Supplements to

High-Resolution Above-Ground Biomass Mapping of the Alps using Satellite Embeddings and GEDI

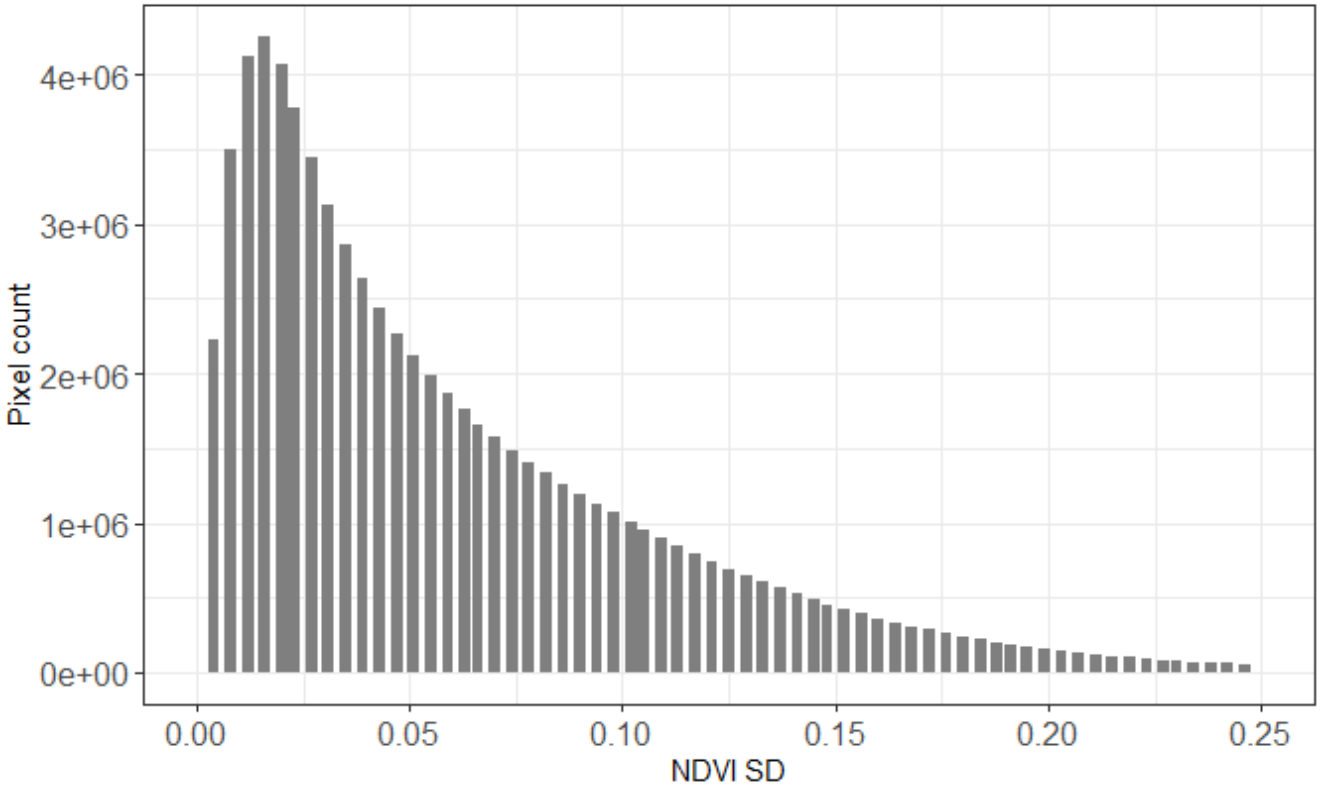
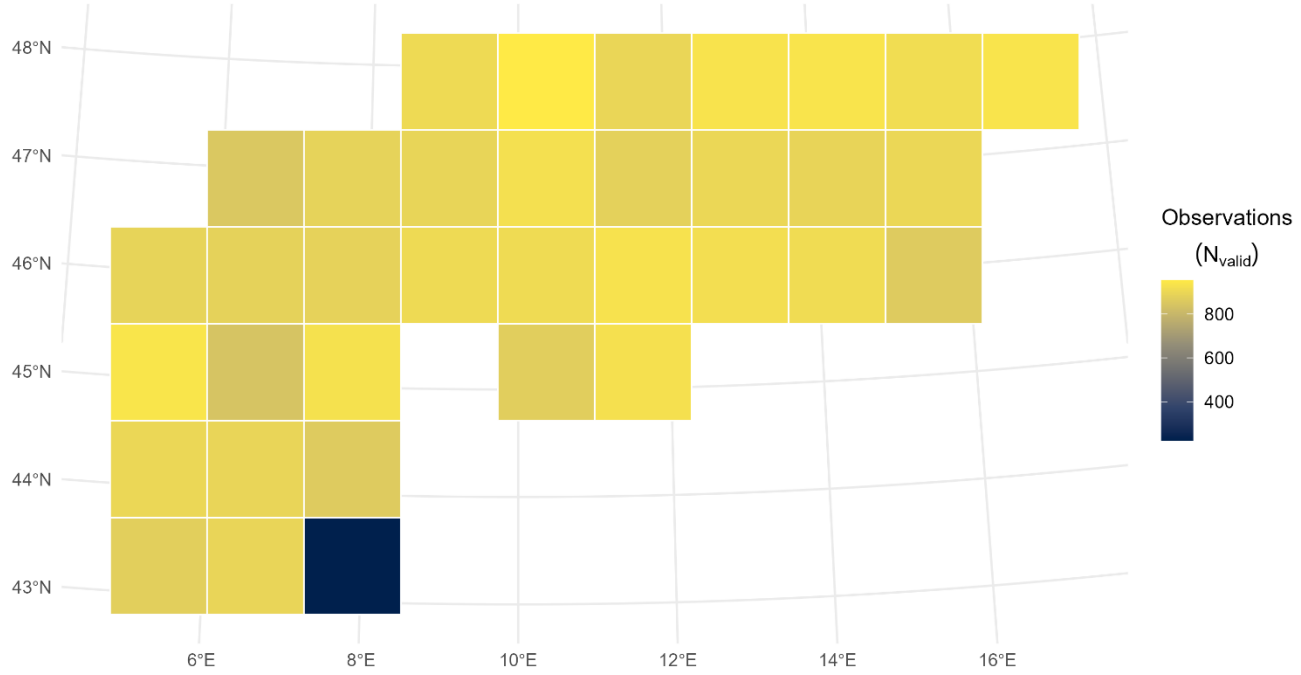


