

Steward's Circle

Slope Correction of Plot Dimensions for Vegetation Sampling in Mountainous Terrain

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Tree basal area and density are criteria used to define plant communities, set conservation priorities, and evaluate management activities (Keddy and Drummond 1996, White and Lloyd 1998). Accurately estimating basal area and density from plots on a range of terrain consisting of different slope gradients is a common goal during ecological field studies. For a plot of given dimensions, the area of the plot on a horizontal plane decreases as slope gradient increases. For example, a 20 x 50 m plot on flat terrain has a 0.1 ha horizontal area, while on a 60% slope gradient, the same plot has only a 0.086 ha horizontal area. Unless plot dimensions are corrected for slope gradient, ecological field studies will underestimate basal area and density per unit area on a horizontal plane (Husch

et al. 1982). Basal area and density estimates are not directly comparable between ecological studies that correct for slope gradient and those that do not, and slope corrections should be applied if resources are to be mapped.

In published ecological studies in mountainous terrain, however, the correction of plot dimensions for slope gradient is rarely mentioned. We also reviewed several vegetation sampling textbooks, and slope correction was mentioned only briefly (Mueller-Dombois and Ellenberg 1974), or more commonly was not mentioned at all (e.g., Bonham 1989, Kent and Coker 1992). Slope correction also was not discussed in a recent standard vegetation sampling protocol advocated for use in the southern Appalachian Mountains (Peet et al. 1998). Ecologists thus have little guidance available about deciding whether or not to correct plot dimensions for slope gradient, how to make these corrections, and how much tree basal area and density estimates differ between corrected and uncorrected plots. This study was undertaken to compare basal area and density estimates between plots corrected and uncorrected for slope gradient in mountainous terrain and to provide guidance for plot dimension correction in ecological studies.

METHODS

We performed this study in the 13,000-ha Jocassee Gorges, managed by the South Carolina Department of Natural Resources, in northwestern South Carolina (35°02' N, 82° 50' W). Jocassee Gorges is in the Blue Ridge Mountain physiographic province of the southern Appalachian Mountains (Cooper and Hardin 1970), within the oak-chestnut forest region (Braun 1950). Typical elevations range from 350-850 m, and

topography consists of stream-dissected hill slopes varying in slope gradient from less than 2% on stream bottoms to near 100% on the steepest hill slopes.

We sampled 48, 20 x 50 m (0.1 ha) plots oriented with the 50-m axis parallel to the elevation contour. Six plots each were randomly located across the landscape on eight different topographic positions (stream bottoms, ridgetops, and lower, middle, and upper slope positions on both north- and south-facing hill slopes) to encompass a range of topography. Plot locations were confined to late-successional forests greater than age 70 y (based on stand records). On each plot, we determined the species and measured the diameter to the nearest centimeter at 1.4 m on the uphill side for each tree greater than 1 cm diameter. Slope gradient was measured to the nearest percent at the plot center by averaging upslope and downslope clinometer measurements. We corrected the 20-m plot axis for slope gradient in the downslope direction and measured trees in this corrected area separately from the uncorrected plot area. We computed the length that the 20-m axis needed to be corrected (elongated) using the equation: $20/(\cosine(\arctangent(\text{slope gradient as a decimal})))$. For example, a plot on a 50% slope gradient needed to be 22.36 x 50 m to be 0.1 ha on a horizontal plane [$20/(0.8944)$].

Using data from the uncorrected portions of plots, we mathematically corrected tree basal area and density estimates to be on a per hectare basis on a horizontal plane by computing the horizontal area sampled by a plot: $50*(20*(\cosine(\arctangent(\text{slope gradient as a decimal}))))$. For example, an uncorrected plot on a 50% slope gradient has a horizontal area of 0.08944 ha or 894.4 m² ($50*(20*0.8944)$). Using two-tailed paired *t* tests, we compared mathematically corrected mean basal area and density estimates with estimates from field corrections utilizing corrected portions of plots. We compared uncorrected mean basal area and density estimates to mathematically and field corrected estimates using one-tailed paired *t* tests of the null hypothesis that corrected estimates were not greater than uncorrected estimates.

