

Supplementary Material

Ungulate Species and Abundance as well as Environmental Factors Determine the Probability of Terminal Shoot Browsing on Temperate Forest Trees

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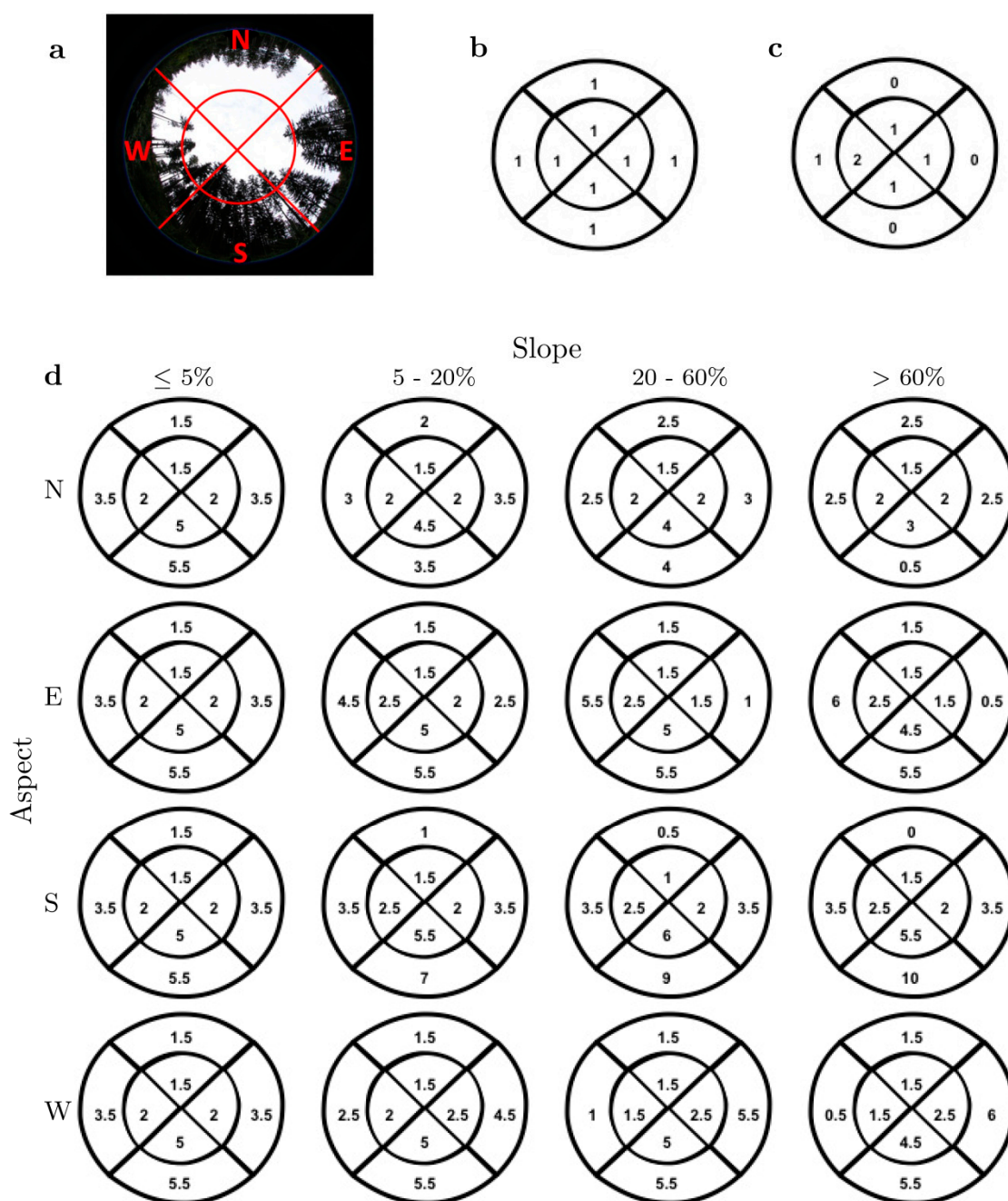


Figure S1. Construction of canopy opening covariates. (a) The canopy above a plot was optically split into eight sectors, based on proximity to zenith (2 levels) and cardinal direction (4 levels). Each sector was recorded as gap if less than half of the sector was covered by treetops. The canopy covariates were calculated as the sum of the weighted gaps. (b) Equal weighting was used for gap size. (c) Snow depth was approximated by increasing the weight of gaps at the centre and in the West. (d) Light transmission was approximated by taking aspect and slope into account. The respective weights were calculated using the Gap Light Analyzer software. Assuming a slope of 10% and an aspect in northern direction, the example in (a) has a gap size and snow depth of 4 and a light transmittance of 7.5.

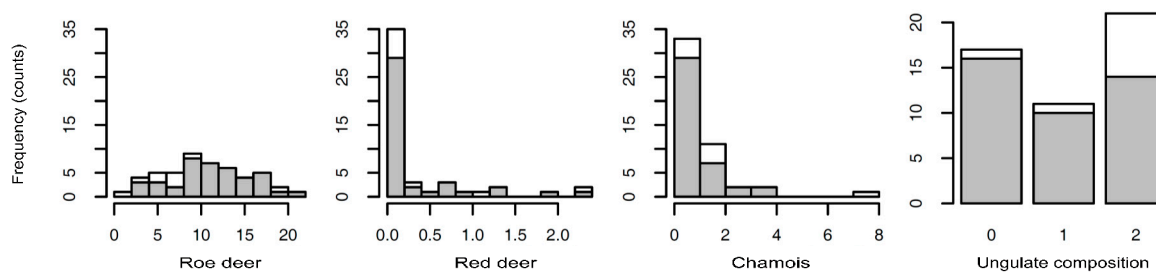


Figure S2. Distribution of the ungulate variables (averaged over the observation period) in all 49 indicator areas (white bars) and the 40 indicator areas included in the supplementary field data collection 2012 (grey bars).

