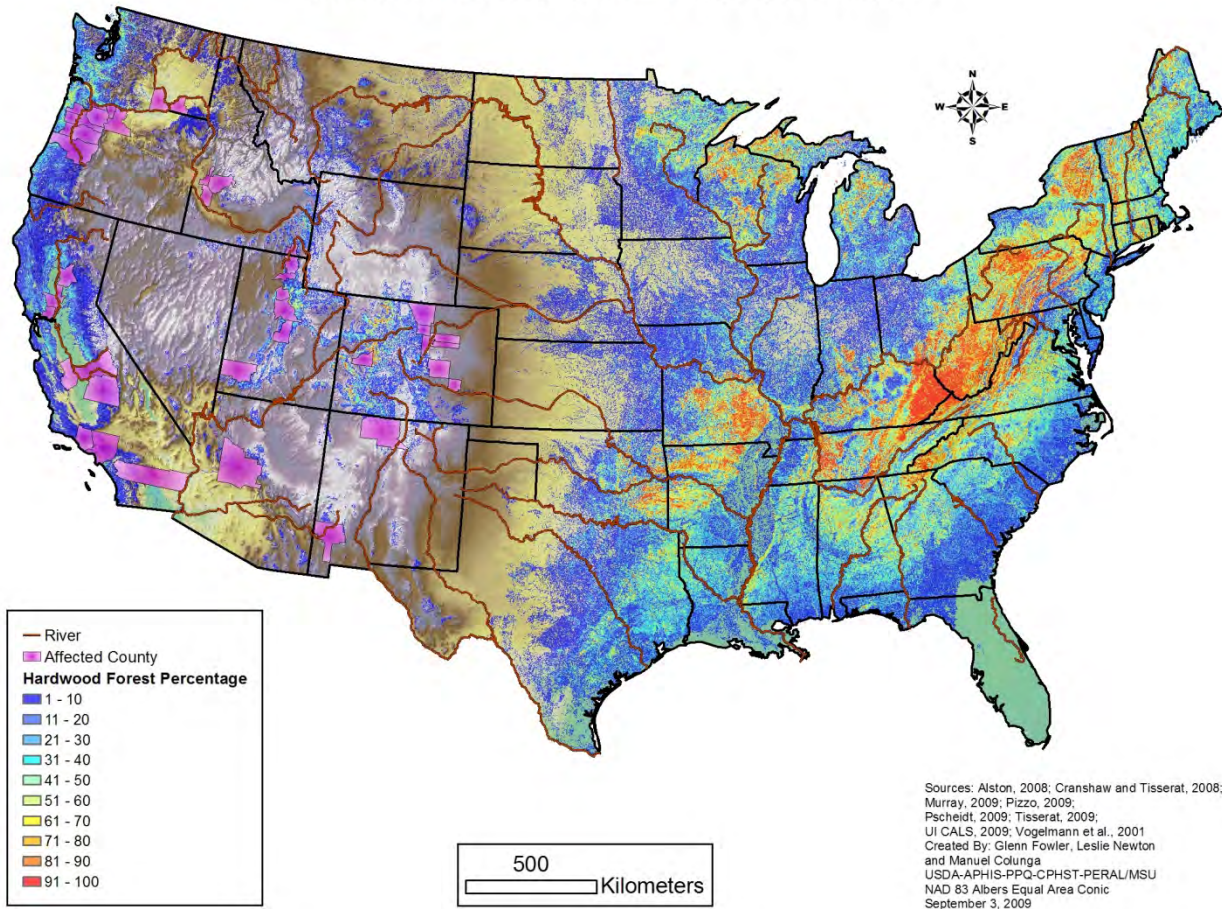


Figure 12. U.S. hardwood forests and TCD affected counties.

