remote sensing

MDPI

**Table S1.** Coefficient of determination (R2) Leaf biochemical traits (chlorophyll a, b, a+b, carotenoids content), Chlorophyll a/b and Carotenoids/Chlorophyll ratio detected by the biochemical way; Leaf internal structure (leaf thickness, mesophyll thickness, palisade and spongy parenchyma thickness, palisade/spongy parenchyma ratio, adaxial and abaxial epidermis thickness; and structural traits and water content: Dry/Fresh leaf ratio (DW/FW), Leaf mass per area (LMA), fresh leaf mass per area (fLMA), Water content per leaf area (WCLA), Nitrogen content per mass and area (N mass (%), N/area), carbon content per mass(carbon (%)); and vegetation indices (VI) based on adaxial leaf side reflectance

| R2 | Chla | Chlb | Carotenoids | Chlorophyll a+b | Car/Chl | Chlorophyll a/b | Leaf thickness | Mesophyll thickness | PP thickness | SP thickness | Adaxial epidermis thickness | Abaxial epidermis thickness | PP/SP | DW/FW | LMA | fLMA | WCLA | Nitrogen (%) | Nitrogen/ area | Carbon (%) | Formula | Source | Related to | Scale |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BI | 0.25 | 0.30 | 0.21 | 0.27 | 0.73 | 0.37 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.03 | 0.00 | 0.10 | 0.01 | 0.07 | 0.09 | 0.34 | 0.27 | 0.00 | (R800.5+R669.8+R549.6)/sqrt(3) | [1] | Chl | Canopy |
| Carter | 0.58 | 0.57 | 0.47 | 0.59 | 0.56 | 0.50 | 0.14 | 0.15 | 0.19 | 0.06 | 0.06 | 0.06 | 0.10 | 0.01 | 0.02 | 0.02 | 0.02 | 0.12 | 0.27 | 0.00 | R695.7/R419.8 | [2] | Stress | Leaf |
| CI | 0.54 | 0.58 | 0.42 | 0.56 | 0.49 | 0.36 | 0.28 | 0.29 | 0.33 | 0.16 | 0.10 | 0.03 | 0.20 | 0.00 | 0.05 | 0.06 | 0.04 | 0.05 | 0.19 | 0.00 | (R800.5-R549.6)/R800.5 | [1] | Chl | Canopy |
| Datt | 0.57 | 0.45 | 0.32 | 0.55 | 0.01 | 0.14 | 0.42 | 0.42 | 0.53 | 0.20 | 0.24 | 0.07 | 0.32 | 0.03 | 0.01 | 0.00 | 0.00 | 0.03 | 0.03 | 0.09 | (R849.9-R710.4)/(R849.9-R680.8) | [3] | Chl | Leaf |
| Datt2 | 0.87 | 0.77 | 0.58 | 0.86 | 0.22 | 0.41 | 0.48 | 0.48 | 0.60 | 0.23 | 0.25 | 0.08 | 0.36 | 0.00 | 0.02 | 0.01 | 0.01 | 0.00 | 0.16 | 0.05 | R849.9/R709.1 | [3] | Chl | Leaf |
| DLAI | 0.06 | 0.09 | 0.17 | 0.07 | 0.00 | 0.00 | 0.17 | 0.14 | 0.19 | 0.06 | 0.20 | 0.02 | 0.11 | 0.05 | 0.58 | 0.46 | 0.23 | 0.07 | 0.15 | 0.05 | R1724.7-R970.5 | [4] | LAI | Canopy |
| DVI | 0.50 | 0.49 | 0.41 | 0.50 | 0.73 | 0.63 | 0.34 | 0.34 | 0.41 | 0.17 | 0.20 | 0.05 | 0.23 | 0.02 | 0.05 | 0.07 | 0.07 | 0.07 | 0.26 | 0.00 | R800.5-R669.8 | [5] | LAI | Canopy /Forest |
| Gitelson 2 | 0.83 | 0.72 | 0.54 | 0.82 | 0.28 | 0.49 | 0.42 | 0.44 | 0.56 | 0.19 | 0.20 | 0.06 | 0.37 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.16 | 0.07 | (R749.9-R800.5/R695.7-R739.5)-1 | [6] | Chl | Leaf |
| GM_94a | 0.86 | 0.76 | 0.57 | 0.85 | 0.26 | 0.45 | 0.46 | 0.47 | 0.58 | 0.22 | 0.23 | 0.07 | 0.36 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.16 | 0.06 | (R749.9/R699.7) | [7] | Chl | Leaf |
| gNDVI780 | 0.56 | 0.58 | 0.41 | 0.57 | 0.42 | 0.31 | 0.27 | 0.28 | 0.32 | 0.15 | 0.09 | 0.03 | 0.19 | 0.00 | 0.04 | 0.05 | 0.04 | 0.03 | 0.15 | 0.00 | (R780.6-R549.6)/(R780.6+R549.6) | [8] | Chl | |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GRg | 0.22 | 0.23 | 0.13 | 0.23 | 0.13 | 0.08 | 0.10 | 0.11 | 0.12 | 0.06 | 0.01 | 0.01 | 0.08 | 0.01 | 0.01 | 0.02 | 0.02 | 0.00 | 0.01 | 0.00 | (R800.5/R549.6)-1 | [6] | Chl | Leaf |
| Maccioni | 0.71 | 0.58 | 0.43 | 0.69 | 0.08 | 0.25 | 0.41 | 0.41 | 0.53 | 0.19 | 0.23 | 0.07 | 0.32 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.08 | 0.08 | (R779.3-R709.1)/(R779.3-R679.4) | [9] | Chl | Canopy |
| MCARI | 0.17 | 0.11 | 0.10 | 0.16 | 0.15 | 0.00 | 0.39 | 0.37 | 0.45 | 0.21 | 0.24 | 0.14 | 0.21 | 0.08 | 0.00 | 0.03 | 0.06 | 0.14 | 0.00 | 0.02 | ((R701-R669.8)-0.2*(R701-R551))*(R701/R669.8) | [10] | Chl, LAI | Canopy |
| MCARI/OSAVI | 0.16 | 0.10 | 0.08 | 0.15 | 0.18 | 0.01 | 0.39 | 0.38 | 0.46 | 0.20 | 0.24 | 0.12 | 0.24 | 0.07 | 0.00 | 0.02 | 0.04 | 0.14 | 0.00 | 0.04 | MCARI/OSAVI | [10] | Chl | Canopy |
| MCARI1 | 0.31 | 0.31 | 0.27 | 0.31 | 0.75 | 0.60 | 0.04 | 0.04 | 0.06 | 0.01 | 0.04 | 0.00 | 0.04 | 0.06 | 0.03 | 0.07 | 0.08 | 0.13 | 0.24 | 0.00 | 1.2*(2.5*(R800.5-R669.8)-1.3*(R800.5-R549.6)) | [11] | LAI | Canopy |
| MCARI2 | 0.87 | 0.76 | 0.58 | 0.86 | 0.22 | 0.42 | 0.49 | 0.49 | 0.60 | 0.25 | 0.27 | 0.08 | 0.33 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.15 | 0.06 | ((R749.9-R705.1)-0.2*(R749.9-R551))*(R749.9/R705.1) | [12] | Chl | Canopy |
| MCARI2/OSAVI2 | 0.57 | 0.56 | 0.45 | 0.58 | 0.76 | 0.61 | 0.42 | 0.42 | 0.53 | 0.20 | 0.25 | 0.07 | 0.30 | 0.01 | 0.02 | 0.04 | 0.03 | 0.10 | 0.25 | 0.00 | MCARI2/OSAVI2 | [12] | Chl | Canopy |
| McM_94 | 0.06 | 0.03 | 0.04 | 0.05 | 0.24 | 0.05 | 0.33 | 0.29 | 0.33 | 0.21 | 0.25 | 0.21 | 0.11 | 0.15 | 0.00 | 0.03 | 0.08 | 0.25 | 0.02 | 0.00 | R699.7/R669.8 | [13] | Chl | Leaf |
| MND | 0.81 | 0.71 | 0.55 | 0.80 | 0.16 | 0.33 | 0.46 | 0.45 | 0.56 | 0.23 | 0.26 | 0.12 | 0.31 | 0.00 | 0.03 | 0.01 | 0.00 | 0.00 | 0.12 | 0.03 | (R749.9-R744.7)/(R749.9+R705.1-2*R445.7) | [14] | Chl | Leaf |
