TRENDS IN STANDING BIOMASS IN INTERIOR WEST FORESTS: REASSESSING BASELINE DATA FROM PERIODIC INVENTORIES

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Abstract.—Trends in U.S. forest biomass and carbon are assessed using Forest Inventory and Analysis (FIA) data relative to baseline assessments from the 1990s. The integrity of baseline data varies by state and depends largely on the comparability of periodic versus annual forest inventory data. In most states in the Interior West FIA region, the periodic inventory's sample design, plot configuration, estimation procedures, and definitions were different from those for the annual inventory, which are nationally consistent. Direct comparisons of periodic versus annual inventory data are therefore tenuous and may reflect changing protocols rather than actual changes, yet they comprise the best available method of assessing recent trends in some states. This study attempts to clarify trends in aboveground tree biomass in the Interior West region by comparing estimates at matched plots that were sampled during both periodic and annual inventories. To illustrate the ramifications of ignoring changes in inventory protocols, mean trends at paired plots were compared to those demonstrated by unpaired comparisons of entire periodic and annual inventories. In some states, the results produced by the two methods are contradictory. This demonstrates the importance of reassessing the use of estimates based on periodic forest inventories as reference conditions.

INTRODUCTION

The Forest Inventory and Analysis (FIA) program provides data for monitoring forest biomass at state, regional, and national scales. At a national scale, the U.S. Greenhouse Gas Inventory monitors trends in forest biomass and carbon based on FIA data (Heath et al. 2011). However, in the Interior West FIA region, the sample designs used in the historical forest inventories of the 1980s and 1990s, including those used for Resource Planning Act assessments (Smith et al. 2009), were neither internally consistent nor spatially balanced (Fig. 1). In 2000, the national FIA program implemented the spatially and temporally balanced sample design referred to as the annual inventory. Implementation in Interior West states occurred between 2000 and 2009, and due to a 10-year cycle length, most states have not yet completed a full annual inventory cycle. This constrains temporal monitoring to periodic inventory data coupled with a single measurement from the annual inventory.

The forest inventories conducted in the state of Idaho between 1980 and 2002 exemplify the quandary presented by comparing periodic and annual forest inventory data (see Witt et al. 2012). Idaho's most recent periodic inventories relied partially on aerial photograph interpretation to assess changes since the 1981 Idaho woodland inventory, and if no change was observed, then the 1981 data were merged with the 1990s inventory dataset. Each inventory also targeted specific ownership groups. For example, Idaho periodic inventories prior to 1992 did not include national forest lands. In contrast, periodic inventories conducted from 1993 to 2002 consisted almost solely of national forest lands. Each national forest was responsible for conducting its own periodic inventory, so inventory methods, sample grids, and the actual

