Eurasian Journal of Soil Science 2023, 12(1), 37- 62

Eurasian Journal of Soil Science

Journal homepage : http://ejss.fesss.org

Identification of species of the genus *Quercus* L. with different responses to soil and climatic conditions according to hyperspectral survey data

Pavel Dmitriev, Boris Kozlovsky, Anastasiya Dmitrieva, Vladimir Lysenko, Vasily Chokheli, Tatiana Minkina, Saglara Mandzhieva, Svetlana Sushkova*, Tatyana Varduni

Southern Federal University, Rostov-on-Don, Russia

Article Info

Received : 15.05.2022
Accepted : 01.10.2022
Available online : 03.10.2022

Author(s)

P.Dmitriev
B.Kozlovsky
A.Dmitrieva
V.Lysenko
V.Chokheli
T.Minkina
S.Mandzhieva
S.Sushkova *
T.Varduni

* Corresponding author

Abstract

Soil standing may be studied indirectly using remote sensing through an assessment of state of the plants growing on it. The ability to evaluate the physiological state of plants using the hyperspectral survey data also provides a tool to characterize vegetation cover and individual samples of woody plants. In the present work the hyperspectral imaging was applied to identify the species of the woody plants evaluating the differences in their physiological state. Samples of *Quercus macrocarpa* Michx., *Q. robur* L. and *Q. rubra* L. were studied using Cubert UHD-185 hyperspectral camera over five periods with an interval of 7-10 days. In total, 80 vegetation indices (VIs) were calculated. Sample sets of values of VIs were analyzed using analysis of variance (ANOVA), principal component analysis (PCA), decision tree (DT), random forest (RF) methods. It was shown using the ANOVA, that the following VIs are the most dependent on the species affiliation of the samples: Carter2, Carter3, Carter4, CI, CI2, CRI4, Datt, Datt2, GMI2, Maccioni, mSR2, MTCI, NDVI2, OSAVI2, PRI, REP_Li, SR1, SR2, SR6, Vogelmann, Vogelmann2, Vogelmann4. VIs that are effective for the separation of oak species, were also revealed using the DT method – these are Boochs, Boochs2, CARI, CRI1, CRI3, D1, D2, Datt, Datt3; Datt4, Datt5, DD, DDn, EGFN, Gitelson, MCARI2, MTCI, MTVI, NDVI3, PRI, PSND, PSRI, RDVI, REP_Li, SPVI, SR4, Vogelmann, Vogelmann2, Vogelmann3. PCA and RF methods reliably differentiated *Q. rubra* from *Q. robur* and *Q. macrocarpa*. *Q. rubra*, unlike other species, was under stress from the impact of soil pH against the background of drought. This was manifested in leaf chlorosis. Influence of the environmental stress factors on the reliability and efficiency of species identification was demonstrated. *Q. robur* and *Q. macrocarpa*were were poorly separated by PCA and RF methods all over the five periods of the experiment.

Keywords: Hyperspectral imaging, vegetation indices, *Quercus macrocarpa*, *Quercus robur*, *Quercus rubra*, environmental stress, drought stress, reflection spectra.

Introduction

Remote sensing of Earth's surface allows to assess the state of vegetation and its species composition. The number of works devoted to establishing the species affiliation of woody plant samples using remote sensing methods has been steadily growing in recent years (Dainelli et al., 2021; Fassnachtet al., 2016).Various technologies and types of sensors are used to identify tree species, with great interest being shown in the possibilities of hyperspectral imaging (Cao et al., 2018; Tuominen et al., 2018; Saarinen et al., 2018; Nezami et

: https://doi.org/10.18393/ejss.1183524
: http://ejss.fesss.org/10.18393/ejss.1183524
Publisher : Federation of Eurasian Soil Science Societies
e-ISSN : 2147-4249

al., 2020; Miyoshi et al., 2020a,b; Sothe et al., 2020). However, many questions regarding the reliability of tree species identification by remote sensing remain open.

In addition, the remote monitoring of soil, as a component of biogeocenoses, is a more complicated and difficult since it is hidden by vegetation in many areas. However, the assessment of the soil standing can be achieved indirectly through the state of plants growing on it. The values of vegetation indices (VIs) and spectral channels data primarily depend on the physiological state of plants (Oppelt and Mauser 2004; Ronay et al., 2021). Therefore, it is of great interest to study the spectral characteristics of a group of the related plant species having different responses to the specific soil and climatic conditions, varying from optimum to stress. Particularly, oak species *Quercus macrocarpa* Michx., *Q. robur* L. and *Q. rubra* L. are of interest considering their wide distribution and occurrence in the central and southern regions of Russia (Kozlovsky et al., 2009).

In the Rostov region, oak forests from *Q. robur* L. are considered the most valuable formations of ravine and floodplain forests (Zozulin, 1992). *Q. robur* is the leading species in protective forest belts and plantations of settlements in the Rostov region of Russia (Kozlovsky et al., 2009). *Q. macrocarpa* Michx. – the most promising species from the genus *Quercus* for the regional culture according to the results of the introduction test. *Q. rubra* L. in its biological properties does not correspond to the climatic and soil conditions of the steppe zone - it does not tolerate drought well and needs the acidic soils (Kozlovsky et al., 2016).

