Reconstruction of the Historical Composition and Structure of Forests in the Middle Applegate Area, Oregon, using the General Land Office Surveys, and Implications for the Pilot Joe Project

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Introduction

The Middle Applegate area of southwestern Oregon has been the site of collaboration to restore forests and watershed health (http://www.applegatepartnership.org), and part of the area is now the site of a pilot area (USDI BLM 2011) to demonstrate proposed methods for combining logging and forest restoration (Johnson and Franklin 2009). Here I present information from the original late-19th century surveys about historical forest structure in the Middle Applegate and discuss its relevance to the proposed Pilot Joe project (USDI BLM 2011).

Projects, such as Pilot Joe, that seek to restore ecosystems, require reference information about the state of the ecosystem and landscape prior to the land uses that are the reason restoration is needed. Johnson and Franklin (2009), which is the foundation for the Pilot Joe project (USDI BLM 2011) discuss land-use changes that occurred in dry forests, which they say "have been drastically modified by human activities" (p. 5), they identify the attributes that they suggest these forests had before modification (based on reference information), and they then suggest how to restore those attributes. They identify the importance of reference information to restoration, suggesting a goal should be to "restore characteristic forest structures" (p. 11) and they identify how to do this: "we begin with the principle of using plant associations and historical landscape analysis as a basis for management" (p. 11).

However, the proposed Pilot Joe project (USDI BLM 2011) does not present new and detailed historical landscape analysis specific to the project area, but instead summaries from past BLM analyses supplemented by general ideas about how dry forests have changed, largely from Johnson and Franklin (2009). Here are some of the BLM summaries: (1) "historically, forest stands had fewer trees per acre, trees of larger diameter, and a different species composition because of the more open conditions" (p. 3-3 to 3-4), (2) "frequent, low intensity fires served as a thinning mechanism, thereby, naturally regulating the density of the forests. A more open crown structure would have allowed fire to travel more rapidly across the site with intensities that were short-lived" (p. 3-18), and (3) "forested stands in the Analysis Area have become predisposed to stand replacing fires and disease epidemics" (p. 3-11). Central to the proposed project is the idea that fire exclusion has allowed stands to become denser, Douglas-fir to encroach, and led fire-tolerant trees (pines) to decline. Here is the explanation from USDI BLM (2011):

> "the absence of fire has converted open savannahs and grasslands to hardwood woodlands and initiated the recruitment of conifers. As hardwoods and shrubs encroach into open savannahs and grasslands, over time, shade tolerant conifers begin proliferating through the understory converting the site to a mixed hardwood/conifer woodland condition. As a result, Oregon white oak is now a declining species largely due to fire suppression and encroachment by Douglas-fir on most sites" (p. 3-5).

Similarly, pine forests are thought to have declined due to fire suppression:

> "Conversions from pine to fir are also evident and occur in the same sequence as the conversion from hardwoods to conifers. The conversion from pine to fir has created stands that are stressed. These non-vigorous conifers become susceptible to insect and disease mortality or prematurely die off due to overstocked conditions. The absence of fire due to suppression efforts has changed the forest composition from a fire dependent ecosystem to a densely forested fire intolerant condition. Shade-tolerant conifers have decreased the numbers of ponderosa pine, Oregon white oak, and sugar pine" (p. 3-5).

These ideas are generally consistent with broader concepts about how dry forests have changed that are explained in Johnson and Franklin (2009). For example, these authors suggest that:

"Compared to historical conditions, current conditions generally have: 1) much lower population levels of old fire-resistant trees, such as ponderosa pine, 2) more forests with multiple canopy layers and high stem densities, 3) more continuously and densely forested landscapes with continuous and high surface and ladder fuel levels, and, consequently, 4) forests and landscapes that are highly susceptible to loss from stand-replacement wildfire or insect outbreaks." (p. 28).

To expand the available historical landscape analysis that Johnson and Franklin (2009) suggest provides the reference information that is the essential foundation for restoration actions, here I present a new historical reconstruction of detailed forest conditions in the last half of the 1800s in the Middle Applegate watershed. This new information, however, is compatible with previous scientific analyses of the Applegate area and similar nearby areas (e.g., Detling 1961, Odion et al. 2004, 2010, Hosten et al. 2007, Colombaroli and Gavin 2010) that suggest the reference framework in Johnson and Franklin (2009) and USDI BLM (2011) is not correct and would not generally lead to restoration relative to historical conditions in the Applegate landscape. Moreover, I show that proposals for actions to increase the resistance and resilience of the Applegate landscape to future climate change are also mis-directed, because they are based on this incorrect reference framework.

Methods

The new historical information comes from the General Land Office (GLO) surveys, typically conducted in the late-1800s, which contain observations of vegetation composition and structure, often prior to widespread land-use changes accompanying EuroAmerican settlement. Surveyors recorded the distance, bearing, diameter, and species of two "witness" trees at quarter corners (1/2 mile along 1-mile section lines) and four trees at section corners. At the end of each section line, they also summarized the type of vegetation, including major shrubs and small trees found along the line, listed in order of abundance, and often with qualitative descriptions of density (e.g., "dense," "scattered"). Witness-tree and section-line data can be used to reconstruct some major components of forest structure (e.g., tree density, size-class structure) and characteristics of the vegetation. The GLO data have been used in interpreting vegetation in this general area (Hosten et al. 2007). Of course, reconstructions from surveyor data provide information about vegetation across landscapes at only a single period in time, but this information is certainly valuable in understanding the fuller historical range of variability of ecosystems. Survey-based reconstruction is likely the only source of information that is potentially spatially comprehensive and detailed across large land areas prior to widespread EuroAmerican land uses (Williams and Baker 2011).

We have recently developed new methods to reconstruct tree density, tree-species composition, stand basal area, and diameter distributions (e.g., Figure 1) with reasonable accuracy (i.e., within 20-25% of true values), as well as understory vegetation, across dry forests in the West from the GLO data. Details of the new methods are in Williams and Baker (2011). We have also shown that surveyors generally chose witness trees with very little bias, so witness-tree data represent a valid statistical sample of the trees present at the time of the surveys (Williams and Baker 2010).

Here I present a reconstruction of forest structure and vegetation in the Middle Applegate area in the last half of the 1800s using these data and the new methods. The reconstruction (Figure 1) is for about 4.5 townships (46,445 ha or 114, 719 acres). The boundaries do not quite correspond with a watershed area that is part of the focus of the Applegate Partnership, and includes the Pilot Joe area. About 2/3 of the 4.5 township area was surveyed in A.D. 1854-1857, another 1/3 in A.D. 1872-1896, and a few small parts not until A.D. 1910. Some sections in the western half of township T39S R3W were not surveyed until later, and earlier data were simply extrapolated across the missing areas. Data are only for forested areas; for simplicity non-forested valleys are not mapped and removed from the polygons. Two white polygons (Figure 1) do represent openings recorded by the surveyors.

Surveyors identified the major tree species in the study area by common names (Table 1), but not always beyond the genus level. For example, it is likely that a very large fraction of what the surveyors called “PINE” was ponderosa pine (*Pinus ponderosa*), although the PINE name likely also includes some sugar pine (*Pinus lambertiana*) and perhaps a few knobcone pine (*Pinus attenuata*). For shrubs, surveyors sometimes individually used different common names for the same shrub (Table 2). For example, *C. cuneatus* was called buck brush, chaparral, and greasewood by different surveyors in this area. To translate surveyor common names for species into scientific names (Tables 1 and 2), I visited about 30-40 section corners and section lines in the Applegate study area where species with unidentified common names were dominant or where they were co-dominant with a known shrub.

To do the reconstructions, I used pooled crown radius and Voronoi equations (Williams and Baker 2011) developed nearby for most of the same tree species in dry forests of the eastern Cascades of Oregon, with the exception of equations for oaks developed from field work in the Applegate study area. I assumed madrone and the oaks had similar crown radius and Voronoi relationships. Crown radius and Voronoi relationships are typically similar across large land areas (Williams and Baker 2011). The Eastern Cascade equations were shown through validation with plot data in the eastern Cascades (Baker, in prep.) to lead to reconstruction accuracies similar to those published in a more extensive validation study (Williams and Baker 2011). The reconstructions use the mean-based harmonic Voronoi (MHVD) estimator for tree density, which was shown to be the most accurate estimator in the Blue Mountains, Oregon (Williams and Baker 2011) and also in our eastern Cascades study area (Baker, in prep.). For basal area, I used the PCQ method, which was the most accurate estimator (Williams and Baker 2011). To simplify patterns in diameter and composition reconstructions, I classified reconstructed diameter distributions for madrone, oaks, firs, and pines (omitting minor trees) into 4 groups using complete linkage cluster analysis with Euclidean distance.