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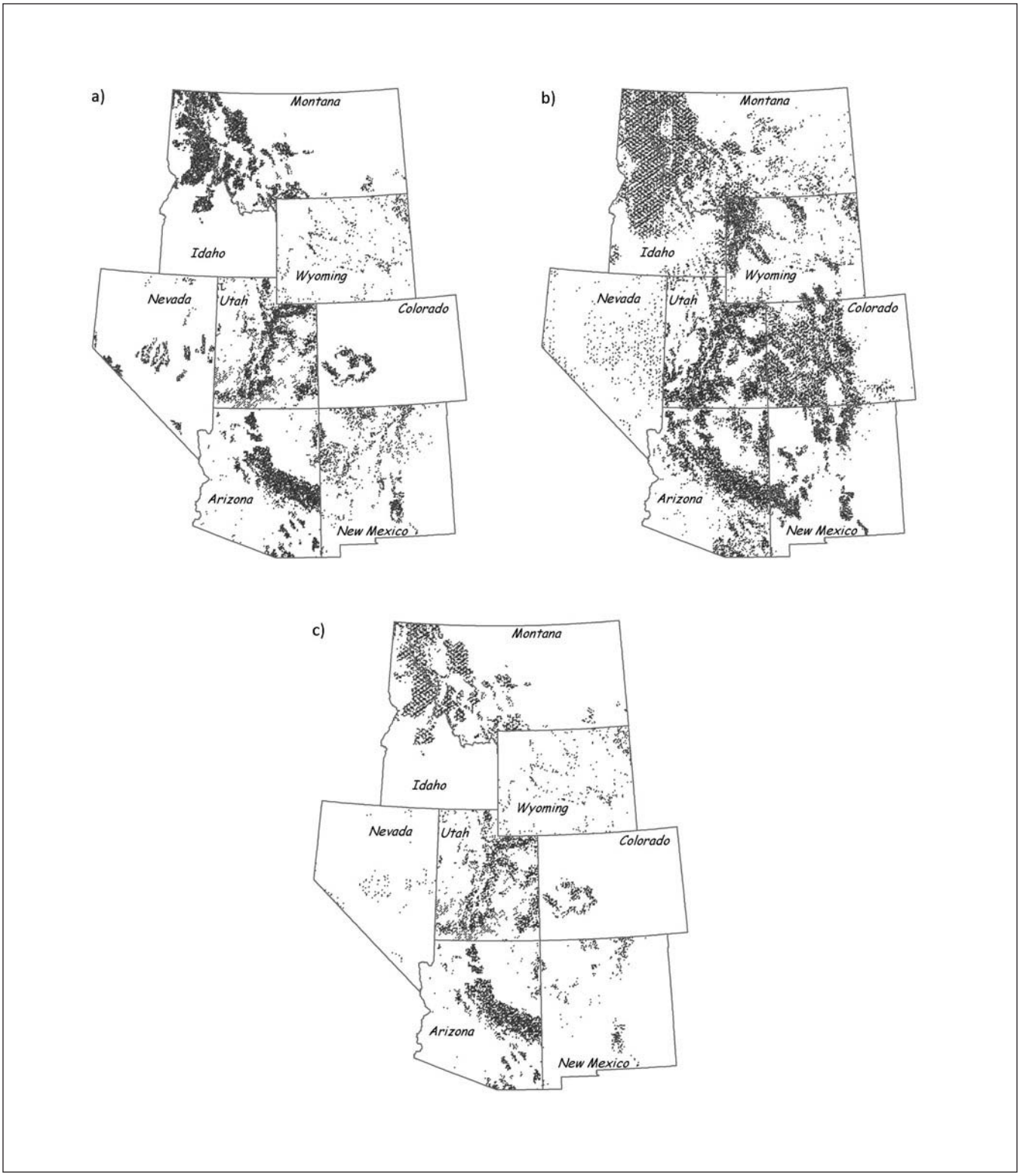

Figure 1.—Maps showing the spatial distribution of a) time 1, b) time 2, and c) time 1/time 2 matched plots in the Interior West FIA region.

inventory year(s) varied among forests, and vast areas within some national forests were completely omitted from the periodic inventory's sample grid. Due to these spatial and temporal inconsistencies in Idaho's periodic inventory, direct comparisons between periodic and annual inventory estimates are somewhat incongruous at both the statewide and the ownership group levels.

Despite their incompatibilities, comparisons of periodic versus annual inventories are the primary method of assessing recent trends in forest resources in the Interior West region. Due to the phased implementation of the annual inventory as well as the 10-year cycle length, annual-to-annual remeasurement data are only available for a small percentage of plots. The purposes of this study were: 1) to assess trends in mean aboveground tree biomass per plot by comparing only plots that were measured during the two most recent forest inventories (i.e., paired measurements); and 2) to identify cases where these trends contradict those demonstrated by comparisons of unpaired plot measurements.

METHODS

The study area consisted of eight Interior West states: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Each state was evaluated separately due to temporal inconsistencies in the timing of both periodic inventories and the initiation of the annual inventory. For most states, time 1 consisted of the most recent periodic inventory while time 2 represents the annual inventory (Table 1). In New Mexico and Wyoming, the annual inventory was not

Table 1.—Measurement years of the periodic and annual inventories included in this study, by state, in the Interior West FIA region. For each state, only the most recent periodic inventory cycle was included. Total plots measured (n) and the number of paired plots between the two inventories is indicated. Asterisks indicate annual inventory cycles where the first measurement year indicates initiation of the annual inventory.