| mND705 | 0.87 | 0.78 | 0.60 | 0.86 | 0.39 | 0.55 | 0.42 | 0.43 | 0.54 | 0.21 | 0.23 | 0.07 | 0.31 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 | 0.23 | 0.04 | (R749.9-R705.1)/(R749.9+R705.1-2*R445.7) | [14] | Chl total | Leaf |
| MNDVI8 | 0.88 | 0.78 | 0.59 | 0.87 | 0.24 | 0.42 | 0.45 | 0.45 | 0.58 | 0.21 | 0.25 | 0.07 | 0.36 | 0.00 | 0.02 | 0.02 | 0.01 | 0.00 | 0.17 | 0.05 | (R755.1-R730.3)/(R755.1+R730.3) | [15] | Chl | Leaf |
| MNDVIre | 0.86 | 0.78 | 0.60 | 0.85 | 0.40 | 0.56 | 0.42 | 0.43 | 0.54 | 0.20 | 0.23 | 0.06 | 0.33 | 0.01 | 0.02 | 0.02 | 0.02 | 0.04 | 0.23 | 0.04 | (R749.9-R705.1)/(R749.9+R705.1-R445.7) | [14] | Chl | Leaf |
| MSAVI | 0.48 | 0.48 | 0.40 | 0.49 | 0.75 | 0.63 | 0.34 | 0.34 | 0.42 | 0.17 | 0.20 | 0.04 | 0.24 | 0.03 | 0.04 | 0.08 | 0.07 | 0.09 | 0.27 | 0.00 | 0.5*((2*R800.5+1-sqrt((R800.5+1)^(2))-8*(R800.5-R669.8))) | [16] | vegetation | Canopy |
| MSI | 0.00 | 0.02 | 0.05 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.06 | 0.38 | 0.63 | 0.55 | 0.11 | 0.32 | 0.00 | (R1600.8/R818.9) | [17] | RWC/EWT | Leaf |
| MTCI | 0.77 | 0.67 | 0.48 | 0.76 | 0.09 | 0.23 | 0.48 | 0.48 | 0.59 | 0.25 | 0.27 | 0.09 | 0.32 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.09 | 0.06 | (R753.8-R709.1)/(R709.1-R680.8) | [18] | Chl | Canopy |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N705 | 0.80 | 0.69 | 0.52 | 0.78 | 0.22 | 0.40 | 0.38 | 0.39 | 0.50 | 0.18 | 0.22 | 0.06 | 0.30 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 | 0.16 | 0.06 | (R705.1-R675.3)/(R749.9-R669.8) | [19] | Leaf damage level | Leaf |
| N715 | 0.73 | 0.61 | 0.44 | 0.71 | 0.09 | 0.26 | 0.42 | 0.42 | 0.54 | 0.20 | 0.23 | 0.06 | 0.32 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.09 | 0.08 | (R715.8-R675.3)/(R749.9-R669.8) | [19] | Leaf damage level | Leaf |
| N725 | 0.56 | 0.45 | 0.31 | 0.54 | 0.01 | 0.11 | 0.42 | 0.42 | 0.55 | 0.20 | 0.24 | 0.07 | 0.34 | 0.03 | 0.01 | 0.00 | 0.00 | 0.02 | 0.03 | 0.09 | (R725-R675.3)/(R749.9-R669.8) | [19] | Leaf damage level | Leaf |
| Ncont1510 | 0.01 | 0.00 | 0.00 | 0.01 | 0.05 | 0.00 | 0.10 | 0.11 | 0.13 | 0.07 | 0.05 | 0.05 | 0.06 | 0.21 | 0.08 | 0.31 | 0.39 | 0.29 | 0.18 | 0.00 | R1511.9 | [20] | Nitrogen | Canopy |
| NDchl | 0.88 | 0.77 | 0.60 | 0.86 | 0.31 | 0.50 | 0.44 | 0.45 | 0.57 | 0.21 | 0.24 | 0.07 | 0.35 | 0.00 | 0.02 | 0.02 | 0.01 | 0.01 | 0.19 | 0.05 | (R925.5-R710.4)/(R925.5+R710.4) | [4] | Chl | Canopy |
| NDII | 0.00 | 0.01 | 0.03 | 0.00 | 0.04 | 0.00 | 0.01 | 0.01 | 0.02 | 0.00 | 0.00 | 0.02 | 0.02 | 0.03 | 0.41 | 0.64 | 0.54 | 0.11 | 0.33 | 0.02 | ((R818.9-R1648.5)/(R818.9+R1648.5)) | [21] | Lignin | Canopy |
| NDLI | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.00 | 0.24 | 0.25 | 0.24 | 0.18 | 0.04 | 0.03 | 0.06 | 0.02 | 0.01 | 0.00 | 0.01 | 0.15 | 0.01 | 0.04 | (log(1/R1753.4)-log(1/R1681.3))/(log(1/R1753.4)+log(1/R1681.3)) | [21] | Lignin | Canopy |
| NDNI | 0.16 | 0.08 | 0.09 | 0.13 | 0.01 | 0.12 | 0.35 | 0.36 | 0.40 | 0.21 | 0.14 | 0.07 | 0.17 | 0.05 | 0.02 | 0.04 | 0.05 | 0.01 | 0.02 | 0.14 | (log(1/R1511.9)-log(1/R1681.3))/(log(1/R1511.9)+log(1/R1681.3)) | [21] | N | Canopy |
| NDVI | 0.37 | 0.39 | 0.30 | 0.38 | 0.79 | 0.58 | 0.10 | 0.12 | 0.20 | 0.02 | 0.04 | 0.01 | 0.23 | 0.09 | 0.02 | 0.07 | 0.10 | 0.24 | 0.30 | 0.00 | (R800.5-R669.8)/(R800.5+R669.8) | [22] | green biomass | Leaf/ Canopy |
| NDVIchen | 0.50 | 0.49 | 0.38 | 0.51 | 0.74 | 0.63 | 0.19 | 0.21 | 0.31 | 0.05 | 0.09 | 0.00 | 0.27 | 0.07 | 0.01 | 0.06 | 0.08 | 0.21 | 0.31 | 0.01 | ((R858-R649.1)/(R858+R649.1)) | [23] | green biomass | Canopy |
| NDVIre | 0.86 | 0.77 | 0.59 | 0.85 | 0.40 | 0.57 | 0.42 | 0.42 | 0.54 | 0.19 | 0.23 | 0.06 | 0.34 | 0.02 | 0.02 | 0.03 | 0.02 | 0.04 | 0.23 | 0.05 | (R749.9-R705.1)/(R749.9+R705.1) | [7] | Chl a | Leaf |
| NDWI | 0.01 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.12 | 0.12 | 0.14 | 0.07 | 0.06 | 0.08 | 0.06 | 0.21 | 0.11 | 0.40 | 0.50 | 0.33 | 0.23 | 0.00 | ((R860.4-R1242.2)/(R860.4+R1242.2)) | [24] | Liquid water | Canopy |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NPCI | 0.40 | 0.42 | 0.33 | 0.41 | 0.65 | 0.49 | 0.12 | 0.14 | 0.13 | 0.07 | 0.02 | 0.03 | 0.04 | 0.04 | 0.01 | 0.03 | 0.04 | 0.15 | 0.20 | 0.00 | (R680.8-R430.5)/(R680.8+R430.5) | [25] | Chl | leaf |
| OSAVI | 0.41 | 0.43 | 0.33 | 0.42 | 0.79 | 0.60 | 0.21 | 0.23 | 0.33 | 0.07 | 0.10 | 0.00 | 0.28 | 0.07 | 0.02 | 0.08 | 0.09 | 0.19 | 0.30 | 0.00 | (1+0.16)*(R800.5-R669.8)/(R800.5+R669.8+0.16) | [26] | Chl | Canopy |
| OSAVI2 | 0.85 | 0.77 | 0.59 | 0.84 | 0.41 | 0.57 | 0.42 | 0.43 | 0.54 | 0.20 | 0.23 | 0.06 | 0.33 | 0.01 | 0.02 | 0.03 | 0.02 | 0.03 | 0.23 | 0.04 | (1+0.16)*(R749.9-R705.1)/(R749.9+R705.1+0.16) | [12] | Chl | Canopy |
| PSNDa | 0.37 | 0.39 | 0.30 | 0.38 | 0.79 | 0.58 | 0.12 | 0.14 | 0.22 | 0.02 | 0.04 | 0.01 | 0.24 | 0.09 | 0.02 | 0.08 | 0.10 | 0.23 | 0.29 | 0.00 | (R800.5-R680.8)/(R800.5+R680.8) | [27] | Chla | Leaf/ Canopy |
