MAPPING FIRE REGIMES FROM DATA YOU MAY ALREADY HAVE: ASSESSING LANDFIRE FIRE REGIME MAPS USING LOCAL PRODUCTS

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Abstract—LANDFIRE maps of fire regime groups are frequently used by land managers to help plan and execute prescribed burns for ecosystem restoration. Since LANDFIRE maps are generally applicable at coarse scales, questions often arise regarding their utility and accuracy. Here, the two recently published products from West Virginia, a rule-based and a witness tree-based model, are compared to LANDFIRE fire regime groups. A cell-by-cell comparison of fire regime groups revealed a 56-percent correspondence between the rule-based map and LANDFIRE and a 61-percent correspondence with the witness tree-based map and LANDFIRE. All three maps assign the same fire regime group on about 45 percent of the study area with most of the agreement in wetter areas where fire regime group V predominates. Subsectional boundary differences are distinct in the LANDFIRE map compared to the local products which placed a greater emphasis on forest composition. The intent of this work was to describe alternative means of estimating fire regime groups where LANDFIRE products may not represent local conditions.

INTRODUCTION

The determination of fire regime and condition class (FRCC) on federally owned land is needed for prescribed fire and wildland fire management. Determining fire regimes for large areas, particularly natural or historic fire regimes can be difficult without fire-scar or dendrochronogical records from old-growth forests or sediment charcoal from paleoecological sites. Few old-growth stands remain in eastern forests, and while there is success in establishing disturbance regimes at specific locations (Abrams and others 1995, Aldrich and others 2010, Cutter and Guyette 1994, Guyette and others 2002, Guyette and others 2006a, Schuler and McClain 2003, Shumway and others 2001), determining fire histories over a large area remains difficult. Even with a fire-scar record, fires at both ends of the severity spectrum may be missed as low-intensity fires may not damage the cambium of mature trees (McEwan and others 2007) and high-severity fires, by definition, remove most existing trees. When direct measures are unavailable, other methods can be used to infer historical fire, including paleoecology, witness tree studies, historical documents, and ethnographic records (Egan and Howell 2001, Ruffner 2006).

Recently, large-scale efforts to map fire regimes have been made incorporating fire ecology of tree species to assign fire regimes (Nowacki and Abrams 2008), fire scars from dendrochronology studies (Guyette and others 2006b), and climate and chemistry (Guyette and others 2012). Early nation-wide maps incorporated many lines of evidence to map the role of fire in forested ecosystems. Frost (1998) compiled fire histories from across the contiguous United States and, combined with landform characteristics, created a map of pre-European settlement fire regimes. Where fire history studies were lacking, Frost (1998) used additional lines of evidence to infer fire regimes including charcoal deposits, oral histories, tree species in old land surveys, presence of fire-adapted vegetation, vegetation response to reintroduced fire, and vegetation responses to fire exclusion. Using current and potential vegetation, ecological regions, and expert opinion Schmidt and others (2002) mapped historical natural fire regimes for the contiguous United States at a coarse resolution. The authors stressed that this was not a reconstruction of exact historical conditions, but represented typical fire frequencies expected in the absence of fire suppression (Schmidt and others 2002). Unfortunately, the fine-scale detail required by fire ecologists, land managers, and conservationists for field application was lacking in these nation-wide efforts.

To help identify areas where prescribed burning is appropriate for restoration purposes, two local mapping products were created for the Monongahela National Forest. The first was a rule-based map (Thomas-Van Gundy and others 2007), which applied a simple weighted-averaging technique of fire-adapted scores to polygon data in a GIS. The resultant map of fire-adapted vegetation was directly converted to a fire regime group map (see figs. 5 and 7 of Thomas-Van Gundy and others 2007). The second was a witness tree-based map that converted point-based witness trees from early land surveys into a continuous surface depicting percentage of pyrophilic species (Thomas-Van Gundy and Nowacki 2013). The pyrophilic percentage map was converted

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to a fire-adapted vegetation map for comparison with the rule-based map, but not into a fire regime group map; that conversion will be made in this paper. In this paper, fire regime groups derived from both mapping products will be compared to LANDFIRE fire regime groups for assessment and comparison. LANDFIRE fire regime groups and other products are a consistent and scientifically reliable set of mapped fire and vegetation characteristics to be used for national, regional, and sub-regional planning. LANDFIRE is not meant to replace local data; however, for this analysis it is being used as a comparison for the locally-derived fire regime groups created with different methods.