State	Cycle	n	Measurement Years	Plot Design
ARIZONA	2	1,966	1995-1999	4-subplot fixed-radius
	3*	3,291	2001-2009	4-subplot fixed-radius
	Paired plots	1,600		
COLORADO	1	388	1997	4-subplot fixed-radius
	2*	3,315	2002-2009	4-subplot fixed-radius
	Paired plots	270		
IDAHO	1	1,215	1998-2002	4-subplot fixed-radius
	2*	2,319	2004-2009	4-subplot fixed-radius
	Paired plots	664		
MONTANA	1	2,368	1993-1999	variable radius
	2*	3,217	2003-2009	4-subplot fixed-radius
	Paired plots	1,522		
NEVADA	1	588	1994-1997	variable radius
	2*	465	2004-2005	4-subplot fixed-radius
	Paired plots	101		
NEW MEXICO	1	1,287	1985-1987	variable radius
	2	1,741	1996-2000	mixed
	Paired plots	343		
UTAH	1	2,686	1991-1995	variable radius
	2*	3,526	2000-2009	4-subplot fixed-radius
	Paired plots	1,838		
WYOMING	1	501	1983	variable radius
	2	1,981	1998-2002	4-subplot fixed-radius
	Paired plots	398		

implemented until 2008 and 2009, respectively, but periodic inventories were conducted in both states in the late 1990s through early 2000s. Due to a paucity of annual inventory data in these two states, the time 2 measurements consisted of the most recent periodic inventories and an earlier periodic inventory was treated as time 1. Figure 1 portrays the spatial distribution of all time 1 plots, all time 2 plots, and the paired time 1 and time 2 plots.

The tree-level variable DRYBIOT (total gross biomass ovendry weight per tree in pounds) was queried for all live and standing dead trees from the national forest inventory database (Miles et al. 2001); trees measured under obsolete protocols (e.g., down dead trees) or with diameter at breast height (d.b.h.) of less than 5.0 inches were omitted. For periodic plots where data collection protocols did not include condition mapping, individual tree biomass was multiplied by a tree-level expansion factor and a unit adjustment to obtain total plot biomass in oven-dry tons per acre. For plots where conditions may have been delineated (i.e., annual inventory plots and periodic fixed-radius plots), this expansion was performed at the condition level first, and then condition-level biomass was aggregated to the plot level. Plot-level biomass was aggregated separately for live and dead trees.

The periodic and annual inventory datasets were then merged to identify plots that were measured during both inventories. Plots were assumed to be colocated, or measured more than once, if they had the same combination of state, county, and plot identifiers. Interior West FIA protocols stipulate that annual inventory plots should be colocated with periodic plots with the same state, county, and plot identifiers. At a small proportion of these plots, the periodic plot center could not be located so it was assumed that even plots that were not colocated sampled the same or a similar condition as the original measurement. Comparisons based on this subset of "matched" periodic-to-annual plots allowed for paired comparisons.

Trends were assessed by comparing mean tree biomass per plot, first using comparisons of all plots in each inventory and then using only paired plots that were measured during both time 1 and time 2 inventories. Cases where the paired-plot trends conflicted with unpaired comparisons were identified.

RESULTS

In every state analyzed in this study, comparisons of paired plots that were measured during both inventories yielded different trends than those identified from comparisons of all plots (Fig. 2). In six states (Arizona, Colorado, Idaho, Montana, Nevada, and Utah), comparisons of all periodic and annual inventory plot data demonstrated declines in both mean live tree biomass and mean total (live plus dead) tree biomass per plot. However, comparisons of paired plots showed very little change in live tree biomass and increases in total tree biomass. Therefore, the two comparisons produced conflicting trends not only in magnitude but also in direction of change. Changes in dead tree biomass were similar among the two comparisons.