Figure S1: Frequency distribution of GEDI pixels categorized by Normalized Difference Vegetation Index (NDVI) from Sentinel-2 standard deviation (SD). The SD is calculated over a 3×3 pixel moving window to characterize local spatial heterogeneity and vegetation variability. SD served as the basis for filtering out GEDI pixels located within highly heterogeneous patches or forest edges to minimize spatial misalignment errors during model training.



10

Figure S2: Valid GEDI observations per tile after applying quality indicators, the terrain slope mask and the variance filter as described in Section 2.3.

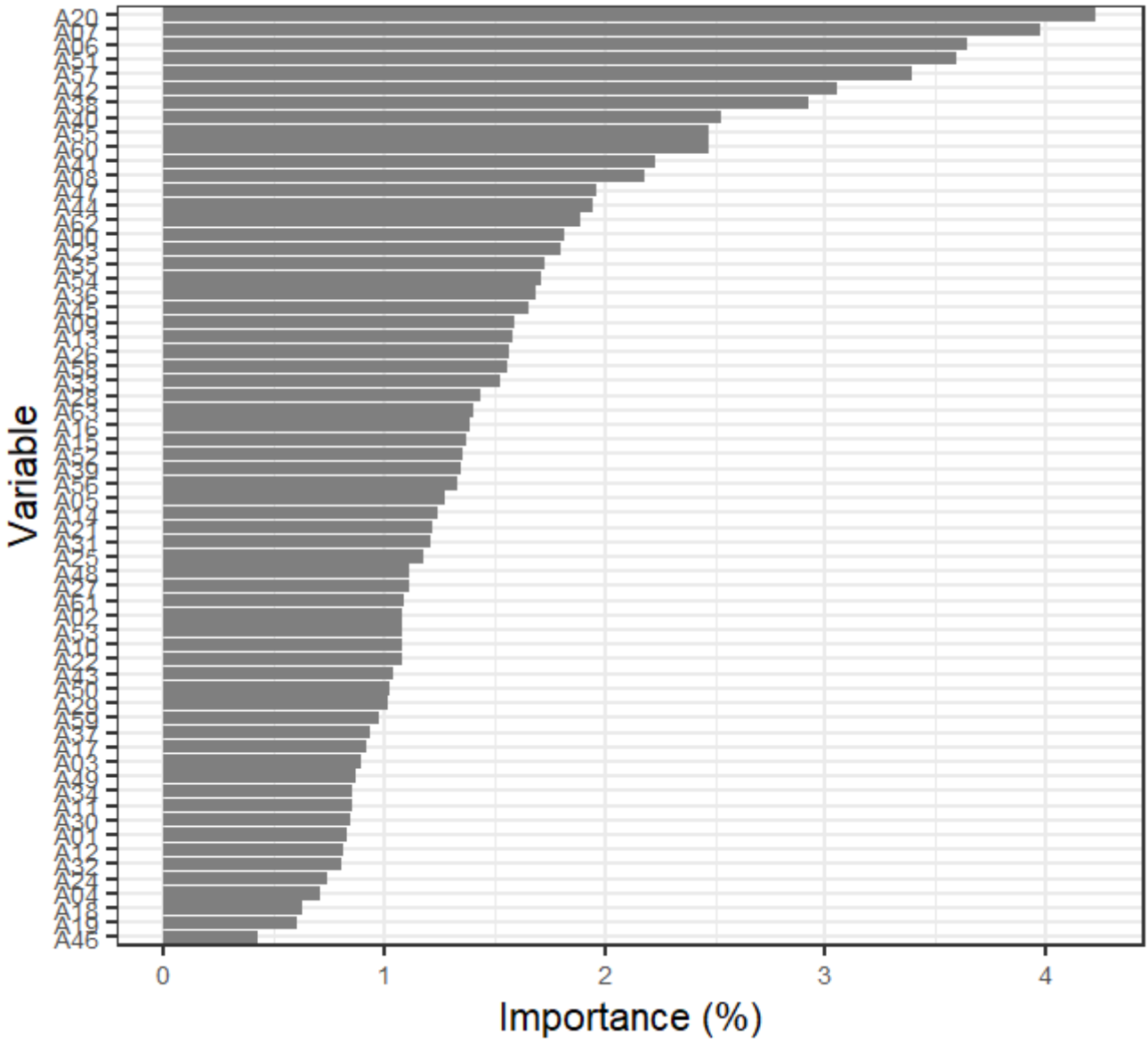


Figure S3: Variable importance ranking from the Random Forest (RF) regressor for predicting Aboveground Biomass (AGB). Features are derived from the 64-dimensional (A1-A64) Alpha Earth satellite embeddings.

NFI plot to pixel comparison bias can arise if the plot falls within grid cells with heterogeneous values. For example, if a plot is selected to lie within pixels of a diverse forest landscape, their weighted average could incorrectly represent AGB. For this reason, pixel variance from AEF embeddings and Sentinel-2 derived NDVI was estimated in a buffer of 100-m around the

plot's center coordinates. We then assessed the relationship between the NDVI (Fig. S4) and AEF embeddings (Fig. S5) variance within the designated spatial buffer and the deviation between plot-based NFI AGB measurements and corresponding pixel-level AGB predictions. No correlation was found between spatial variance and residuals.