STUDY AREA

Fire-adapted vegetation was mapped for the Monongahela National Forest (MNF) (fig. 1). The proclamation boundary of the MNF covers about 1.7 million acres in east-central West Virginia, with national forest land making up about 919,000 acres. The study area includes portions of the Allegheny Mountains and the Northern Ridge and Valley (Cleland and others 2005), two ecological sections with distinct geomorphologies and climates.

The Allegheny Mountains Section has a wet and cool climate, with 39 to 54 inches of precipitation per year (about 20 percent as snow; 30 percent at higher elevations), an annual average temperature of 46 to 52 °F, an average annual maximum temperature of 58 to 63 °F, an average annual minimum temperature of 36 to 39 °F, and a growing season of 126 to 155 days in the study area (Cleland and others 2005). The vegetation of the Allegheny Mountains is strongly influenced by elevation, forming four broad zones: oak, mixed mesophytic, northern hardwoods, and red spruce. The lowest elevations (valleys and foothills) are dominated by oaks (*Quercus* spp.), with sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), and various mesophytes along riparian corridors and in floodplains. Upslope, the vegetation transitions into mixed mesophytic forests, which include yellow-poplar (*Liriodendron tulipifera*), basswood (*Tilia americana*), white ash (*Fraxinus americana*), sugar maple (*Acer saccharum*), and northern red oak (*Quercus rubra*). The northern hardwood group is found on upper slopes and ridge tops and features sugar maple, yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), and black cherry (*Prunus serotina*). Red spruce (*Picea rubens*) forests occur at the highest elevations (above ~3,000 feet), often mixing with northern hardwoods.

Much of the Northern Ridge and Valley Section lies in the rain shadow of the Allegheny Mountains and supports vegetation reflective of drier conditions (Abrams and McCay 1996, McCay and others 1997). Annual precipitation ranges from 39 to 42 inches (Cleland and others 2005). Annual temperature ranges from 50 to 54 °F, with an average annual maximum temperature of 63 to 66 °F, an average annual minimum temperature of 39 to 41 °F, and the growing season ranges from 149 to 170 days (Cleland and others 2005). In general, northern red oak and white oak (*Quercus alba*) occur on productive mesic sites, often intermixed with eastern white pine (*Pinus strobus*) on side slopes. Increases in scarlet (*Q. coccinea*) and black oak (*Q. velutina*) occur on progressively drier sites. On the driest sites, pitch (*P. rigida*), Table Mountain (*P. pungens*), or Virginia (*P. virginiana*) pines predominate, either in pure stands or mixed with scrub oak (*Q. ilicifolia*) or other oak species.

METHODS

A map of fire-adapted vegetation was created from multiple GIS-based data sources through assigning fire-adapted scores to attributes and calculating a weighted average (for details see: Thomas-Van Gundy and others 2007). Data input included existing vegetation (forest type), potential natural vegetation (primary and secondary plant associations as separate inputs), and landtype association (a mid-level ecological hierarchical unit, essentially giving the biophysical setting). For each dataset, existing literature on species-fire relationships were reviewed to assign a fire adapted score of 1 (most adapted) to 5 (least adapted) to each forest type, plant association, and landtype association. If a fire relationship was unknown or unclear, a 5 was assigned. The data inputs were assigned weights for the calculation of an average fire-adapted score with primary potential vegetation and current vegetation weighted equally and higher than landtype association and secondary plant associations. Fire-adapted scores were converted to standardized fire regime groups (FRGs) as used in LANDFIRE (Barrett and others 2010; see table 1 for definitions) by expert opinion. Considering the dominant vegetation, annual rainfall, and elevation range of the study area, the existence of fire regime group II (stand replacement fires with a return interval of 0-35 years) was unlikely. The fire regime assignments were; fire adaptation score of 2 = FRG I, fire adapted score of 3 = FGR III, fire adapted score of 1 = FRG IV, and fire adapted scores of 4 and 5 = FRG V.