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RESULTS AND DISCUSSION

Differences between uncorrected and corrected basal area and density estimates progressively increased with increasing slope gradient (Figure 1). Uncorrected basal area estimates averaged more than 4.5 m²/ha lower than corrected estimates on slope gradients 40-60%, and about 8 m²/ha lower

on slope gradients above 60%. Uncorrected density estimates averaged more than 160 trees/ha less than corrected estimates on 40-60% slope gradients and more than 220 trees/ha less on slope gradients above 60%. Substantial portions of plots occurred on 40-60% slope gradients (21/48 plots) and greater than 60% slope gradients (12/48 plots). Field and mathematically corrected

estimates did not differ significantly (Figure 1), and were highly correlated for both basal area (Pearson $r = 0.97$) and density ($r = 0.99$). Corrections for basal area and density estimates were strongly correlated with slope gradient for field corrections ($r = 0.81$ basal area, $r = 0.83$ density) and mathematical corrections ($r = 0.91$ basal area, $r = 0.80$ density).

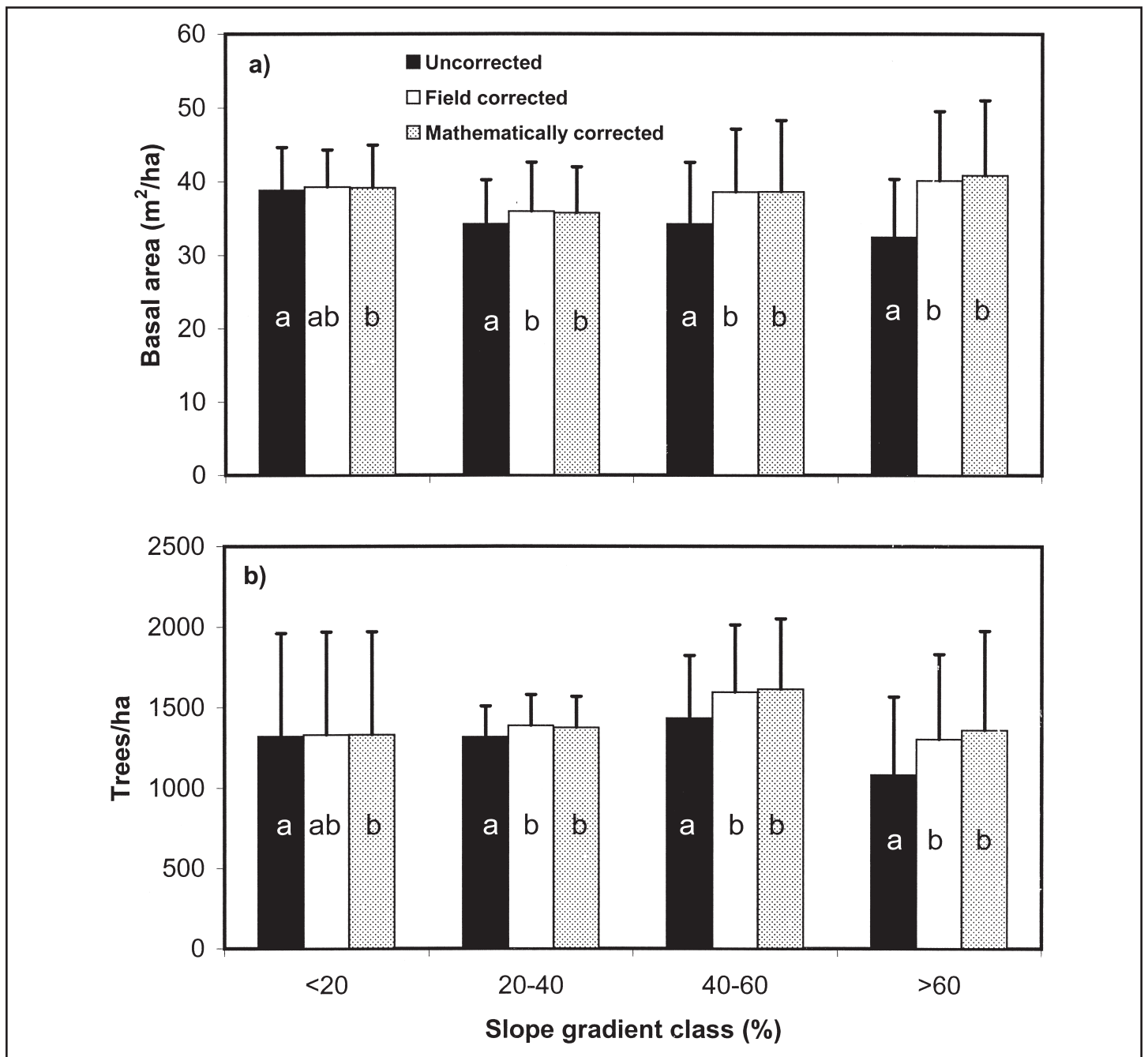


Figure 1. Comparison of (a) basal area and (b) density estimates among plots uncorrected, field corrected, and mathematically corrected for slope gradient, Jocassee Gorges, southern Appalachian Mountains. Means within a slope gradient class without shared letters differ at $p < 0.05$ (paired t tests). Error bars are 1 standard deviation.

Basal area and density estimates vary considerably depending on whether plots are corrected for slope gradient, especially for slope gradients above 40%. Since the majority (69%) of plots occurred on slope gradients greater than 40%, slope correction in mountainous regions is an important consideration in ecological studies reporting forest basal area and density. Two options are available for sampling plots in sloping terrain. The slope area sampled by plots can be held constant by sampling consistent slope plot dimensions (not correcting plot dimensions for slope gradient), or the area on a horizontal plane sampled by plots can be held constant by correcting plot dimensions for slope gradient in the field. As long as slope gradients are measured, basal area and density estimates from plots that sample a consistent slope area can be mathematically converted to a per unit area on a horizontal plane basis. Since field and mathematically corrected basal area and density estimates were highly correlated, it is probably easiest to mathematically correct estimates rather than sampling additional horizontal area in the field. However, mathematical corrections do not account for new species that may be found if the plot area was corrected while in the field.