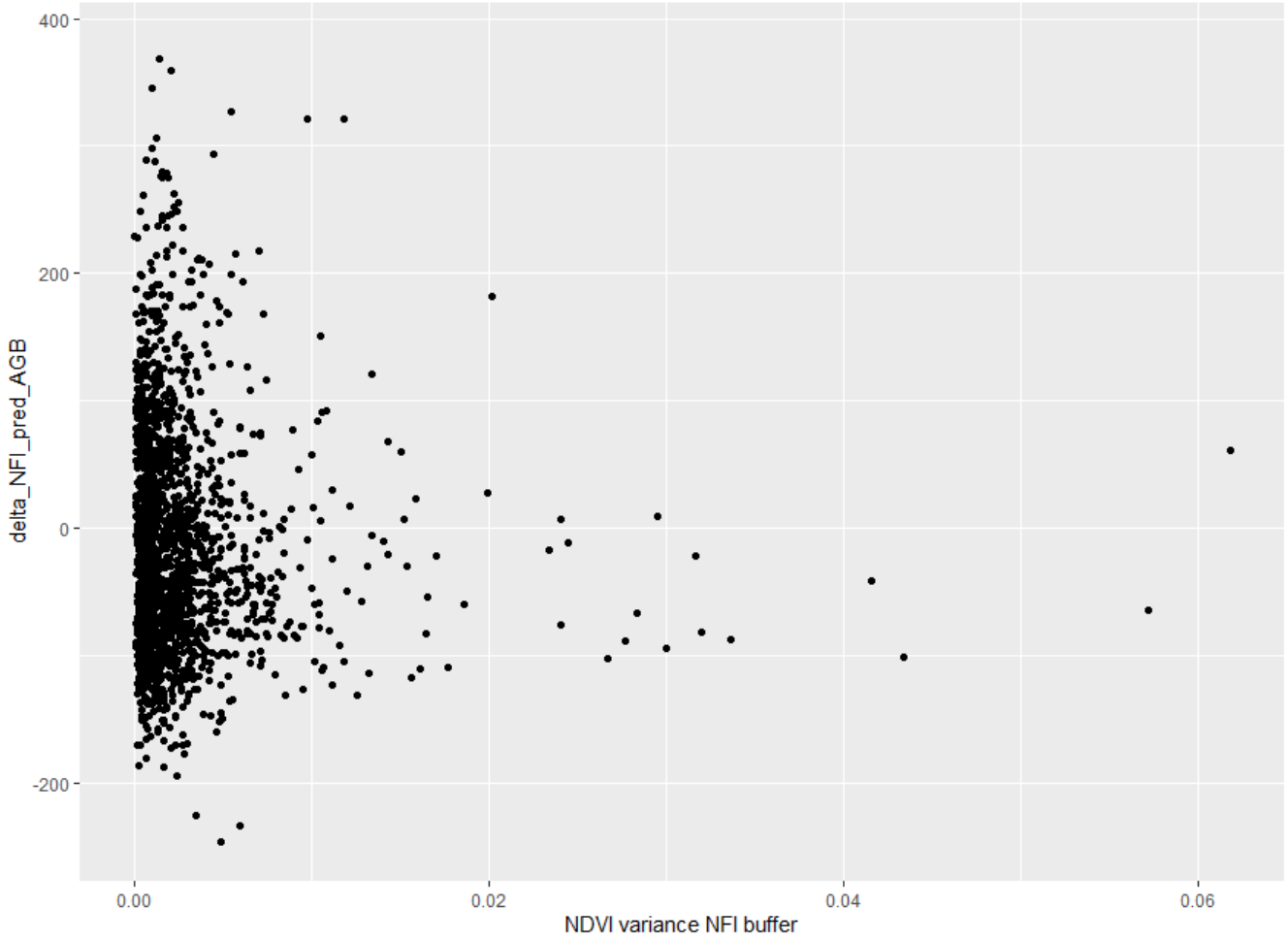


Figure S4: Normalized Difference Vegetation Index (NDVI) from Sentinel-2 variance within the prescribed buffer on the x axis and deviation between plot-based NFI AGB measurements and corresponding pixel-level AGB predictions.