The creation of a map of fire-adapted vegetation from witness tree data is documented in Thomas-Van Gundy and Nowacki (2013). Briefly, the tree species listed in early deeds from the MNF (Thomas-Van Gundy and Strager 2012) were categorized as pyrophilic or pyrophobic based on current literature and assuming recurring fire of low to moderate intensity. At each deed corner, this categorization was used to calculate a percent pyrophilic species value. These values were interpolated between points through ordinary kriging to create a continuous surface. Maps were created displaying the percentage of pyrophilic species in classes, and these classes were translated into fire-adapted scores used in the previous fire-adapted vegetation map.

The percentage pyrophilic values were simply binned by 20-percent classes with 0-20 percent = fire adapted score of 5, 20-40 percent = fire adapted score of 4, 40-60 percent = fire adapted score of 3, 60-80 percent = fire adapted score of 2, and 80-100 percent = fire adapted score of 1. Since FRGs were not approximated from the witness tree data in the 2013 publication, fire-adapted scores similar to the methods used in the rule-based map were assigned to percent pyrophilic classes and assigned an FRG. With further consideration of the standard FRGs and considering characteristics of the study area such as the dominant forested conditions, main tree species, annual rainfall, and elevation range, I do not believe FRGs II and IV (stand replacement fires with a return intervals of 0-35 and 35-200 years, respectively) are appropriate for the study area at the scale of this analysis. Therefore, in this analysis, fire-adapted scores of 1 and 2 (60-100 percent pyrophilic) were assigned to FRG I, score of 3 (40-60 percent pyrophilic) was assigned to FGR III, and scores of 4 and 5 (0-40 percent pyrophilic) were assigned to FRG V.

With these FRG assignments, the rule-based and witness tree-based maps were compared to the most recent LANDFIRE FRG map (LANDFIRE 2013). The locally derived maps were converted to ~98-foot (30-m) grids for these comparisons. All maps were compared on a cell-by-cell basis in ArcMap 10 to spatially display and calculate FRG departure. All three maps were also compared directly in ArcMap 10 through calculating the number of unique values (variety) for fire regime group between the three maps for each cell.

RESULTS

The three estimates of FRG (table 1; figs. 2a, 2b, and 3a) are very different and it is not surprising that differences were found. The cell-by-cell comparison of the rule-based map and LANDFIRE shows that the two versions of FRGs agree exactly on about 57 percent of the area (table 2; fig. 2c). Most of the departures (about 36 percent of the area) were positive 2 or 4 meaning the rule-based map FRGs were greater than LANDFIRE; about 8 percent of the area was in departures of negative 2 or 4.

Creating FRGs from the witness tree-based map resulted in about 30 percent of the study area classified as FR I, about 14 percent as FR III, and about 56 percent as FR V (table 1, fig. 3a). The fire regime groups inferred from the witness tree data matched LANDFIRE on about 61 percent of the area (table 2). Departures from LANDFIRE from the witness tree-based map were more evenly distributed above and below zero (compared to departures between LANDFIRE and the rule-based map) with about 22 percent of the area with a difference of positive 2 or 4 and about 17 percent in negative 2 or 4 differences.

The grids resulting from these calculations spatially depict where the agreements and departures occur (figs. 2c and 3c). All three versions of FRGs for the study area identify the higher elevations in the mountainous center of the study area as an area of low fire frequency. The influence of subsection boundaries (Cleland and others 2005) is more obvious in the LANDFIRE estimation of FRG (fig. 2b) and is a main contributor to departures from the two locally-derived maps. Also, the influence of river corridors is more defined in the LANDFIRE FRGs than either the rule-based or witness-tree based maps.

The simultaneous comparison of the three maps shows that all three maps agree on FRG assignments on about 45 percent of the study area, and mostly agree on the location of FRG V (38 percent; table 3). Two of the three maps agree on about 46 percent of the study area and areas of no agreement make up only 9 percent of the study area. When viewed spatially, with FRG estimations for the witness tree-based map as background (fig. 4), all three maps have greatest agreement in areas where fire is not likely to be used as management tool or be re-introduced as a disturbance (FRG V, table 3). These areas are the highest elevations and receive higher inputs of precipitation relative to other parts of the MNF.

