Supplemental Material for "Forest Carbon Calculators: A Review for Managers, Policymakers, and Educators" (Zald et al.)

Table S1. Answers to survey question for forest carbon calculators

Question	CBM-CFS3	CCTv4.0	COLEv3.0	CR-FVS	AFOLU-CC	FORGATE	FSCC	THPGGEC	GTR-NE-343	LMS	FICAT	FORPLAN
1	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
2	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
3	Yes	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes
4	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	No	Yes
5	Yes	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No
6	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	No	No
7	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	Yes
8	Yes	No	No	Yes	No	No	Yes	No	No	No	No	No
9	No	No	No	Yes	No	No	No	No	No	No	No	No
10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
11	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
12	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13	Yes	No	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No
14	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	No	No
15	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	No	No
16	No	No	No	Yes	No	No	No	No	No	Yes	No	No
17	Yes	No	No	Yes	No	No	Yes	Yes	No	Yes	No	No
18	Yes	No	No	Yes	No	No	Yes	No	No	No	No	No
19	Yes	No	No	Yes	No	No	Yes	No	No	No	No	No
20	Yes	No	No	Yes	No	No	Yes	No	No	No	No	No
21	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
22	No	No	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No
23	No	No	No	No	No	Yes	No	Yes	No	No	Yes	No
24	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	No	Yes
25	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
26	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes
27	Yes	No	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes
28	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	No	No
29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
31	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No
32	No	No	Yes	No	Yes	No	Yes	No	No	No	No	Yes
33	Yes	No	No	Yes	No	No	No	No	No	No	No	No
34	Yes	No	No	Yes	No	No	No	No	No	Yes	No	No
35	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
36	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
37	Yes	No	Yes	No	No	Yes	Yes	No	No	Yes	No	Yes
38	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
39	No	No	No	Yes	No	No	No	No	No	Yes	No	No
40	No	No	No	Yes	Yes	Yes	No	No	No	Yes	No	Yes
41	Tier III IPCC 2003	1605b	1605b	1605b	No	1605b	No	No	1605b	1605b	Tier I IPC 2006	No

Note: 1605b refers to voluntary 1605(b) reporting by federal agencies under the U.S. Energy Policy Act of 1992. Tier III IPCC 2003 refers to Tier III carbon estimation methods outlined in the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003) report. Tier I IPCC 2006 refers to Tier I methods outlined in the IPCC Guidelines for National Greenhouse Gas Inventories (2006)

Statistical Analyses

All statistical analyses were conducted in PC-ORD, Version 6.04 (McCune and Mefford 2011). We classified forest carbon calculators into groups using cluster analysis. We applied hierarchical, polythetic, agglomerative cluster analysis to a matrix of answers to 41 survey questions (hereafter referred to as characteristics) for the 12 forest carbon calculators; where yes/no answers were converted to binary 1/0 responses. Cluster analysis used Euclidean distance metric, natural weighting, and Ward's linkage method (Ward 1963, Orloci 1967, Mielke 1984). An important consideration in cluster analysis is determining the total number of groups. We determined the number of groups in the cluster analysis using indicator species analysis (ISA, Dufrêne and Legendre 1997). ISA is traditionally used in plant ecology research to determine what species indicate differences in vegetation composition between plots or stands, but in our analysis ISA is used to determine which characteristics indicate differences between groups of forest carbon calculators. Group membership was calculated at each level of grouping (i.e. 2-11 possible groups) in the cluster analysis, and ISA was used to calculate indicator values for each characteristic at each level of grouping. Following Dufrêne and Legendre (1997), we averaged the resulting p-values for characteristics (calculated by randomization tests with 5000 randomizations) across all characteristics, repeating at each clustering step. We also tallied the number of characteristics that were significant indicators ($p \leq 0.05$) at each level of grouping. We plotted the average p-values and number of characteristics that were significant indicators against each level of grouping (Figure S1), and selected the total number of groups based on the lowest average p-value and local maxima of the number of significant indicator characteristics. In addition to determining the total number of groups, indicator values for characteristics were also used to determine which attributes were most important in determining group membership (Table S2).