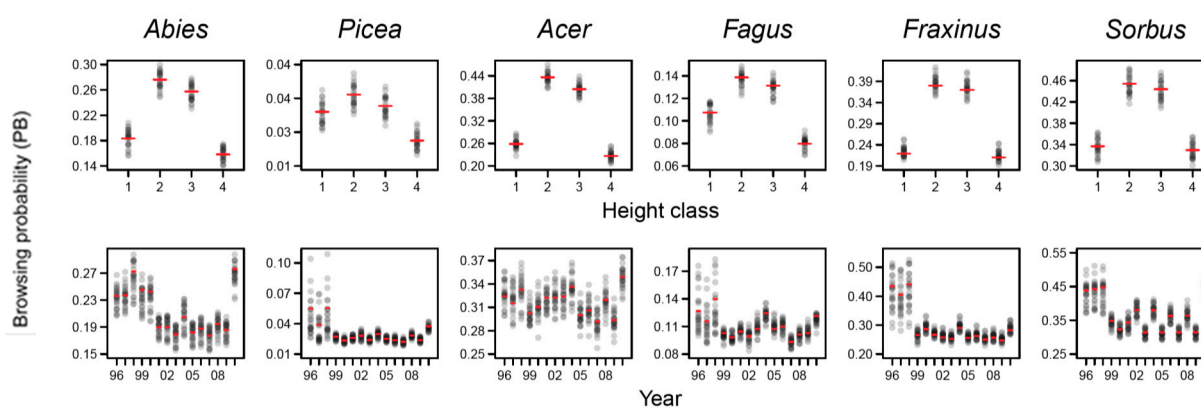


Figure S3: Partial dependence plots with marginal effects of height class and year on browsing probability (PB) of *Abies*, *Picea*, *Acer*, *Fagus*, *Fraxinus*, and *Sorbus* estimated by random forest models. Red lines are based on all data. Grey lines are a measure for the variation among indicator areas (IAs) and were estimated from random resamples of 25 out of the 40 IAs. Note that the scaling of the y axis varies among tree species.

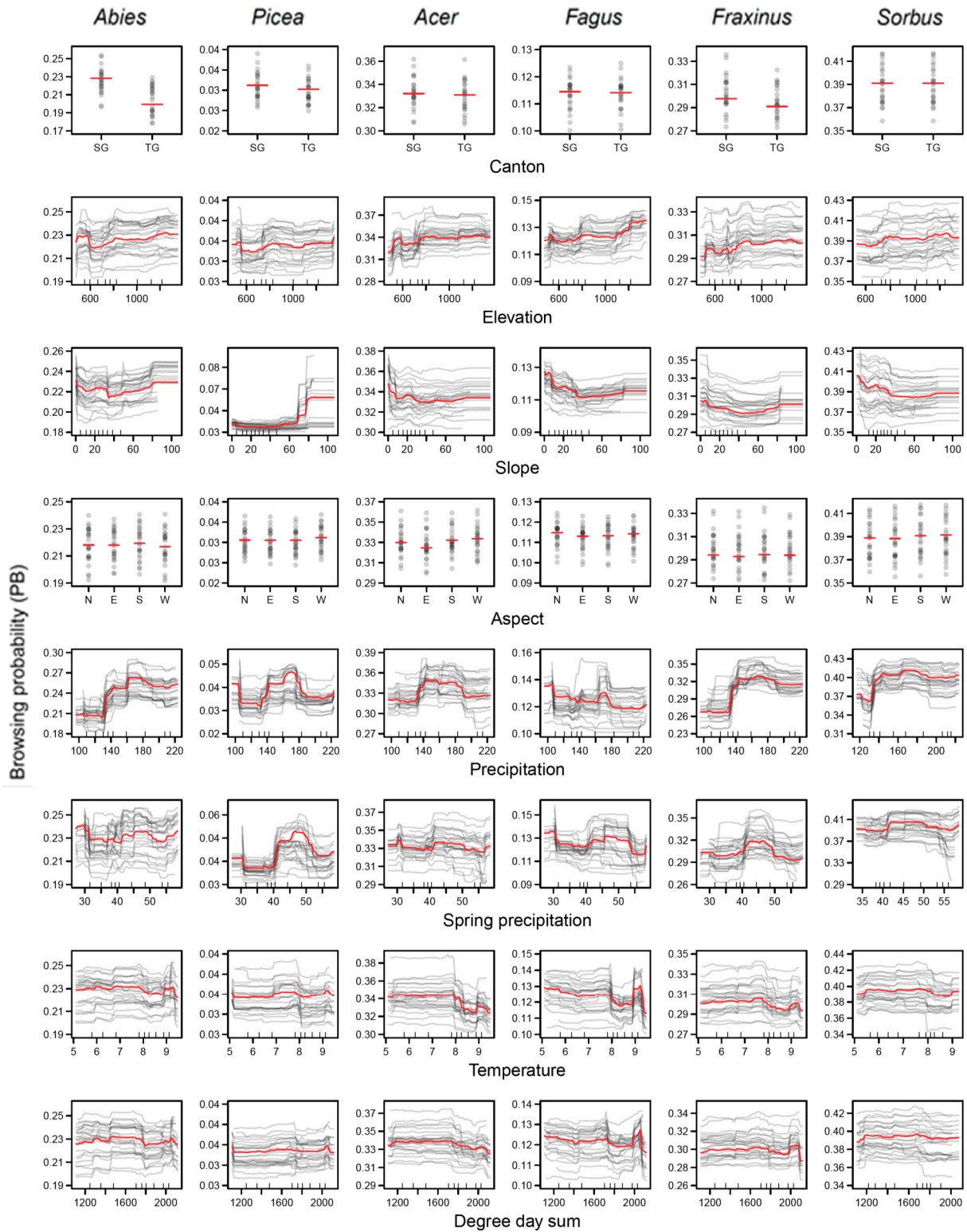


Figure S4: Partial dependence plots with marginal effects of location and climate on browsing probability (PB) of *Abies*, *Picea*, *Acer*, *Fagus*, *Fraxinus*, and *Sorbus* estimated by random forest models. Red lines are based on all data. Grey lines are a measure for the variation among indicator areas (IAs) and were estimated from random resamples of 25 out of the 40 IAs. Internal tick marks on the x axes indicate the deciles of continuous explanatory variables. Note that the scaling of the y axis varies among tree species.

