POTENTIAL OF THE SENTINEL-2 RED EDGE SPECTRAL BANDS FOR ESTIMATION OF ECO-PHYSIOLOGICAL PLANT PARAMETERS

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INTRODUCTION

Sentinel-2 (S2) multispectral data contain several spectral bands in the red edge region of the electromagnetic spectrum (i.e. 675–760 nm), which offer new capabilities for temporal monitoring of terrestrial vegetation characteristics. A number of studies [1, 2] indicated that the red edge reflectance region is sensitive to changes in plant eco-physiological status, particularly to parameters such as leaf area index (LAI) and leaf chlorophyll *a+b* content (Cab). Therefore, objective of this study was to assess the potential of the red edge spectral bands and the red edge inflection point (REP) [3] computed from the simulated Sentinel-2 multispectral data for quantitative estimations of Cab and LAI.

METHODS

Discrete Anisotropic Radiative Transfer (DART) model [4] was employed to simulate spectral databases of top-of-canopy bidirectional reflectance factor (BRF) of three structurally different vegetation types: i) a maize agricultural field, ii) a beech forest, and iii) a spruce forest stand (*Figure 1*). In the first phase of the study, we applied a machine learning approach called support vector regression (SVR) [5] on the simulated spectral databases of all four vegetation types to investigate contribution of individual S2 spectral bands and to test importance of reconstructed REP in retrievals of LAI, Cab and canopy chlorophyll content (CCC; defined as product of LAI*Cab). In the second phase, we applied the SVR retrieval machines trained with DART BRF simulations on S2 data that were simulated from existing airborne hyperspectral images. These images were for the maize site acquired with a CASI instrument (Itres, Ltd., Canada) during the SEN3EXP/ESA campaign, and for the beech and spruce sites with an AISA Eagle instrument (Specim, Ltd., Finland) in frame of CzechGlobe field/airborne campaigns. The S2 Cab and LAI estimates were compared with the airborne Cab and LAI maps of higher spatial resolution, validated with ground measurements collected during the airborne campaigns.

RESULTS

SVR outcomes of the first phase, carried out with the DART simulated BRF data, demonstrated that the single REP wavelength retrieved from reconstructed red edge S2 vegetation reflectance is important for retrieval of CCC, slightly less important for estimation of Cab and rather unimportant for retrieval of LAI (*Figure 2*). Despite of this, retrievals of all three variables performed with and without presence of REP were statistically indifferent. Unlike the single REP wavelength, contribution of spectral bands located in the red edge region was found to be important for retrievals of all three parameters of interest, especially for Cab and CCC (*Figure 2*).

In the second phase, retrievals were applied on S2 data simulated from real airborne hyperspectral images. Since we had no suitable field data for direct validation of the S2 estimates, the only way of an indirect validation was the comparison with similar retrievals obtained from the original airborne hyperspectral images. The S2 Cab predictions were in general overestimated (c.f. *Figures 3, 5* and *6*), whereas the S2 LAI values were underestimated (c.f. *Figures 4, 7* and *8*) when compared to the results from airborne data. Regarding the investigated vegetation types, the least reliable results were obtained for the architecturally most complex spruce forest (*results not shown)*, which seems to still represent a challenge for radiative transfer modelling. Since our DART spectral simulations of S2 multispectral data provided reasonable Cab and LAI outputs, we conclude that the S2 image simulations, generated from airborne datasets of various spatial and spectral characteristics, suffered from insufficiencies that caused the mismatch with the airborne maps of generally acceptable accuracies (*Figures 3, 4, 5* and *7*).