| PSRI | 0.29 | 0.33 | 0.25 | 0.30 | 0.85 | 0.50 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.06 | 0.03 | 0.08 | 0.09 | 0.25 | 0.29 | 0.00 | (R680.8-R499.6)/R749.9 | [28] | Car/Chl | Leaf |
| PSSRa | 0.38 | 0.34 | 0.23 | 0.38 | 0.47 | 0.54 | 0.08 | 0.10 | 0.16 | 0.01 | 0.01 | 0.01 | 0.19 | 0.09 | 0.00 | 0.02 | 0.05 | 0.10 | 0.15 | 0.10 | R800.5/R680.8 | [27] | Chla | Leaf/ Canopy |
| RDVI | 0.44 | 0.45 | 0.36 | 0.45 | 0.78 | 0.62 | 0.29 | 0.30 | 0.39 | 0.12 | 0.16 | 0.02 | 0.27 | 0.05 | 0.03 | 0.08 | 0.08 | 0.14 | 0.29 | 0.00 | (R800.5-R669.8)/sqrt(R800.5+R669.8) | [29] | fAPAR | Canopy |
| REIP | 0.42 | 0.39 | 0.29 | 0.42 | 0.25 | 0.29 | 0.27 | 0.27 | 0.38 | 0.10 | 0.19 | 0.05 | 0.26 | 0.00 | 0.02 | 0.02 | 0.01 | 0.03 | 0.14 | 0.04 | (699.7+40*((Rre-R699.7)/(R739.5-R699.7)))/100 | [30] | Red edge | |
| REP | 0.42 | 0.39 | 0.29 | 0.42 | 0.25 | 0.29 | 0.27 | 0.27 | 0.38 | 0.10 | 0.19 | 0.05 | 0.26 | 0.00 | 0.02 | 0.02 | 0.01 | 0.03 | 0.14 | 0.04 | 699.7+40*((((R669.8+R780.6)/2)-R699.7)/(R739.5-R699.7)) | [31] | Chl | leaf |
| REP_LI | 0.19 | 0.22 | 0.20 | 0.20 | 0.66 | 0.40 | 0.19 | 0.20 | 0.31 | 0.05 | 0.12 | 0.01 | 0.26 | 0.01 | 0.02 | 0.04 | 0.04 | 0.14 | 0.18 | 0.02 | 699.7+40*((R669.8+R780.6/2)/(R739.5-R699.7)) | [32] | Chl | Leaf |
| RMSR | 0.88 | 0.78 | 0.59 | 0.87 | 0.31 | 0.49 | 0.45 | 0.46 | 0.58 | 0.21 | 0.24 | 0.07 | 0.35 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.19 | 0.05 | ((R749.9/R705.1)-1)/sqrt((R749.9/R705.1)+1) | [12] | Chl | Model |
| Rre | 0.13 | 0.17 | 0.12 | 0.14 | 0.72 | 0.34 | 0.28 | 0.26 | 0.28 | 0.19 | 0.20 | 0.12 | 0.09 | 0.14 | 0.00 | 0.06 | 0.10 | 0.43 | 0.25 | 0.00 | (R669.8+R780.6)/2 | [30] | Red edge | |
| RTCARI | 0.25 | 0.22 | 0.23 | 0.25 | 0.55 | 0.56 | 0.01 | 0.01 | 0.02 | 0.00 | 0.01 | 0.00 | 0.02 | 0.04 | 0.01 | 0.04 | 0.05 | 0.10 | 0.20 | 0.00 | 3*((R749.9-R705.1)-0.2*(R749.9-R549.6)*(R749.9/R705.1)) | [12] | Chl | Model |
| SIPI | 0.19 | 0.22 | 0.20 | 0.20 | 0.72 | 0.40 | 0.02 | 0.03 | 0.04 | 0.00 | 0.00 | 0.00 | 0.04 | 0.01 | 0.02 | 0.04 | 0.04 | 0.14 | 0.17 | 0.02 | (R800.5-R445.7)/(R800.5-R680.8) | [33] | Pig./chl, stress | Leaf |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SR | 0.39 | 0.34 | 0.23 | 0.38 | 0.45 | 0.53 | 0.07 | 0.09 | 0.14 | 0.01 | 0.01 | 0.02 | 0.19 | 0.10 | 0.00 | 0.02 | 0.05 | 0.11 | 0.15 | 0.11 | R800.5/R669.8 | [5] | LAI | Canopy /Forest |
| SR1 | 0.88 | 0.78 | 0.58 | 0.86 | 0.24 | 0.42 | 0.47 | 0.47 | 0.59 | 0.23 | 0.25 | 0.07 | 0.35 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.17 | 0.06 | R749.9/R709.1 | [34] | Chl | Model |
| SR736/751 | 0.87 | 0.77 | 0.59 | 0.86 | 0.23 | 0.42 | 0.44 | 0.44 | 0.57 | 0.20 | 0.25 | 0.08 | 0.36 | 0.00 | 0.02 | 0.02 | 0.01 | 0.00 | 0.17 | 0.05 | (R735.6/R751.2) | [35] | Chl | Leaf |
| SR750550 | 0.20 | 0.22 | 0.11 | 0.21 | 0.13 | 0.07 | 0.09 | 0.10 | 0.10 | 0.05 | 0.01 | 0.01 | 0.07 | 0.01 | 0.01 | 0.02 | 0.02 | 0.00 | 0.01 | 0.00 | R749.9/R549.6 | [36] | Chl | Leaf |
| SRPI | 0.37 | 0.37 | 0.29 | 0.38 | 0.47 | 0.41 | 0.13 | 0.15 | 0.13 | 0.08 | 0.02 | 0.02 | 0.04 | 0.03 | 0.00 | 0.01 | 0.02 | 0.08 | 0.11 | 0.01 | R430.5/R680.8 | [33] | Chl | Leaf |
| SRWI | 0.01 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.12 | 0.12 | 0.14 | 0.06 | 0.06 | 0.08 | 0.07 | 0.21 | 0.11 | 0.41 | 0.51 | 0.33 | 0.23 | 0.00 | (R860.4/R1242.2) | [37] | Water content | Canopy |
| TCARI | 0.03 | 0.02 | 0.00 | 0.03 | 0.25 | 0.10 | 0.30 | 0.31 | 0.34 | 0.19 | 0.11 | 0.06 | 0.17 | 0.04 | 0.00 | 0.02 | 0.03 | 0.11 | 0.05 | 0.03 | 3*((R699.7-R669.8)-0.2*(R699.7-R551)*(R699.7/R669.8)) | [38] | Chl | Canopy Model |
| TCARI/OSAVI | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.11 | 0.34 | 0.35 | 0.40 | 0.20 | 0.12 | 0.05 | 0.22 | 0.02 | 0.00 | 0.01 | 0.01 | 0.07 | 0.04 | 0.05 | TCARI/OSAVI | [38] | Chl | Canopy Model |
| TVI | 0.34 | 0.34 | 0.29 | 0.34 | 0.76 | 0.61 | 0.07 | 0.08 | 0.10 | 0.03 | 0.07 | 0.00 | 0.06 | 0.06 | 0.03 | 0.07 | 0.08 | 0.12 | 0.25 | 0.00 | 0.5*(120*(R749.9-R551)-200*(R669.8-R551)) | [39] | LAI, Canopy Chl. density | Canopy |
| VI700 | 0.00 | 0.00 | 0.00 | 0.00 | 0.44 | 0.15 | 0.38 | 0.35 | 0.39 | 0.25 | 0.26 | 0.20 | 0.13 | 0.14 | 0.00 | 0.05 | 0.10 | 0.27 | 0.09 | 0.00 | (R699.7-R669.8)/(R699.7+R669.8) | [40] | Vegetation fraction | Canopy |
| Vogelmann | 0.88 | 0.78 | 0.59 | 0.87 | 0.25 | 0.43 | 0.45 | 0.46 | 0.58 | 0.22 | 0.24 | 0.07 | 0.35 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.18 | 0.06 | R739.5/R719.7 | [41] | Chl | Leaf |
| WI | 0.01 | 0.00 | 0.00 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 | 0.07 | 0.08 | 0.03 | 0.03 | 0.01 | (R900.8/R970.5) | [42] | Water status | Leaf |
| WINDVI | 0.19 | 0.22 | 0.20 | 0.20 | 0.72 | 0.41 | 0.09 | 0.11 | 0.19 | 0.01 | 0.04 | 0.01 | 0.25 | 0.01 | 0.02 | 0.04 | 0.04 | 0.15 | 0.18 | 0.02 | ((R900.8/R970.5)/((R800.5-R680.8)/(R800.5+R680.8))) | [43] | Water conc. | Leaf |