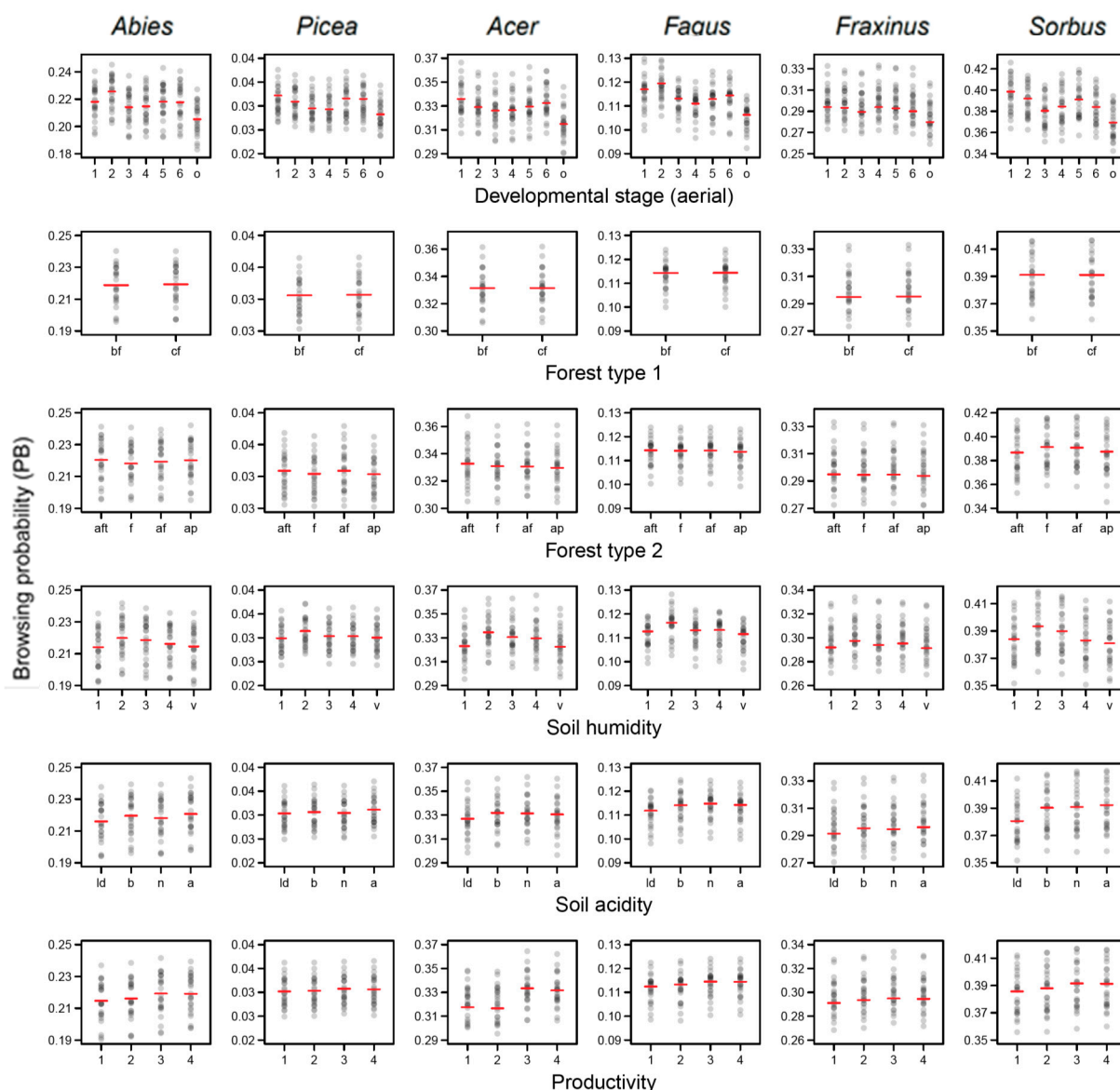


Figure S5: Partial dependence plots with marginal effects of forest characteristics on browsing probability (PB) of *Abies*, *Picea*, *Acer*, *Fagus*, *Fraxinus*, and *Sorbus* estimated by random forest models. Red lines are based on all data. Grey lines are a measure for the variation among indicator areas (IAs) and were estimated from random resamples of 25 out of the 40 IAs. Note that the scaling of the y axis varies among tree species.

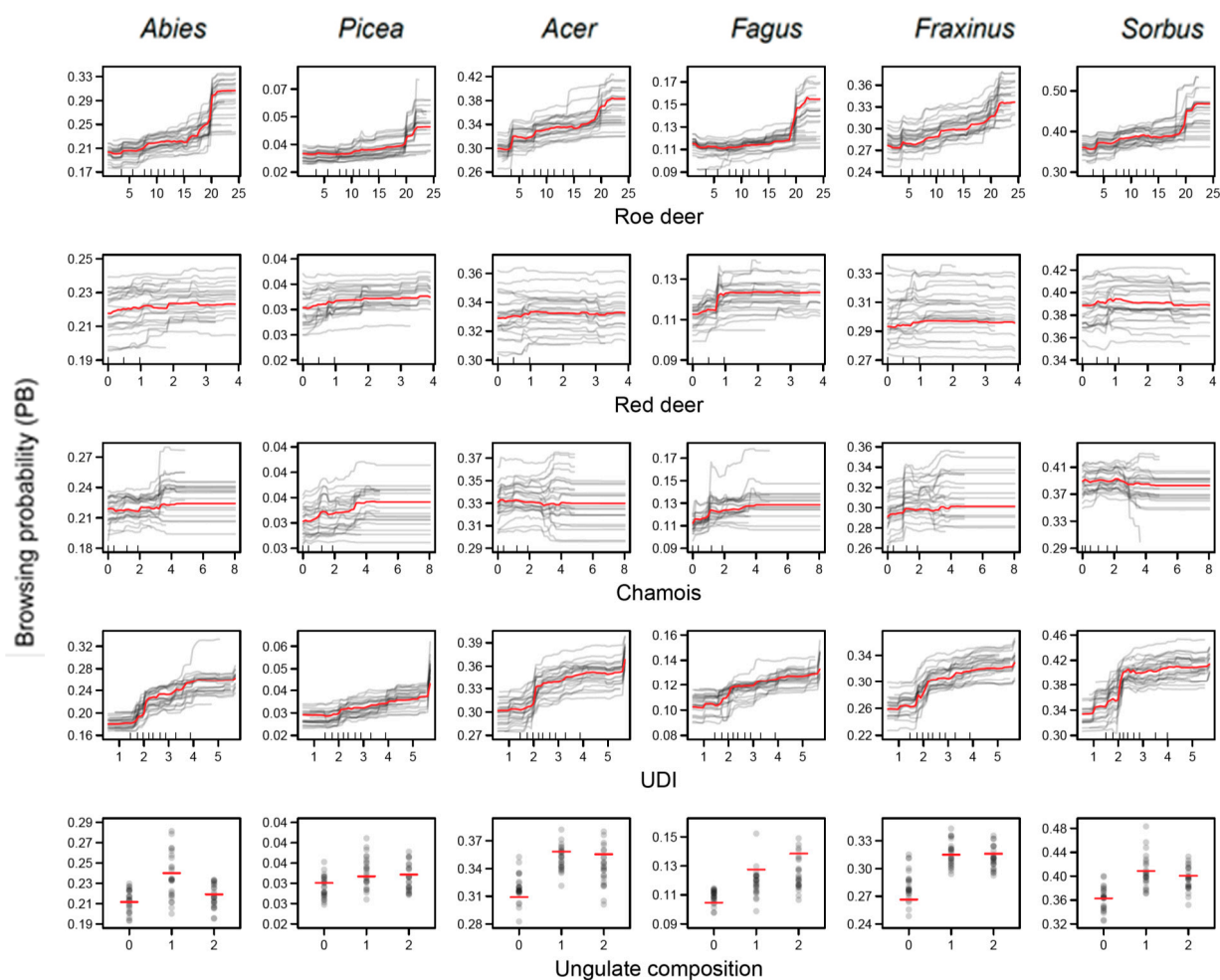


Figure S6: Partial dependence plots with marginal effects of variables regarding ungulates on browsing probability (PB) of *Abies*, *Picea*, *Acer*, *Fagus*, *Fraxinus*, and *Sorbus* estimated by random forest models. Red lines are based on all data. Grey lines are a measure for the variation among indicator areas (IAs) and were estimated from random resamples of 25 out of the 40 IAs. Internal tick marks on the x axes indicate the deciles of continuous explanatory variables. Note that the scaling of the y axis varies among tree species.