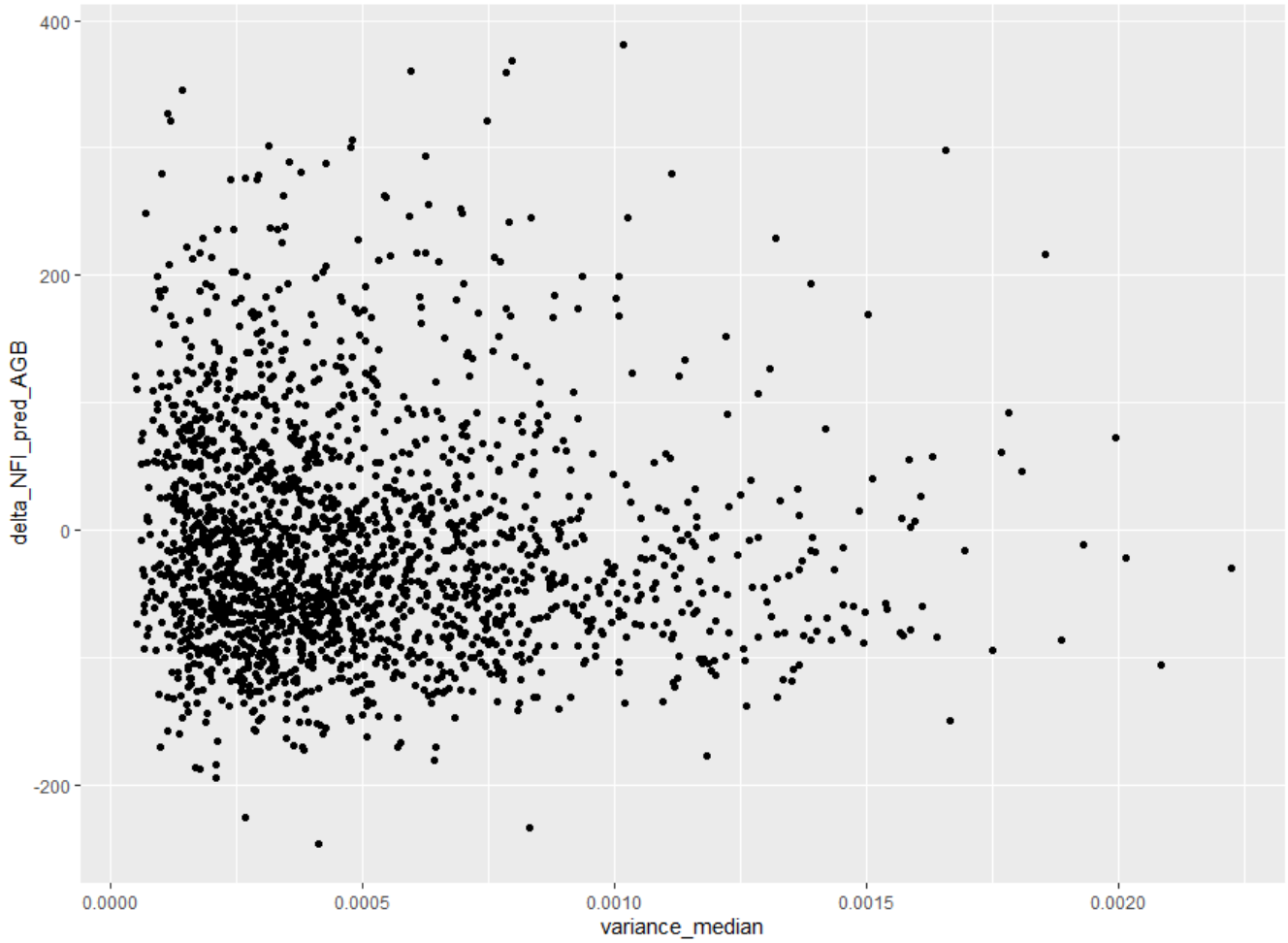


Figure S5: AEF embeddings variance within the prescribed buffer on the x axis and deviation between plot-based NFI AGB measurements and corresponding pixel-level AGB predictions.