DISCUSSION

In creating the FRG map from witness tree data, the cut-off values of percent pyrophilic witness tree species were subjectively set based on knowledge of the general ecology of the study area. Using 0-40 percent pyrophilic species to create the FRG V group may have included areas where fire may have occurred more frequently than the national definition would suggest. Other break-point values were considered; however, to remain consistent with published comparisons between the rule-based and witness tree-based maps (Thomas-Van Gundy and Nowacki 2013), the break points were retained. This also demonstrates the difficulty in applying a nation-wide standard. The witness tree data could easily be used without conversion to FRGs to aid managers in planning and designing projects.

The LANDFIRE FRGs were mapped similarly to the methods of Schmidt and others (2002), incorporating existing and potential vegetation and the biophysical setting. The rule-based mapping effort (Thomas-Van Gundy and others 2007) attempted to mirror the methods of Schmidt and others (2002); however, the choice of landtype association as the biophysical setting limited fire score inputs as binary, aiding in the resulting conservative nature of the inferred FRGs (fig. 2a). In the witness tree-based map, no biophysical setting was included. The distinct breaks between FRGs in LANDFIRE (especially the western edge of the MNF, fig. 2b) correspond to subsection boundaries (fig. 1). The potential natural vegetation for the Western Allegheny Mountains subsection is 38 percent mixed mesophytic, 35 percent northern hardwoods, and 27 percent Appalachian oak; and for the Eastern Coal Fields, 52 percent mixed mesophytic, 28 percent Appalachian oak, and 20 percent northern hardwoods (Cleland and others 2005). The representation of these two subsections within the MNF may not be typical of the subsection as a whole as these areas are at either the extreme northern (Eastern Coal Fields) or extreme southern (Western Allegheny Mountains) end of the larger subsection. For these reasons, the methods for estimating FRGs in LANDFIRE may have overstated the role of fire in these two subsections. However, the two locally-derived FRG estimations may have understated the role of fire in these areas. The areas where either local estimate differs greatly from LANDFIRE are likely areas where more field-based information is needed.

Although LANDFIRE data are best suited for national, regional, and sub-regional questions, the FRGs from LANDFIRE are useful for comparison with locally-derived fire regimes since LANDFIRE data are consistent across boundaries and supported by science. While LANDFIRE products are not a substitute for local products, these inferred fire regime groups from fire-adapted vegetation are not a substitute for stand-level data but are useful for local planning and placing fire in a larger context. Although issues with witness tree data are known, for example they do not represent a random sample or a systematic sample, the witness tree-derived map appears to be an improvement and refinement over the rule-based map.

The mapped differences between the two locally-derived FRGs and LANDFIRE FRGs are a useful starting point for detailed, site-specific reviews for project planning. The methods described here are applicable to other landscapes and should be useful for others trying to define areas to restore fire-adapted vegetation. Managers should not limit themselves to one product—witness trees, historical records, potential natural vegetation mapping, fire scars, responses to prescribed fire—all can inform options for restoring fire as a disturbance regime.

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Table 1—Fire regime groups derived from the rule-based map and from the witness tree-based map of fire-adapted vegetation of Monongahela National Forest maps and from 2010 LANDFIRE data

Fire regime group	% total area rule-based map	% total area witness tree map	% total area LANDFIRE
I - ≤ 35 yr return interval, low & mixed severity	13.9	29.8	30.6
II - ≤ 35 yr return interval, stand replacement severity	0	0	0
III - 35-200 yr return interval, low & mixed severity	13.9	13.8	20.9
IV - 35-200 yr return interval, stand replacing severity	0.3	0	0.3
V - >200 yr return interval, any severity	71.9	56.4	48.1

Table 2—Results of cell-by-cell comparisons of the rule-based map and the witness tree-based map of fire regime groups to LANDFIRE

Difference from LANDFIRE	2007 version % total area	Witness tree version % total area
-4	1.3	3.8
-3	0.0	0.0
-2	6.2	13.0
-1	0.0	0.1
0	55.6	60.8
1	0.3	0.2
2	20.6	15.1
3	0.1	0.0
4	15.8	7.0