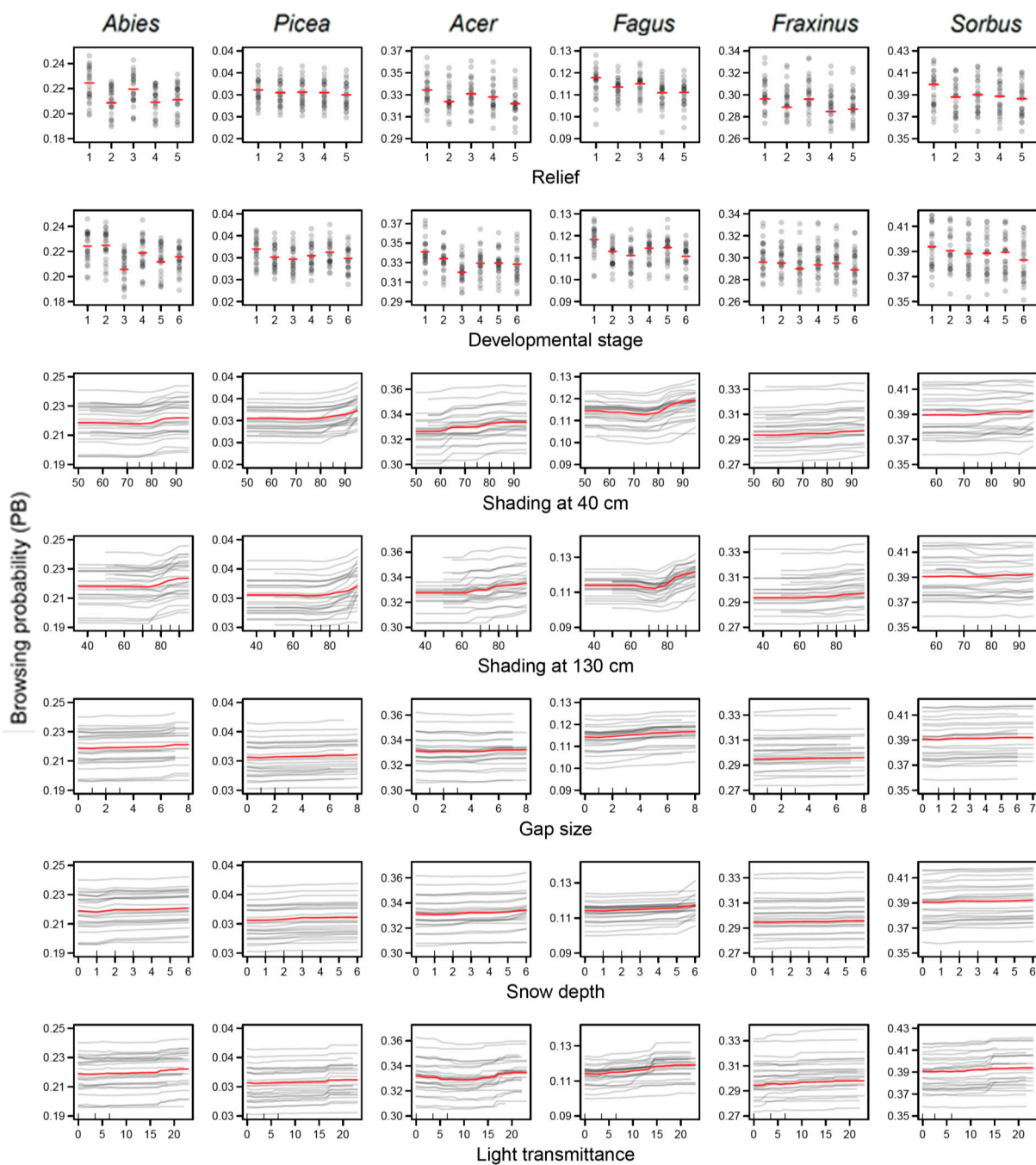


Figure S7: Partial dependence plots with marginal effects of variables concerning location and light on browsing probability (PB) of *Abies*, *Picea*, *Acer*, *Fagus*, *Fraxinus*, and *Sorbus* estimated by random forest models. Red lines are based on all data. Grey lines are a measure for the variation among indicator areas (IAs) and were estimated from random resamples of 25 out of the 40 IAs. Internal tick marks on the x axes indicate the deciles of continuous explanatory variables. Note that the scaling of the y axis varies among tree species.