ACKNOWLEDGEMENTS

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FIGURES

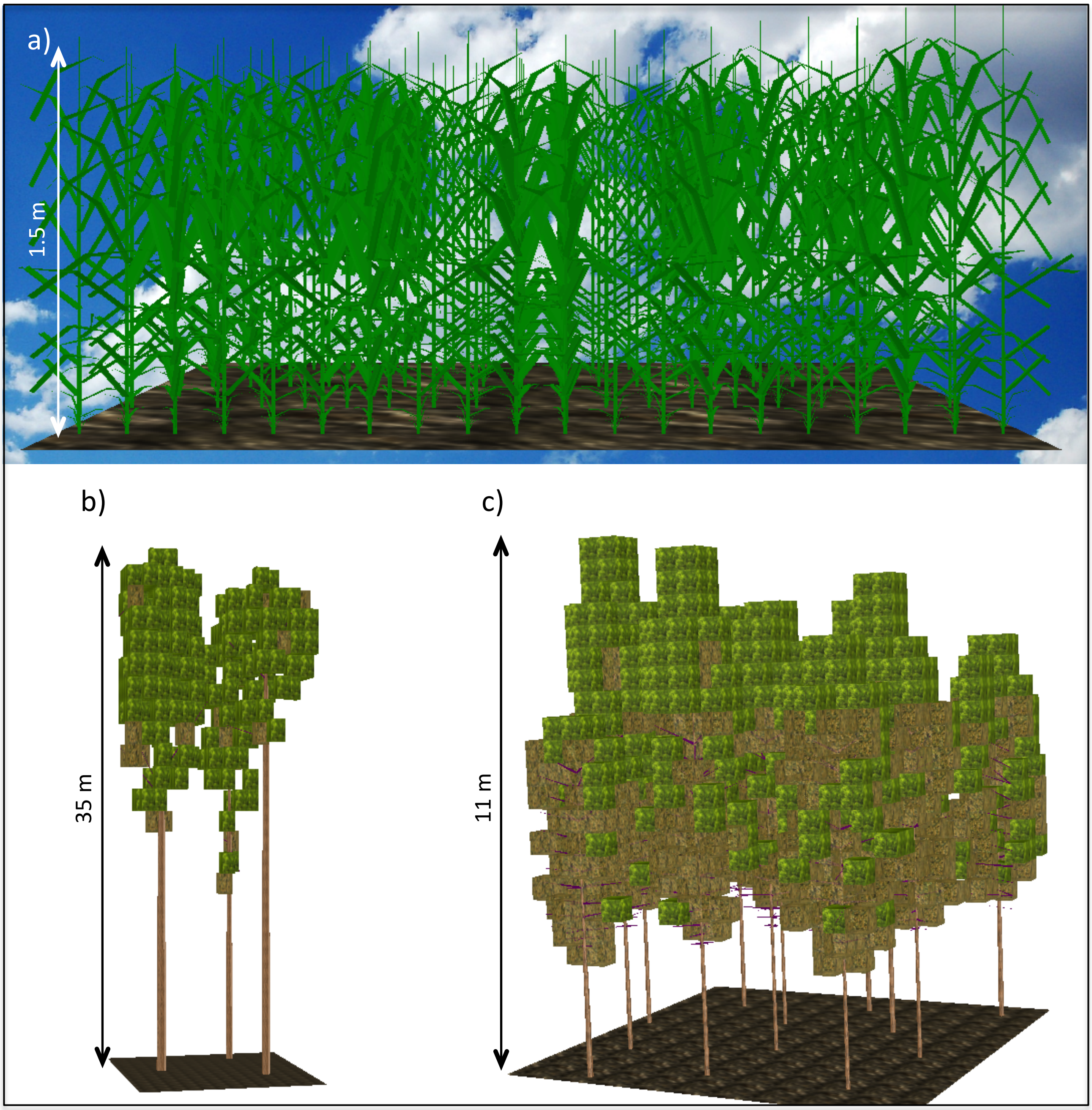

Figure 1: Visualization of the DART-simulated scenes for: a) maize field, b) beech and c) spruce forest stands. Green represents geometrical primitives or voxels of photosynthetically active foliage, whereas brown colour indicates voxels of mixed foliage and woody components and dark brown is ground.