Table 3—Results (percent of study area) of three-way comparison of rule-based, witness tree-based, and LANDFIRE estimations of fire regime groups

Agreement	FRG I	FRG III	FRG V	Total
All three	7.0	0.5	38.0	45.4
Two maps	18.6	9.1	17.9	45.6
None	4.3	4.2	0.5	9.0

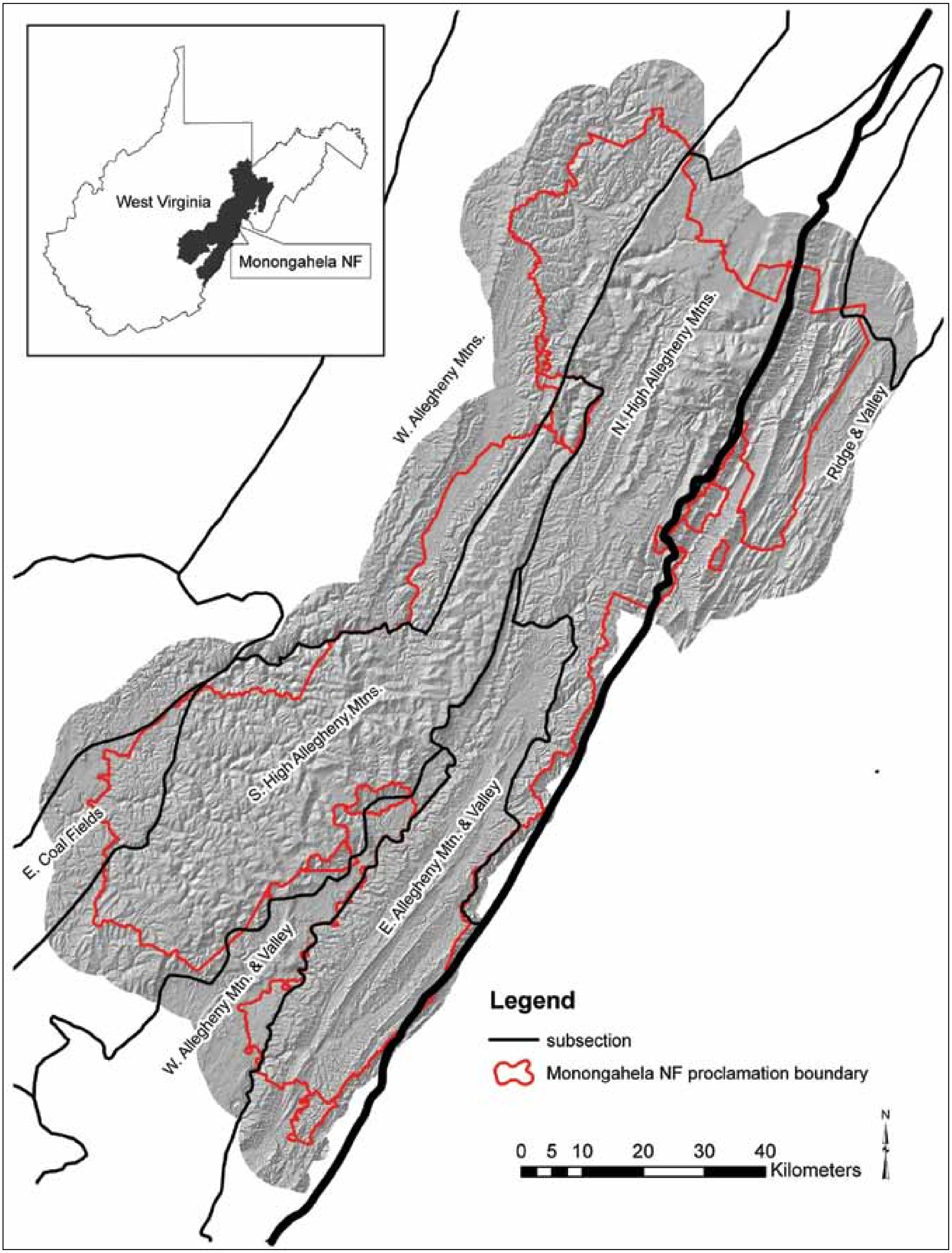

Figure 1—Study area; bold line is the boundary between Northern Ridge and Valley (east) and Allegheny Mountains (west).