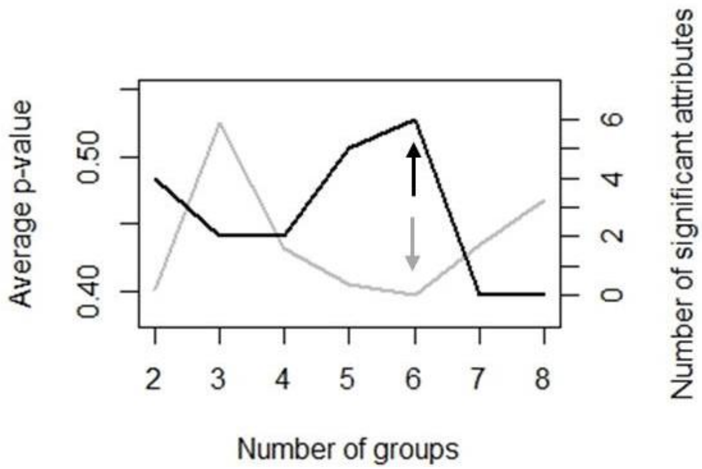

Figure S1. Results of indicator species analysis for pruning dendrogram in Figure 1. Average p-value for each level of grouping shown in black, number of significant answers ($p \leq 0.05$) at each level of grouping shown in grey. clustering step. Vertical arrows in figure show local minimum average p-value and local maximum number of significant answers in relation to number of groups.

Table S2. List of significant and suggestive questions indicating carbon calculator group membership, indicator species analysis results, and proportion of yes answers for selected questions by group membership.

Question Number	Question	Observed Indicator Value (IV)	IV from randomized groups Mean	Std Dev	p*	Proportion of yes anwsers by group 1	2	3	4	5	6
7	Does it directly incorporate the primary limiting factors ?	100	37.3	18.69	0.011	0	100	0	0	100	100
8	Does it incorporate effects of natural disturbance events/regimes on forest C?	100	37.3	18.69	0.011	0	0	0	0	0	100
14	Can the user specify the treatment intensity (percent of stand BA, BF, cover, LAI)?	66.7	39.1	18.22	0.0934	0	0	100	50	100	100
15	Can the user specify the treatment rotation length or interval?	66.7	39.1	18.22	0.0934	0	0	100	50	100	100
17	Can the user specify any post-harvest site preparation?	100	37.3	18.69	0.011	0	0	100	0	100	100
18	Can the user specify the intensity/magnitude/severity of a natural disturbance event or regime?	100	37.3	18.69	0.011	0	0	0	0	0	100
19	Can the user specify the frequency or frequency distribution of a natural disturbance event or regime?	100	37.3	18.69	0.011	0	0	0	0	0	100
20	Can the user specify the size or size distribution of a natural disturbance event or regime?	100	37.3	18.69	0.011	0	0	0	0	0	100
28	Can the user design their own specific treatment/disturbance scenarios?	66.7	39.1	18.22	0.0934	0	0	100	50	100	100

We also wanted to know how similar forest carbon calculators were to each other with respect to surveyed characteristics. Similarities of forest carbon calculators were visualized using nonmetric multidimensional scaling (NMS, Kruskal 1964, Mather 1976). NMS is an ordination method based on iterative searches for the best positions of *n* entities in *k* dimensions (axes) that minimize stress in the *k*-dimensional solution (McCune and Grace 2002). Stress is defined as the measure of departure from monotonicity in the relationship between the dissimilarity (distance) in the original p-dimensional space and distance in the reduced k-dimensional space (McCune and Grace 2002). NMS was used with Euclidean distance metric, 100 runs of real data with random starting configurations, and 500 runs of randomized data. Dimensionality (number of ordination axes) of the final model was determined by considering additional dimensions useful if they reduce final stress by 5 percent or more. Stress and instability in relation to dimensionality of ordinations were qualitatively assessed for both real and randomized data graphically using scree plots (not shown). Additionally, randomization tests were used to evaluate if the axes in the NMS ordination model were stronger than expected by chance. Interpretability, final model stress, and instability were used to assess final ordination quality. NMS ordination resulted in a stable, 2-dimensional solution with low instability and ordination axes were stronger than expected by chance ($p = 0.0196$). The cumulative proportion of variance in the original data described by the ordination was 89.6%, predominantly along the first ordination axis.

References

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