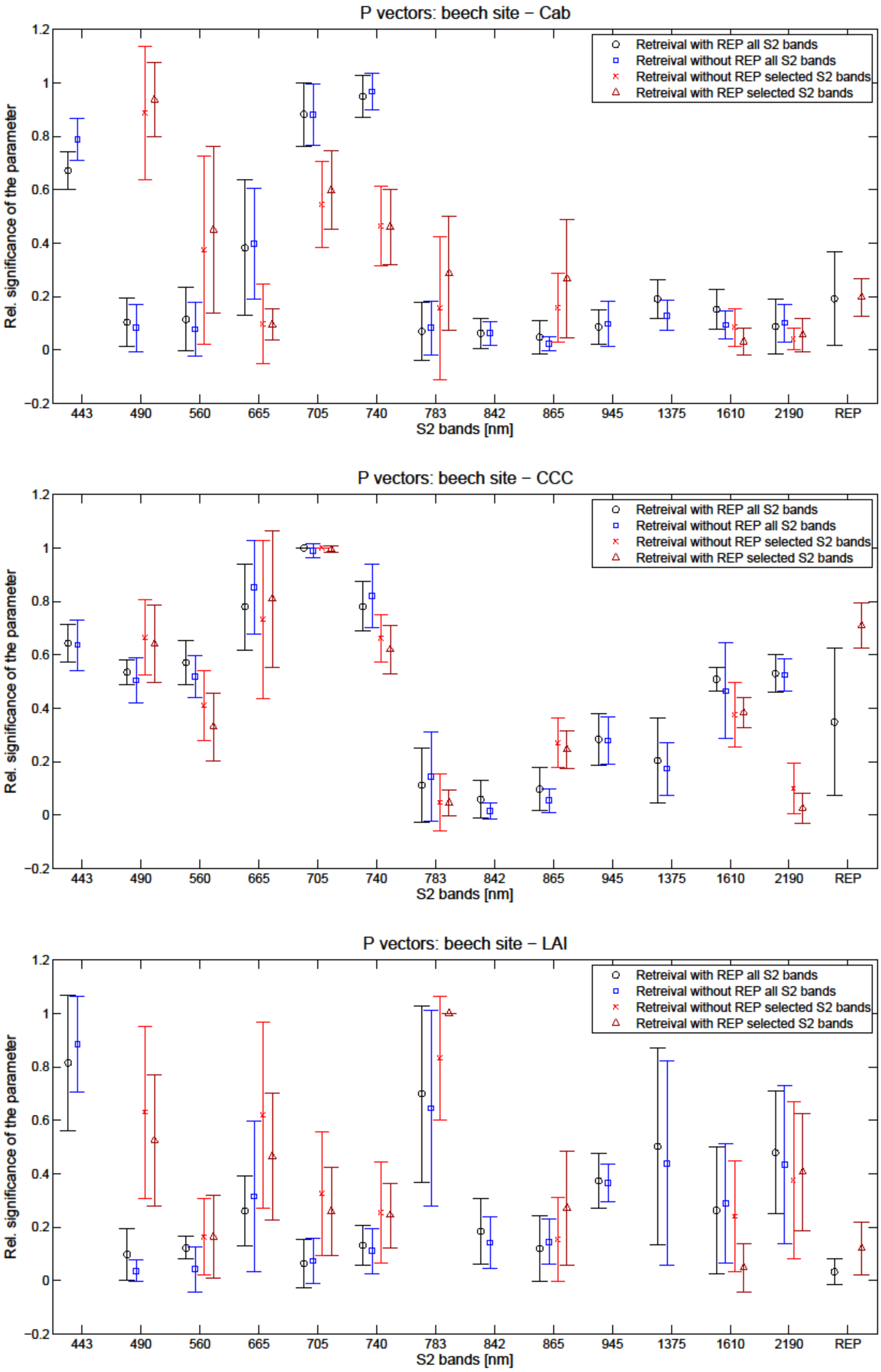

Figure 2: P-vectors for the Sentinel-2 spectral bands and REP indicating the contribution of individual inputs to the retrievals of vegetation parameters: Cab (top), CCC (middle), and LAI (bottom graphs) from the DART simulated LUT of the beech stand. Results for all S2 bands and for a selected band subset are displayed.