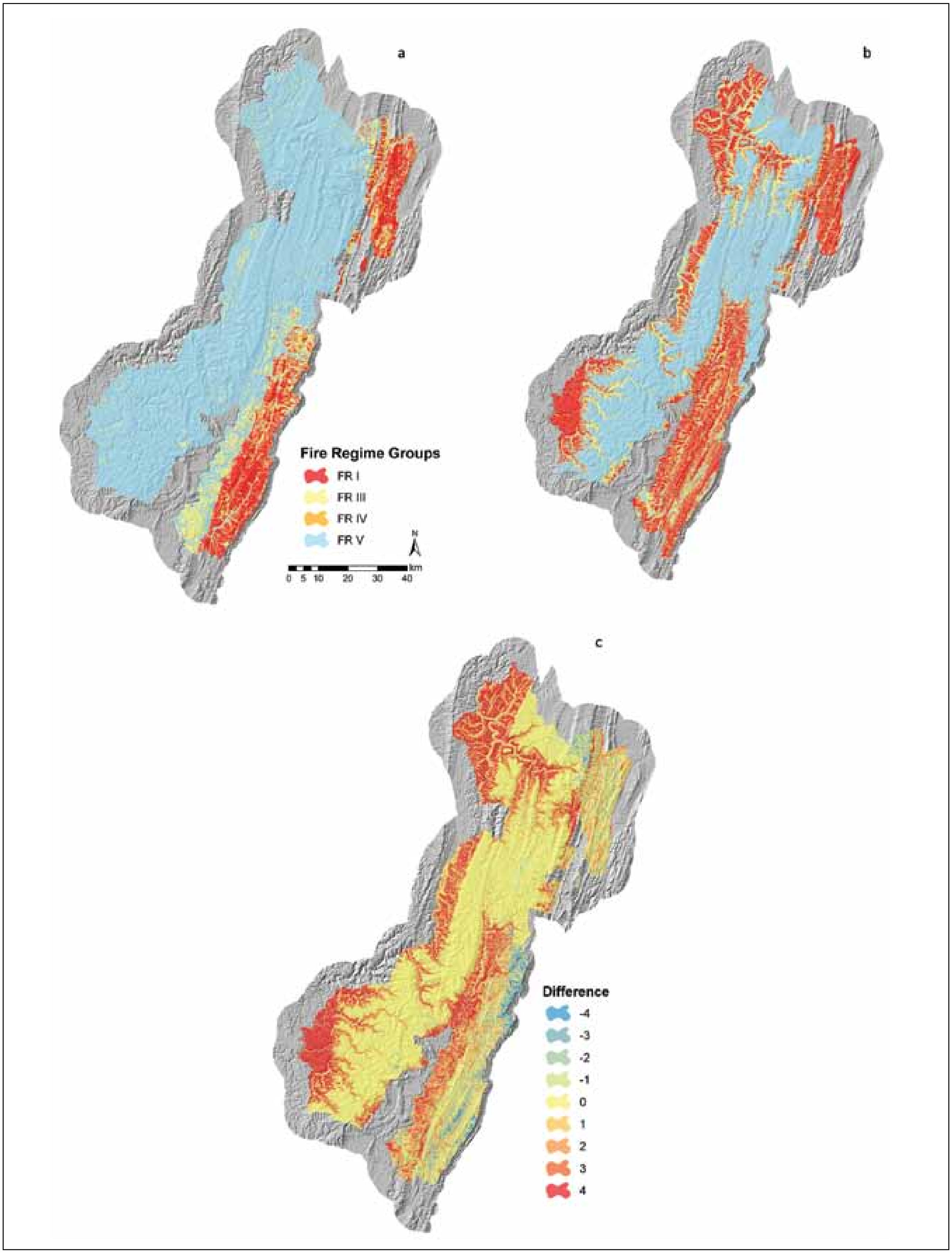

Figure 2—Fire regime group maps derived from (a) the rule-based map (Thomas-Van Gundy and others 2007), (b) LANDFIRE, and (c) the difference between them.