The two states that did not fit the pattern previously described were New Mexico and Wyoming, where unpaired comparisons showed increases in total, live, and dead tree biomass while paired comparisons demonstrated very little change in any tree biomass component. This is likely due to the fact that the time 2 measurement consisted of a second periodic inventory. As previously mentioned, periodic inventories typically targeted specific ownership groups. The time 1 periodic inventories in both states were completed in the early to mid-1980s and sampled a disproportionate amount of private and non-national forest public lands. The time 2 periodic inventories in both states were conducted in the late 1990s and sampled a relatively large amount of national forest lands. Therefore, the apparent increases in biomass, based on unpaired analyses, were primarily due to differences in sampling. Comparison of paired plots in both states showed very little change between the 1980s and late 1990s.

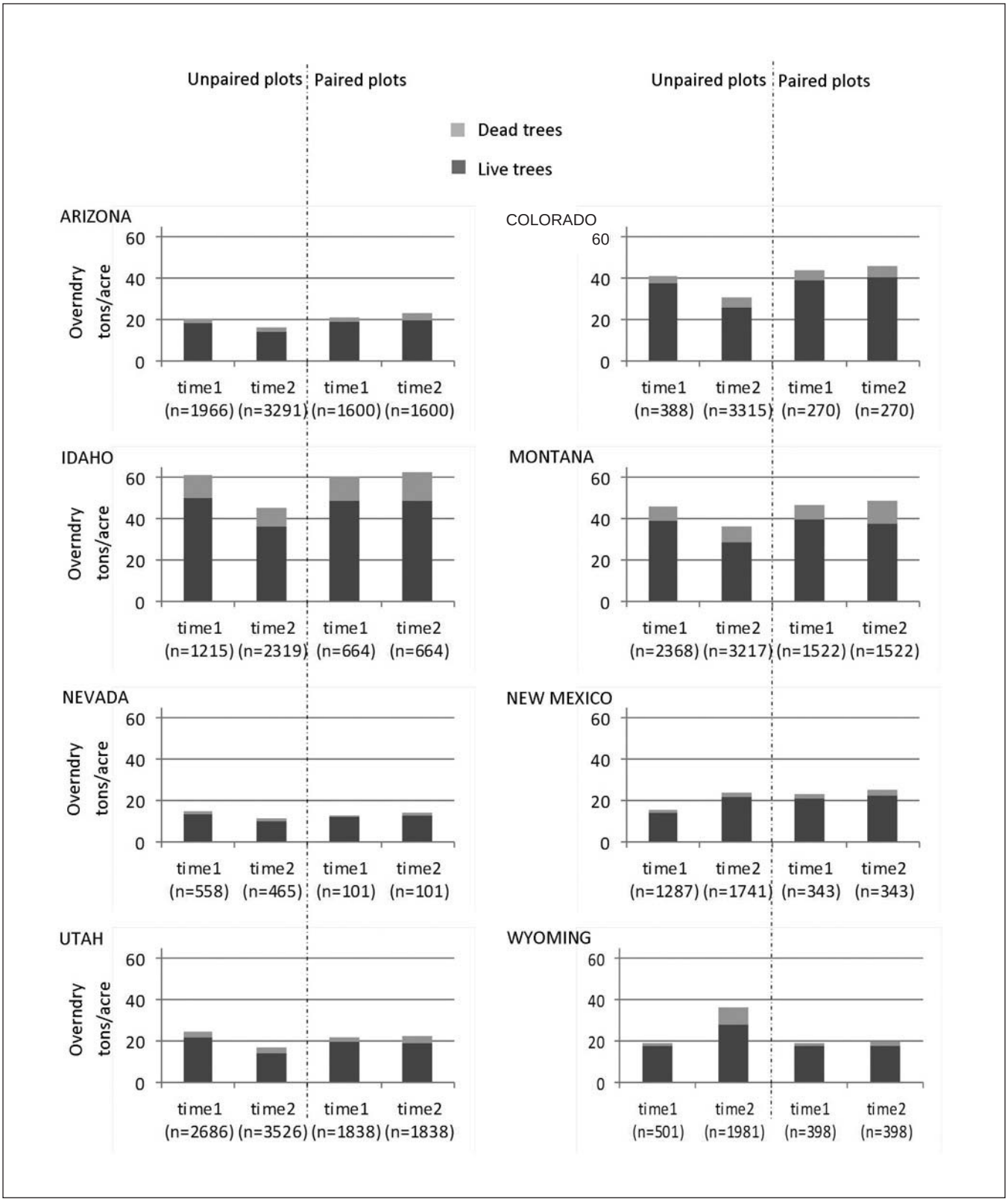

Figure 2.—Graphs showing mean aboveground biomass of live (dark gray) and dead (light gray) trees by state, in tons per acre.

Figure 3 shows the change in live, dead, and total aboveground mean biomass per plot from time 1 to time 2, by ecoregion subsection. Specific trends in live and dead biomass varied geographically, where areas of greatest decrease in live biomass presumably represent the occurrence of wildfires and/or disturbances such as insects that affect specific forest types.