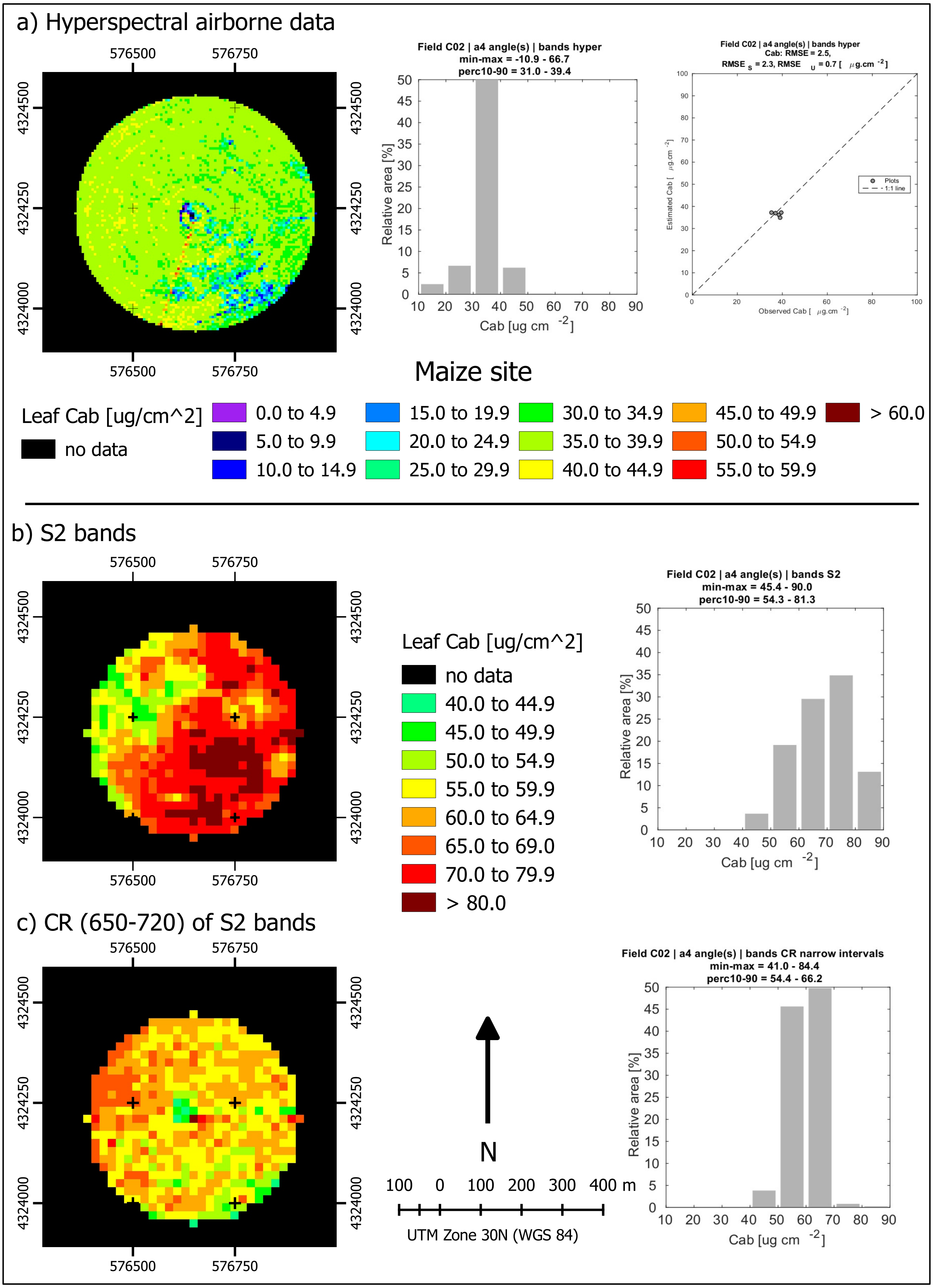

Figure 3: Leaf Cab maps and histograms retrieved for a maize field in Barrax (Spain) from: a) CASI airborne image (including comparison between observed and estimated values), b) S2 simulated reflectance, and c) S2 simulated continuum removed (CR) reflectance between 560 and 740 nm.