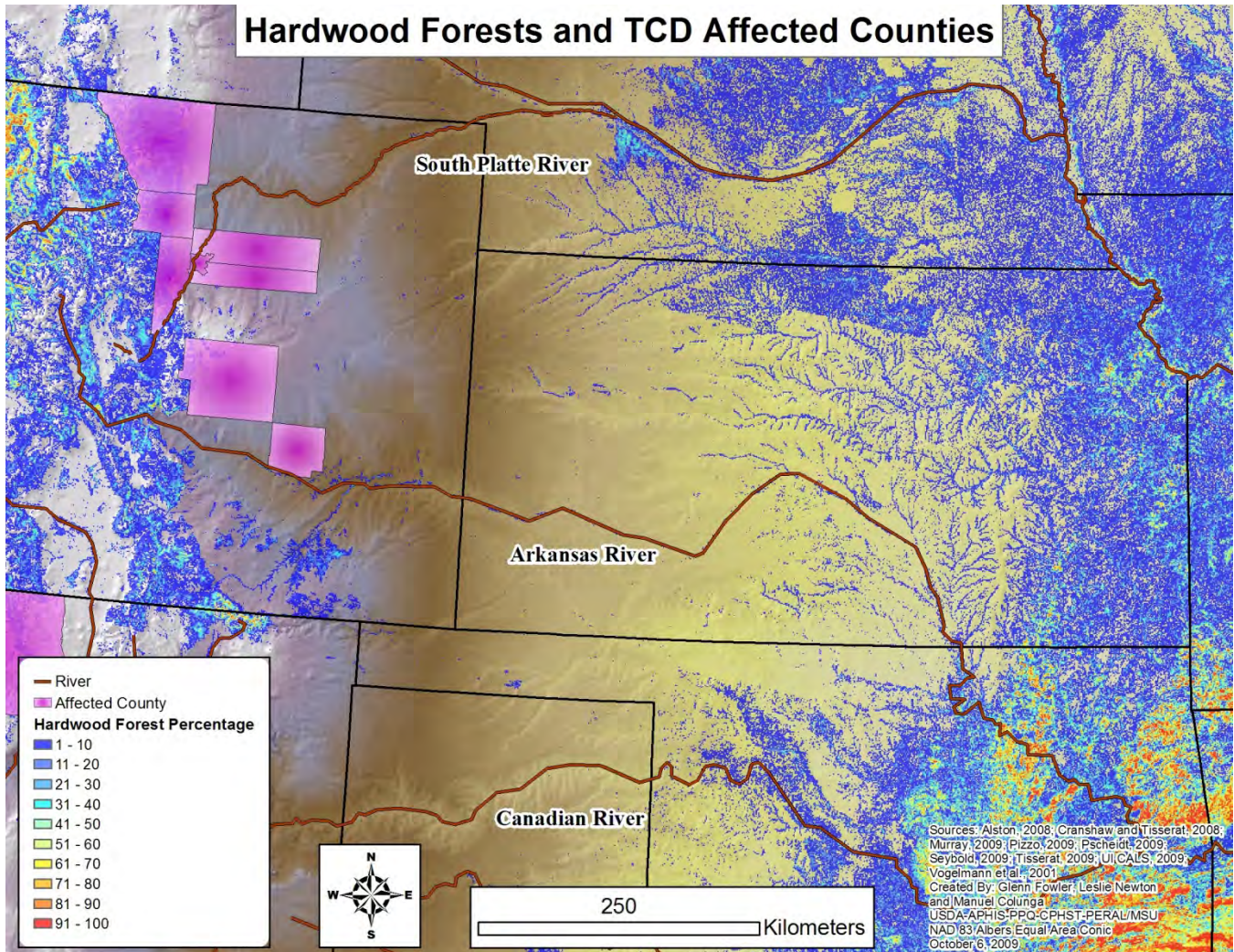


Figure 13. U.S. hardwood forests and potential river corridors across the Great Plains.

V. Possible consequences of introduction of TCD in the east

A. Economic considerations

Juglans nigra and *J. regia* are the two economically important species in the eastern United States. We assumed that *Geosmithia* sp. and its vector can survive throughout the east, and that all walnuts are at risk. We also assumed that any loss of *J. nigra* would negatively impact the following: timber harvesting (very high value per thousand board feet), furniture manufacturing (high value as veneer log), nut production, recreation, nursery stock production, homeowners (removal of trees may be costly), and ecosystems (especially wildlife).

Nut production

Virtually all commercially produced walnut varieties in the United States are hybrids of *J. regia*. Walnuts from *J. nigra* are generally not used for commercial production (Boriss et al., 2006). In 2001, over 216,000 metric tons of walnuts from *J. regia* were produced in the United States (FAS, 2002), compared with only 17,000 metric tons of walnuts from *J. nigra* (Ares and Brauer, 2004). This production level may increase, as research is currently being conducted to develop varieties of *J. nigra* walnuts suitable for commercial walnut production (Hammons et al., 2004).

California supplies approximately 99 percent of the walnuts consumed in the United States (Boriss et al., 2006) and 33 percent of the walnuts consumed worldwide (FAS, 2002). California has over 5,300 walnut growers and about 55 walnut processors (CWB, 2009). According to Crop Values: 2007 Summary (USDA-NASS, 2004), the value of the walnut crop in California was \$563 million in 2006.

The United States is the world's largest exporter of walnuts, with about 35 percent of the U.S. crop destined for exports (Boriss et al., 2006). The annual average value of the U.S. export trade for walnuts (shelled and inshell nuts) is \$373.9 million.

Although nuts represent a growing commodity in black walnut stands, production in the eastern United States is relatively negligible. Nuts are not damaged by TCD, so losses are likely to be due to decreased nut production (from the loss of twigs and branches) and decline or death of the producing tree. Therefore, the direct economic impact (to nut production) of the establishment of *Geosmithia* sp. in the east is not expected to be significant in the near term, although possible future earnings may be impacted.

Lumber and veneer

Black walnuts are highly valued for lumber and veneer (Boriss et al., 2006) and comprise 1.9 percent of the total hardwoods commercially available in the United States (Forest Information Center, 2008). According to the U.S. Forest Service, the net volume of black walnut growing stock on timber land in the United States in 2002 was estimated to be over 3.4 billion cubic feet (USFS, 2002). Using that

number, the estimated value in dollars for the black walnut growing stock in the United States is estimated to be over half a trillion dollars (Table 3). These values do not include walnut species grown in western states.

Table 3. Estimated value of black walnut growing stock in the eastern United States.

Region of black walnut growing stock	Net volume of growing stock on timberland in cubic feet ¹	Conversion from million cubic feet to thousand board feet ²	Lumber grade price No. 2 A ³	Estimated value in dollars for net volume of growing stock in 2002
North	1,125,000,000	205,875,000	\$850	\$174,993,750,000
South	608,000,000	111,264,000	\$850	\$94,574,400,000
East	1,733,000,000	317,139,000	\$850	\$269,568,150,000
Total	3,466,000,000	634,278,000	\$850	\$539,136,300,000

There are several factors which affect the quality and thus the value of walnut trees for lumber and veneer. Bark surface irregularities such as overgrown branch stubs, insect damage or disease, and mechanical wounds will likely disqualify a log as veneer. Other factors being equal, the fewer the defects there are, the more valuable the tree. Additionally, color and uniformity of color in walnut veneer is an important factor in determining value (Cassens, 2004). U.S. hardwood lumber is separated by grades. Top grade lumber is typically used for millwork and veneer, and is also exported. Medium grade lumber goes to furniture, cabinet, flooring, and other manufacturers. Material in the below medium grade area is used as sleepers (railroad ties), mine timbers, pallet parts and flooring (Cassens, 2004). Approximately 12 percent of walnut timber in the eastern United States is in the top grade, approximately 50 percent is in the middle grades, and approximately 38 percent is in the low grade (Dixon and Eves, 1991).