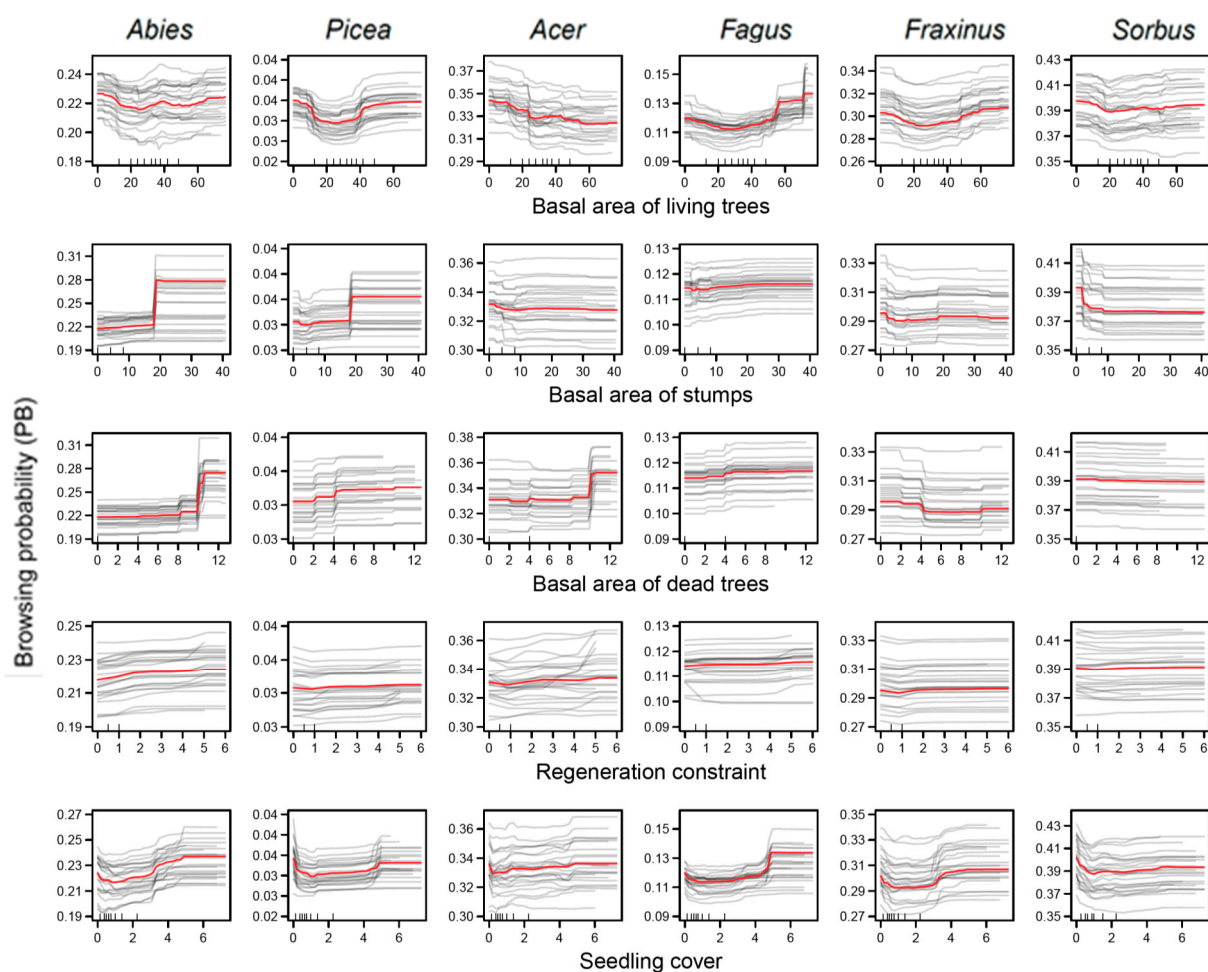


Figure S8: Partial dependence plots with marginal effects of basal are and seedling cover on browsing probability (PB) of *Abies*, *Picea*, *Acer*, *Fagus*, *Fraxinus*, and *Sorbus* estimated by random forest models. Red lines are based on all data. Grey lines are a measure for the variation among indicator areas (IAs) and were estimated from random resamples of 25 out of the 40 IAs. Internal tick marks on the x axes indicate the deciles of continuous explanatory variables. Note that the scaling of the y axis varies among tree species.

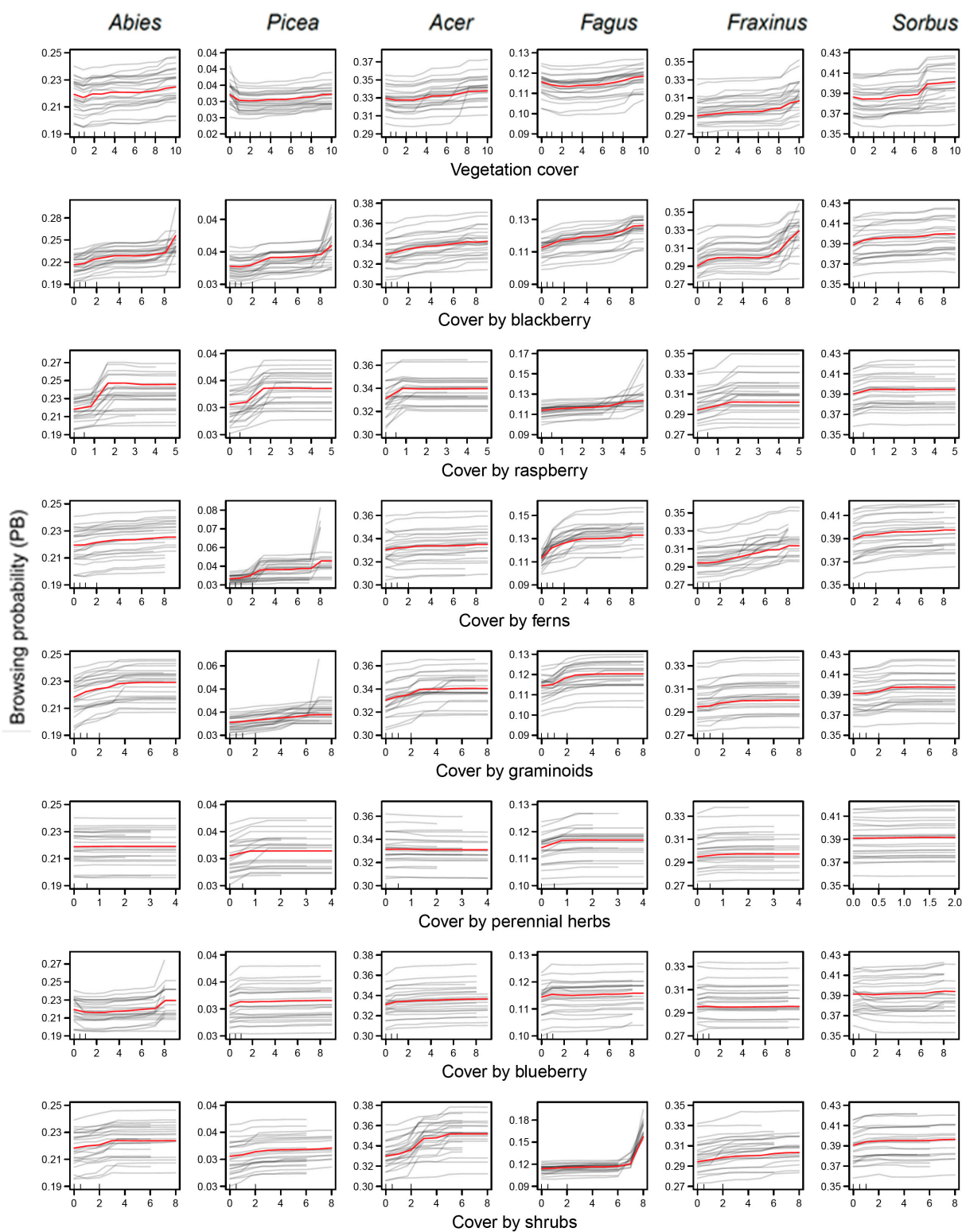


Figure S9: Partial dependence plots with marginal effects of vegetation cover on browsing probability (PB) of *Abies*, *Picea*, *Acer*, *Fagus*, *Fraxinus*, and *Sorbus* estimated by random forest models. Red lines are based on all data. Grey lines are a measure for the variation among indicator areas (IAs) and were estimated from random resamples of 25 out of the 40 IAs. Internal tick marks on the x axes indicate the deciles of continuous explanatory variables. Note that the scaling of the y axis varies among tree species.