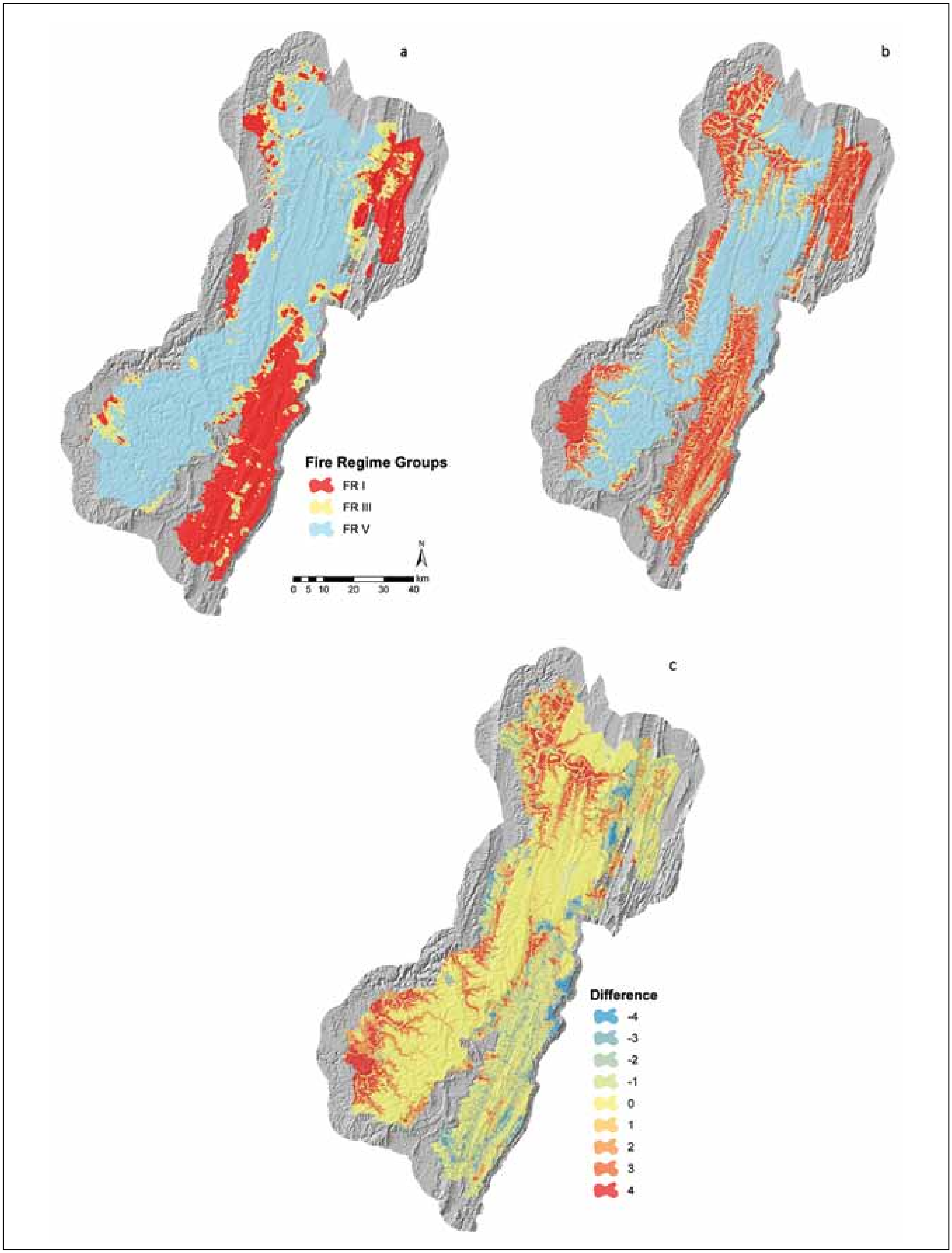

Figure 3—Fire regime group maps derived from (a) the witness tree-based map (Thomas-Van Gundy and Nowacki 2013), (b) LANDFIRE, and (c) the difference between them.