The walnut lumber and veneer industry may have direct and indirect impacts if the *Geosmithia* sp. becomes established in the east. Infected trees may have to be cut down before they have a chance to grow to their optimal size. Additionally, although TCD generally does not impact the cambium of the tree, under heavy infestation it may, which could change the color or quality of the wood.

The establishment of TCD in the east may have a significant impact on U.S. exports of black walnut. Currently, the annual average value of U.S. export trade for walnut wood and wood products is \$325 million (U.S. Bureau of the Census: Foreign Trade Division USA Trade ® Online).

Additionally, the disease may affect natural regeneration of black walnut in native stands, where timber is often harvested.

¹ Source: USDA, Forest Service, Forest Resources of the United States, 2002. General Technical Report NC-241 April

² Calculated as follows: thousand board feet = (Net growing stock cubic feet / 1,000) * 183). Assumes that 1000 board feet (mbf) = approximately 183 cubic feet (range: 160 to 220)

³ Reported for October 2006 by *Hardwood Market Report* (\$ per thousand board feet) MBF one-inch thick (4/4).

Nursery production and ornamental trees

Between 1990 and 1995 more than three million black walnut seedlings were distributed annually by state nurseries in the eastern United States (NCGR, 2001). These trees are planted by landowners for timber and nut production rather than for ornamental purposes. Black walnut is an important agroforestry crop, particularly in Missouri (Reid et al., 2007). Efforts to prevent or control the disease may increase production costs.

More than 400 black walnut cultivars have been named and released during the past century, selected for either nut production or timber (Williams, 1990) and black walnuts are available through nurseries scattered throughout the eastern range (Figure 8). However, it is difficult to estimate the value of horticultural black walnut tree production in the United States. In the U.S. Census of Horticultural Specialties, they are lumped in the category “other deciduous shade trees,” and therefore, specific data on the number of walnut trees sold in the horticultural industry is not readily available.

The establishment of *Geosmithia* sp. in the east is likely to impact ornamental walnut trees. As an example, the total value of black walnut trees affected by TCD on public and private property in Boulder, Colorado, is estimated at nearly \$3 million (Tisserat, 2009).

B. Environmental and social considerations

Black walnut is a small, but important, component in eastern hardwood forests (Figure 14). Black walnut is seldom found in pure stands and is generally found as scattered single trees or as small isolated groups within hardwood stands (Fischer, 1982). Black walnut grows best on moist, deep, fertile, well-drained, loamy soils and is often found in coves, bottomlands, abandoned agricultural fields, and rich woodlands. Nut meats are consumed by people and are an important food source for wildlife. The bark is used medicinally and to make a dark brown or black dye (Michler, 2004).

In addition to timber and commercial nut production, black walnuts provide an important social benefit in some rural areas. In southwestern Missouri, a culture all its own has grown up around a wild crop; generations of families each fall work to gather walnuts on their farms – a field full of fallen wild black walnuts is considered a great source of charity funds or spare holiday gift money and a typical pick-up load of 600 pounds of nuts can yield a nice profit (Clarke, 2000).

The introduction, establishment and spread of the walnut twig beetle and TCD could impact mast for wildlife, and could lower production and increase costs for small family operations such as the example cited above.