30

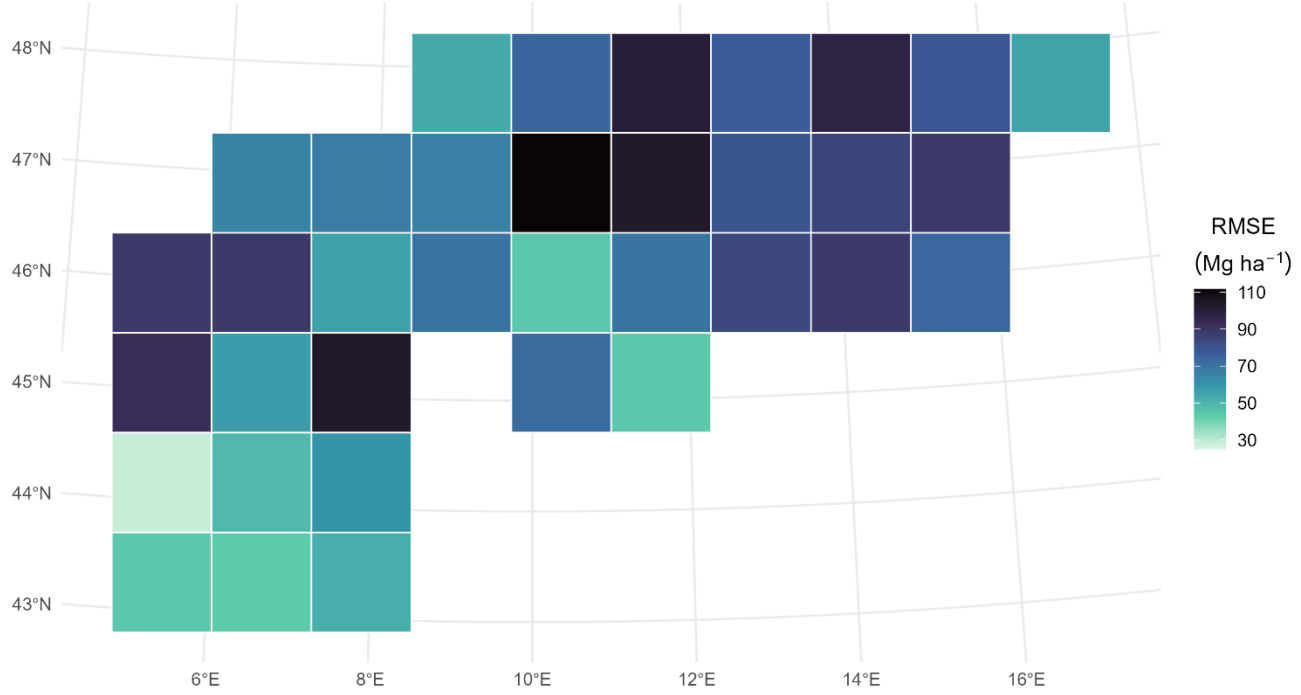


Figure S6: Root Mean Squared Error (RMSE) (Mg ha-1) between predicted and GEDI-derived Above-Ground Biomass (AGB) per tile.