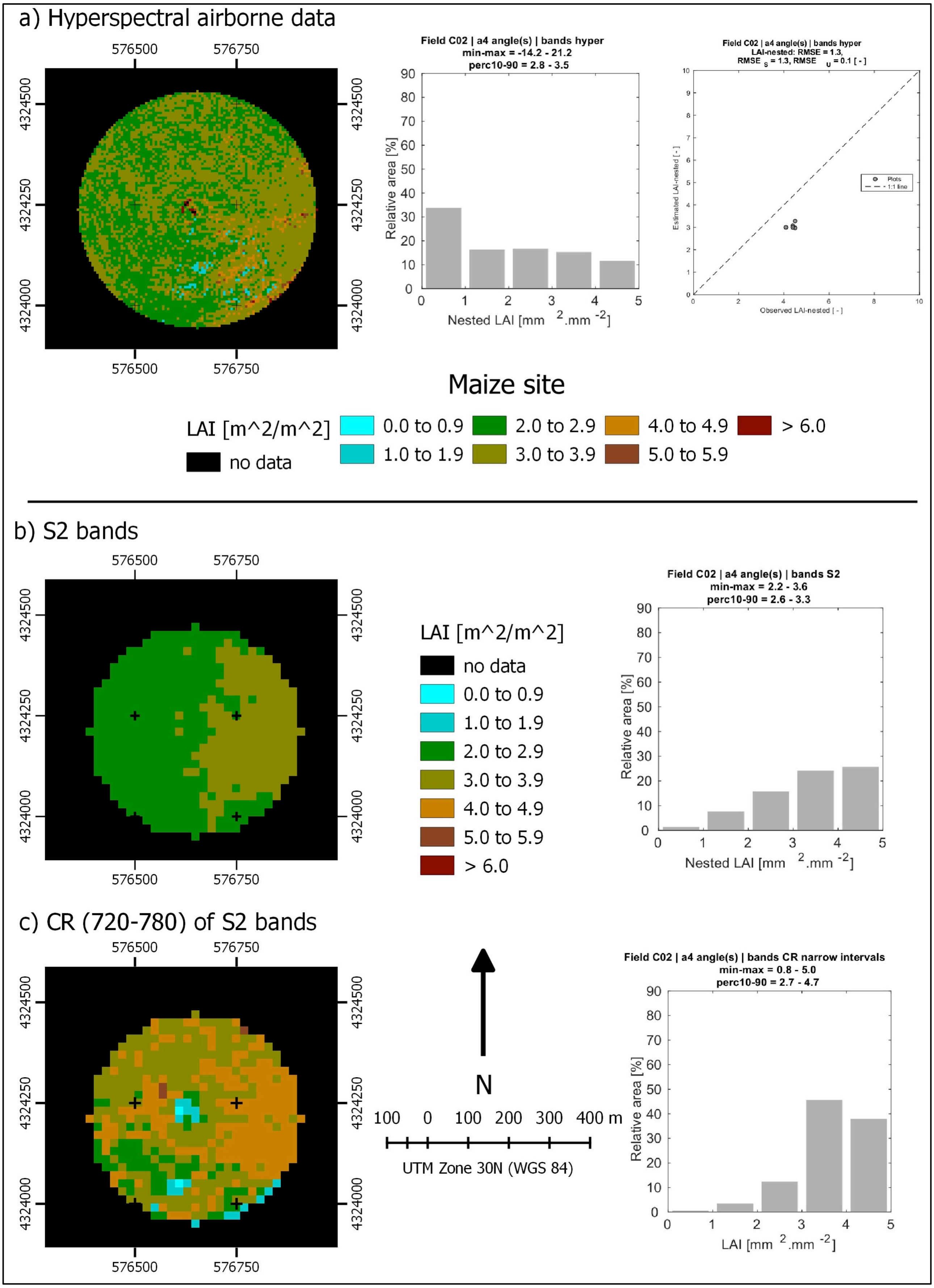

Figure 4: LAI maps and histograms retrieved for a maize field in Barrax (Spain) from: a) CASI airborne image (including comparison between observed and estimated values), b) S2 simulated reflectance, and c) S2 simulated continuum removed (CR) reflectance between 700 and 800 nm.