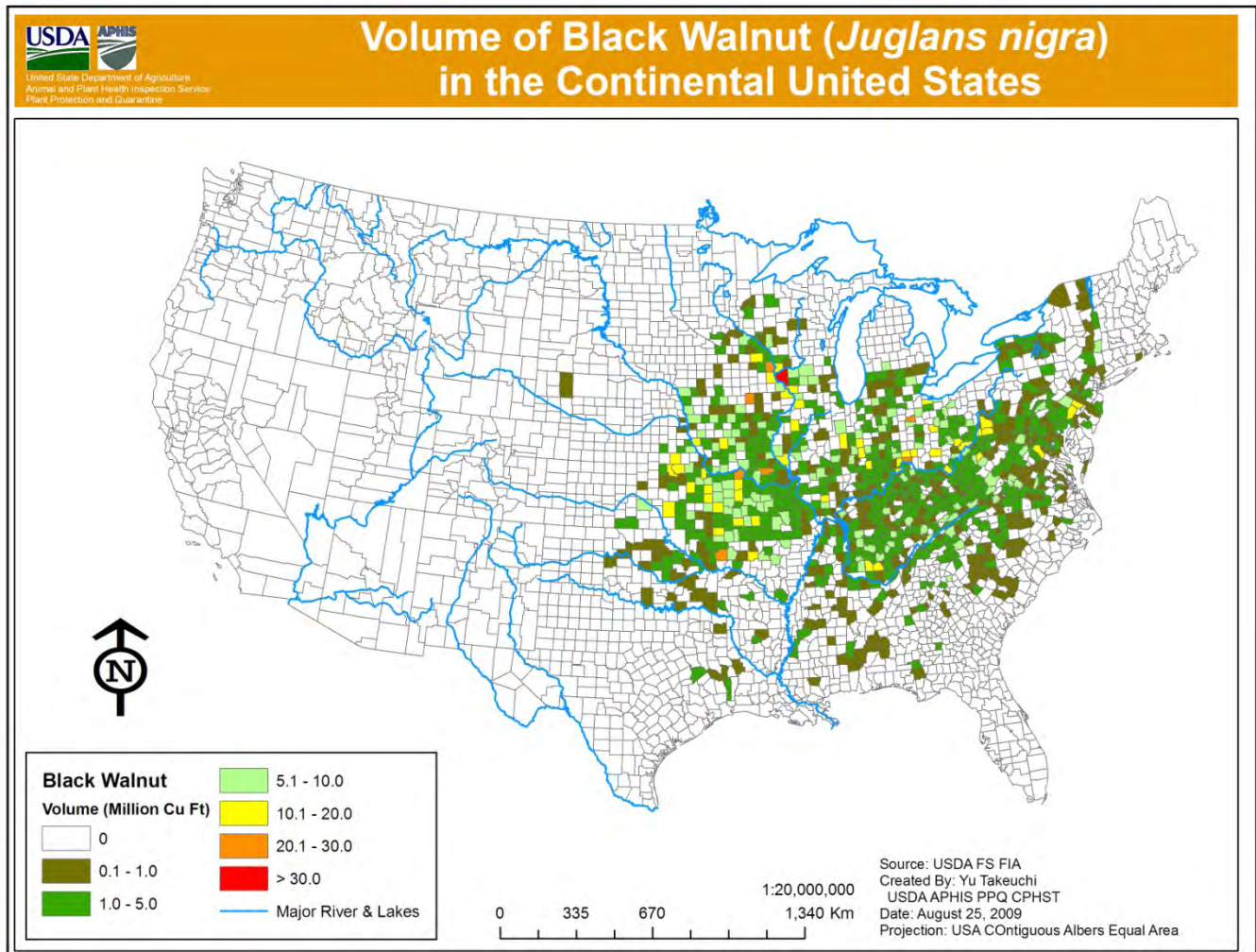


Figure 14. U.S. (native range) black walnut volume (million cubic feet) per county.

VI. Summary and Conclusions

Several species of walnut that grow throughout the United States are hosts to the walnut twig beetle and may vary in susceptibility to *Geosmithia* and thousand cankers disease. *Juglans nigra* and *J. regia* are the primary species in the east considered at risk for infection.

The disease is scattered throughout western states and reports of walnut mortality are occurring simultaneously in areas that are connected by major highways (Figure 1). This distribution along major commerce routes suggests that movement of thousand cankers disease and its vector may be human-assisted.

The pathogen and its vector are likely to move through pathways consistently identified with forest pests: raw wood (logs, sawlogs, burls, stumps, firewood, wood packaging material (WPM)), nursery stock, scion wood for grafting, and by natural spread. We evaluated the potential movement of TCD east

via these pathways utilizing a geographic information system (GIS) approach based on extant information. Our conclusions regarding the approach rate into the eastern United States for each pathway are summarized in Table 4. The approach rate of TCD into the eastern United States is likely to be low but consistent. Specifically, the beetle/pathogen complex is likely to enter the east gradually and in relatively low quantities with each entrance event, as follows:

- Movement of untreated walnut (logs, burls, stumps, firewood) across the country from the west into eastern states appears limited but it does occur and it is rarely documented. Low grade walnut may be utilized in WPM; if bark is attached this could be an important pathway. Raw wood is the most critical pathway.
- Campsites and sawmills in the Great Plains states may facilitate TCD movement eastward (Appendix I).
- To date there have been no reports of infected trees in walnut production nurseries; however, if nurseries do become infected, this could become an important pathway.
- Natural spread along riparian corridors out of Colorado (Platte and Arkansas Rivers) may occur.

Table 4. TCD pathway summary table.

Pathway	Estimated Approach Rate	Justification	Areas of Uncertainty
Timber	Low	Walnut production is very low in the west relative to other species and timber is shipped only rarely from west to east.	Movement (frequency, quantity, distance) of walnut by individuals is unknown.
Firewood	Low to Moderate	There are 18 campgrounds in Kansas and Nebraska that may facilitate movement of TCD into the eastern range of <i>J. nigra</i> . Long distance movement could occur through firewood distributors and long-distance campers as well.	Quantities and frequency of movement are unknown.
WPM	Low to Moderate	WPM accompanies nearly all types of commodities shipped domestically; 1.2 billion pallets are in circulation.	Infested WPM from the west could move; WPM from the east could become infested.
Nursery Stock	Low	There have been no reports of infected nursery stock. Additionally, very few nurseries in at-risk counties ship walnut to the east.	If nursery stock with WTB and TCD were shipped into the east, the potential for establishment may be high.
Scion wood	Low	Walnut breeding programs in the west are well aware of TCD and have altered their practices to prevent spread of the disease.	Individuals trade scion wood via the internet; frequency and quantities are unknown.
Nuts	Negligible	TCD is not systemic and there is no evidence that it can spread into nuts. WTB unlikely to be attracted to nuts or hulls.	There is no published research affirming that <i>Geosmithia</i> sp. is incapable of moving through nuts or hulls.
Natural Spread	Low	WTB is estimated only fly 1-2 miles. Great Plains States may serve as natural barrier due to limited host material. The WTB (with the pathogen) may move along riparian corridors.	Beetle movement could be assisted by wind currents. Density of planted black walnuts in Plains States is unknown. If TCD becomes established in the east, natural spread is likely to increase.