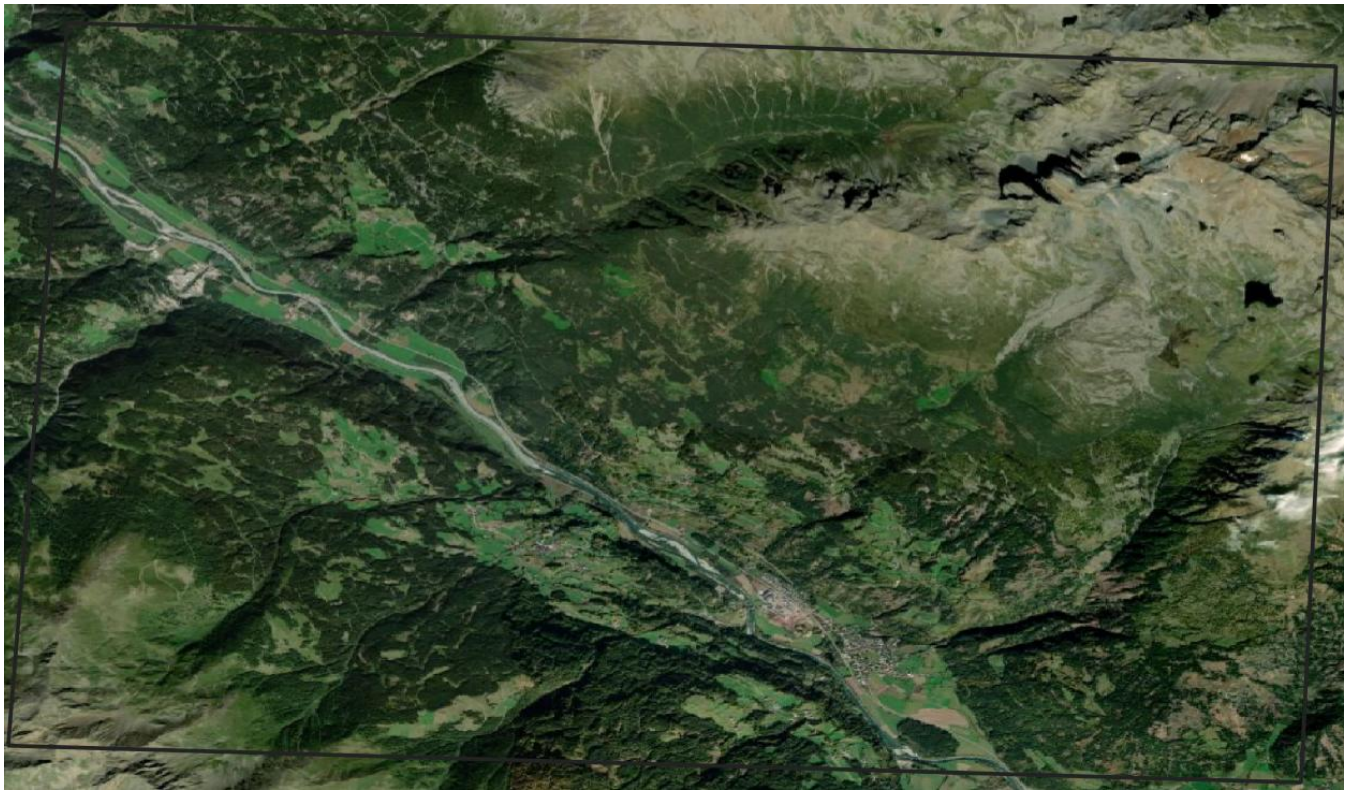


Figure S7: Scene i) featuring pure Norway spruce stands on moderate to steep exposed slopes (20–60°). Source: Esri. Powered by Esri.



Figure S8: Scene ii) comprising mainly montane European beech forests with mixed Norway spruce patches on steep terrain (20–70°). Source: Esri. Powered by Esri.



Figure S9: Scene iii) capturing oak and pine trees in a hilly Mediterranean environment. Source: Esri. Powered by Esri.