We propose that hyperspectral imaging can distinguish stressed *Q. rubra* from *Q. robur* and *Q. macrocarpa*, which grow under optimal conditions, but having differences in their physiological state. We evaluated the possibilities of using hyperspectral survey data (VIs values) to identify woody plant samples based on differences in their physiological state using the species of the genus *Quercus* as a test plants. Influence of soil pH and drought, as environmental stress factors, were studied in regard of such an identification. Performance of the studied VIs was discussed in the context of the various spectral ranges on the basis of which they are calculated.

Material and Methods

The research was performed in the Botanic Garden of the Southern Federal University (SFedU), Rostov-on-Don, Russia (Figure 1). The climate of the Rostov region is temperate continental, arid, average annual rainfall – 548 mm, and most of the precipitation falls in the frost-free period. The summer is hot, the average temperature of July month is + 22 ... + 23 ºC., maximum +40 ºC. Winter is moderately mild, the average air temperature in January is -5 ºC, the average absolute temperature minimum is -20 ...- 25 ºC, the absolute minimum is -32 ºC. The growing season lasts 216 days (from April 1 to November 4), the frost-free period is 258 days.

Figure 1. Research region

The objects of study were *Q. macrocarpa*, *Q. robur* and *Q. rubra*. The ecological and biological properties of these species under local culture conditions are given below (Kozlovsky et al., 2016).

Q. robur is a species of native flora. In the regional culture, it reaches a height of 26 m. It grows relatively fast. The plant is winter-hardy and drought-resistant, leaves can be strongly affected by insects and fungal diseases. It bears fruit abundantly and regularly. The duration of ontogeny is on average 90 years. *Q. robur* is widely used in regional culture.

Q. macrocarpa is a species of North American flora. In the Botanical Garden of Southern Federal University it reaches a height of 26 m. In terms of ecological and biological properties, it is not inferior to the species of the local flora, *Q. robur*, while it is resistant to diseases and pests. Fruiting occurs with a frequency of 3-4 years. The duration of ontogeny is on average 90 years. It is a promising species for the creation of protective forest belts, artificial forests, and landscaping of settlements.

Q. rubra is a species of North American flora. In the Botanical Garden it reaches a height of 15 m, growing slowly. This species is highly winter-hardy, but weakly drought-resistant – against the background of drought the growth processes are stopped, and the plant needs watering at the initial stages of ontogenesis. The tree is disease and pest resistant. It rarely bears fruit and grows poorly on the neutral and alkaline chernozems needing acidic soils. This species may often suffer from leaf chlorosis, especially during the drought period. The duration of ontogeny is about 60 years.

All the studied oak seedlings were grown under the same soil and solar illumination conditions and according to one agricultural technique at the introduction nursery of the Botanical Garden. Their landings were oriented from north to south. At the time of the experiment, all seedlings of *Q. macrocarpa*, *Q. robur*, *Q. rubra* were at the same stage of ontogeny (virginile stage).

For the experiment, five specimens of each species of oak were selected from the plantations. The crown section of each specimen was filmed 3 to 5 times.

Hyperspectral images were obtained using a Cubert UHD-185 video camera in accordance with Aasen et al. (2015), Bareth et al. (2015). The shooting was carried out from 12 to 14 hours in sunny and cloudless weather. For shooting, the most sunlit part of the crown of the plant was chosen. The camera was located on the southeast side of the object at 90 cm. The light reflected from leaves was recorded in the range of 450-950 nm. Each image was represented as a single black-and-white image, 1000 × 1000 pixels in size. All the studied 125 hyperspectral images, 50 × 50 pixels in size, had the square resolution up to 35 mm^2.

The experiment was repeated five times in 2021: Aug 22, Sept 05, Sept 13, Sept 20, and Sept 30.

60 to 100 spectral profiles were randomly selected from each hyperspectral image. The number of spectral profiles were from 1500 to 2500 spectral profiles per one variant of the experiment.

A Savitsky-Golay filter (length 12 nm) was used as a preprocessing step to reduce the measurement error and remove artifacts in the spectral data.

For each variant of the experiment, 80 VIs were calculated (Dmitriev et al., 2022a,b).

Sample sets of VIs values were analyzed using analysis of variance (ANOVA), principal component analysis (PCA), decision tree (DT), random forest (RF) methods. The data was processed in the environment for statistical calculations R (R Core Team) using the «hsdar» package (Lehnert et al., 2019).

Results and Discussion

ANOVA was used to determine the contribution of experimentally controlled factors («species», «sample», «snapshot») to the vegetation index (VI) value. The strength of the influence of factors (the ratio between deviation of the factor and the total deviation) of 80 VIs is shown in Figure 2. VI should be considered suitable for identification of oak species, if the value of the deviation of the factor «species» significantly exceeds the values of the deviation of «sample» and «snapshot», with a low value of the deviation of random factors (Table 1 and Supplementary Table 1). This means that the value of the index depends more on species characteristics than on other factors. It should be noted that the results of the analysis of variance vary depending on the timing of the survey. For all survey periods, effective VIs were Carter2, Carter3, Carter4, CI, CI2, CRI4, Datt, Datt2, GMI2, Maccioni, mSR2, MTCI, NDVI2, OSAVI2, PRI, REP_Li, SR1, SR2, SR6, Vogelmann, Vogelmann2, Vogelmann4. As a positive fact, it should be noted the low value of the deviation of the «snapshot» factor for most VIs, as far as this value includes the operation errors of the instrument and errors of the operator's work when selecting spectral profiles from the snapshot.