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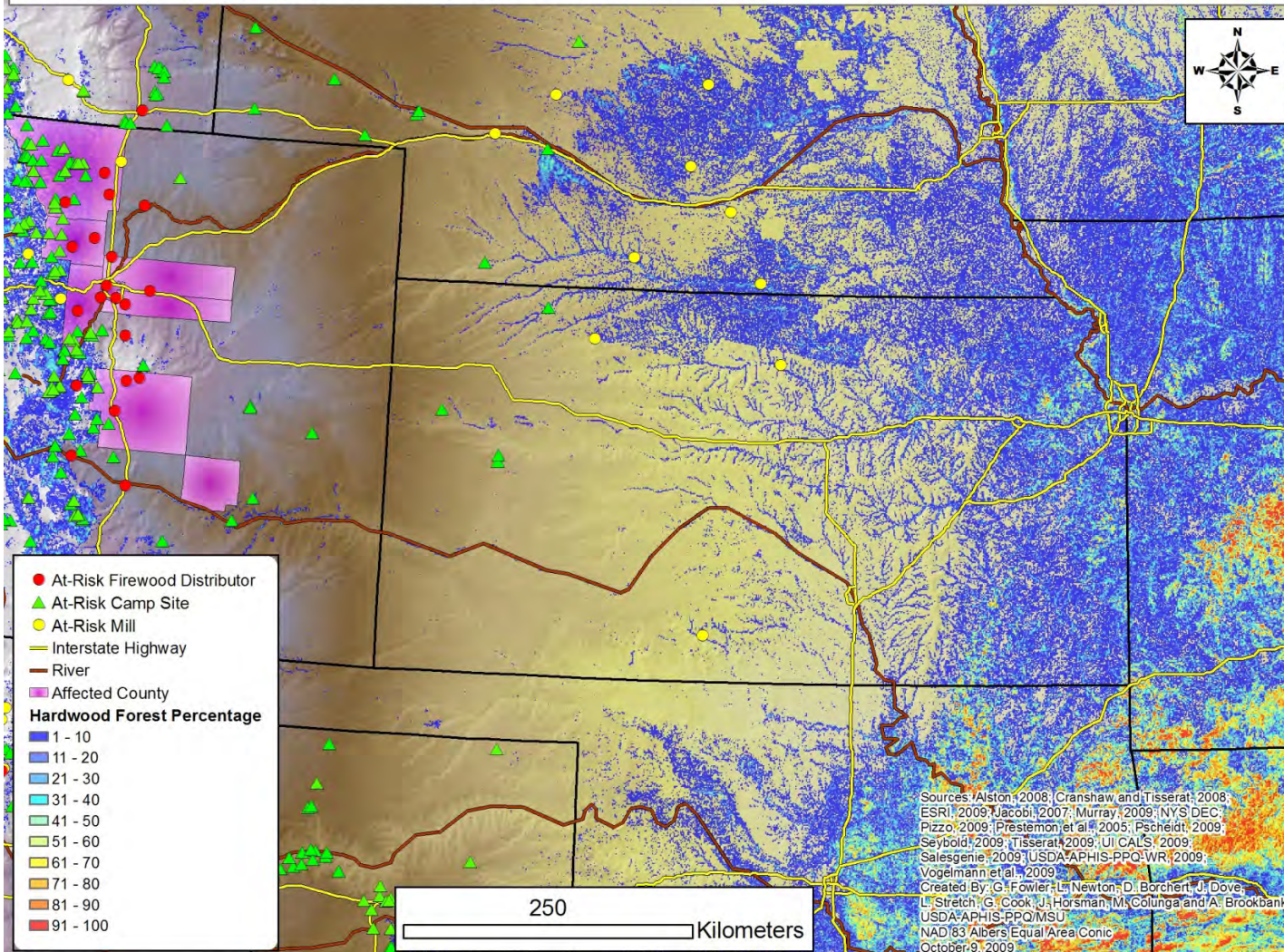
X. Acknowledgements

We would like to express our appreciation to the following individuals: For GIS-related data: Manuel Colunga, Michigan State University; Frank Koch and Bill Smith, USDA Forest Service; and Dan Borchert of USDA APHIS. For their assistance in data collection and updates on the current status of TCD: Ned Tisserat, CSU; Mitch Nelson, Carolyn Pizzo, Tom Culliney, Mikell Tanner, USDA APHIS; Bruce Moltzan, USDA FS; Mark Stirling, CDFA; Chuck Leslie and Steve Seybold, UCA-Davis; Malli Aradhya, USDA ARS NCGR; Tim Ford, IPPFB; Marion Murray and Diane Alston, USU; Jim Hafferty; Todd Morgan, UMT; Jay Pscheidt, OSU. We thank Bob Rabaglia and Bruce Moltzan of the USDA Forest Service; and Heike Meissner, Andrea Lemay and Jim Smith, USDA APHIS for their willingness to serve as reviewers.

XI. Appendices

Appendix 1. Front Range movement of *Geosmithia*.

At-Risk Camp Sites, Firewood Distributors, Mills, Hardwood Forests and TCD Affected Counties



Appendix 2. Internet searches 'walnut logs, burls' – western/central states (August 2009)

Date	Item	Comment	Source	Date Accessed
08/18/09	walnut	(Denver, CO): Walnut \$400. 3 rounds 7' long (10-14" wide). 4th about 3-4' long (14" wide). Smaller diameter wood in lengths. More wood coming	http://denver.craigslist.org	8/21/2009
08/17/09	black walnut trees	(San Francisco Bay, CA): (Napa County): 2 whole black walnut trees - terrific trees 50' fall - \$200...we will cut it down for you and load on your truck...otherwise we will be cutting into firewood for burning and will sell that way...	http://sfbay.craigslist.org	8/21/2009
08/16/09	walnut log	(Portland, OR): Someone must be interested in milling a huge walnut log to make something beautiful; the 80 year old tree just fell down, has a 2 foot diameter trunk; it's in a pasture, you could drive a big truck to it, east of Eugene	http://portland.craigslist.org	8/16/2009
08/14/09	black walnut logs	(Portland, OR): Attention woodworkers...black walnut logs for sale. Make an offer.	http://portland.craigslist.org	8/16/2009
08/13/09	black walnut tree	(Portland, OR): I have a 200 ft tall black walnut tree that I am selling, 5 ft diameter, very old, lots of great straight wood to create stuff with	http://portland.craigslist.org	8/16/2009
08/09/09	walnut log	(Denver, CO): Walnut log \$150. Had to cut down our walnut tree and we are left with some logs the biggest measures approximately 7.5 ft x 17 in diameter. (Arvada)	http://denver.craigslist.org	8/16/2009
08/08/09	black walnut tree trunk	(Oklahoma City, OK): One stump is 112" diameter, 30" long; one trunk is 70" diameter 100" long	http://oklahomacity.craigslist.org	8/16/2009
08/05/09	walnut wood	(Denver, CO): We have a pile of walnut wood (sturdy beautiful hardwood) that could possibly be milled and or just cut directly for furniture making, art, etc. Please come pick up! All we ask is a couple of six packs of delicious microbrew in trade...	http://denver.craigslist.org	8/16/2009
08/03/09	walnut logs	(St. Louis, MO): Six beautiful walnut logs for sale. They are 10 feet long and more than 20 inches in diameter. Other logs are eight feet long and about 15 inches in diameter. Make an offer. Will ship if needed with added cost.	http://stlouis.craiglist.org	8/16/2009
08/02/09	walnut logs	(Kansas City, KS): Walnut logs \$300. Two walnut logs for sale...logs are approx. 14-16 feet in length; first log 7 feet around and 2 feet in diameter; second log is 4 feet around and 1 foot in diameter (Leawood)	http://kansascity.craigslist.org	8/16/2009
07/31/09	walnut logs	(Modesto, CA): Walnut logs for sale \$150. Two black walnut trunks that were cut last week. The larger one is 30" in diameter and about 55" long, the smaller is 20" in diameter and is 60" long (Ceres, CA)	http://modesto.craigslist.org	8/16/2009