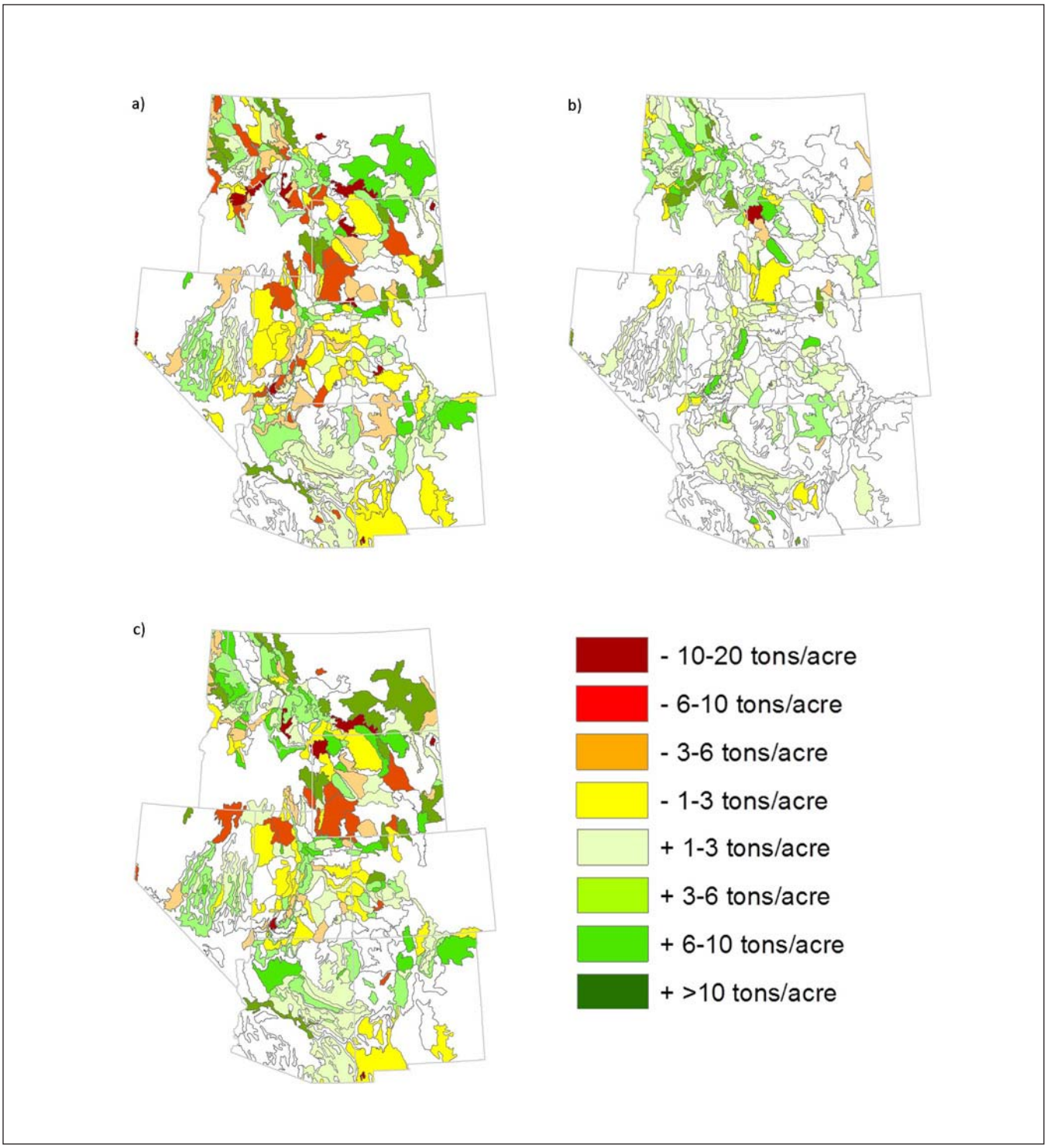

Figure 3.—Maps showing the magnitude of a) live, b) dead, and c) total aboveground tree biomass change at paired plots between time 1 and time 2, in tons per acre, averaged by ecoregion subsections. Blank subsections indicate either absence of paired plots or change less than 1 ton per acre.

DISCUSSION

Comparing periodic and annual inventory data is problematic due to numerous differences in definitions and protocols between the two inventories. Direct comparisons may produce apparent trends that differ from those found when comparing only paired plots, as demonstrated using aboveground tree biomass data from eight Interior West states. The unpaired comparisons for all states except New Mexico and Wyoming showed superficial decreases in standing tree biomass. This is likely due to the fact that most periodic inventories targeted specific ownership groups, which may correspond to oversampling of highly productive versus relatively unproductive forest lands. In contrast, the spatial configuration of the annual inventory represents ownership groups and productivity levels proportional to their existence across the landscape. As might be expected, results of the paired-plot comparisons often conflicted with those from the unpaired comparisons. In this case, using paired plot data versus spatially disparate samples represents the difference between trees in some states acting as a forest carbon source versus sink.

One caveat of this analysis is that conclusions about forest trends may characterize areas that were heavily sampled during the periodic inventory, and may not represent actual trends on a statewide basis. In other words, if areas were oversampled previously, the sample design of the annual inventory constrains them from continuing to be oversampled; yet using paired measurements cannot compensate for areas that were under-represented previously. Therefore, this analysis could not account for the