Table 1. Results of a three-way ANOVA analysis of the statistical complex «species-sample-snapshot» for the Maccioni value

ANOVA	Df	SumSq	MeanSq	F value	Pr(>F)
Species	2	51.044	25.522	12211.401	<2e-16*
Sample	12	10.397	0.866	414.539	<2e-16*
Snapshot	37	0.527	0.014	6.812	<2e-16*
Intragroupvariance	3875	8.099	0.002		

Note: * significancelevel< 0.001

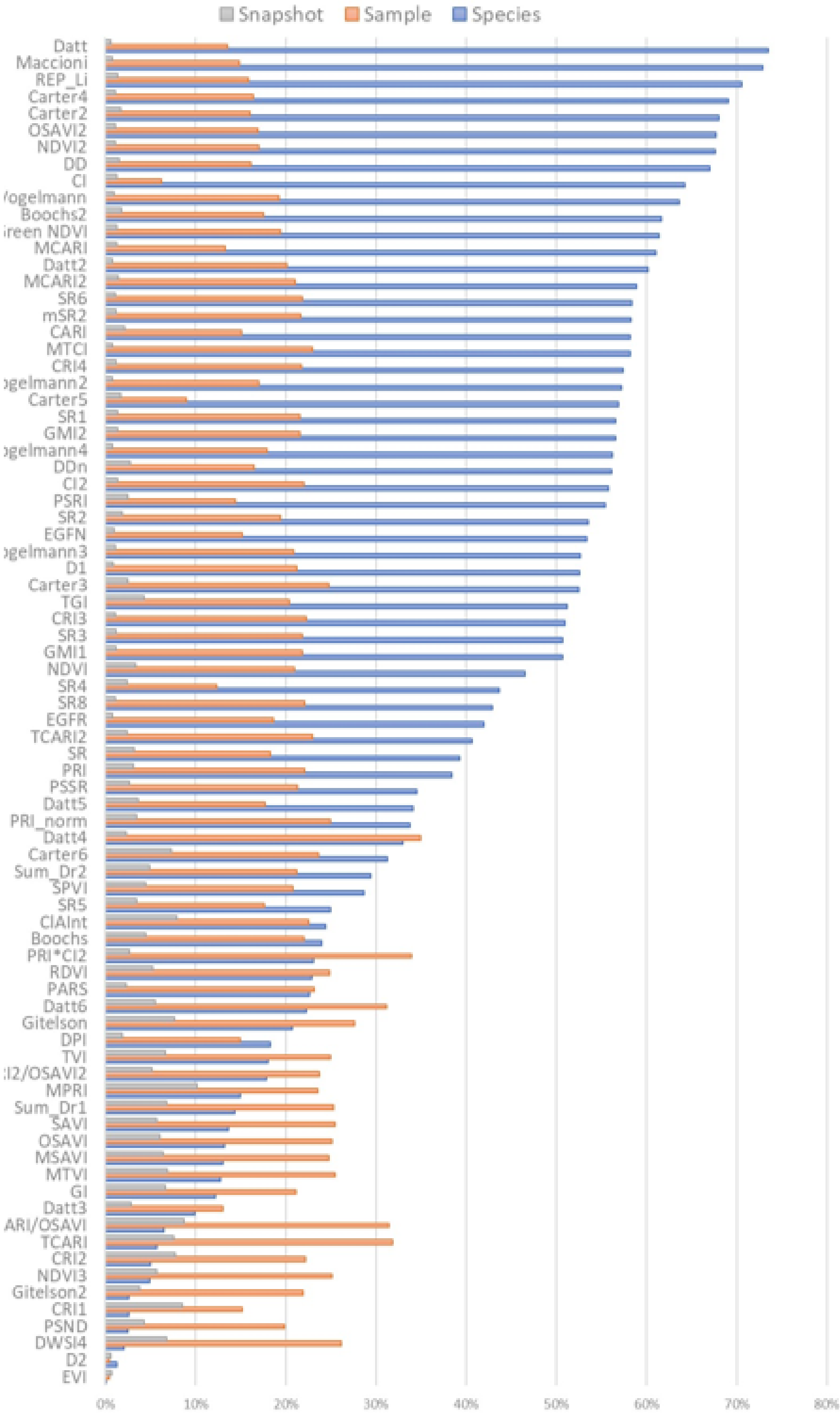

Figure 2. Strength of influence of the factors «species», «sample», «snapshot» on the VIs values of Acer species, Aug 22)

Thus, a set of VIs has been selected to be suitable for the identification of plant species in accordance with the aims of the present work.