Date	Item	Comment	Source	Date Accessed
07/30/09	large black walnut trees	(Sacramento, CA): Wanted to buy***large black walnut trees***top \$ paid -- We buy large black walnut trees anywhere in central or northern California	www.classifiedads.com	8/24/2009
07/29/09	walnut trees	(Omaha, NB): Wanted: walnut trees top prices paid (Eastern NE, Western IA); Do you own timberland? If so, you may have walnut trees that are ready to be harvested...	http://omaha.craigslist.org	8/16/2009
07/27/09	walnut tree	(Kansas City, KS): 8-1/2 feet around and 22 feet log (Independence, MO)	http://kansascity.craigslist.org	8/16/2009
07/26/09	walnut tree	(Parkville, MO): Walnut tree about 4 ft around 18 inches in diameter and 30 feet tall; free to anyone qualified to take down (Parkville, MO)	http://kansascity.craigslist.org	8/16/2009
07/21/09	walnut logs	(Fayetteville, AR): Free walnut and misc wood logs - I have some wood logs, misc wood and walnut. Must take all. Some very big and heavy...	http://fayar.craigslist.org	8/16/2009
07/13/09	walnut burl	(Merced, CA): Old walnut tree. Burl may or may not be good. Must be equipt to take out the tree and burl.	www.forfarmers.com	8/24/2009
07/11/09	black walnut stumps	(Gaston, OR): Black walnut stumps, ready for milling into gun stocks - \$400	portland.craigslist.org	7/12/09
07/08/09	black walnut	Straight and mature black walnut tree; Denver area; 23" diameter with main trunk of approximately 17 feet; no visible nails or other flaws - We are planning on removing a large black walnut tree which has recently died from our yard; the tree is very straight and has a large main trunk; we are willing to be very reasonable on the price.	www.agriseek.com/market/	8/8/2009
05/21/09	black walnut burl & trunk	(Oroville, CA): Request for quotations - Project involves the purchase of 1 black walnut tree burl (approx. 6 feet in diameter) including stump and roots...and 1 black walnut tree trunk section (approx. 6 feet long)...	County of Butte, Department of Public Works - Oroville, CA	8/24/2009
05/14/09	walnut burl	(Denair, CA): Walnut burl for sale that is very large and heavy first reasonable offer will be accepted. I removed a walnut tree from my back yard and dug up the burl so now it is sitting here waiting for someone that wants it. It is pretty big and heavy so bring help to load it.	www.forfarmers.com	8/24/2009
05/02/09	walnut burl	(Auburn, CA): I have two outstanding burls that I would like to sell. they are not dug out yet. The smaller of the two measures approx. 24" in dia. and the larger is approx. 34" x 36" and is 24" above ground level. Very nice indeed!	www.forfarmers.com	8/24/2009

Date	Item	Comment	Source	Date Accessed
04/30/09	black walnut burl wood	(Sacramento, CA): Seeking interested buyers for the purchase of burl wood. Black walnut making up the majority of selection of burl for sale... Various array of selection available, ranging from: raw rounds, pre-cut symmetrical blocks...actual root round in their entirety, etc. All wax coated of coarse.	www.forfarmers.com	8/24/2009
04/27/09	black walnut trees	(Liberty Lake, WA): Three large 150-200 year old black walnut trees for sale...Dimensions are 59 inches in diameter, 32 inches in diameter, and 37 inches in diameter...Great for furniture, gun stocks, flooring, etc....	www.forfarmers.com	8/24/2009
04/23/09	claro walnut logs	High grade claro walnut logs - 3' 20" diameters, available immediately, located in northern CA	www.woodplanet.com	8/11/2009
12/13/08	black walnut	(Yuba City, CA): I have just taken out a dozen large trees, about 30 years old huge trunks but some have pest problems (that's the main reason for taken them out. Asking price is market range. Our organic orchard is off Hwy 99...	www.forfarmers.com	8/24/2009
10/09/08	black walnut trees	(Grizzly Flat, CA): Very old black walnut trees available for sale including burl. Still live and appear to be healthy...There are several smaller trees 20"+ diameter plus one very large tree that should have a beautiful burl and is approx. 4-5 feet in diameter...	www.forfarmers.com	8/24/2009
09/17/08	black walnut burls	(Beaverton, OR): Taking out large number of walnut trees, many with burl roots. At least 10% have veneer grade burls. We have available large number of black walnut burls from removal of walnut farm in Oregon. Mill is on site for custom milling, or will sell whole burls. Price will depend on quantity, and quality desired.	www.forfarmers.com	8/24/2009
07/02/08	California black walnut logs	200,000 lbs+ of black walnut logs; most are 4-6' long, 30" in diameter; trees were pulled in Nov '07 - Feb '08	www.b2bfreezone.com	8/11/2009
05/09/08	claro walnut logs	I have 100,000 lbs of claro walnut logs for sale near Santa Rosa...California prices start at .50 per pound; many logs over 40 inches in diameter...	http://lumberjocks.com	8/9/2009
04/20/08	claro walnut logs	100,000 lbs of walnut logs available in Healdsburg, CA; logs up to 20 ft clear some large diameter logs available	www.b2bfreezone.com	8/11/2009
02/19/08	black walnut burl wood	(Fresno, CA): Black walnut burl wood located in Visalia, CA. Also black walnut burl butt logs available. Over 300 black walnut burls available along with black walnut burl butt logs with excellent color and figure, great for flooring, gunstocks. lumber, general woodworking applications.	www.forfarmers.com	8/24/2009