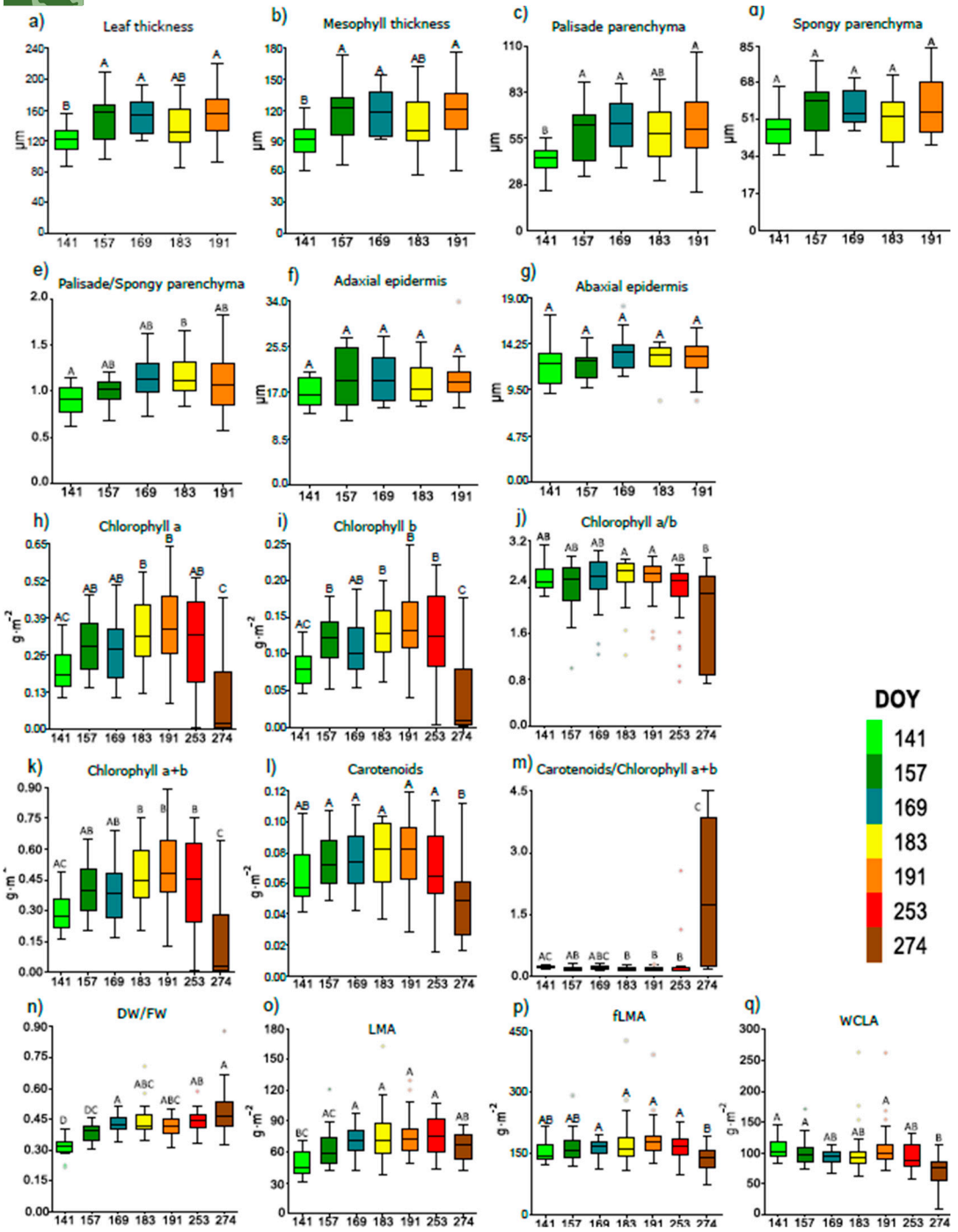


**Figure S1.** The mean values of biophysical and structural traits during the day of year (DOY: 141, 157, 169, 183, 191, 253, 274). Data were pooled for all species (*B. pendula*, *A. incana*, *P. tremula*) and juvenile, mature and senescent leaves together. a) Leaf thickness (µm); b) Mesophyll thickness (µm); c) Palisade parenchyma thickness (µm); d) Spongy parenchyma thickness (µm); E) Palisade/Spongy parenchyma ratio; *f*) Adaxial epidermis thickness (µm); *g*) Abaxial epidermis thickness (µm); a-g DOY 253 and 274 the analyses were not performed. h) Chlorophyll a content (g*m$^{-2}$); i) Chlorophyll b content (g*m$^{-2}$); j) Chlorophyll a/b ratio; k) Carotenoids content (g*m$^{-2}$); l) Chlorophyll a+b content (g*m$^{-2}$); m) Carotenoids/Chlorophyll ratio; n) Dry/fresh weight ratio, o) Leaf mass per area (LMA g*m$^{-2}$); P) fresh Leaf mass per area (fLMA g*m$^{-2}$); Q) Water content per leaf area (WCLA g*m$^{-2}$). Difference among the values for different DOYs in one group was tested by ANOVA, $\alpha$= 0.05. Different colors correspond to individual DOYs during the season; line in boxes corresponds to the median value, error bars show

inter-quartile range; dots correspond to mild and severe outliers; same letters indicate no significance, different letters correspond to significant difference among DOYs within one graph at $\alpha$= 0.05.