The dataset contains information for 1,247 trees recorded at 469 section corners and quarter corners in the 4.5 township area, plus about 300 miles of section-line descriptions, which include 324 individual segments that were described. Section-corner data must be pooled to achieve reasonable accuracy (Williams and Baker 2011), and density is thus reconstructed for 155 three-corner pools (each about 259 ha) and 77 six-corner pools (each about 518 ha), basal area for 51 nine-corner pools (each about 777 ha), and diameter distributions for 38 twelve-corner pools (each about 1036 ha). Only the 3-corner density reconstruction is presented here, as the 6-corner reconstruction is quite similar, but shows less detail. The 3-, 6-corner pooling levels have about 29% and 20-23% relative mean absolute error (RMAE), respectively, for density; the 9-corner pooling level has about 23% RMAE for basal area; diameter distributions at the 12-corner pooling level are about 87% accurate (Williams and Baker 2011). These levels of accuracy are almost as high as can be achieved with detailed tree-ring reconstructions (Williams and Baker 2011), and do not suffer from the problem of evidence disappearing over the last century, which precludes the use of tree-ring methods in landscapes, such as the Applegate, where logging and thinning were widespread. The witness-tree data are somewhat sparse, but systematic and comprehensive, providing much more detailed data than programs such as the U.S. Weather Bureau station network or the U.S. Forest Service’s Forest Inventory and Analysis Program (http://www.fia.fs.fed.us). The reconstructions, however, do not provide information at the level of within-stand variability (e.g., variability across 100-200 m areas in a forest stand), as the finest resolution is at the level of about 1 square mile (about 259 ha).

Results

Historical tree density varied substantially across the study area (Figure 1). Readers more familiar with acres can translate these numbers to trees/acre by multiplying by 0.405. The tree-density variation included some areas of open, low-density forests with < 150 trees/ha and large areas with tree density that was very high (350-590 trees/ha). However, much of the landscape was not “open,” having 150-350 trees/ha (Figure 1). Across the 155 three-corner polygons, mean tree density was 272 trees/ha and median density was 253 trees/ha. The first quartile (each quartile is about 39 of the 155 polygons) was 66-191 trees/ha, the second quartile was 191-253 trees/ha, the third quartile was 253-321 trees/ha and the fourth quartile was 321-590 trees/ha. In general, tree density was lower in the more northern half of the study area where pines were more common and higher in the more southern half of the study area where firs were more common.

Historical basal area, which is the cross-sectional area of tree stems summed across an area, also varied substantially, over a 4-8 fold range across the study area (Figure 2). Readers familiar with basal area expressed as square feet per acre can translate these numbers by multiplying them by 4.35. Basal areas of 30-80 m^2/ha (about 130-350 ft^2/ac) occurred in the southwestern and northwestern portions of the study area, often where firs dominated. Pine- and oak-dominated areas had lower basal areas, often between 10-30 m^2/ha (Figure 2).

Cluster analysis of diameter distributions revealed four groups (Figures 3, 4). Note that the groups include the sum of trees across the polygons that belong in the group, but there are different numbers of polygons in the groups, so the absolute numbers of trees cannot be compared among groups; only the relative amounts of each species within a group can be compared (e.g., both Group 1 and 2 have more abundant madrones than oaks). Groups 1 and 2, which occurred in the southwestern and northeastern parts of the study area (Figure 3), had more firs than pines and also had few oaks and higher tree density and basal area than Groups 3 and 4. Groups 3 and 4, which occurred from the northwestern to the southeastern parts of the study area (Figure 3), had more pines than firs but also had abundant oaks. Group 1 was characterized by firs of various sizes, including large trees, few pines, and only small oaks and madrones (Figure 4), and had the highest mean tree density and basal area of any of the four groups. Group 2 also had firs of various sizes, but had substantial numbers of pines, including large pines, and also included more diversity of sizes of oaks and madrones. Group 2 had lower tree density and basal area than Group 1. Groups 3 and 4 both had somewhat more pines than firs, in both cases including a diversity of tree sizes. Group 3 particularly had abundant moderate and large oaks, but few madrones; also, pines and firs were much less abundant than oaks, and Group 3 had the lowest mean tree density and basal area of any of the four groups. Group 4 had the most pines of any group, but was characterized by moderate to small firs, oaks, and madrones and a mean tree density near the average for the study area (Figure 4).

In every Group except pines in Group 2 and, to a lesser extent, firs in Group 1, large pines and firs (e.g., > 70 cm diameter) were uncommon and certainly not dominant. Also in every group, either the madrones (Groups 1 and 2) or the oaks (Groups 3 and 4) numerically dominated the stand and these trees were primarily < 40 cm (12") in diameter (Figure 4). The less common pines and firs had a relatively uniform distribution across tree sizes from <20 cm to > 70 cm.

Historical tree composition was numerically dominated by oaks, *Quercus garryana* (white oak) and *Quercus kelloggii* (black oak) in roughly similar numbers, together accounting for about 51% of the total surveyed trees (Table 1). About equally common were: (1) madrone, *Arbutus menziesii,* with about 16% of surveyed trees, (2) firs (mostly Douglas-fir, *Pseudotsuga menziesii*) with about 15% of surveyed trees, and (3) pines (mostly ponderosa pine, *Pinus ponderosa*) with about 13% of surveyed trees. Surveyors also recorded other minor trees (Table 1). Firs were common across the study area in most stands, and were absent from stands across only about 7% of the area (Figure 5). Firs were present in a diversity of sizes across all four diameter-class groups (Figure 4).

Understories were commonly dominated by fire-adapted shrubs of the genera *Ceanothus* and

Arctostaphylos that are also dominant shrubs in chaparral further south in California. *Ceanothus cuneatus* and *Arctostaphylos viscida* dominated understories in more pine-dominated areas in the northern half of the study area, particularly in Group 3 and 4 areas (Figures 6 and 7). *Ceanothus integerrimus* and *Ceanothus sanguineus* dominated fir areas in the southwestern and northeastern parts of the study area, particularly in Group 1 and 2 areas (Figure 6). A smaller length of section lines had dominance by more mesic, less strongly fire-adapted shrubs (e.g., chinkapin, hazel, plum, willow).

Where understories along section lines were described, about 1/2 of these lines were described as having "dense" understories (Figure 8). Many of the dense understories were in fir areas in Groups 1 and 2, including both *Ceanothus sanguineus* areas (Figure 6) as well as areas with more mesic shrubs. Dense shrubs were also common in *Ceanothus cuneatus* areas of Group 4 (Figure 8).

A few areas burned at high severity were directly recorded by the surveyors (Figure 9). Surveyors did not recognize young recovering forests as having been burned in the past. Thus, the directly-recorded burned line segments underestimate the amount of high-severity fire in the landscape in the last half of the 1800s.

Discussion

Historical forests in the study area were generally dense, averaging 272 trees/ha across the study area in the last half of the 1800s. Only about 9% of the landscape had the low tree density (< 150 trees/ha) typical of open, low-density dry forests (Figure 1). These areas are visible as 14 yellow polygons on Figure 1. However, these stands were generally numerically dominated by oaks and madrones with relatively few pines and firs, unlike typical pine-dominated dry forests that were described by Johnson and Franklin (2009). The Applegate forests also did not have the open grassy understories that are typically associated with low-density, frequent-fire dry forests. Nearly all had understories dominated by 1-3 m tall *Ceanothus cuneatus* and/or *Arctostaphylos viscida* (Figures 6 and 7). Moreover, of these 14 polygons, 6 had low basal area (10-20 m^2/ha), 7 were in the 20-30 m^2/ha class, and only one had higher basal area (30-50 m^2/ha), suggesting that they were in various stages of successional recovery following past mixed- to high-severity fires, rather than being dominated by large, old pines. Fir-dominant forests in the study area were dense, also not the open, low-density forests typical of low-severity fire regimes in dry-forest areas. The fir areas in Group 1 averaged 385 trees/ha (Figure 4) and varied from about 250-590 trees/ha.

The hypothesis that the study area contained open, low-density forests maintained by frequent low-severity fire is not supported by this evidence, which instead suggests that mixed- and high-severity fires periodically reset succession, even on dry slopes, removing firs and pines and favoring fire-adapted shrubs and resprouting trees. From my fieldwork in the area, it appears that after mixed- to high-severity fire on these drier slopes, resprouting oaks and madrones, with abundant *Ceanothus* and *Arctostaphylos*, dominate and are slowly invaded by recovering pines and occasionally firs, a successional pattern suggested for this area by Detling (1961).

Firs were historically common and appear to have dominated and shaded out oaks and pines historically during post-fire succession, just as they do today. First, firs were historically as abundant as pines (Table 1) and were a significant part of most stands across the study area (Figure 5), including a diversity of fir sizes in most stands (Figure 4). The idea that firs were historically uncommon because they were killed in low-severity fires, and that they have invaded and increased in forest understories because of fire suppression is refuted by this evidence. If firs are more common today than historically, it is because large firs were logged and were each replaced by several small firs. Second, in historical fir-dominated stands that had moderately high basal areas (e.g., Group 1 in Figure 4), the oaks and madrones were generally very small (i.e., < 20 cm or 8") and the pines were generally few and mostly in larger size classes, which suggests they were not reproducing well historically in these stands. Thus, this pattern of overtopped and suppressed oaks and pines, both historically and today, may simply reflect the eventuality of firs returning to dominance in stands that were burned or logged. After disturbance, these stands had more abundant oaks and pines, that gradually were overtopped by recovering firs. The historical evidence of high tree densities and size-class structures with overtopped and suppressed trees refutes the notion that nature maintained the Applegate landscape with fire in such a way that trees were generally growing optimally, free of stress and competition, and thus resistant to insects, drought, and disease.