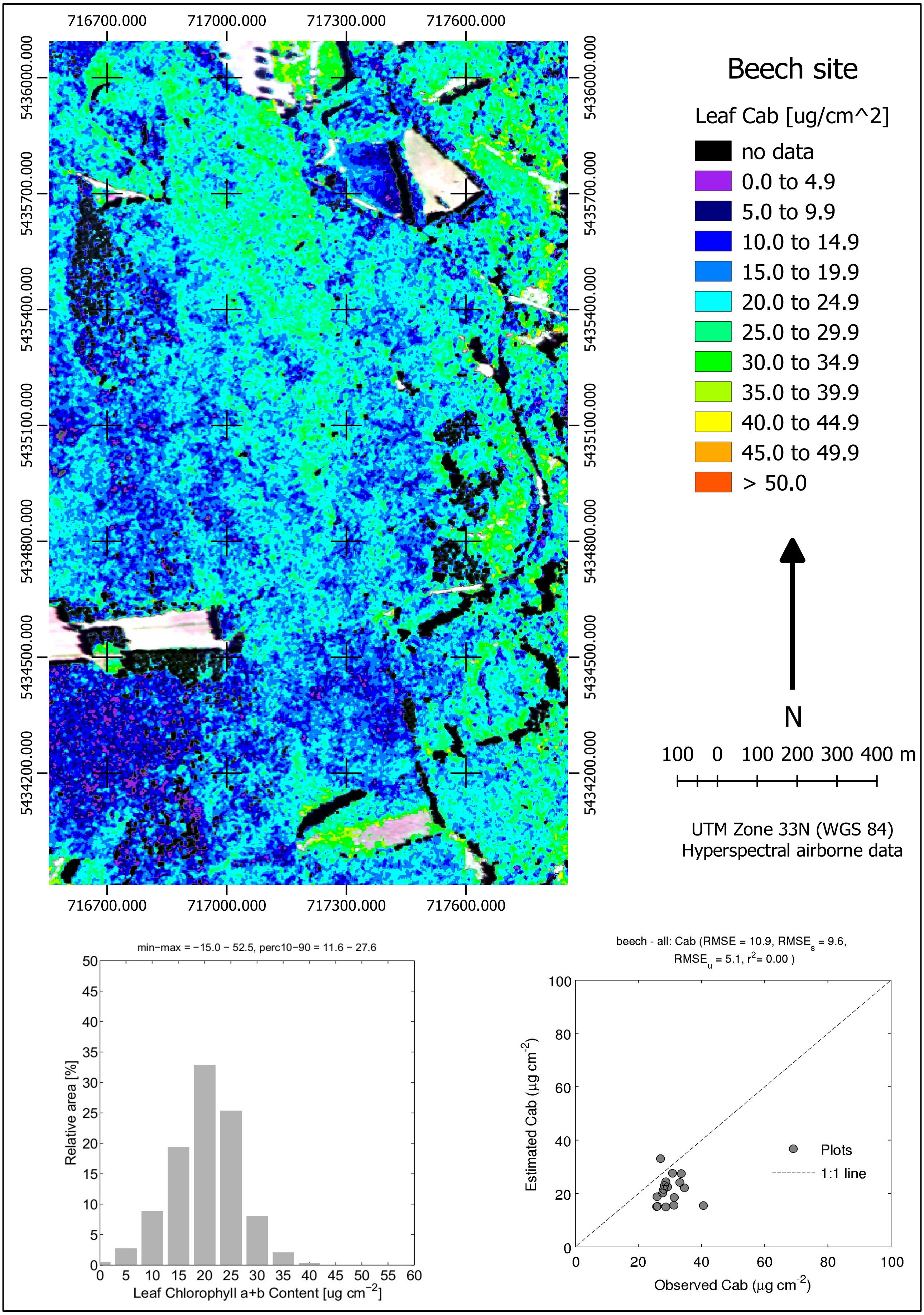

Figure 5: Leaf Cab map and histogram retrieved for beech test site at Štítná (Czech Republic) from an AISA airborne image (including comparison between observed values and estimates).