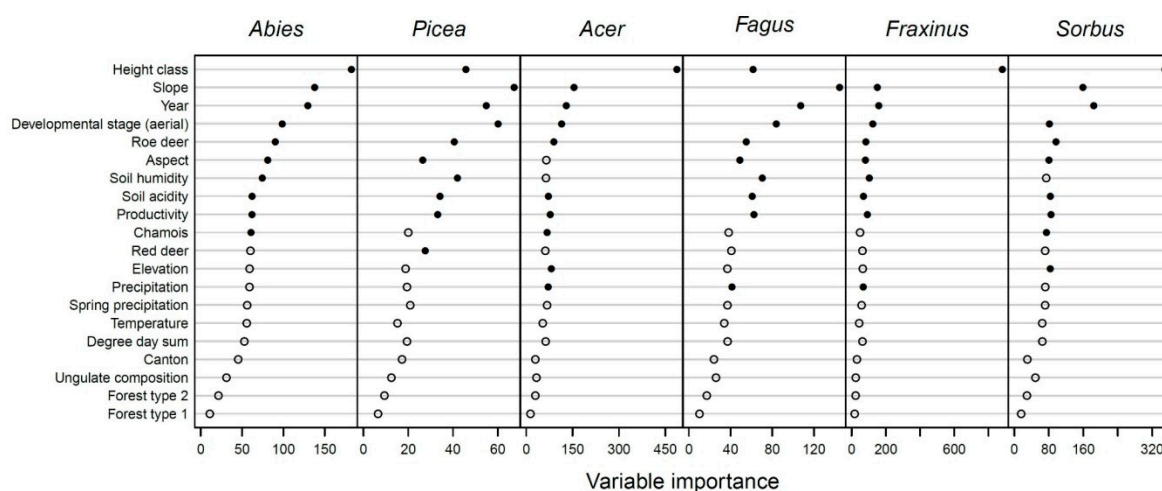


Figure S10: Variable importance in random forest with all plots of the 49 indicator areas. The predictive permutation importance of each explanatory variable (variable importance) in the tree-species specific random forest models for browsing probability (PB) is shown. The variables are ordered according to decreasing importance in the *Abies* model. Only variables available for all 49 indicator areas (Table 1) were included, thus excluding all variables of the supplementary assessment in 2012. To avoid possible correlations between roe deer density and UDI, we omitted UDI in this control analysis. The ten most important variables for each tree species are shown as filled circles.

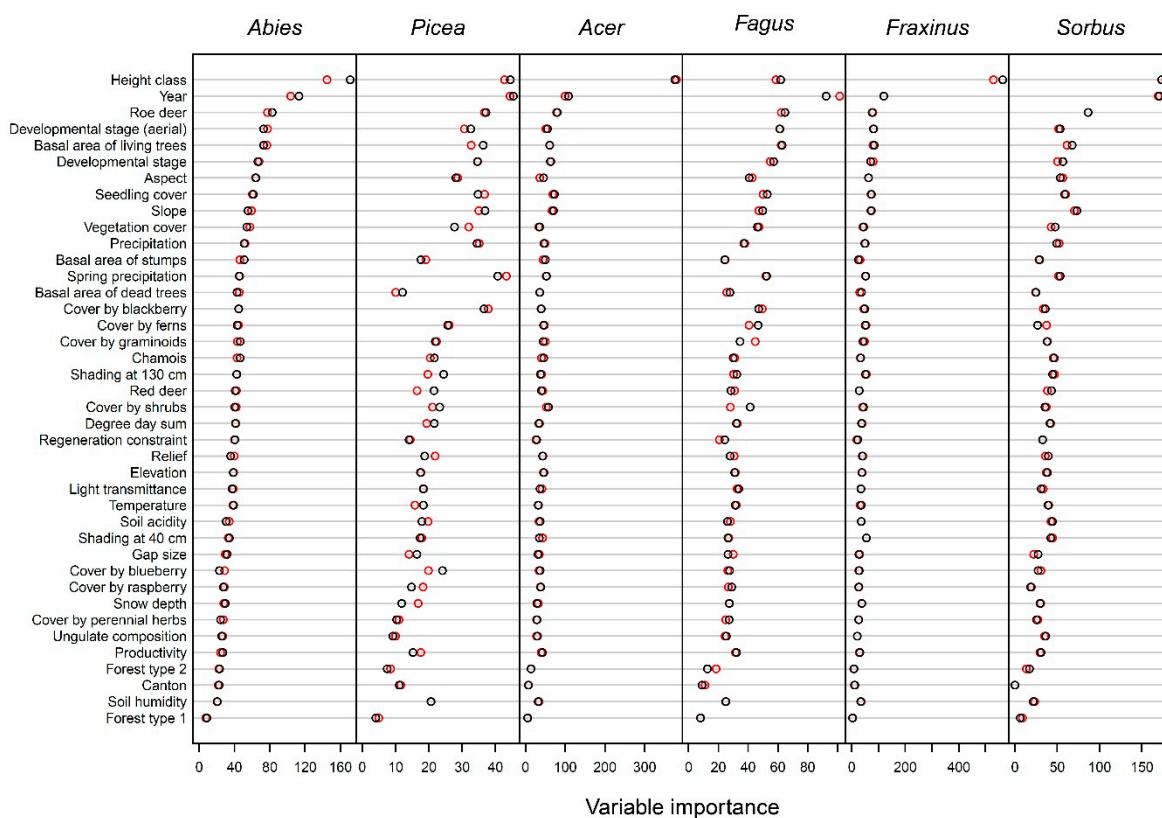


Figure S11: Variable importance in weighted random forests. The predictive permutation importance (variable importance) for random forests weighted by the inverse of the standard error of the browsing probability PB is printed (red circles). The variable importance of standard, unweighted random forests is included for comparison (black circles).