The abundance and often high historical density of the chaparral shrubs, *Ceanothus cuneatus* and *Arctostaphylos viscida*, across both pine and fir forests in the study area (Figures 6-8) are also a strong reflection of the importance of high-intensity fire in these landscapes (Detling 1961). In fact, all three *Ceanothus* and the *Arctostaphylos* have adaptations to high-intensity fire, including the ability to resprout and/or germinate profusely from long-dormant, heat-stimulated seed, and they may even promote fire through branch dieback or flammable oils (see reviews by species at the Fire Effects Information System: http://www.fs.fed.us/database/feis).. Their pyrogenicity promotes recurring fire at shorter intervals than in pure conifer forests (Odion et al. 2010). All occur at times as part of, or a dominant of large brushfields after high-severity fire removes conifers (e.g., Detling 1961, Odion et al. 2010), and all may decline or disappear as recovering conifers slowly re-invade these shrubfields (Detling 1961). These shrubfields, the prominence of these shrubs in the historical Applegate landscape, along with the array of stand size structures, suggest a long history of mixed- and high-severity fire that periodically burned across all the oak, pine, and fir forests of the study area.

The hypothesis of mixed- and high-severity fires followed by successional recovery is supported by the historical array of forest maturities across the study area. Most of the forest stands in the last half of the 19th-century were generally just "mature," with only 25-40% of conifers that were 70 cm or more in diameter. Only a few areas approached old forests with > 90% of conifers > 70 cm diameter, and about an equal number were likely mid-successional, with > 90% trees < 50 cm diameter. This diversity and modest age of most stands suggests a landscape in the last half of the 19th century that was recovering from mixed- and high-severity fires that had occurred in the preceding 100-200 years, not a landscape in which low-severity fire had continually maintained open, old-growth forests.

This was also not a landscape in which fire risk was historically low and one in which fire risk has increased to an unnaturally high level today. First, fire risk was likely not historically low in the Applegate study area. Substantial parts of the area have very steep slopes that tend to promote fire climbing into tree canopies. Some of these slopes today still bear evidence of high-severity fires in the last century. The diversity of basal areas, tree densities, and dominance and density of resprouting trees and fire-adapted shrubs all suggest a landscape in which mixed- and high-severity fire was active, if somewhat infrequent, as is born out by paleoecological evidence in similar forests nearby (Colombaroli and Gavin 2010). Second, fire risk today is not particularly high in the area, based on the actual rate of recent burning; the rate of forest recovery substantially exceeds the rate that early-successional forests are being created by fire (Hanson et al. 2009). Although fire scars may be found in the Applegate landscape, those do not solely indicate low-severity fire (Baker 2009), and low-severity fire was likely not a major independent component of the fire regime, but rather simply part of mixed-severity fires. The general notion that suppression of low-severity fire led to fuel buildup and ladder fuels, that have promoted higher severity fire, is not relevant in this landscape, where fuels and flammability were historically high (i.e., dense understory fire-prone shrubs, oaks, madrones, and small trees, as well as dense fir forests), understories were historically characterized by abundant ladder fuels, many slopes are steep, and mixed- and high-severity fire was historically dominant (e.g., Colombaroli and Gavin 2010).

The hypothesis that mature and late-successional forests existed historically as fire-susceptible patches in a matrix of low-density, fire-resistant forests (and this should be recreated today) is not supported by the historical evidence. The Applegate landscape historically lacked a matrix of fire-resistant conifer stands with low tree density and grassy understories free of ladder fuels. The Applegate landscape instead was one in which mixed- and high-severity fires infrequently burned most areas, resetting succession, perhaps initially with a few surviving conifers amid resprouting oaks and madrones, and fire-adapted shrubs (noted by Detling 1961), followed by eventual recovery of some pines and firs that eventually suppressed and reduced the initial post-fire dominants. This historical landscape pattern was thus more the opposite of that envisioned by Johnson and Franklin (2009) and USDI BLM (2011). Closed canopy, complex forests (e.g., late-successional forests) in this area were likely the least susceptible to high-severity fire (Odion et al. 2004), and they formed patches in a more extensive fire-susceptible matrix.

Was the study area historically heterogeneous and is today's landscape less so? The historical landscape did contain forest stands representing a diversity of tree densities (Figure 1), basal areas (Figure 2), and size-class structures (Figure 3), reflecting a combination of topographic effect and disturbance history. Looking at today's landscape in the field, there are substantial areas of early-successional post-fire vegetation (e.g., Spencer Creek), there are old-forest patches, some recently logged areas, and there are some mid-successional forests. Post-settlement clearcut and selective logging, and development of an expansive road system, of course have fragmented the landscape, increasing landscape heterogeneity relative to the historical landscape. It is not obvious what exactly is the net pattern of landscape change in the uplands, but there is no sound scientific basis for concluding that landscape heterogeneity has declined.

Implications for the Pilot Joe project

Where restoration is a stated goal (Johnson and Franklin 2009, USDI BLM 2011), it is important to distinguish proposed actions that are:

(1) clearly restorative relative to the historical landscape,

(2) not restorative, but will <u>not</u> create uncharacteristic structures relative to the historical landscape, and

(3) not restorative, and <u>will</u> create uncharacteristic structures relative to the historical landscape.

Of course, management can focus on creating structures that are uncharacteristic for a variety of reasons (e.g., fuel breaks to protect human infrastructure), but it is important to make it clear that these particular goals are not designed to be restorative.

The limited data about current tree density presented in USDI BLM (2011–Tables 3-3 to 3-5, p. 3-12 to 3-15), can be compared to the tree-density reconstruction (Figure 1) to determine whether proposed treatments are likely to represent restoration. The historical landscape reconstruction included no pole stands and few mid-successional stands; current trees per acre in mid-successional stands likely are high relative to historical mid-successional stands, probably because the logging that occurred created historically unprecedented tree densities. In the case of mature stands in Table 3-3, 2 of the 5 stands have current tree densities (151 and 155 trees/ac or 373 and 383 trees/ha) that are certainly within the historical range of tree densities (Figure 1), suggesting no thinning is needed if the goal is restoration. However, 3 of the 5 stands have current tree densities (613, 369, and 361 trees/ac. or 1514, 911, and 892 trees/ha) that are well above reconstructed historical tree densities (Figure 1). In these stands, some thinning may be restorative relative to historical forests, if the resulting tree densities were near the historical mean in Group 4 of about 385 trees/ha. However, the level of thinning in a mid-successional stand that is illustrated in Figure 3-3, and the resulting tree densities (i.e., 54 trees/ac. or 133 trees/ha), would result in a mid-successional stand having far fewer trees than characterized mid-successional forests historically. Indeed, the illustrated 50-year untreated stand, which would then be "mature" would have a tree density of 166 trees/acre or 410 trees/ha that would be near the 385 trees/ha average for mature forests historically. Thus, the proposed thinning program is simply not needed for some current forests, which are either already similar to historical forests or would naturally thin to levels of historical forests without treatment. The thinning program is likely too extensive in most forests relative to historical forest structure. Proposed thinning could be restorative if the final densities better matched the densities of historical forests, but what is illustrated in the figures is thinning that would likely instead not only fail to be restorative, but also would create uncharacteristic structures relative to historical forests.

The basal-area goals modeled in Table 3-3 or recommended on p. 2-5 (USDI BLM 2011) would not be restorative, but may not create historically uncharacteristic structures. The five mature stands in Table 3-3 currently have basal areas of 197-250 ft^2/ac or about 45-59 m^2/ha, which are certainly within the range of historical basal areas (Figure 2), thus from the standpoint of restoration of historical basal area, there is no need for any action. Projected basal area after proposed initial harvest for the 5 mature stands in Table 3-3 would be 98-112 ft^2/ac or about 23-26 m^2/ha and would likely recover somewhat by 50 years later. The proposal on p. 2-5 for leaving 60-120 ft^2/ac or about 14-28 m^2/ha is similar. Those post-logging basal areas may not be outside the range of historical basal areas for mature stands, but would be near the low end of historical basal areas for mature stands. Thus, proposed actions are not needed from the standpoint of restoring historical basal area, and thus would not represent restoration, but may not produce uncharacteristic structure, based at least on the few basal areas projected in Table 3-3 and the goals given on p. 2-5.