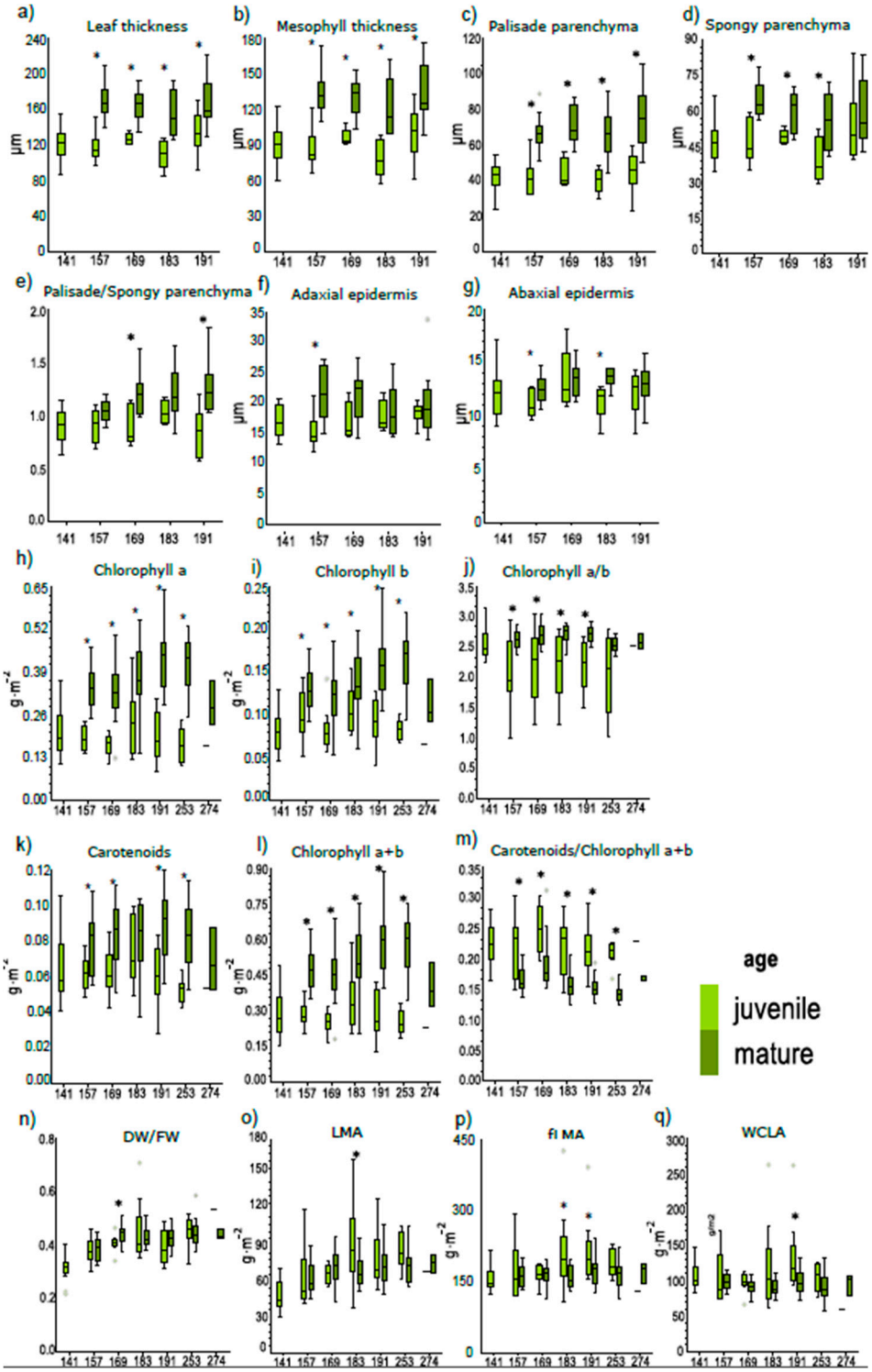


**Figure S2.** The mean values of biophysical and structural traits during the season (day of year -DOY: 141, 157, 169, 183, 191, 253, 274). Data were pooled for all species (*B. pendula*, *A. incana*, *P. tremula*) for two group of leaves (juvenile and mature). a) Leaf thickness (µm); b) Mesophyll thickness (µm); c) Palisade parenchyma thickness (µm); d) Spongy parenchyma thickness (µm); E) Palisade/Spongy parenchyma ratio; *f*) Adaxial epidermis thickness (µm); *g*) Abaxial epidermis thickness (µm); a-g DOY 253 and 274 the analyses were not performed. h) Chlorophyll a content (g*m$^{-2}$); i) Chlorophyll b content (g*m$^{-2}$); j) Chlorophyll a/b ratio; k) Carotenoids content (g*m$^{-2}$); l) Chlorophyll a+b content

(g*m$^{-2}$); m) Carotenoids/Chlorophyll ratio; n) Dry/fresh weight ratio, o) Leaf mass per area (LMA g*m$^{-2}$); P) fresh Leaf mass per area (fLMA g*m$^{-2}$); Q) Water content per leaf area (WCLA g*m$^{-2}$). Difference among the values for different DOYs in one group was tested by ANOVA, p-value=0.05. Different colors correspond to individual DOYs during the season; line in boxes corresponds to median value, error bars show inter-quartile range; dots correspond to mild and severe outliers; same letters indicate no significance, different letters correspond to significant difference among DOYs within one graph at $\alpha$= 0.05

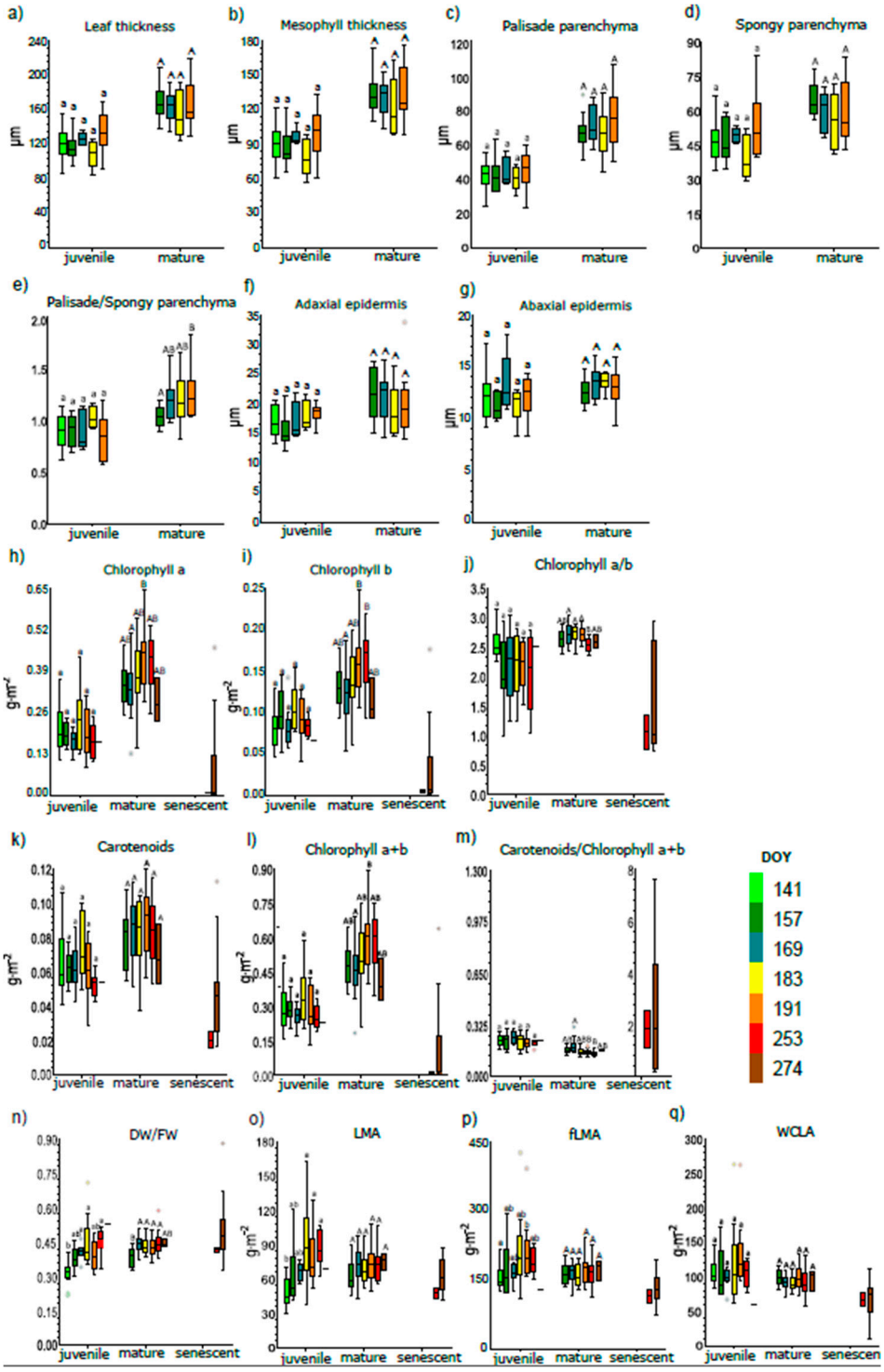


**Figure S3.** The mean values of biophysical and structural traits during the season (day of year -DOY: 141, 157, 169, 183, 191, 253, 274). Data were pooled for all species (*B. pendula*, *A. incana*, *P. tremula*) for three age of leaves (juvenile, mature and senescent). a) Leaf thickness (µm); b) Mesophyll thickness

(µm); c) Palisade parenchyma thickness (µm); d) Spongy parenchyma thickness (µm); E) Palisade/Spongy parenchyma ratio; f) Adaxial epidermis thickness (µm); g) Abaxial epidermis thickness (µm); a-g DOY 253 and 274 the analyses were not performed. h) Chlorophyll a content (g*m$^{-2}$); i) Chlorophyll b content (g*m$^{-2}$); j) Chlorophyll a/b ratio; k) Carotenoids content (g*m$^{-2}$); l) Chlorophyll a+b content (g*m$^{-2}$); m) Carotenoids/Chlorophyll ratio; n) Dry/fresh weight ratio, o) Leaf mass per area (LMA g*m$^{-2}$); P) fresh Leaf mass per area (fLMA g*m$^{-2}$); Q) Water content per leaf area (WCLA g*m$^{-2}$). Difference among the values for different DOYs in one group was tested by ANOVA, p-value=0.05. Different colors correspond to individual DOYs during the season; line in boxes corresponds to median value, error bars show inter-quartile range; dots correspond to mild and severe outliers; same letters indicate no significance, different letters correspond to significant difference among DOYs within one graph at $\alpha$= 0.05