An important criterion for the objectivity of the data obtained is the reproducibility of the results of their processing over a time scale. Figure 3 presents the results of data analysis carried out by the PCA method for the five studied time periods. Projections of the values of 80 VIs on the main components showed that the location of oak species coincides in all periods (in some cases, the images are inverted mirrorwise about the first or second component). Projection of *Q. rubra* data is the most isolated, may be explained by its ecological and biological features (Kozlovsky et al., 2016).

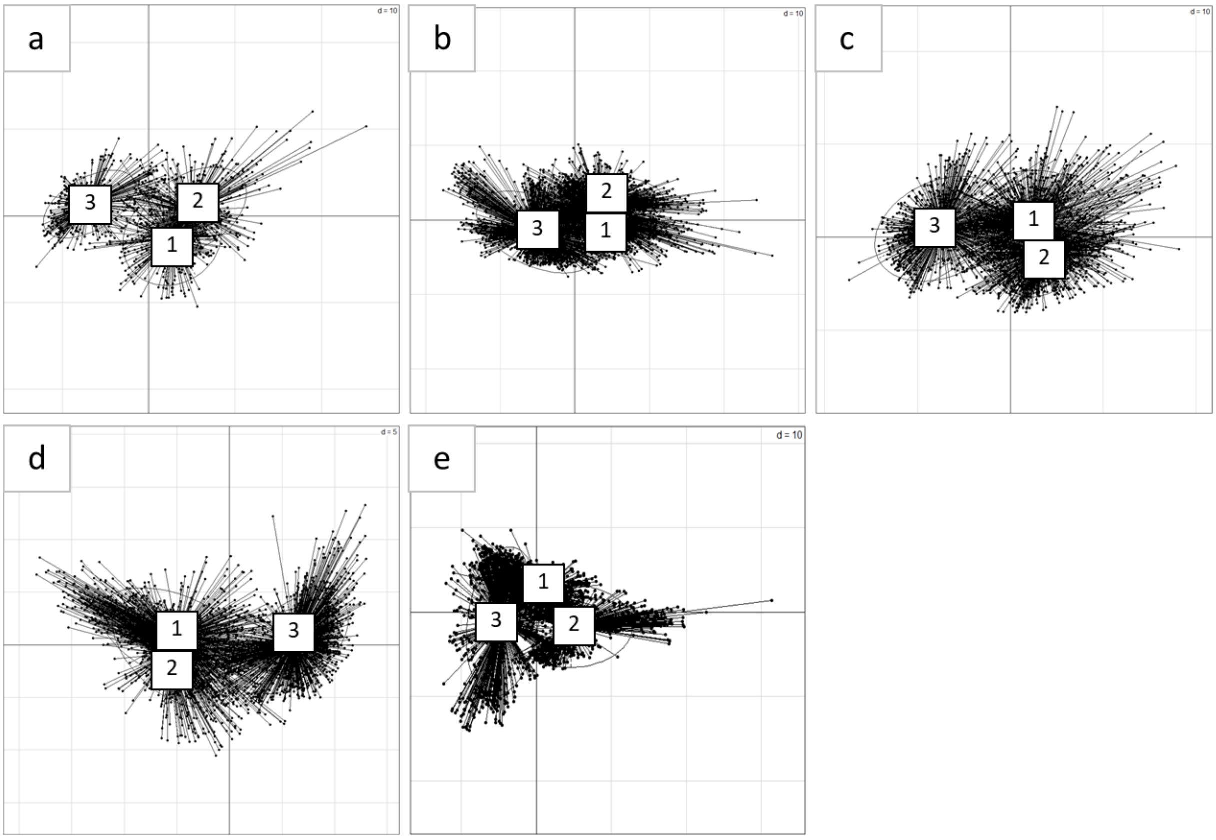

Figure 3. PCA of the 80 VIs values for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) at different survey times. Dates of the experiments: a – Aug 22, b – Sept 05, c – Sept 13, d – Sept 20, e – Sept 30

The proportion of dispersion of the first and second main components varies from 70.4 to 71.5%, the number of significant components (according to the Kaiser criterion) is from 6 to 7 (Table 2).

Factor loads (by analogy with the value of the correlation coefficient) can be considered very weak in the range from 0 to 0.3, weak – from 0.3 to 0.5, medium - from 0.5 to 0.7 and high – from 0.7 to 0.9. VIs Factor loads on the main component are very weak and do not exceed 0.150. They change little depending on the VIs (Aug 22 – Table 3, for other dates – Supplementary Table 2).

Due to the large number of the statisticaly significant components and low factor loads, the PCA results cannot be considered to be satisfactory for the experiment.This problem can be solved by reducing the number of VIs, and by selecting indices that have the largest dispersion by oak species.In order to avoid a subjective approach when choosing such VIs, the DT method was used (Figure 4-8).