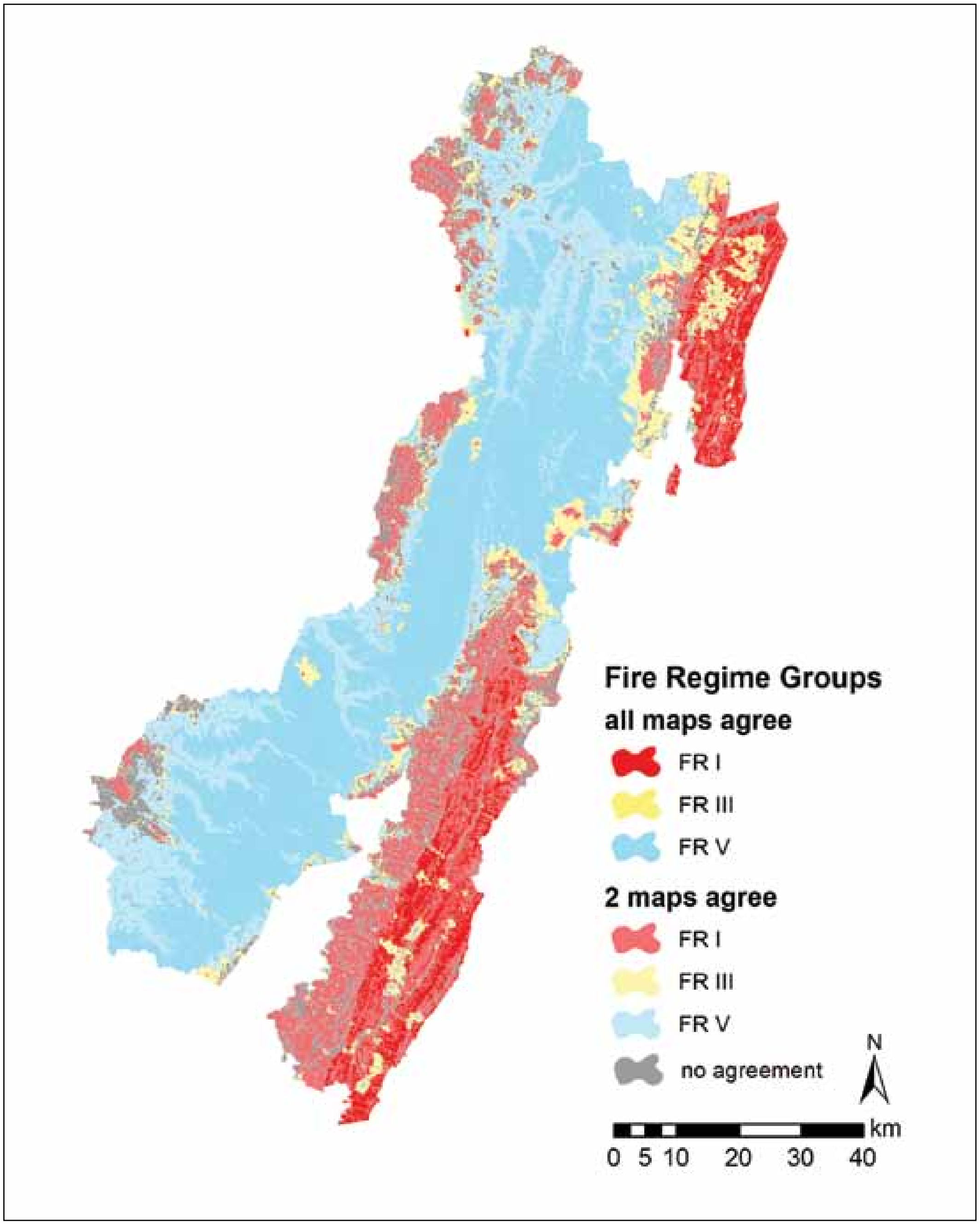

Figure 4—Three-way comparison of all three maps. Areas of full color indicate agreement between all three maps, faded colors represent areas where two maps agreed, and grey areas represent areas of no agreement between the three maps. Fire regime groups from the witness tree-based map are shown.

PROCEEDINGS

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