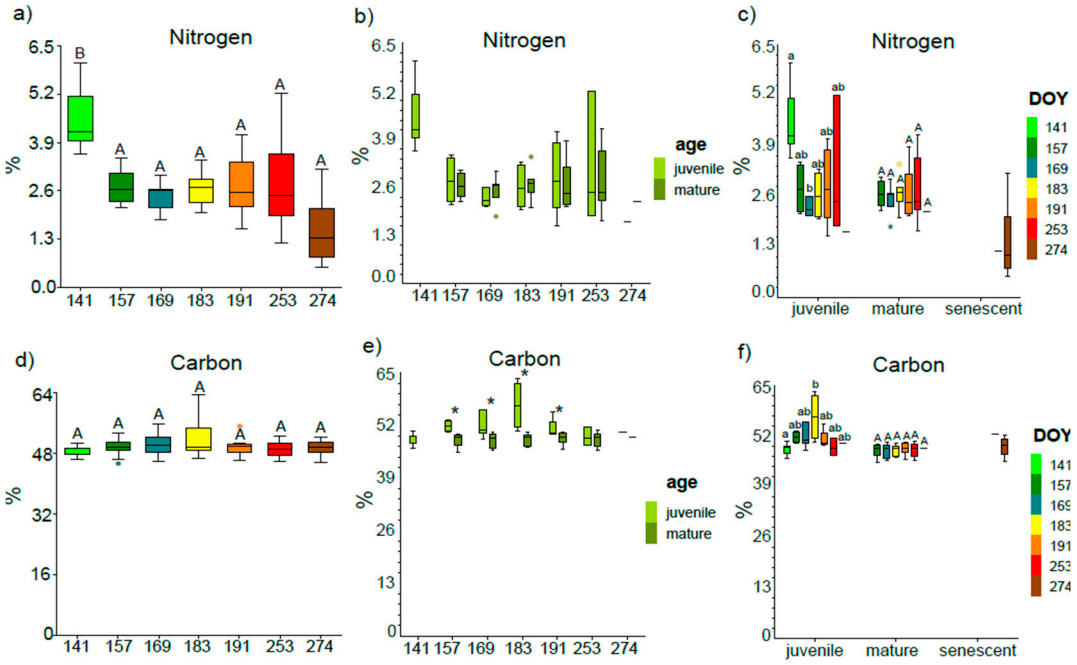


**Figure S4.** Nitrogen content per unit dry mass (%) and Carbon content per unit dry mass (%); a, d) for juvenile, mature and senescent leaves; b, e) two group of leaves (juvenile and mature); c, f) for three age of leaves (juvenile, mature, senescent) for all species (*B. pendula*, *A. incana*, *P. tremula*) during the season (day of year -DOY: 141, 157, 169, 183, 191, 253, 274). Difference among the DOYs in one group tested by Analyze of variance a),c),d),f); p-value=0.05; Comparison in DOYs b), e) was tested by One-sample T-test, $\alpha$ =0.05

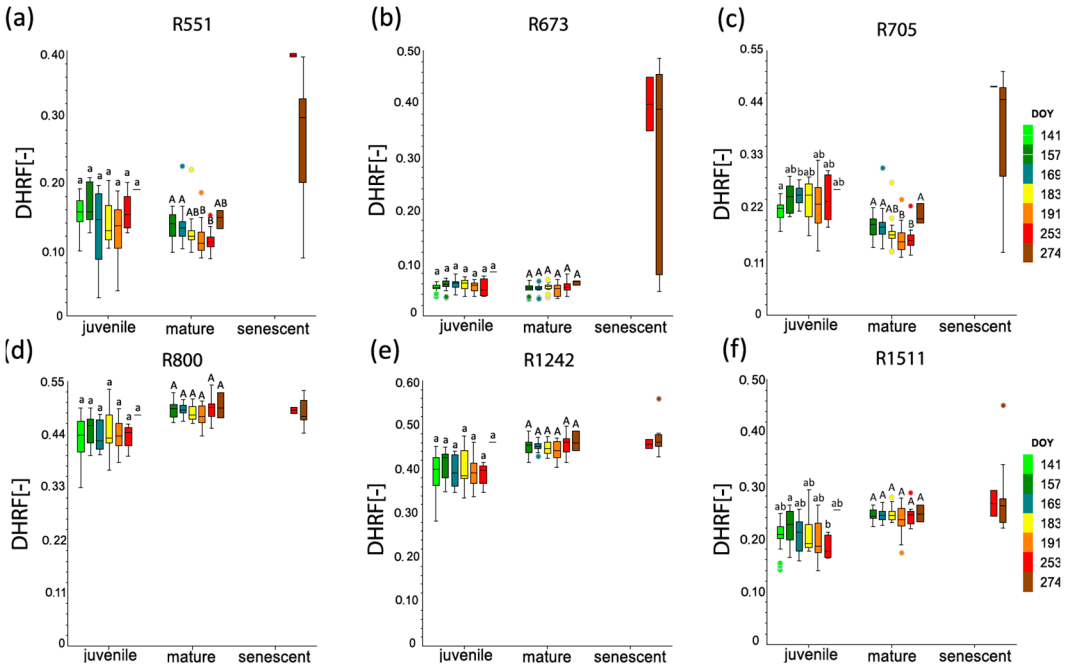


**Figure S5.** The reflectance at selected wavelength during the season (DOY: 141, 157, 169, 183, 191, 253, 274). Data were pooled for all species (*B. pendula*, *A. incana*, *P. tremula*) for three age of leaves (juvenile, mature and senescent). DHRF = directional-hemispherical reflectance factor. a) 551 nm; b) 673 nm; c) 705 nm; d) 800 nm; e) 1242 nm; f) 1511 nm. The difference among the DOY in one group tested by Analysis of variance, $\alpha$= 0.05. Different colors correspond to individual DOYs during the season; line in boxes show median, error bars show inter-quartile range; dots correspond to mild and severe outliers; same letters show no significance, different letter show significant difference among DOYs within one graph at $\alpha$= 0.05.

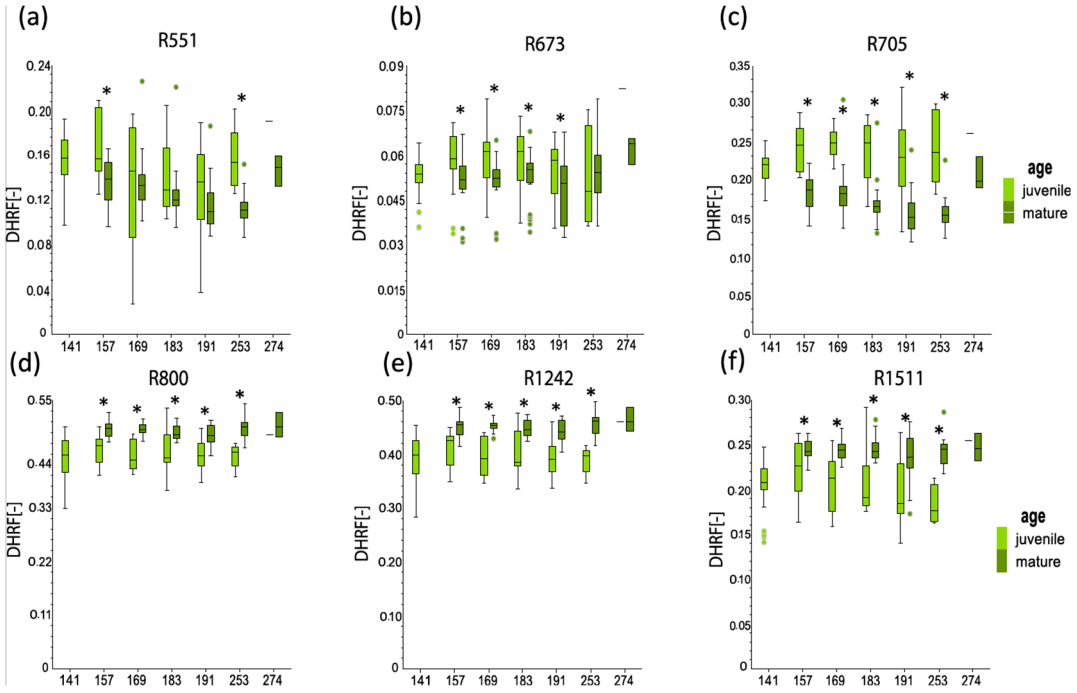


**Figure S6.** The reflectance at selected wavelength during the season (DOY: 141,157,169,183,191,253,274). Pooled for all species (*B. pendula*, *A. incana*, *P. tremula*) for two group of leaves (juvenile and mature). DHRF = directional-hemispherical reflectance factor. a) 551 nm; b) 673 nm; c) 705 nm; d) 800 nm; e) 1242 nm; f) 1511 nm Comparison in DOY was tested by One-sample T-test, $\alpha$= 0.05. Line in boxes show median, error bars show inter-quartile range; dots correspond to mild and severe outliers; same letters show no significance, different letter show significant difference among DOYs within one graph at $\alpha$= 0.05