The decision tree method divided samples of oak species by VI values in five levels. The division of oak samples into clades is not witout alternative. At the same time, most of the *Q. rubra* samples are grouped in one of the two clusters of the higher hierarchy, while *Q. macrocarpa* and *Q. robur* are grouped mainly in the alternative cluster. As a result, the DT method divided the oak samples at different survey times according to the following indices:

- Aug 22 – Boochs2, Carter5, CRI3, Datt, Datt5, DPI, MCARI2, MTVI, PRI, SR8, TGI;
- Sept 05 – Boochs2, CRI3, Datt4, Maccioni, MTCI, NDVI3, PSRI, RDVI, RDVI, REP_Li, SPVI, TCARI2;
- Sept 13 – Boochs2, CRI3, CRI4, Datt5, DD, DWSI4, Gitelson, MCARI, PRI;
- Sept 20 – Boochs, Carter3, D1, Datt, Datt3, Datt5, Gitelson2, MCARI2, Sum_Dr1, Vogelmann;
- Sept 30 – Boochs2, Carter6, Datt5, NDVI3, PRI_norm, SPVI, SR5, Sum_Dr1, TCARI2, Vogelmann2.

Table 2. Dispersion values calculated for the main components of the projection of 80 VIs for *Q. robur*, *Q. macrocarpa*, *Q. rubra*

Experimentdates	Aug 22			Sept 05			Sept 13			Sept 20			Sept 30		
Statistics	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion
Comp.1	6.595	0.544	0.544	6.704	0.562	0.562	6.503	0.529	0.529	6.954	0.605	0.605	5.482	0.376	0.376
Comp.2	3.571	0.160	0.704	3.501	0.153	0.715	3.835	0.184	0.713	3.302	0.136	0.741	4.466	0.249	0.625
Comp.3	3.083	0.119	0.823	2.895	0.105	0.820	3.392	0.144	0.856	2.886	0.104	0.845	2.972	0.110	0.736
Comp.4	1.650	0.034	0.857	2.166	0.059	0.879	1.549	0.030	0.886	1.672	0.035	0.880	2.400	0.072	0.808
Comp.5	1.444	0.026	0.883	1.381	0.024	0.902	1.229	0.019	0.905	1.339	0.022	0.902	2.053	0.053	0.860
Comp.6	1.256	0.020	0.903	1.110	0.015	0.918	1.080	0.015	0.920	1.176	0.017	0.920	1.515	0.029	0.889
Comp.7	1.058	0.014	0.917	1.000	0.012	0.930	1.000	0.013	0.932	1.000	0.013	0.932	1.049	0.014	0.903
Comp.8	0.999	0.012	0.929				0.920	0.011	0.943				1.011	0.013	0.916
Comp.9													1.000	0.012	0.928

Table 3. VI factor loads on significant components for *Q. robur*, *Q. macrocarpa*, *Q. rubra* (Aug 22)

Factors	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8
Boochs		0.239	0.133					0.209
Boochs2	0.101	0.189			0.1			
CARI	-0.131		0.112	0.152	-0.118			
Carter2	-0.146							
Carter3	-0.137				-0.183			
Carter4	-0.15							
Carter5		-0.101	0.21	0.106				-0.106
Carter6	-0.125	0.133			-0.174	-0.111		
CI	0.121			-0.163				0.194
CI2	0.148				-0.111			
ClAInt	-0.113	0.168		0.11	-0.118			
CRI1		-0.194	0.176					
CRI2		-0.206	0.105					0.181
CRI3	-0.144			-0.145				-0.112
CRI4	-0.147				0.115			
D1	0.116				-0.241		0.184	
D2						-0.102	0.168	-0.96
Datt	0.145					0.112		
Datt2	0.144				-0.147			
Datt3						-0.311	-0.609	-0.123
Datt4	0.106	-0.114	-0.16					
Datt5			-0.254	0.169	0.106	0.132		0.107
Datt6	0.115	-0.124			-0.188			0.175
DD	0.145							
DDn		-0.211						
DPI					0.265	-0.302	-0.302	-0.354
DWSI4			0.227	-0.382				
EGFN	0.127			0.17			-0.123	
EGFR	0.12			0.189			-0.147	
EVI							0.114	0.987
GI			0.255	-0.321	-0.112			
Gitelson	0.121	-0.136			-0.117			
Gitelson2		0.172				0.324		-0.557
GMI1	0.144			0.138				0.108

Table 3. Continue

Factors	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8
GMI2	0.148				-0.114			
Green NDVI	0.145					0.114		
Maccioni	0.148							
MCARI	-0.124		0.143	0.151	-0.112			
MCARI2	0.131	0.126						-0.147
MPRI		0.176				-0.152		
MSAVI	0.104		0.218					
mSR2	0.148				-0.103			
MTCI	0.145				-0.106			-0.101
MTVI		0.256		0.109	-0.12			
NDVI	0.137		0.117					
NDVI2	0.15							
NDVI3			-0.187	0.404				
OSAVI	0.105		0.219					
OSAVI2	0.15							
PARS	0.115		0.171	0.138				
PRI	0.116				0.201	-0.3	0.305	
PRI_norm	-0.117				-0.15	0.319	-0.316	
PRI*CI2	0.106					-0.393	0.307	0.135
PSRI	-0.128			0.203	-0.129			-0.113
PSSR	0.129		0.12					0.123
PSND		-0.101	0.237	0.185	-0.13			
RDVI		0.232	0.131	0.132				
REP_Li	0.142				0.147	0.103		
SAVI	0.105		0.22					
SPVI		0.248		0.141				
SR	0.138		0.109					
SR1	0.148				-0.114			
SR2	0.147				-0.119			
SR3	0.144			0.138				0.108
SR4		-0.1	0.247					
SR5			-0.277					-0.113
SR6	0.148				-0.113			
SR8	0.102		-0.2		0.112		0.106	
Sum_Dr1		0.255		0.139	-0.126			
Sum_Dr2		0.253						
TCARI		0.175	-0.134	-0.131	-0.171		-0.104	0.153
TCARI/OSAVI		0.161	-0.146	-0.121	-0.164			0.163
TCARI2		0.219		-0.107	0.237	0.126		
TCARI2/OSAVI2		0.187			0.118			0.187
TGI	-0.134				-0.215	-0.129		
TVI		0.257	0.103	0.102				
Vogelmann	0.145				-0.135			
Vogelmann2	-0.133				0.207			0.129
Vogelmann3	0.13					-0.149	-0.103	-0.156
Vogelmann4	-0.133				0.212			0.128