Proposed thinning with a focus on retaining large conifer trees is likely to not be restorative of stand size-class structures, and is instead likely to produce historically uncharacteristic stand structures. Reconstructed size-class structures (Figure 4) indicate that historical forests had a diversity of tree sizes in populations of both the firs and pines and were certainly not dominated solely by large conifers. This, of course, is fully expected in mixed-severity fire regimes, where uneven age structures and size structures are characteristic. Proposed skips and gaps may allow some diversity in age and size structures, but it is unlikely that these will offset the proposed substantial reduction in small and medium-sized trees. Perhaps there is a dilemma in that large, old trees could be deficient across the Applegate landscape due to past logging. However, extensively logging medium-sized trees does not help solve that deficiency, but instead simply creates another deficiency, this time in medium-sized trees, which were an important component of historical forests (Figure 4), and also are the source of the fastest means to restore old trees to logged forests.

Proposed thinning may open up some dense mid-successional and mature stands, allowing understory oaks and small trees to grow faster and allowing somewhat increasing tree diversity. This too is likely not restorative, as it would simply set back what appears to be the normal successional process that was evident in the historical landscape. This may not create uncharacteristic structure, but is mis-directed and not restorative relative to historical forests.

Proposed reductions in understory shrubs and small trees would not be restorative. The wording is ambiguous (USDI BLM 2011 p. 2-6), but it appears that whiteleaf manzanita, buckbrush and deerbrush ceanothus will be removed from understories within commercial stands, as these shrubs will not be reserved from cutting. In non-commercial ponderosa pine forests, shrubs would be removed where they compete with trees or form ladder fuels (p. 2-9), which would certainly have been historically common. Similarly, madrone < 6" in diameter would be thinned and spaced, but madrone < 8 " (20 cm) was historically the most abundant component of the madrone population in these forests (Figure 4 Groups 1, 2, and 4). The proposed shrub and madrone removal is not at all restorative, as these were the dominant shrubs and madrones of historical forests, and their removal will create uncharacteristic understories. Moreover, these shrubs and madrones, as discussed below, are an important component of ecosystem resilience, and reducing or removing them will substantially reduce the resilience of these landscapes to future fire.

Efforts to protect old trees from competition, lower competition in mid-successional and mature forests, and otherwise increase the health and growth rate of individual trees, are not restorative and may produce historically uncharacteristic structures. Certainly some thinning in places could be restorative, as discussed above. However, historical forests in the study area were not characterized by an open, low-density structure in which individual trees grew optimally in conditions relatively free of competition. Stands instead were historically dense, understories were often dense with shrubs, and small trees and ladder fuels were common.

Similarly, the idea of increasing fire resistance has a misdirected focus on individual trees, particularly large conifers, rather than the whole forest and ecosystem, which was clearly not historically fire resistant. In the Applegate, the historical landscape was oak-dominated, with conifers a relatively minor component numerically. The conifers were not present in low-density fire-resistant open stands dominated by large trees and with little understory fuel. They were instead vulnerable to fire, as they were growing in historically dense forests, often on steep slopes, and often had dense understories of shrubs and small trees that provided abundant and flammable ladder fuels. The dominant oaks are not very fire resistant, but perhaps are more so than the conifers (Odion et al. 2010). The main understory shrubs, three species of *Ceanothus* and an *Arctostaphylos* also were not fire resistant, and they arguably may have favored fire through branch dieback and abundant volatile oils. None of the dominant plants effectively resists fire, as all face mortality or topkill in typical historical fires burning during droughts and under high winds. Fire resistance is generally uncharacteristic of the historical Applegate landscape. Moreover, in planning for future fire, it is less effective to attempt to maintain fire resistance than fire resilience (Millar et al. 2007).

The Applegate landscape was likely highly fire resilient and remains so today, suggesting there is little need to increase fire resilience. Conifers may be readily killed in mixed- and high-severity fires and slowly recover by reseeding from unburned areas or scattered survivors. This is a typical slow, seed-based fire-resilience strategy of most conifers, and it obviously has been successful for millennia (Baker 2009). Nearby paleoecological evidence shows longterm persistence of these conifers in a landscape with infrequent severe fires (Colombaroli and Gavin 2010). More rapid fire resilience is exemplified by the resprouting dominant oaks and madrones, and by both resprouting and reseeding fire-stimulated shrubs that dominated forest understories. The idea of favoring more drought- and fire-tolerant tree species to increase resistance and resilience might appear compelling, but those trees are certainly not the conifers, but instead the oaks and madrones, which are resilient. These trees, however, are already abundant, and do not require restoration. Applegate ecosystems were historically characterized by a suite of plants with low resistance to fire, but diverse abilities to rapidly or slowly recover after fire, and these plants remain abundant and diverse today. There is no need to enhance resilience to fire across the Applegate, as it is already very high.

Reshaping the Pilot Project to Better Maintain and Restore Forests

If the goal of the pilot project is to demonstrate a new way to both restore forests and produce wood, this document shows that both components can be improved, now that this evidence of the historical structure of the Applegate landscape is available to complement similar evidence from other studies (Detling 1961, Hosten et al. 2007, Odion et al. 2004, 2010, Colombaroli and Gavin 2010).

There are already some good things in the proposed pilot, given the perspective of historical forests and the idea of ecologically compatible forestry. These include the idea of accelerating development of structural complexity (such as large trees and decadence), preserving the large trees rather than logging them, designating late-successional emphasis areas, sustaining a hardwood component, retaining large snags and large down wood, multiparty monitoring and third-party review. Focusing on the things to leave and marking them carefully also seems good.

Relative to the historical evidence presented here, the pilot could be made more restorative in two ways. First, thinning and logging could focus in stands where tree density and basal area are elevated relative to historical levels for forests of the same stage (e.g, mature), and avoid thinning forests that are already at density and basal-area levels congruent with historical forests. Thinning could be less intensive, perhaps instead removing trees only down only to the mean density levels of historical forests, and not seeking to lower RDI and other values to produce low competition and rapid growth, which were not characteristic of historical forests.

Second, it is possible to use silviculture to enhance development of structural attributes of old forests, which could be restorative, given that logging removed old trees. The pilot suggests that may be a goal, but I do not see specific identification of where and how this would be accomplished. In my opinion, that would require less or no logging of medium-sized trees, less reduction in basal area, and different marking/leave guidelines, including leaving more down wood, snags etc. The silvicultural techniques that are to be employed and the projected stand attributes (e.g., density, basal area, down wood, snags etc.) after treatment and in 25-30 years warrant a separate section in the document. It should be clear from the projection work that the treated stands will definitely acquire more late-successional attributes within 25-30 years. I would suggest that restorative silviculture be highlighted, modeled, and presented as a separate treatment from the ones that include more wood production. Also, why not avoid the wood-production treatments anywhere near the late-successional emphasis areas (LSEAs), and instead designate all areas near the LSEAs for late-successional enhancement silviculture only? I would suggest that if this is done, it is important to do this work in a way that is least damaging to nearby spotted owls, their prey, and other late-successional species, and to specifically monitor the response of owls, their prey, and other late-successional species.

It is important to be accurate and forthright about whether proposed actions represent restoration or are seeking other goals. The evidence presented here shows that the pilot, as it is formulated in USDI BLM (2011), cannot achieve the dual goals of restoration and substantial wood production without compromising on restoration, based on the evidence presented here for historical forests. The evidence shows that the only real surplus, relative to historical forests, is in tree density in some subset of stands, and probably not in basal area, based on the comparisons made above. I think it would be better to identify a wood production component that is potentially restorative (e.g., restoring historical tree density) and a component that is not restorative (e.g. reducing basal area), but will not create uncharacteristic structure and is perhaps the least damaging way to remove wood. It is probably impossible to obtain timber volume without reducing basal area below historical mean levels temporarily. To be least damaging, the level of wood removal that lowers basal area could, for example, be limited to that which would be no greater than would allow full recovery of basal area to historical mean levels appropriate to the stage the stand will have reached within 25-30 years. If that were the case, the logging could be identified as not restorative, but will not create uncharacteristic structures. Other ideas of course might achieve the same goal, which is to remove wood, but keep the stand close to historical forests.

The pilot could also be reformulated to simply avoid doing several things that are clearly not restorative, and would likely create uncharacteristic structures relative to historical forests. First retain all large trees, since they are deficient from past logging, but also retain most middle-sized trees, needed to provide future old trees, and a diversity of other tree sizes, so that the forests are multi-sized and have multi-aged trees as they did historically. Second, avoid reducing native understory shrubs (including whiteleaf manzanita, buckbrush and deerbrush ceanothus) and madrones at all, as these shrubs and trees were historically dominant and are an important component of ecosystem resilience to fire. This would also limit the amount of surface disturbance that would occur. Third, do not focus on enhancing fire- and drought-resistant conifers, as these trees were not historically dominant in these forests and fire resistance was not the hallmark of these ecosystems. Instead, focus on maintaining the historically high fire resilience by leaving all native understory shrubs, madrones, and oaks.

I suggest that the largest source of enhanced fire risk in the Applegate landscape is from accidental or intentional ignitions by the large number of residents and visitors living and recreating in and near the forests. The pilot could increase attention to this risk, including doing some limited and focused fuel reduction combined with wood production in close proximity to human infrastructure. That would not be restorative, and would create uncharacteristic structures in limited areas, but at least would provide some protection for human infrastructure and perhaps reduce the spread of human-caused fires. Closing and obliterating roads would also reduce the risk of human-caused fires.