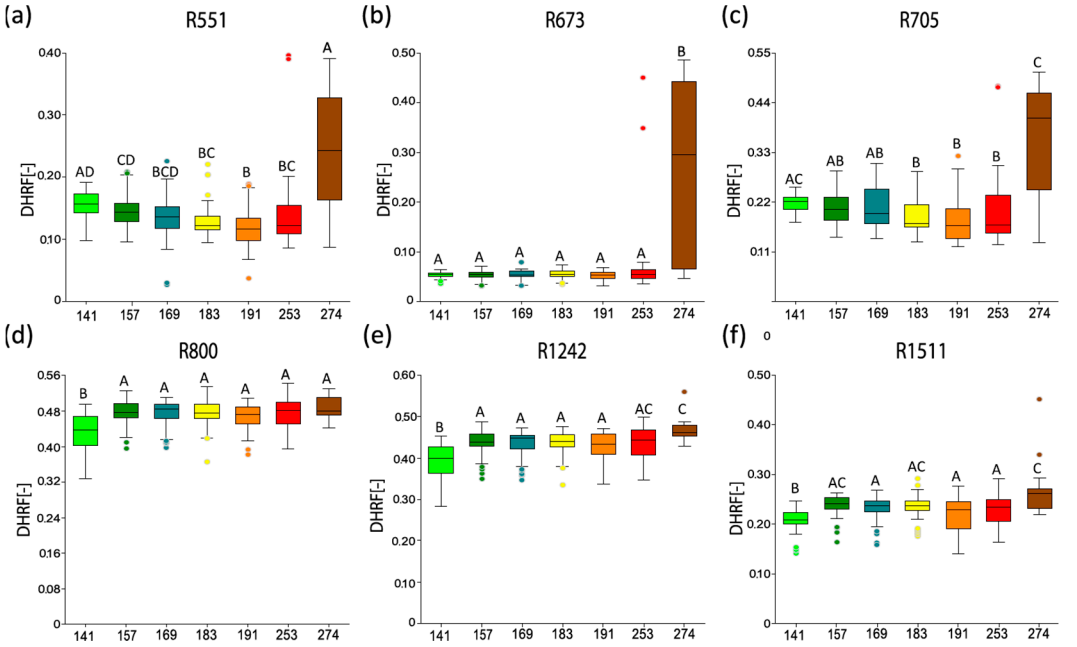


**Figure S7.** The reflectance at selected wavelength during the season (day of the year - DOY: 141,157,169,183,191,253,274). Data were pooled for all species (*B. pendula*, *A. incana*, *P. tremula*) and juvenile, mature and senescent leaves together. DHRF = directional-hemispherical reflectance factor. a) 551 nm; b) 673 nm; c) 705 nm; d) 800 nm; e) 1242 nm; f) 1511 nm; Difference among the DOYs in one group tested by Analysis of variance, $\alpha$= 0.05. Different colors correspond to individual

DOYs during the season; line in boxes show median, error bars show inter-quartile range; dots correspond to mild and severe outliers; same letters show no significance, different letter show significant difference among DOYs within one graph at $\alpha$= 0.05.


1. Liu, J.G.; Moore, J.M. Hue Image RGB Colour Composition. A Simple Technique to Suppress Shadow and Enhance Spectral Signature. *International Journal of Remote Sensing* **1990**, *11*, 1521–1530, doi:10.1080/01431169008955110.
2. Carter, G.A. Ratios of Leaf Reflectances in Narrow Wavebands as Indicators of Plant Stress. *International Journal of Remote Sensing* **1994**, *15*, 697–703, doi:10.1080/01431169408954109.
3. Datt, B. A New Reflectance Index for Remote Sensing of Chlorophyll Content in Higher Plants: Tests Using Eucalyptus Leaves. *Journal of Plant Physiology* **1999**, *154*, 30–36, doi:10.1016/S0176-1617(99)80314-9.
4. Lemaire, G.; Francois, C.; Soudani, K.; Berveiller, D.; Pontailler, J.; Breda, N.; Genet, H.; Davi, H.; Dufrene, E. Calibration and Validation of Hyperspectral Indices for the Estimation of Broadleaved Forest Leaf Chlorophyll Content, Leaf Mass per Area, Leaf Area Index and Leaf Canopy Biomass. *Remote Sensing of Environment* **2008**, *112*, 3846–3864, doi:10.1016/j.rse.2008.06.005.
5. Jordan, C.F. Derivation of Leaf-Area Index from Quality of Light on the Forest Floor. *Ecology* **1969**, *50*, 663–666, doi:10.2307/1936256.
6. Gitelson, A.A.; Gritz, Y.; Merzlyak, M.N. Relationships between Leaf Chlorophyll Content and Spectral Reflectance and Algorithms for Non-Destructive Chlorophyll Assessment in Higher Plant Leaves. *J.Plant Physiol.* **2003**, *160*, 271–282.
7. Gitelson, A.; Merzlyak, M.N. Spectral Reflectance Changes Associated with Autumn Senescence of *Aesculus Hippocastanum* L. and *Acer Platanoides* L. Leaves. Spectral Features and Relation to Chlorophyll Estimation. *Journal of Plant Physiology* **1994**, *143*, 286–292, doi:10.1016/S0176-1617(11)81633-0.
8. Smith, R.C.G.; Adams, J.; Stephens, D.J.; Hick, P.T.; Smith, R.C.G.; Adams, J.; Stephens, D.J.; Hick, P.T. Forecasting Wheat Yield in a Mediterranean-Type Environment from the NOAA Satellite, Forecasting Wheat Yield in a Mediterranean-Type Environment from the NOAA Satellite. *Crop Pasture Sci., Crop Pasture Sci.* **1995**, *46*, *46*, 113, 113–125, 125, doi:10.1071/AR9950113, 10.1071/AR9950113.
9. Maccioni, A.; Agati, G.; Mazzinghi, P. New Vegetation Indices for Remote Measurement of Chlorophylls Based on Leaf Directional Reflectance Spectra. *Journal of Photochemistry and Photobiology B: Biology* **2001**, *61*, 52–61, doi:10.1016/S1011-1344(01)00145-2.
10. Daughtry, C.S.T.; Walthall, C.L.; Kim, M.S.; De Colstoun, E.B.; McMurtrey, J.E. Estimating Corn Leaf Chlorophyll Concentration from Leaf and Canopy Reflectance. *Remote sensing of Environment* **2000**, *74*, 229–239.
11. Haboudane, D. Hyperspectral Vegetation Indices and Novel Algorithms for Predicting Green LAI of Crop Canopies: Modeling and Validation in the Context of Precision Agriculture. *Remote Sensing of Environment* **2004**, *90*, 337–352, doi:10.1016/j.rse.2003.12.013.
12. Wu, C.; Niu, Z.; Tang, Q.; Huang, W. Estimating Chlorophyll Content from Hyperspectral Vegetation Indices: Modeling and Validation. *Agricultural and Forest Meteorology* **2008**, *148*, 1230–1241, doi:10.1016/j.agrformet.2008.03.005.
13. McMurtrey, J.E.; Chappelle, E.W.; Kim, M.S.; Meisinger, J.J.; Corp, L.A. Distinguishing Nitrogen Fertilization Levels in Field Corn (Zea Mays L.) with Actively Induced Fluorescence and Passive Reflectance Measurements. *Remote Sensing of Environment* **1994**, *47*, 36–44, doi:10.1016/0034-4257(94)90125-2.