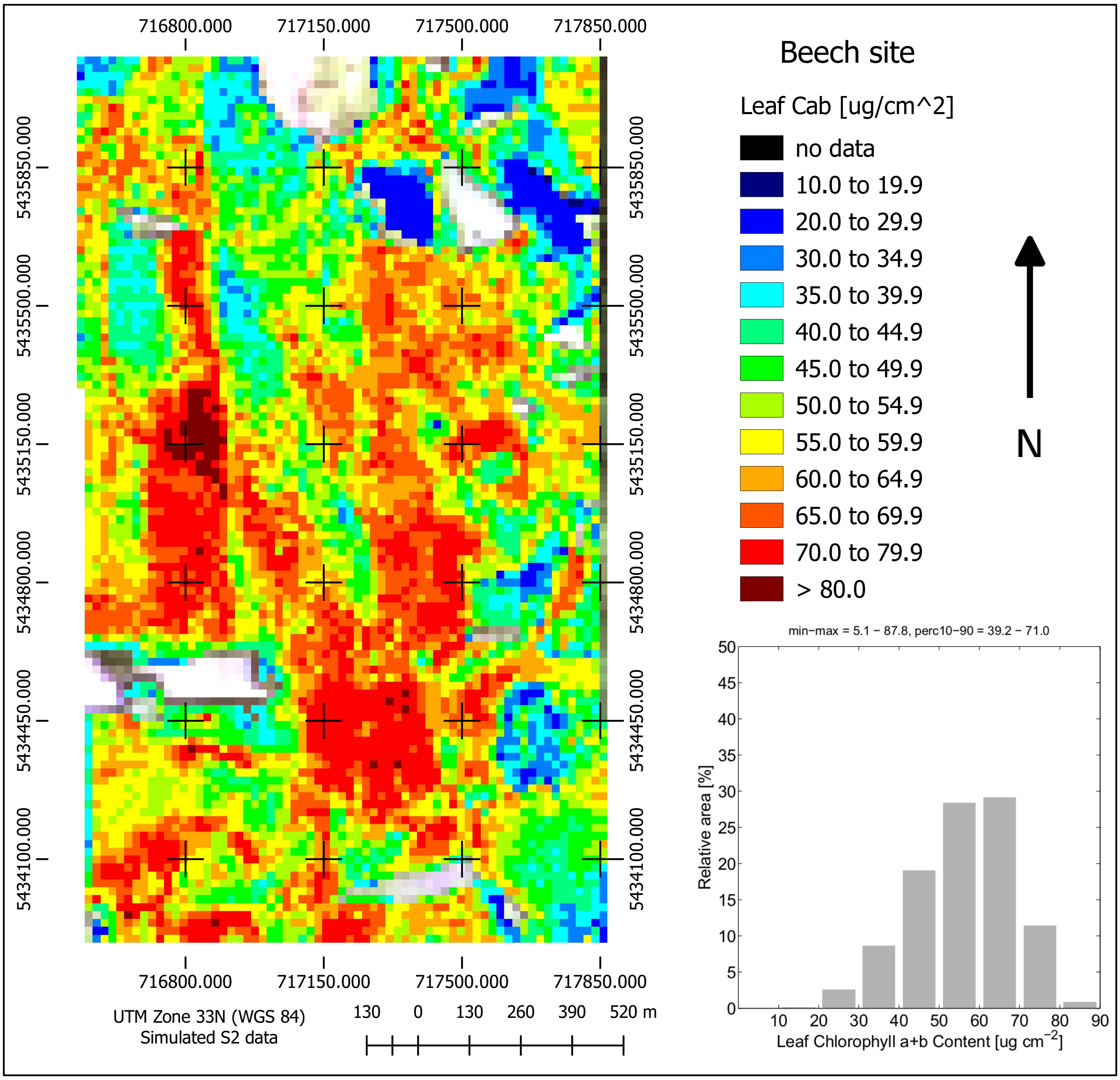

Figure 6: Leaf Cab map and histogram retrieved for beech test site at Štítná (Czech Republic) from simulated multispectral S2 bands.

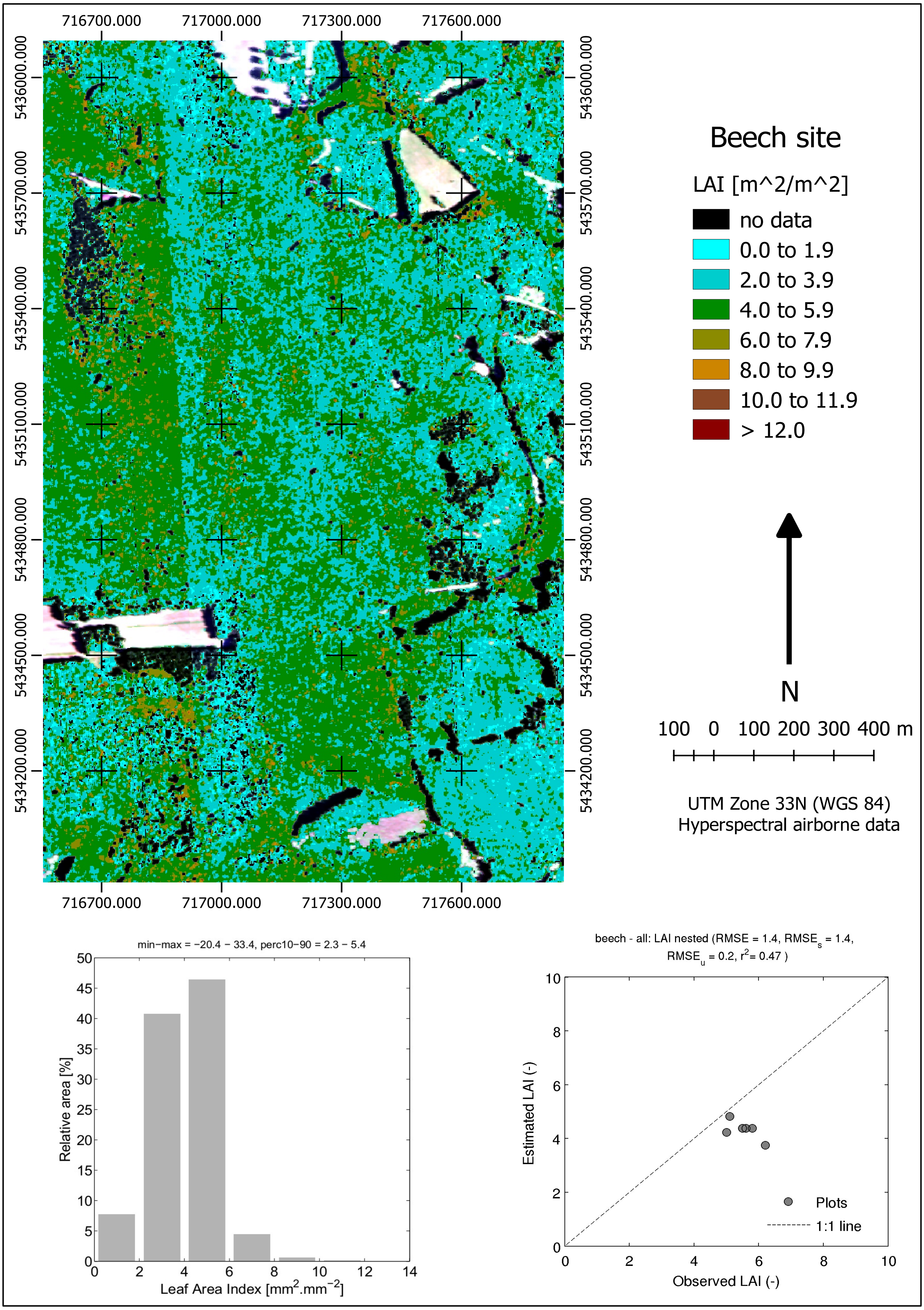

Figure 7: LAI map and histogram retrieved for beech test site at Štítná (Czech Republic) from an AISA airborne image (including comparison between observed values and estimates).