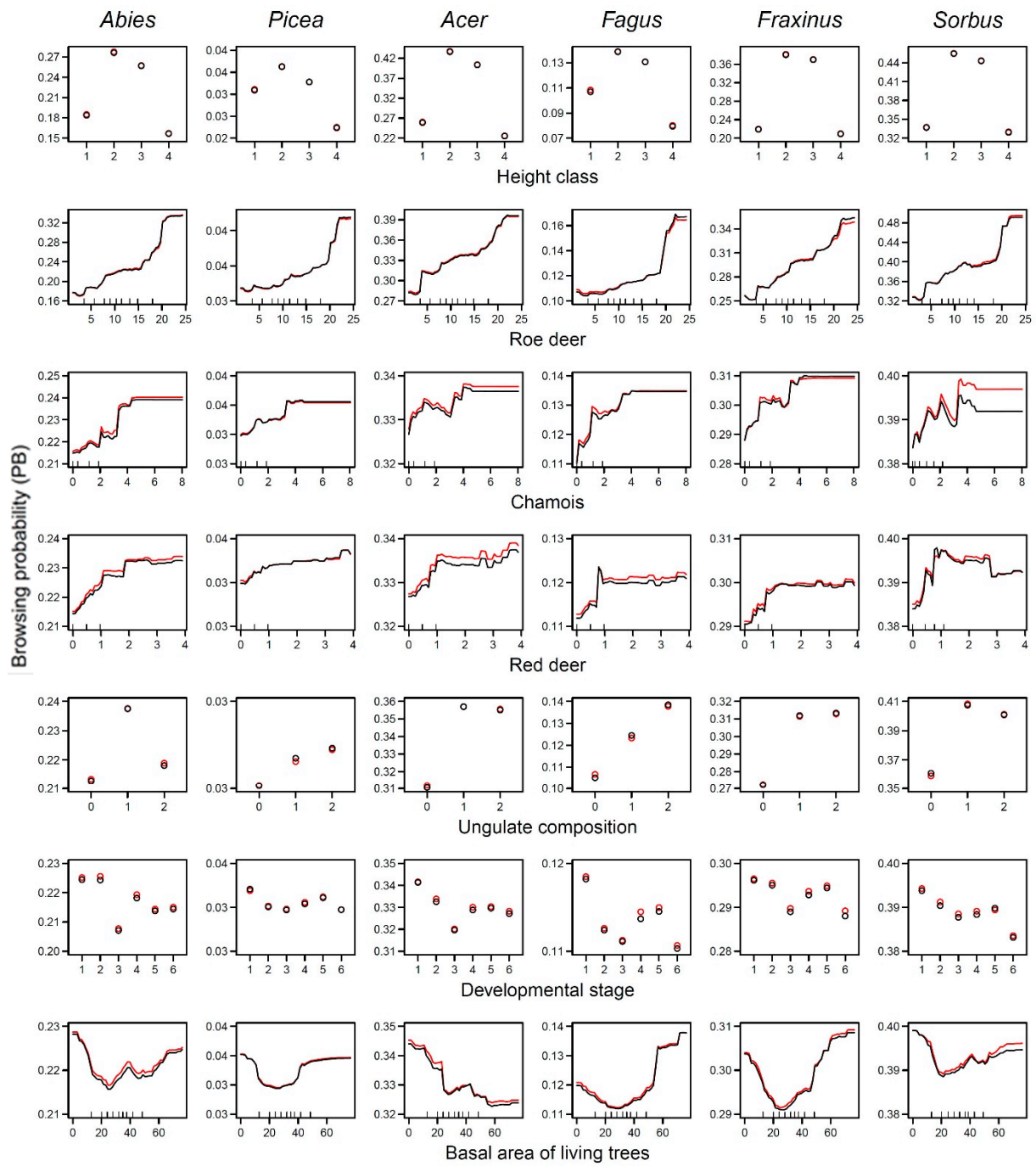


Figure S12: Partial dependence plots with marginal effects of selected variables on browsing probability (PB) estimated by random forests weighted by the inverse of the standard error of PB (red circles). The variable importance of standard, unweighted random forests is included for comparison (black circles or black lines).

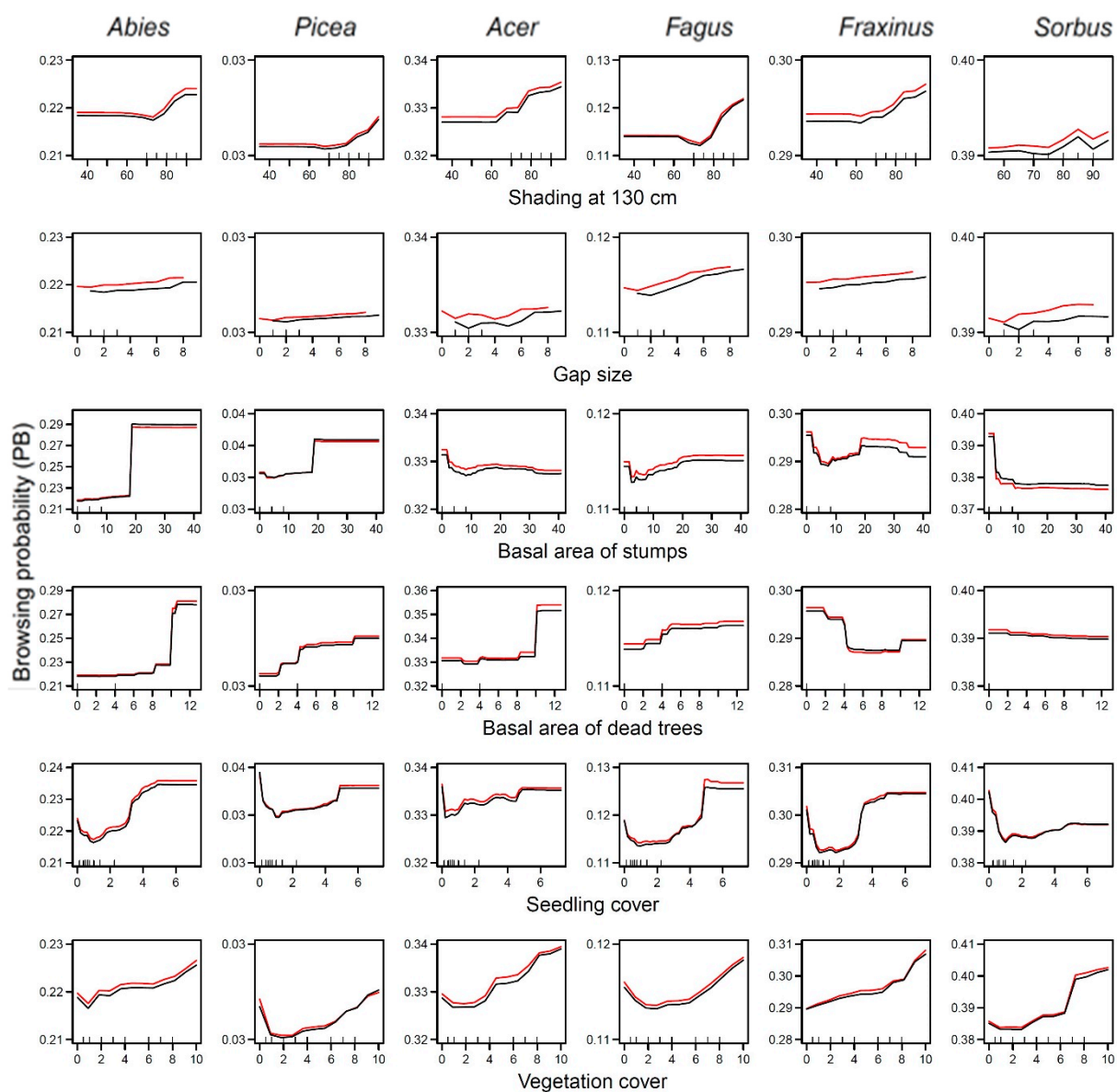


Figure S13: Further partial dependence plots in weighted random forests. See Figure S12.