If the Pilot Joe project is going to achieve restoration while also producing wood, I suggest that the proposed alternative needs to be reshaped to be congruent with the local science-based historical information contained in this report and in previous research (Detling 1961, Hosten et al. 2007, Odion et al. 2004, 2010, Colombaroli and Gavin 2010). These are congruent in showing that the ideas of Johnson and Franklin (2009) and summaries by BLM (USDI BLM 2011) are incorrect for the Applegate landscape, so that the proposed Pilot Joe project will not restore these forests, relative to historical conditions, nor will it create forests that are resistant and resilient to future climate change. However, the scientific information presented here, along with that in previous studies, should be sufficient to allow a new proposal to be crafted that will achieve restoration and wood production, while maintaining resilience to future climate change.

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Table 1. Trees of the Middle Applegate study area. Also given are the 4-5 letter code, the group within which the species was placed when reconstructing basal area and diameter distributions, and the number of each tree recorded by the surveyor across the 4.5 township area.

Code	**Species**	**Surveyor names**	**GP**	**No.**
ACMA	*Acer macrophyllum*	Maple	HARD	5
ALNUS	*Alnus rhombifolia?*	Alder	HARD	5
ARCTO	*Arctostaphylos* spp.	Manzanita	HARD	3
ARME	*Arbutus menziesii*	Matherone, Manzanita, Laurel	ARME	201
CADE	*Calocedrus decurrens*	Cedar	CADE	2
CERCO	*Cercocarpus* spp.	Mountain mahogany, mahogany	HARD	10
FIRS	*Abies* sp., *Pseudotsuga*	Fir	FIRS	182
FRAXI	*Fraxinus* spp.	Ash	HARD	3
PIAT	*Pinus attenuata*	Not mentioned by surveyors	-	0
PILA	*Pinus lambertiana*	Not mentioned by surveyors	-	0
PINUS	*Pinus* spp.	Pine	PINE	56
PIPO	*Pinus ponderosa*	Yellow pine, Y Pine	PINE	117
POPUL	*Populus* spp.	Balm gilead	HARD	9
PRUNU	*Prunus* spp.	Plum, Plumb	HARD	8
QUCH	*Quercus chrysolepis*	Live oak	OAKS	13
QUERC	*Quercus* spp.	Oak	OAKS	59
QUGA	*Quercus garryana*	White oak, W Oak	OAKS	309
QUKE	*Quercus kelloggii*	Black oak, B Oak	OAKS	258
SALIX	*Salix* spp.	Willow	HARD	2
SAMBU	*Sambucus* spp.	Elder	HARD	1
TABR	*Taxus brevifolia*	Not mentioned by surveyors	-	0
UNKN	Unknown spp.	Bugwood	UNKN	4
			Total	1247

Groups
ARME: ARME
CADE: CADE
FIRS: FIR including PSME and Abies sp.
HARD: ACMA, ALNUS, ARCTO, CERCO, FRAXI, POPUL, PRUNU, SALIX, SAMBU
OAKS: QUCH, QUERC, QUGA, QUKE
PINE: PINE, PIPO including Pinus lambertiana, occasional Pinus attenuata
UNKN: UNKN

Table 2. Understory species of the Middle Applegate study area identified by surveyors

Surveyor names	Likely Species
Arrowwood	Unknown
Buck brush, Chaparral, greasewood	*Ceanothus cuneatus*
Buckhorn	Unknown, but probably *C. cuneatus*
Bugwood	Unknown
Chinkapin	*Castanopsis chrysophylla*
Elk frake, elk brake	*Ceanothus sanguineus*
Hazel	*Corylus cornuta*
Laurel	*Arbutus menziesii*
Lilach, buckbrush	*Ceanothus integerrimus*
Mahogany	*Cercocarpus* sp.
Manzanita	*Arctostaphylos viscida*
Plum	*Prunus* spp.
Scrub oak, shrub oak	*Quercus* sp.
Willow	*Salix* spp.

The likely species was determined by field visits to section lines where each species was dominant.

Figure 1. Reconstructed tree density for the Middle Applegate study area, including the boundary of the Middle Applegate watershed (red). Tree density (trees/ha) was reconstructed for 3-corner polygons, each representing about 260 ha (1 square mile).

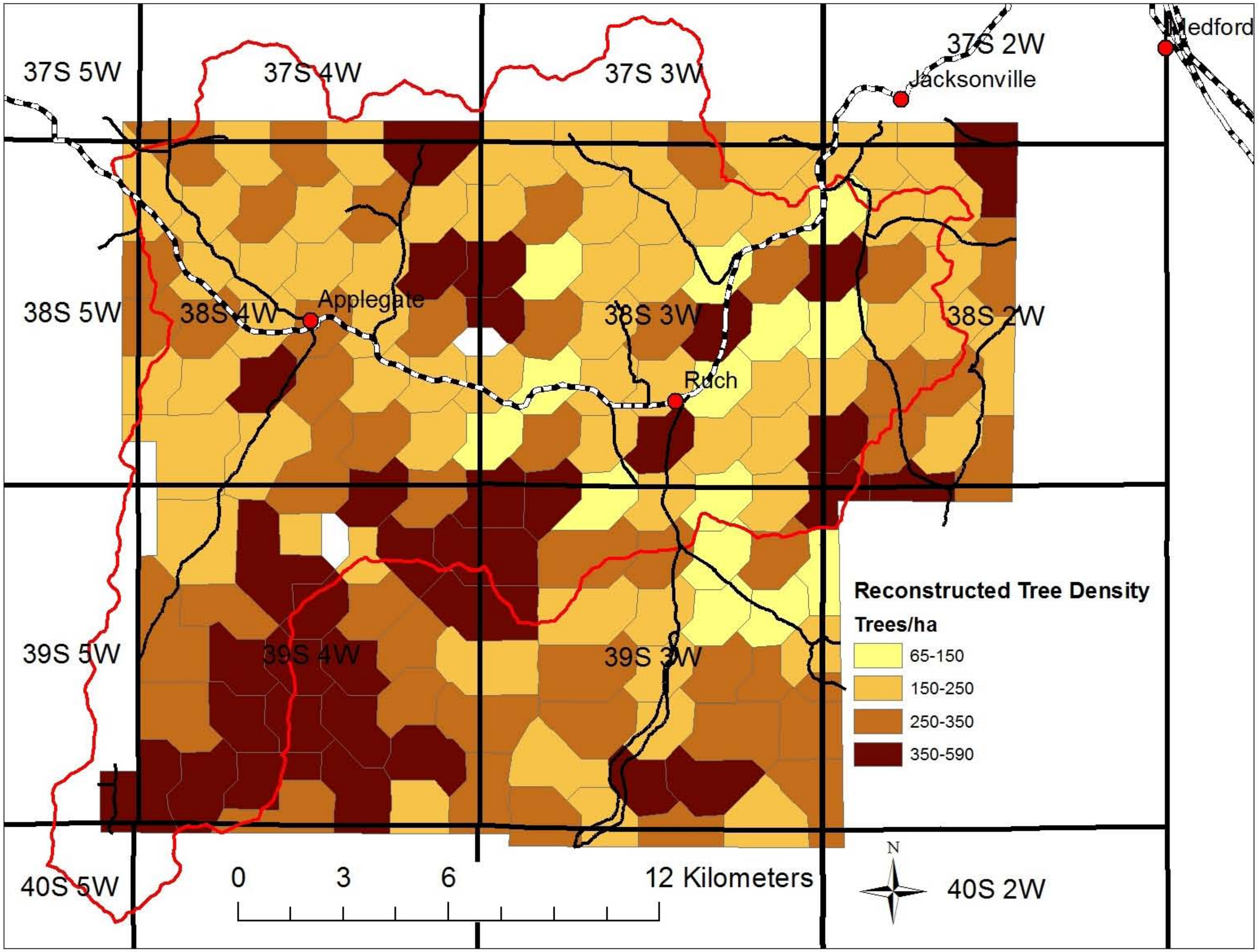

Figure 2. Reconstructed basal area for the Middle Applegate study area, including the boundary of the Middle Applegate watershed (red). Basal area (m^2 /ha) was reconstructed for 9-corner polygons, each representing about 780 ha (3 square miles).