It should be noted that the VIs that are significant for clustering coincide at many times (for example, Boochs2, Datt5, CRI3) or are derived from the same index (for example, Carter3, Carter5, Carter6 or CRI3, CRI4, Vogelmann, Vogelmann2) or are close in the used spectral channels.

Visualization of the results of species differentiation using PCA according to the value of VIs selected using DT is shown in Figure 9. The dispersion values of the first two principal components in all survey periods are from 74 to 80% (Table 4). Factor loads of VI on the main components are on average doubled (in some cases they exceeded 0.4), but for most of the VI they remained low (Table 5).

In more detail, the separation of oak species by PCA can be demonstrated by their samples. Projection of VI values Boochs2, Carter5, CRI3, Datt, Datt5, DPI, MCARI2, MTVI, PRI, SR8, TGI by main components for samples of oak species on the first survey date is shown in Figure 10, for other dates in Supplementary Table 3.

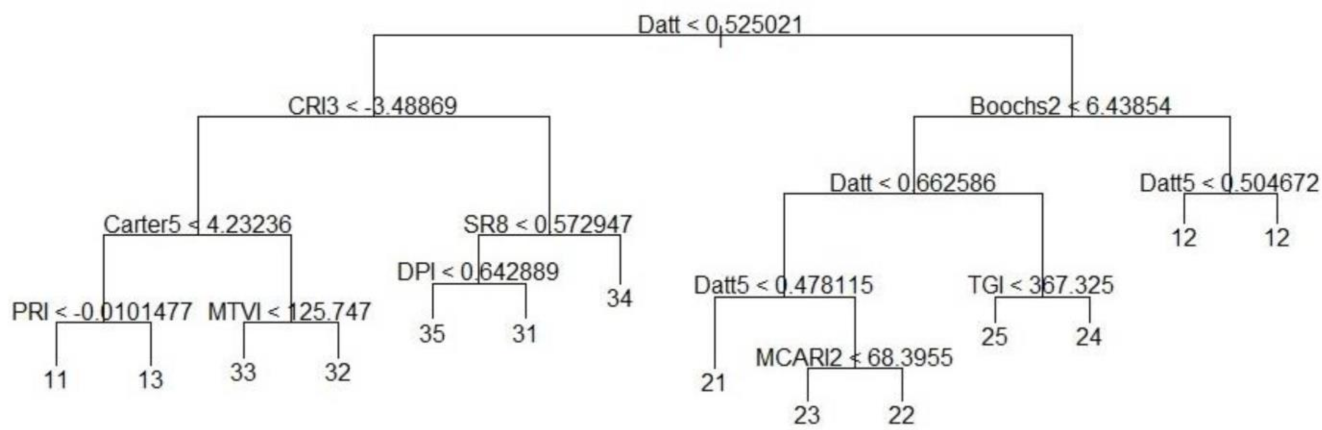

Figure 4. Decision tree of the 80 VIs values for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) (Aug 22). Numerical designation, bottom digits: the first digit indicates the species; the second is the sample of the species.

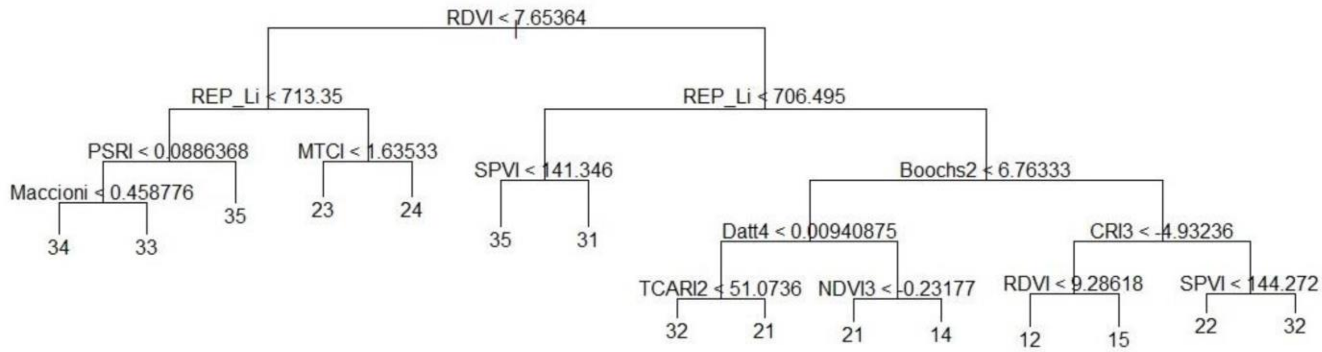

Figure 5. Decision tree of the 80 VIs values for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) (Sept 05). Numerical designation, bottom digits: the first digit indicates the species; the second is the sample of the species.