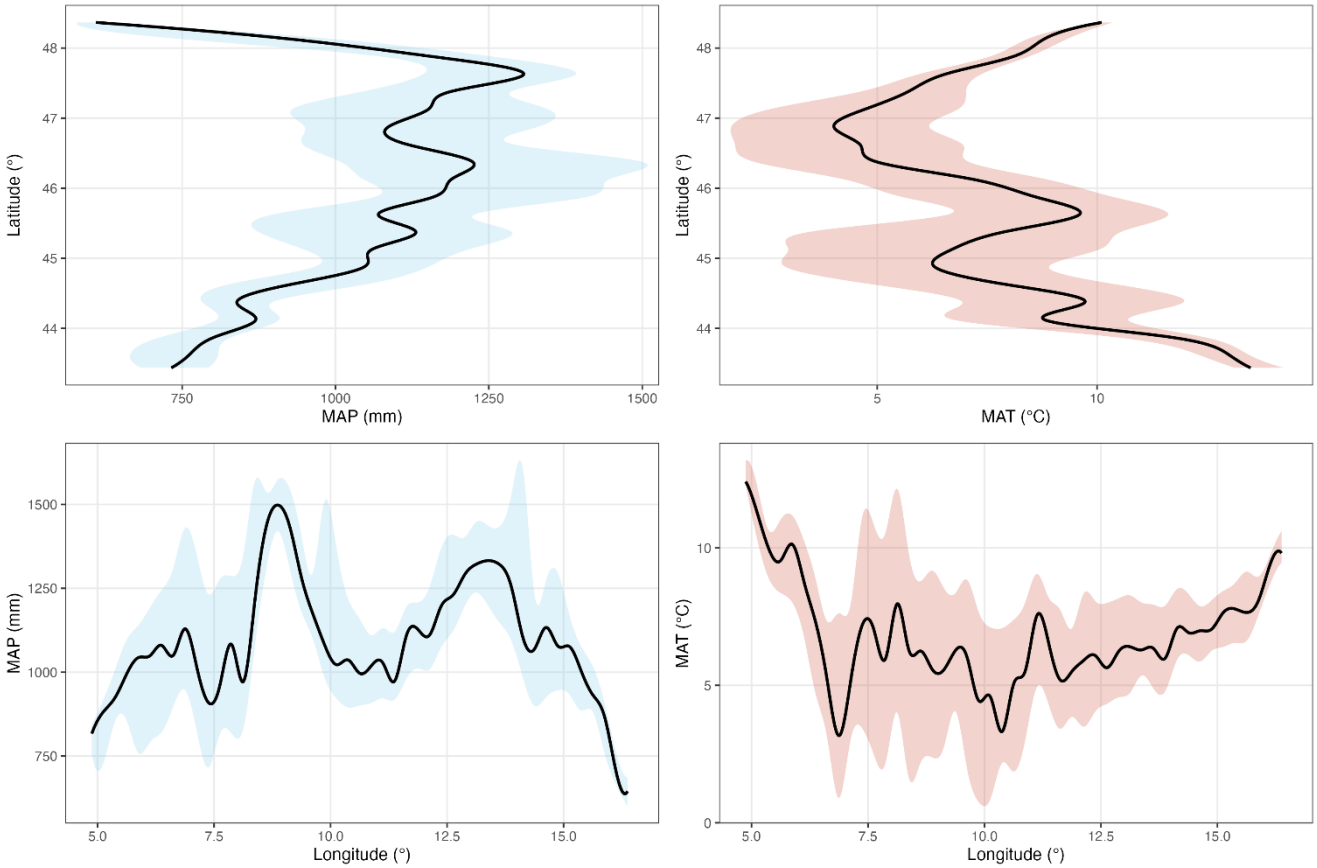


Figure S10: Mean annual precipitation (MAP mm) and mean annual temperature (MAT °C) derived from gridded (0.1°) E-OBS climate data (10.24381/cds.151d3ec6) visualized by latitude and longitude over the alpine region extent. Climate data are binned by 0.25° of longitude and latitude and within each bin the first quartile, median and third quartile are shown.

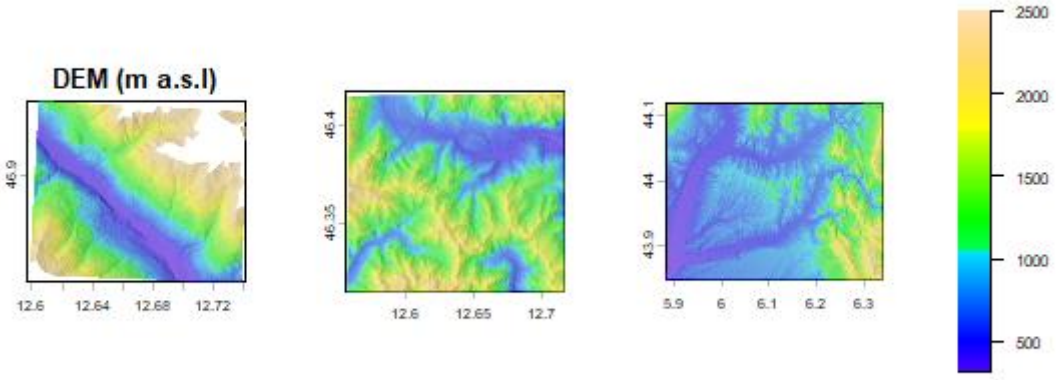


Figure S11: Digital Elevation Models (DEMs) of the selected forest cut-out-areas described in section 2.8 and depicted in Fig. 9.