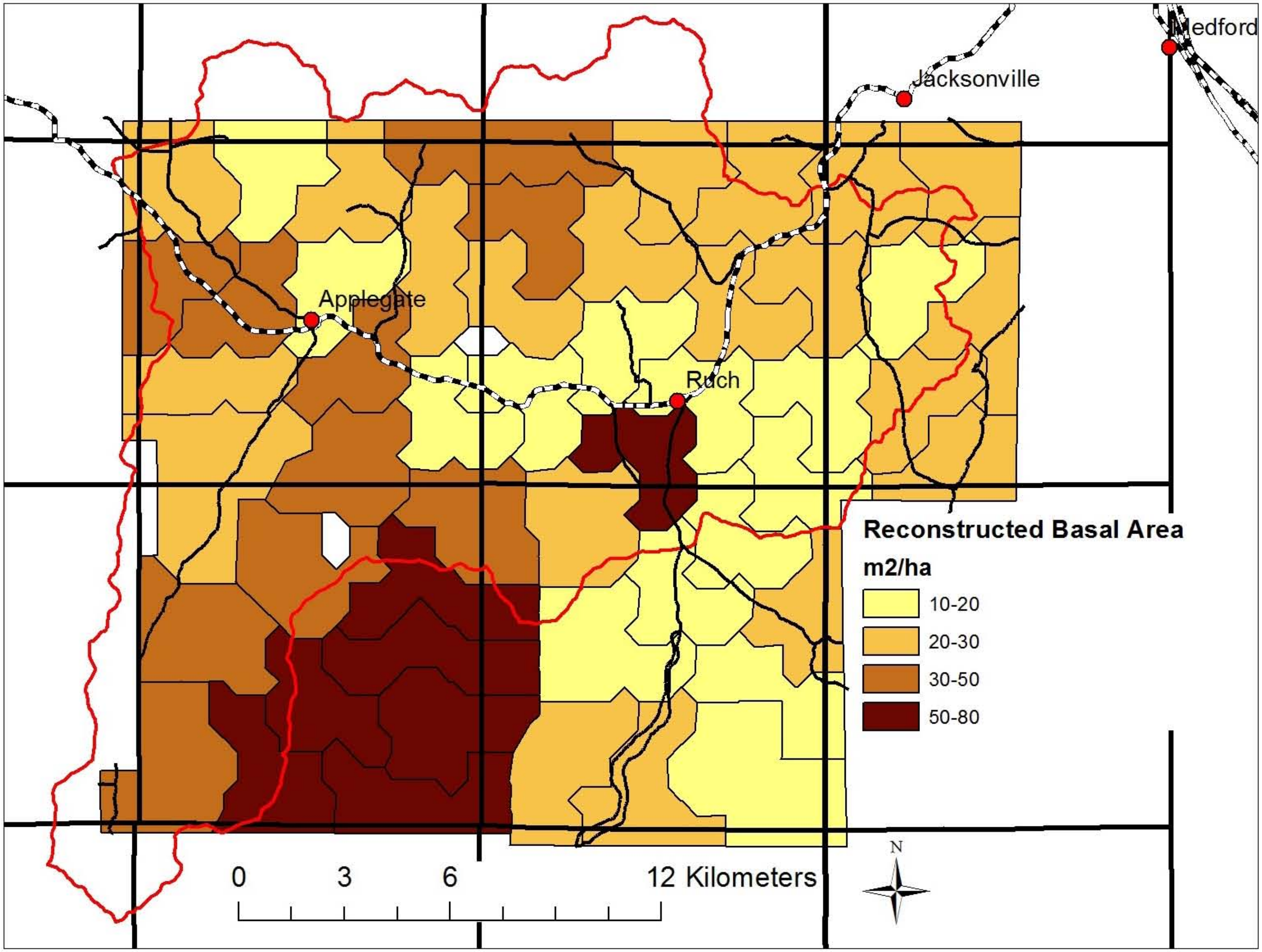

Figure 3. Four groups of classified 12-corner polygons, each representing about 1040 ha. The polygons were classified using reconstructed diameter distributions, with seven 10-cm size classes, for madrone, oaks, firs, and pines. The groups were identified using a complete-linkage cluster analysis with Euclidean distance. See Figure 4 for the mean size-class distribution within each group.

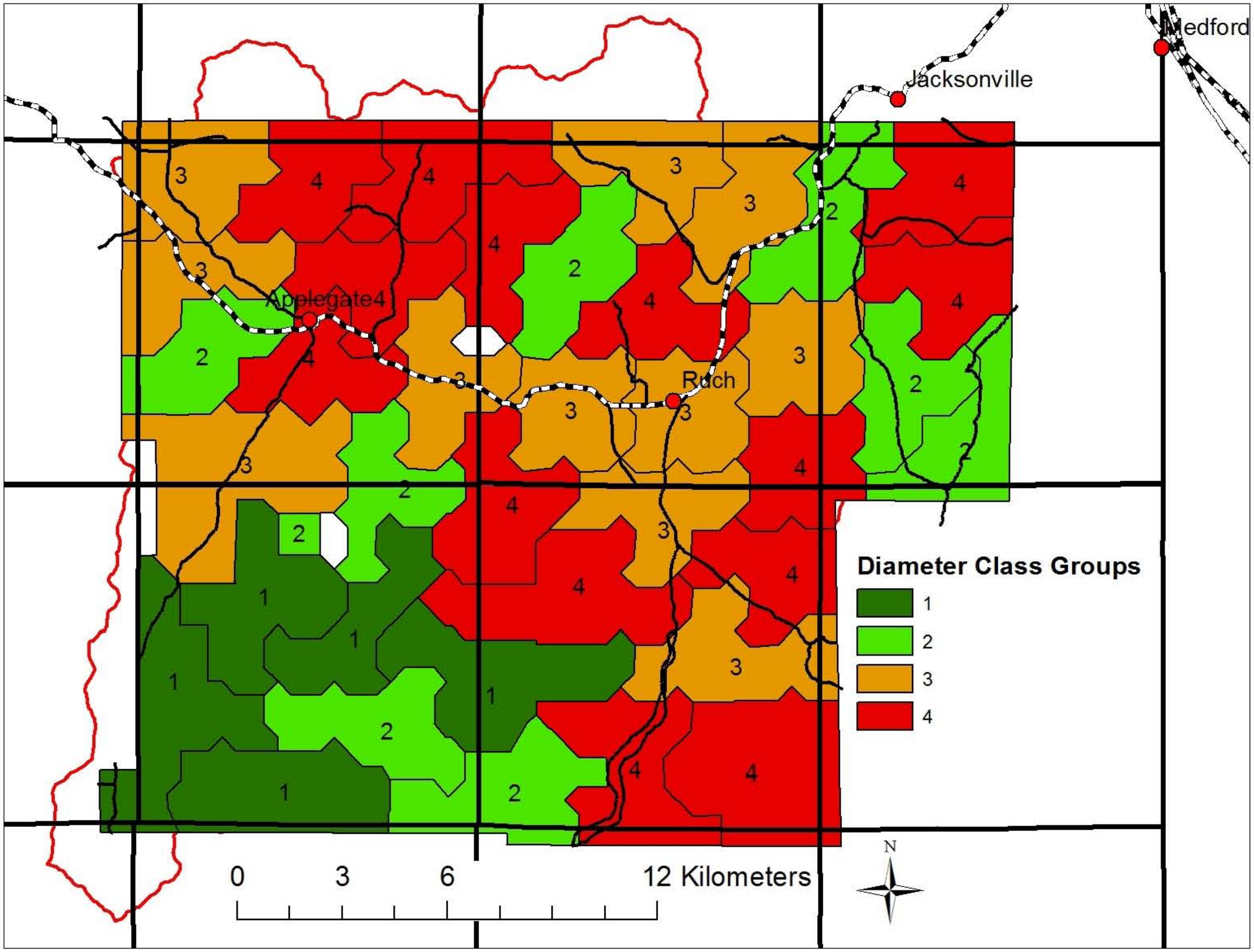

Figure 4. Mean size-class distribution, mean tree density, and mean basal area for madrone, oaks, pines, and firs in each of four groups (see Figure 3 for a map of the groups).