Date	Item	Comment	Source	Date Accessed
01/23/08	walnut burl and logs	California grown black walnut, high graft 70 yr old orchard, trees were dug out and not bulldozed, over 100 in the 20-36 inch diameter with logs to the first branch, 4-8 foot; lots of burl and pin-stock	www.b2bfreezone.com	8/11/2009
01/21/08	claro walnut stumps	(Dunneville, CA): I have caro walnut stumps connected to the high graft log, 20-36" diameter and 4-8' length, dug out not bulldozed. Burl figured wood. These stumps with log are from a 70 year old orchard, well maintained...the stumps are connected to the main trunk of the trees, most have a 6 foot log, prior to the graft and forked branches.	www.forfarmers.com	8/24/2009
11/08/07	black walnut burl	(Roseville, CA): Want to sell black walnut burl aprox. size 54" dia. 4' ht. This burl is approx. 45 years old. I got this burl out of a walnut orchard in northern California black walnut with an English walnut graft.	www.forfarmers.com	8/24/2009
?	claro walnut logs	I have 150,000 lbs of these logs ready for shipment 24-40 inch diameters and lengths up to 20 feet	www.alibaba.com	8/11/2009

Appendix 3. Internet searches ‘walnut firewood’ – western/central states July/August 2009

Date	Item	Comment	Source	Date Accessed
7/7/2009	firewood	(Guthrie, OK): I have about 400 cords for sale, white (post) oak, pecan, ... black walnut,.... \$100 per cord, pick up. Call for delivery price. Seasoned firewood has been seasoned around a year, green firewood is a month or two old or freshly cut...	okalahomacity.craigslist.org	7/12/2009
7/9/2009	firewood	(Wheat Ridge, CO): Take down and remove black walnut trees for firewood or furniture	denver.craiglist.org	7/12/2009
7/10/2009	black walnut firewood	(Sacramento, CA): Dry black walnut firewood - free - come pick it up - you load it, it's yours for free.	sacramento.craigslist.org	7/12/2009
7/11/2009	firewood	(Council Bluffs/Omaha, NE): Firewood for sale. Awesome for backyard firepits, campers, or stockpile...Mixed hardwoods of various species of ash, walnut, maple...	omaha.craigslist.org	7/12/2009
7/11/2009	firewood	(Council Bluffs/ Omaha, NE): Firewood for sale \$150 a cord. All wood is ash, elm, mulberry, oak and walnut.	omaha.craigslist.org	7/12/2009
7/12/2009	walnut firewood	(Hillsboro, OR): Walnut firewood - \$200 cord	portland.craigslist.org	7/12/2009
7/12/2009	bundled firewood	(Oklahoma City, OK): Bundled firewood for campfires and smokers \$5. I have oak, pecan, and walnut bundled up for \$5 and hickory bundles for \$8, I also sell firewood by the rick and cord... We will be at different lakes on the weekends.	okalahomacity.craigslist.org	7/12/2009
7/26/2009	lots free firewood	(Kansas City, KS): Had 5 trees fall in my yard: 1 walnut, 2 hickories, and 2 oaks. You cut them up and stack the brush in a burn pile...free.	kansascity.craigslist.org	8/16/2009
7/28/2009	firewood	(Pea Ridge, AR): Seasoned walnut	fayar.craigslist.org	8/16/2009
7/28/2009	bl. walnut firewood	(Bakersfield, CA): I just paid to have an 80 -year-old, dead black walnut cut down. There is at least 6 cords...It is dry and ready to cut/split and put in the fireplace. The first \$700 takes it all.	bakersfield.craigslist.org	8/24/2009
7/29/2009	bundled firewood	(Oklahoma City, OK): I have bundled up firewood.. I have oak, pecan, and walnut bundled up for \$5 and hickory bundles for \$8.	oklahomacity.craigslist.org	8/16/2009
8/3/2009	firewood	(Oklahoma City, OK): I have walnut, pecan, oak, ... It's \$60 a rick or \$120 a cord. Prices vary for wood delivered into your backyard...	oklahomacity.craigslist.org	8/16/2009