fact that large areas were omitted from some periodic inventories, nor could it account for different plot configurations (i.e., variable-radius versus mapped-plot designs). Using paired-plot comparisons to infer statewide trends cannot account for small-scale disturbances that may have affected trends in under-sampled areas. Instead, it assumes that temporally variable processes operating at those plots (e.g., precipitation, temperature, and disturbances such as fire or insects) exhibit trends that are spatially representative of the state as a whole.

In terms of the absolute quantity of mean biomass per plot, the spatially balanced design of the annual inventory qualifies it as the most representative metric of the state as a whole. This means that the unpaired time 2 estimate (Fig. 2) is likely more accurate than the paired time 2 estimate. The two quantities differ in most states, suggesting that the paired plots used for trend assessment are not representative of actual mean conditions statewide. Note that this interpretation of absolute mean biomass per plot does not hold true in New Mexico and Wyoming because time 2 data in those states were collected during periodic inventories that targeted a narrow range of ownership groups and regions (see Fig. 1).

Finally, the sometimes conflicting trends produced by comparing paired plots versus entire statewide inventories confirm the need to account for discrepancies between the periodic and annual inventory estimates. Because many Interior West states are still in their first annual forest inventory cycle, additional plots can be incorporated into paired-plot comparisons as additional panels are completed and new annual plots are colocated with existing periodic plot locations. In some states, statistical modeling efforts may produce a more representative pre-2000 baseline of forest metrics, and thus enable more reliable trend assessment.

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