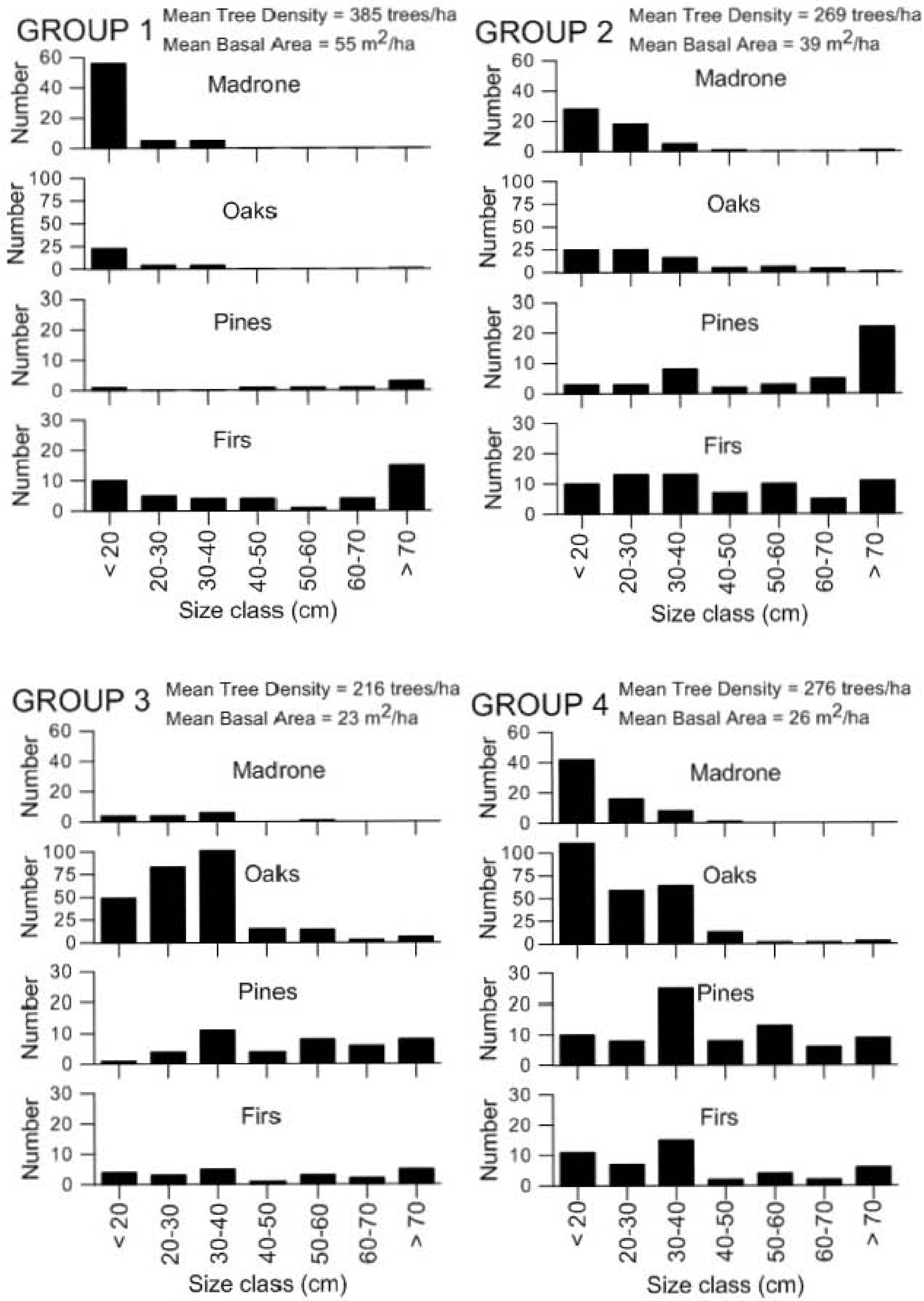

Figure 5. The fraction of total trees that were firs.

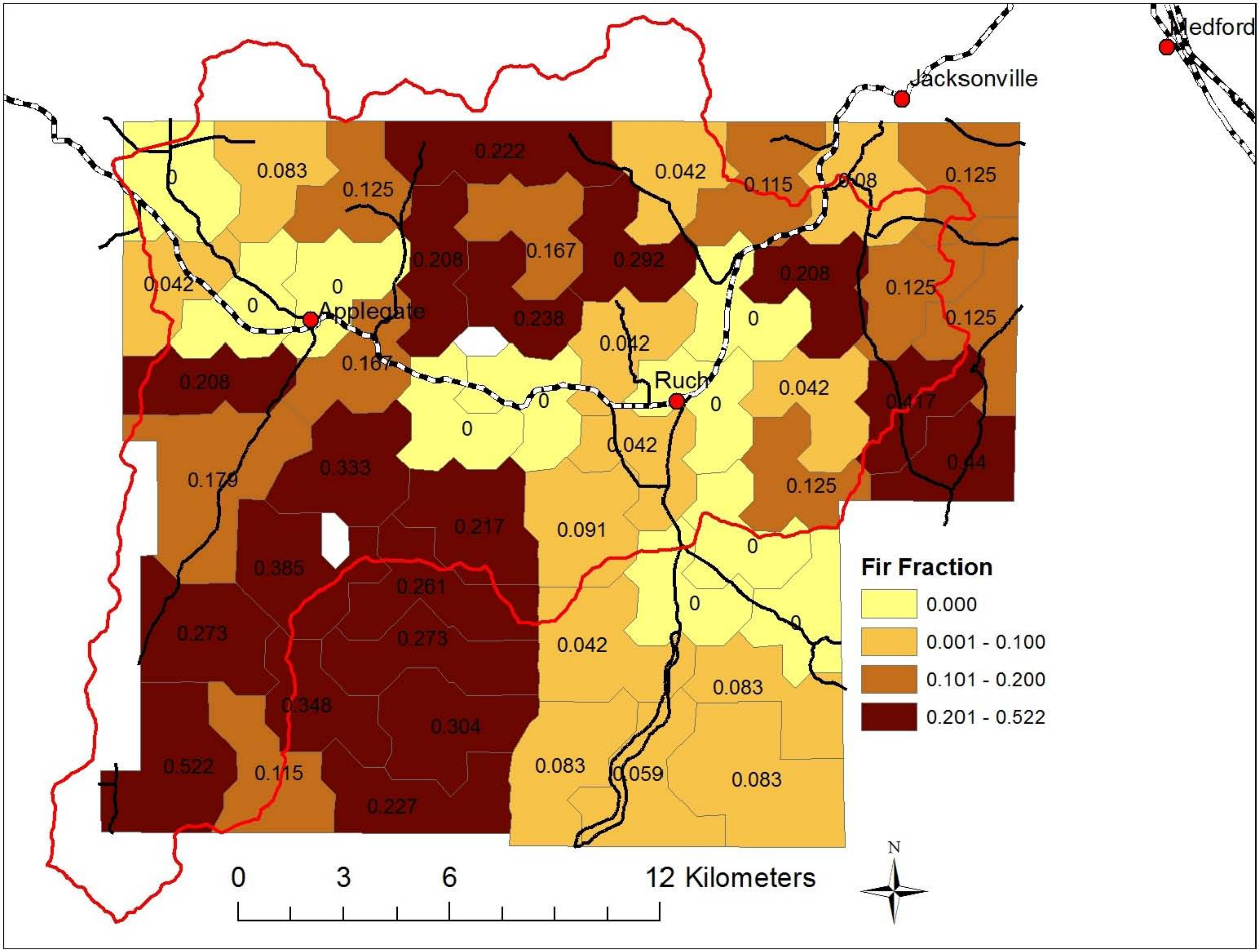

Figure 6. Section lines where one of three species of fire-adapted *Ceanothus* was either the most abundant understory species or the second-most abundant understory species. The backdrop color map is the set of four diameter-class groups (Figure 3)

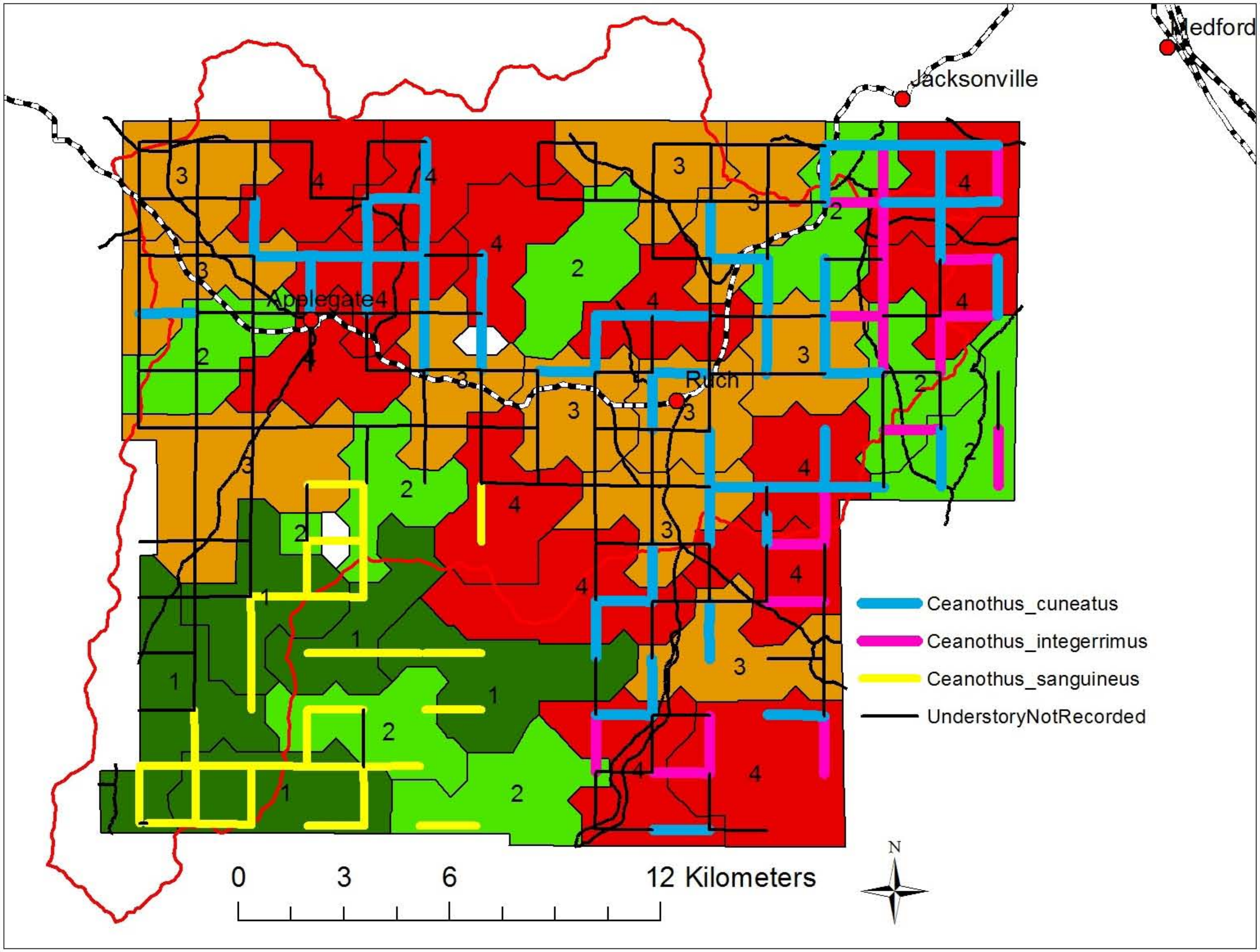

Figure 7. Section lines where the fire-adapted *Arctostaphylos viscida* was either the most abundant understory species or the second-most abundant understory species. The backdrop color map is the set of four diameter-class groups (Figure 3)