There are reasons both for and against field or mathematically correcting basal area and density to be on a per horizontal area basis in ecological field studies. If resources are planned to be mapped or if there are other reasons to standardize basal area and density on a horizontal area basis, slope corrections should be applied. Because trees grow on actual slope surfaces rather than on horizontal planes and if trees can efficiently exploit soil volumes on sloping terrain, applying slope corrections may slightly overestimate basal area and density on a horizontal plane unit area basis (Mueller-Dombois and Ellenberg 1974). The amount of this overestimate, if any, is difficult to determine without knowledge of tree-soil volume relationships (Stone and Kalisz 1991). Similar considerations also apply to sampling ground-flora on plots in mountainous terrain.

CONCLUSIONS

On hilly or mountainous terrain, the horizontal area sampled by a plot of given dimensions decreases with increasing slope gradient, impacting tree basal area and density estimates. Plot dimensions can be corrected for slope gradient to standardize basal area and density on a horizontal plane unit area basis, but slope correction is rarely addressed in published ecological studies, in vegetation sampling textbooks, or in standard vegetation sampling protocols. Using data from 48 0.1-ha plots in the southern Appalachians, we found that uncorrected estimates of basal area averaged 8 m²/ha lower and density more than 220 trees/ha lower than corrected estimates for slope gradients greater than 60%. There are reasons both for and against correcting plots for slope gradient in ecological studies, such as whether or not forest resources are to be mapped. Ecologists should be aware, however, that tree basal area and density estimates are not directly comparable between studies that correct for slope gradient and those that do not. Guidance about slope correction of plot dimensions should be provided in vegetation sampling textbooks and in standard vegetation sampling protocols.

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