14. Sims, D.A.; Gamon, J.A. Relationships between Leaf Pigment Content and Spectral Reflectance across a Wide Range of Species, Leaf Structures and Developmental Stages. *Remote sensing of environment* **2002**, *81*, 337–354.
15. Mutanga, O.; Skidmore, A.K. Narrow Band Vegetation Indices Overcome the Saturation Problem in Biomass Estimation. *International Journal of Remote Sensing* **2004**, *25*, 3999–4014, doi:10.1080/01431160310001654923.
16. Qi, J.; Chehbouni, A.; Huete, A.R.; Kerr, Y.H.; Sorooshian, S. A Modified Soil Adjusted Vegetation Index. *Remote Sensing of Environment* **1994**, *48*, 119–126, doi:10.1016/0034-4257(94)90134-1.
17. Hunt, E.R.; Rock, B.N. Detection of Changes in Leaf Water Content Using Near- and Middle-Infrared Reflectances. *Remote Sensing of Environment* **1989**, *30*, 43–54, doi:10.1016/0034-4257(89)90046-1.
18. Dash, J.; Curran, P.J. The MERIS Terrestrial Chlorophyll Index. *International Journal of Remote Sensing* **2004**, *25*, 5403–5413, doi:10.1080/01431160420000274015.
19. Campbell, P.K.E.; Rock, B.N.; Martin, M.E.; Neefus, C.D.; Irons, J.R.; Middleton, E.M.; Albrechtova, J. Detection of Initial Damage in Norway Spruce Canopies Using Hyperspectral Airborne Data. *International Journal of Remote Sensing* **2004**, *25*, 5557–5584, doi:10.1080/01431160410001726058.
20. Curran, P.J. Remote Sensing of Foliar Chemistry. *Remote Sensing of Environment* **1989**, *30*, 271–278, doi:10.1016/0034-4257(89)90069-2.
21. Serrano, L.; Peñuelas, J.; Ustin, S.L. Remote Sensing of Nitrogen and Lignin in Mediterranean Vegetation from AVIRIS Data: Decomposing Biochemical from Structural Signals. *Remote Sensing of Environment* **2002**, *81*, 355–364, doi:10.1016/S0034-4257(02)00011-1.
22. Rouse, J.W. *Monitoring the Vernal Advancement and Retrogradation (Green Wave Effect) of Natural Vegetation*; 1974;
23. Chen, D.; Huang, J.; Jackson, T.J. Vegetation Water Content Estimation for Corn and Soybeans Using Spectral Indices Derived from MODIS Near- and Short-Wave Infrared Bands. *Remote Sensing of Environment* **2005**, *98*, 225–236, doi:10.1016/j.rse.2005.07.008.
24. Gao, B. NDWI—A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water from Space. *Remote Sensing of Environment* **1996**, *58*, 257–266, doi:10.1016/S0034-4257(96)00067-3.
25. Riedell, W.E.; Blackmer, T.M. Leaf Reflectance Spectra of Cereal Aphid-Damaged Wheat. *Crop Sci.* **1999**, *39*, 1835–1840, doi:10.2135/cropsci1999.3961835x.
26. Rondeaux, G.; Steven, M.; Baret, F. Optimization of Soil-Adjusted Vegetation Indices. *Remote Sensing of Environment* **1996**, *55*, 95–107, doi:10.1016/0034-4257(95)00186-7.
27. Blackburn, G.A. Quantifying Chlorophylls and Caroteniods at Leaf and Canopy Scales: An Evaluation of Some Hyperspectral Approaches. *Remote sensing of environment* **1998**, *66*, 273–285.
28. Merzlyak, M.N.; Gitelson, A.A.; Chivkunova, O.B.; Rakitin, V.YU. Non-Destructive Optical Detection of Pigment Changes during Leaf Senescence and Fruit Ripening. *Physiol Plant* **1999**, *106*, 135–141, doi:10.1034/j.1399-3054.1999.106119.x.
29. Roujean, J.-L.; Breon, F.-M. Estimating PAR Absorbed by Vegetation from Bidirectional Reflectance Measurements. *Remote Sensing of Environment* **1995**, *51*, 375–384, doi:10.1016/0034-4257(94)00114-3.
30. Guyot, G.; Baret, F. Utilisation de La Haute Resolution Spectrale Pour Suivre L'etat Des Couverts Vegetaux 1988.
31. Mišurec, J.; Kopačková, V.; Lhotáková, Z.; Campbell, P.; Albrechtová, J. Detection of Spatio-Temporal Changes of Norway Spruce Forest Stands in Ore Mountains Using Landsat Time Series and Airborne Hyperspectral Imagery. *Remote Sensing* **2016**, *8*, 92, doi:10.3390/rs8020092.

32. Main, R.; Cho, M.A.; Mathieu, R.; O'Kennedy, M.M.; Ramoelo, A.; Koch, S. An Investigation into Robust Spectral Indices for Leaf Chlorophyll Estimation. *ISPRS Journal of Photogrammetry and Remote Sensing* **2011**, *66*, 751–761, doi:10.1016/j.isprsjprs.2011.08.001.
33. Peňuelas, J.; Fillela, I.; Lloret, P.; Muňoz, F.; Vilajeliu, M. Reflectance Assessment of Mite Effects on Apple Trees. *International Journal of Remote Sensing* **1995**, *16*, 2727–2733, doi:10.1080/01431169508954588.
34. Zarco-Tejada, P.J.; Miller, J.R.; Noland, T.L.; Mohammed, G.H.; Sampson, P.H. Scaling-up and Model Inversion Methods with Narrowband Optical Indices for Chlorophyll Content Estimation in Closed Forest Canopies with Hyperspectral Data. *IEEE Transactions on Geoscience and Remote Sensing* **2001**, *39*, 1491–1507, doi:10.1109/36.934080.
35. Hallik, L.; Kazantsev, T.; Kuusk, A.; Galmés, J.; Tomás, M.; Niinemets, Ü. Generality of Relationships between Leaf Pigment Contents and Spectral Vegetation Indices in Mallorca (Spain). *Reg Environ Change* **2017**, *17*, 2097–2109, doi:10.1007/s10113-017-1202-9.
36. Gitelson, A.A.; Merzlyak, M.N. Remote Estimation of Chlorophyll Content in Higher Plant Leaves. *International Journal of Remote Sensing* **1997**, *18*, 2691–2697, doi:10.1080/014311697217558.
37. Zarco-Tejada, P.J.; Rueda, C.A.; Ustin, S.L. Water Content Estimation in Vegetation with MODIS Reflectance Data and Model Inversion Methods. *Remote Sensing of Environment* **2003**, *85*, 109–124, doi:10.1016/S0034-4257(02)00197-9.
38. Haboudane, D.; Miller, J.R.; Tremblay, N.; Zarco-Tejada, P.J.; Dextraze, L. Integrated Narrow-Band Vegetation Indices for Prediction of Crop Chlorophyll Content for Application to Precision Agriculture. *Remote Sensing of Environment* **2002**, *81*, 416–426, doi:10.1016/S0034-4257(02)00018-4.
39. Broge, N.H.; Leblanc, E. Comparing Prediction Power and Stability of Broadband and Hyperspectral Vegetation Indices for Estimation of Green Leaf Area Index and Canopy Chlorophyll Density. *Remote Sensing of Environment* **2000**, *76*, 156–172, doi:10.1016/S0034-4257(00)00197-8.
40. Gitelson, A.A.; Kaufman, Y.J.; Stark, R.; Rundquist, D. Novel Algorithms for Remote Estimation of Vegetation Fraction. *Remote Sensing of Environment* **2002**, *80*, 76–87, doi:10.1016/S0034-4257(01)00289-9.
41. Vogelmann, J.E.; Rock, B.N.; Moss, D.M. Red Edge Spectral Measurements from Sugar Maple Leaves. *International Journal of Remote Sensing* **1993**, *14*, 1563–1575, doi:10.1080/01431169308953986.
42. Penuelas, J.; Fillela, I.; Biel, C.; Serrano, L.; Savé, R. The Reflectance at the 950–970 Nm Region as an Indicator of Plant Water Status. *International Journal of Remote Sensing* **1993**, *14*, 1887–1905, doi:10.1080/01431169308954010.
43. Penuelas, J.; Pinol, J.; Ogaya, R.; Filella, I. Estimation of Plant Water Concentration by the Reflectance Water Index WI (R900/R970). *International Journal of Remote Sensing* **1997**, *18*, 2869–2875, doi:10.1080/014311697217396.