Date	Item	Comment	Source	Date Accessed
8/7/2009	firewood	(Omaha/Council Bluffs, NE): Firewood for sale. Mixed hardwoods of various species: ash, walnut, maple, elm, hackberry, mulberry, and locust.	omaha.craigslist.org	8/16/2009
8/7/2009	free tree limbs	(Lee's Summit, KS): I have a huge pile of tree trimmings on the driveway behind my house and would like to give them to someone...a few of the limbs are from a walnut tree..	kansascity.craigslist.org	8/16/2009
8/7/2009	firewood for sale	(Raytown, KS): Mixed firewood for sale from locust, hedge, walnut, ... Depending on the location, I haul the wood...Also, if you have some trees that you would like cut down or hauled away, I can do this for you.	kansascity.craigslist.org	8/16/2009
8/10/2009	firewood	(Omaha/Council Bluffs, NE): Firewood for sale. Mixed hardwoods of of various species: ash, walnut, maple, elm, hackberry, mulberry, and locust.	omaha.craigslist.org	8/16/2009
8/10/2009	firewood for sale	(Western Iowa): This firewood comes straight from the Midwest. Ash, walnut, oak, ...kentucky coffee bean, elm, and more. We can deliver straight to your door, summer home, camper, business, or wherever you want it! Delivery is a three cord minimum. Firewood is located in western Iowa. P. S. I am looking for brokers to sell this firewood!	omaha.craigslist.org	8/16/2009
8/11/2009	firewood by truckload	(Auburn, CA (Sacramento): Unseasoned oak \$50 a truckload. Looking for oak, mulberry, Modesto ash, maple, almond and walnut wood.	sacramento.craigslist.org	8/16/2009
8/12/2009	firewood	(Dixon, CA (Sacramento): Red eucalyptus is \$260 cord...Poplar 1/2 cord \$90 and some unseasoned black walnut for \$220 a cord. You can pick up or we can deliver (free locally).	sacramento.craigslist.org	8/16/2009
8/12/2009	wanted firewood	(Siloam Springs, AR): Firewood oak/walnut wanted	fayar.craigslist.org	8/16/2009
8/12/2009	free firewood	(Glodsby, OK): Lots of downed trees..oak, pecan, walnut, elm, all kinds...free	oklahomacity.craigslist.org	8/16/2009
8/12/2009	wood for sale	(Banks, OR (Portland): Wood for sale. Black walnut \$225 per cord	portland.craigslist.org	8/16/2009
8/12/2009	firewood special	(Hillsboro, OR (Portland): Firewood \$150 per cord, \$25 delivery to local area. I have alder, plum, and walnut.	portland.craigslist.org	8/16/2009
8/14/2009	firewood/walnut	(Wheatland, CA): Walnut \$175, price is per cord, \$25 delivery in Sacramento.	sacramento.craigslist.org	8/16/2009

Date	Item	Comment	Source	Date Accessed
8/14/2009	firewood by truckload	(Sacramento, CA): Seasoned firewood, locust, oak, and walnut. If you pickup, \$50 for unsplit wood. If you pick up, \$85 for split wood. Add \$50 if I deliver within 50 miles of 95605.	sacramento.craigslist.org	8/16/2009
8/15/2009	firewood	(Aptos/Rio del Mar/Santa Cruz, CA (San Francisco)): Hardwoods (to keep your house warm) such as white oak,...dark and English walnut...We also have 1/2 cords of oak \$165..., almond \$160, cherry \$150, eucalyptus \$150, and walnut \$150.	sfbay.craigslist.org	8/16/2009
8/15/2009	firewood	(Independence, KS): Firewood is on the curb today. I believe the wood is walnut.	kansascity.craigslist.org	8/16/2009
8/16/2009	firewood	(San Francisco, CA): Dry almond firewood, walnut firewood - \$80. \$175 1/2 cord, \$350 full cord.	sfbay.craigslist.org	8/16/2009
8/16/2009	quality firewood	(Auburn to Tahoe, CA (Sacramento): Full cords: Some delivery might require a \$20 to \$50, depending on area. Oak \$320. Almond \$320. Walnut \$320.	sacramento.craigslist.org	8/16/2009
8/17/2009	walnut firewood	(Tehachapi, CA): Taking orders for walnut firewood. Price depends on quantity, it's ready to burn.	bakersfield.craigslist.org	8/24/2009
8/17/2009	fire wood for sale	(Paradise, CA): \$35. Walnut and liquidambar wood for sale. Half cord, plus or minus...	chico.craigslist.org	8/24/2009
8/17/2009	black walnut firewood	(Napa County, CA): Huge pile..\$200...about a pickup load and another half a pick up load - you come and get it.	sfbay.craigslist.org	8/21/2009
8/17/2009	firewood	(San Francisco Bay area, CA): Delivered daily firewood. Free delivery and stacking most areas. Walnut \$175 1/2 cord.	sfbay.craigslist.org	8/21/2009
8/18/2009	black walnut firewood	(Sacramento, CA): Seasoned black walnut firewood. Not split. Only \$50 per 1/2 cord...	sacramento.craigslist.org	8/21/2009
8/19/2009	firewood	(San Francisco, CA): Hardwoods such as white oak,...dark and English walnut...We also have 1/2 cords of oak \$165, almond \$160, cherry \$150, eucalyptus \$150, and walnut \$150.	sfbay.craigslist.org	8/21/2009
8/19/2009	mixed firewood	(Santa Rosa, CA): Split live oak,... madrone, eucalyptus, and walnut, seasoned and green, full and half cords available. Free delivery. Full cord \$250. Half cord \$125.	sfbay.craigslist.org	8/21/2009

Date	Item	Comment	Source	Date Accessed
8/20/2009	firewood	(Dixon, CA): Red eucalyptus is \$260 cord...Poplar 1/2 cord \$90 and some unseasoned black walnut for \$220 a cord. You can pick up or we can deliver (free locally).	sacramento.craigslist.org	8/21/2009
8/20/2009	firewood	(Lebanon, OR): I have two cords of walnut and a little bit of redwood mixed...\$150 cord	corvallis.craigslist.org	8/21/2009
8/21/2009	firewood	(Orangevale, CA): Oak firewood \$349, eucalyptus \$349, black walnut or English walnut \$349: these are all premium hardwoods in separate piles.	sacramento.craigslist.org	8/21/2009