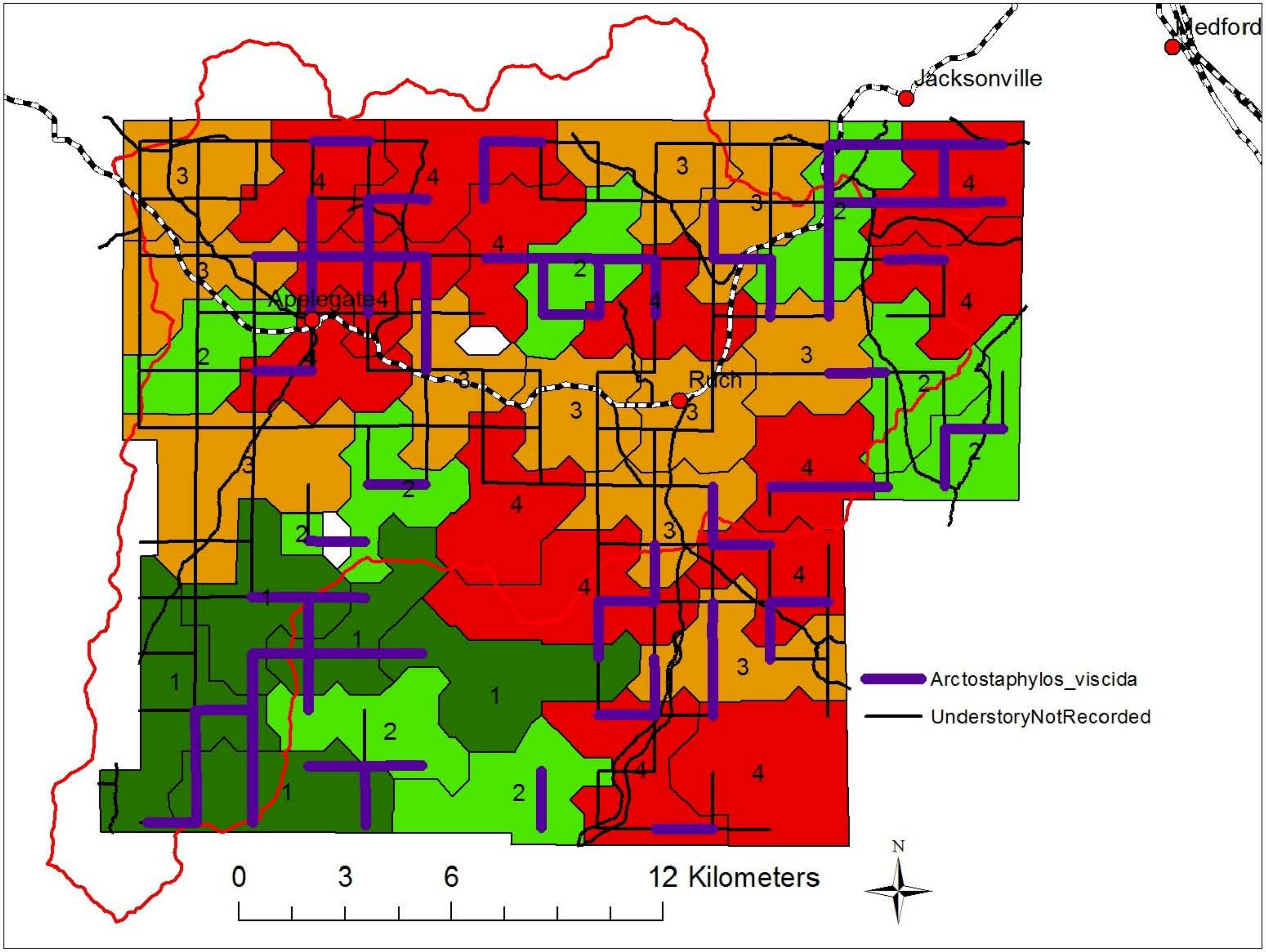

Figure 8. Section lines described by the surveyors as having "dense" understories, or not described as "dense" understories, and lines for which surveyors did not record understory information at all.

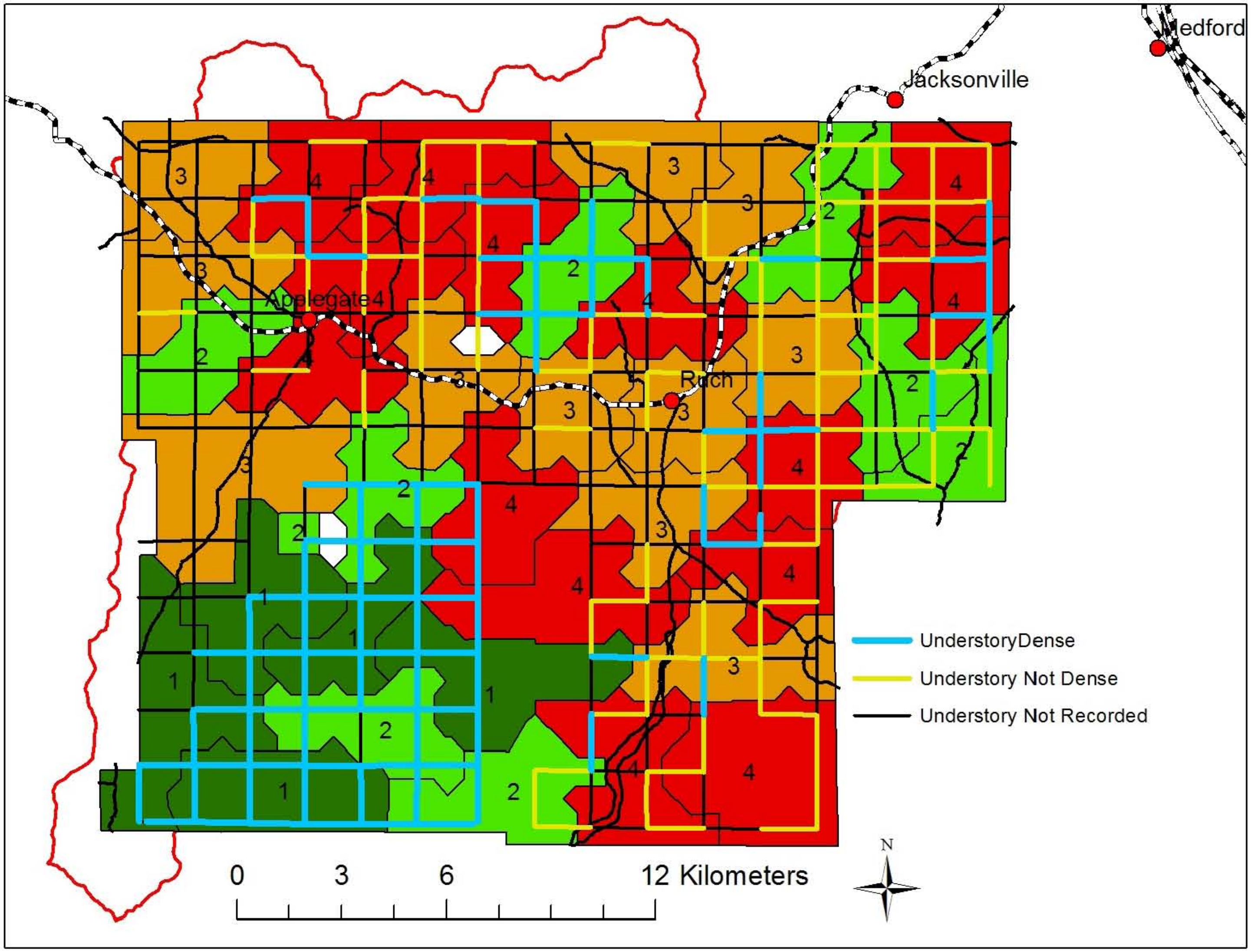

Figure 9. High-severity burned areas recorded directly by the surveyors along section lines.