70

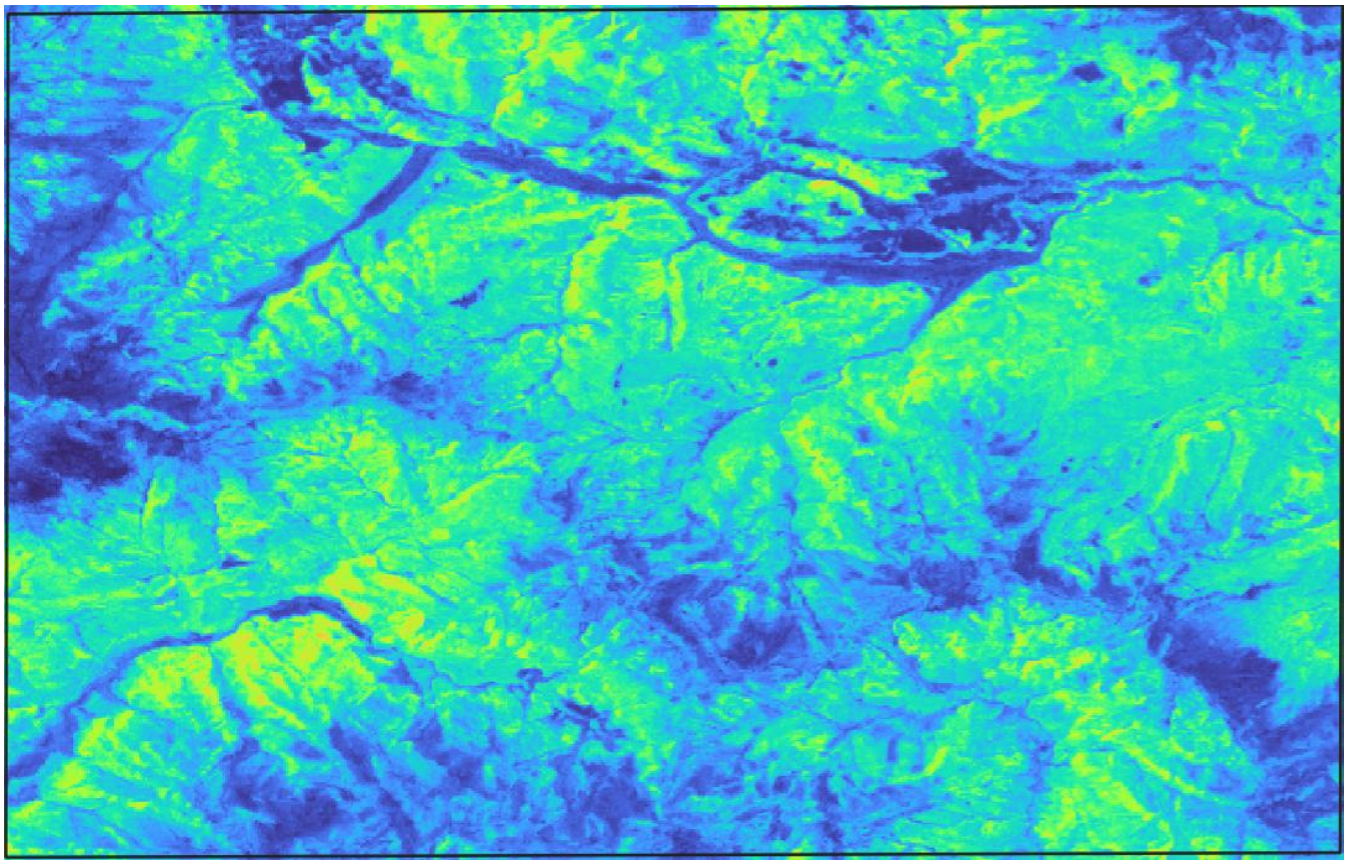


Figure S12: (a) Scene ii) comprising mainly montane European beech forests with mixed Norway spruce patches on steep terrain (20–70° slope). Source: © 2026 Google, Maxar Technologies. (b) Spatial variation of predicted Above-Ground Biomass (AGB) over scene ii).

85