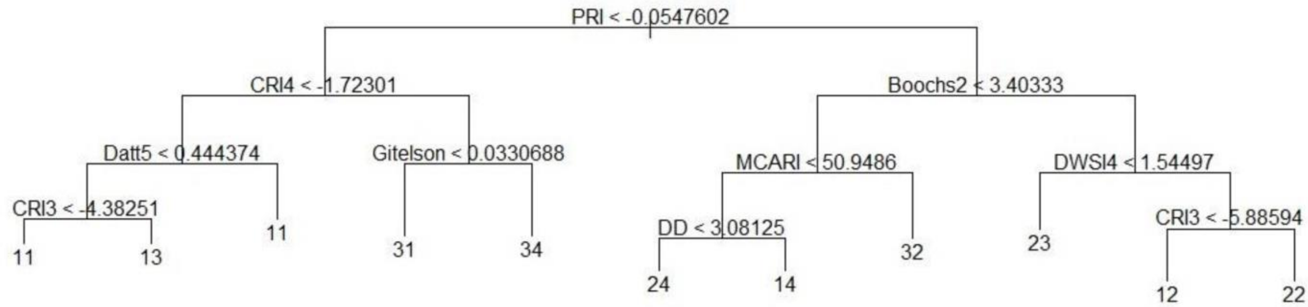

Figure 6. Decision tree of the 80 VIs values for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) (Sept 13). Numerical designation, bottom digits: the first digit indicates the species; the second is the sample of the species.

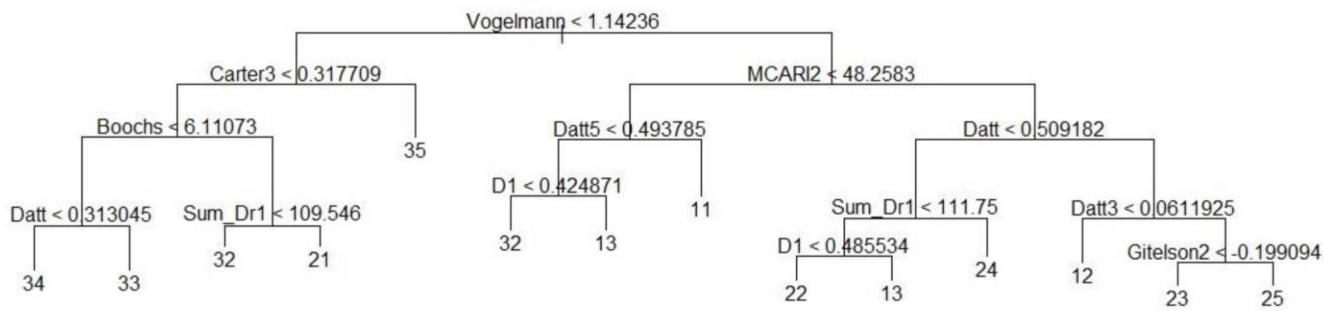

Figure 7. Decision tree of the 80 VIs values for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) (Sept 20). Numerical designation, bottom digits: the first digit indicates the species; the second is the sample of the species.

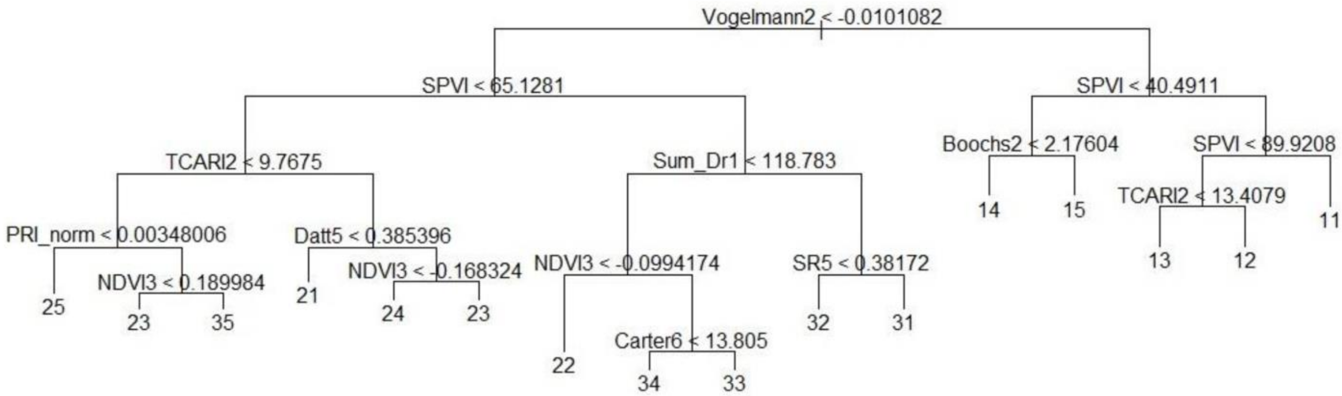

Figure 8. Decision tree of the 80 VIs values for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) (Sept 30). Numerical designation, bottom digits: the first digit indicates the species; the second is the sample of the species.