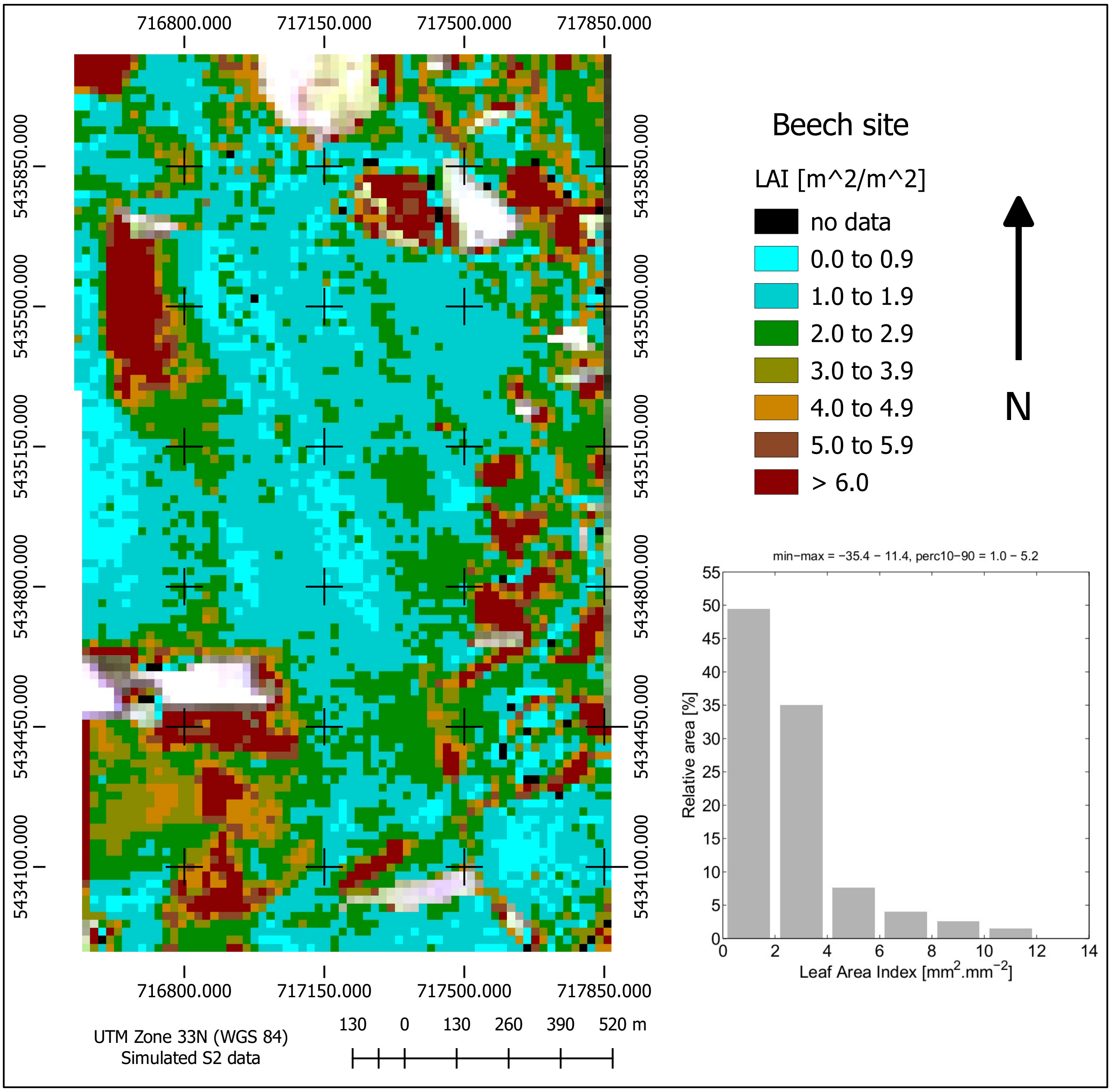

Figure 8: LAI map and histogram retrieved for beech test site at Štítná (Czech Republic) from simulated S2 multispectral bands.