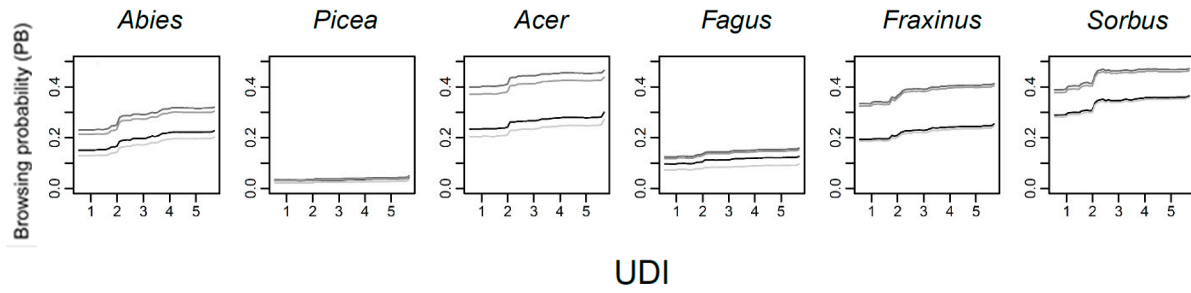


Figure S14: Joint marginal effects of UDI and height class on browsing probability (PB) of each tree species. Height class 1 (10-40 cm) is shown in black, height classes 2 (41-70 cm), 3 (71-100 cm), and 4 (101-130 cm) in dark to light grey.

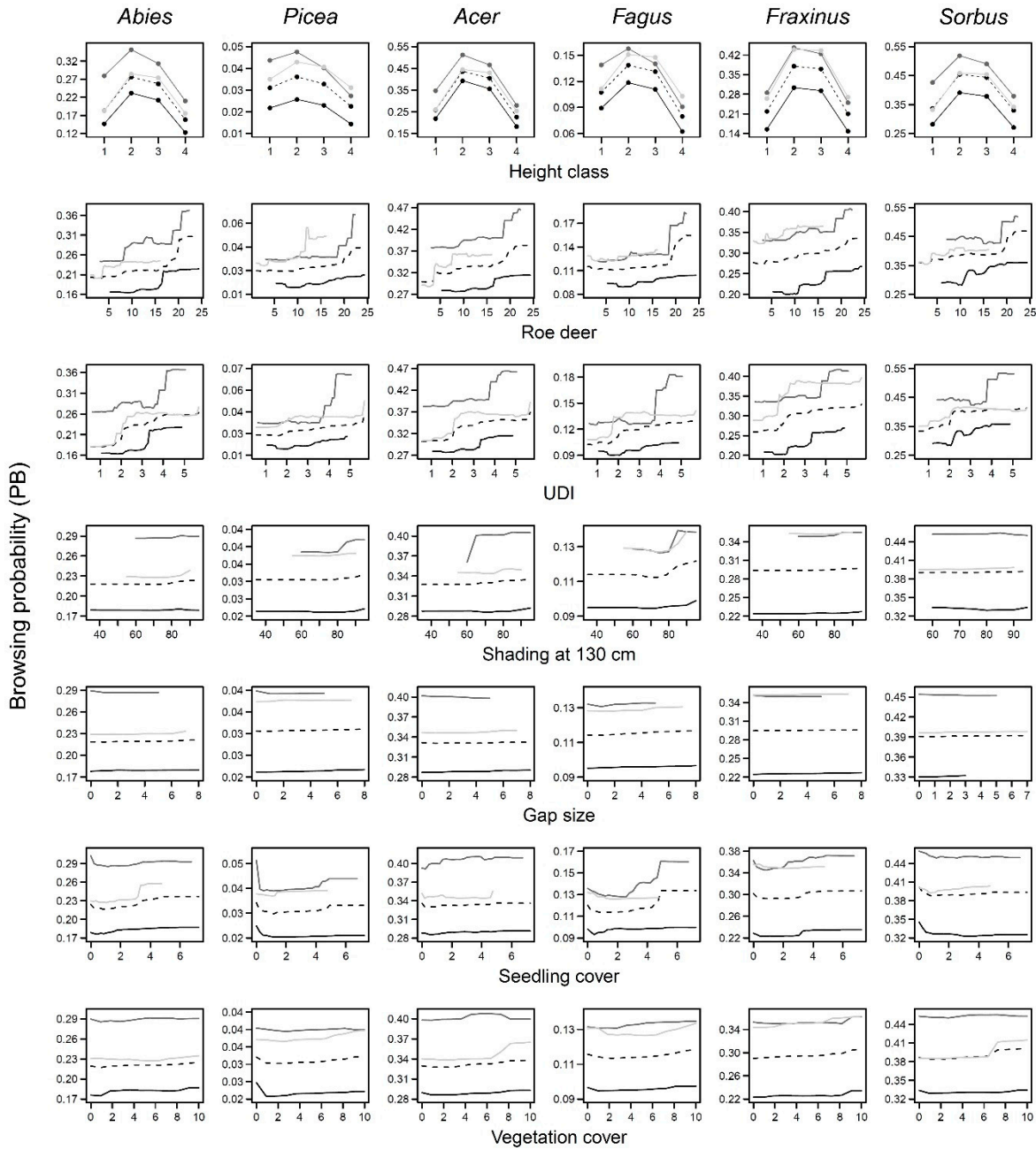


Figure S15: Subset analyses for ungulate composition. Partial dependence plots with marginal effects of selected variables on browsing probability (PB) as estimated by random forest models based on subsets of the data defined by ungulate composition: roe deer only (category 0, black), red deer and chamois making less (category 1, dark grey) and more than 5% of roe deer (category 2, light grey). Dotted lines represent the standard model including all ungulate composition categories.