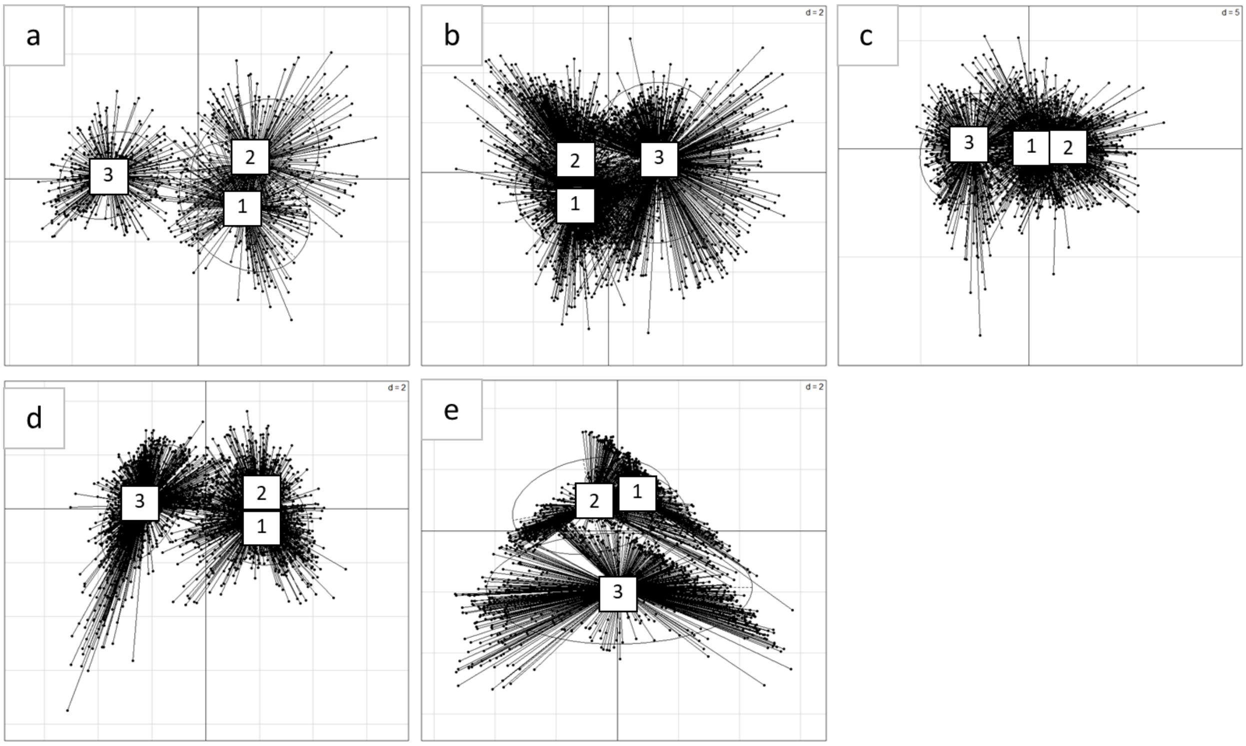

Figure 9. PCA of the VIs values selected by the DT method, Q. macrocarpa (1), Q. robur (2), Q. rubra (3) VIs at different survey times. Experiment dates: a – Aug 22, b – Sept 05, c – Sept 13, d – Sept 20, e – Sept 30.

Table 4. Dispersions of the principal components of the projection of the values selected by the DT method, VI for *Q. robur*, *Q. macrocarpa*, *Q. rubra*

Experimentdates	Aug 22			Sept 05			Sept 13			Sept 20			Sept 30		
Statistics	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion	Standard deviation	ProportionofVariance	CumulativeProportion
Comp.1	2.510	0.573	0.573	2.283	0.434	0.434	2.247	0.561	0.561	2.365	0.559	0.559	2.130	0.454	0.454
Comp.2	1.345	0.165	0.738	2.071	0.357	0.792	1.484	0.245	0.806	1.342	0.180	0.740	1.696	0.288	0.742
Comp.3	1.087	0.108	0.845	1.221	0.124	0.916	1.005	0.112	0.918	1.118	0.125	0.865	1.069	0.114	0.856
Comp.4	0.872	0.069	0.914	0.775	0.050	0.966	0.571	0.036	0.955	0.766	0.059	0.923	0.893	0.080	0.936

Table 5. Factor loads selected by the DT method, VI for significant components for *Q. robur*, *Q. macrocarpa*, *Q. rubra*

Factors	Comp.1	Comp.2	Comp.3	Comp.4
		Aug 22		
Boochs2	0.296	0.465		
Carter5	-0.318		-0.472	
CRI3	-0.343		0.280	-0.251
Datt	0.372			0.253
Datt5	0.269	-0.276	0.489	-0.213
DPI	0.188		-0.401	-0.855
MCARI2	0.351	0.293		0.146
MTVI		0.687	0.303	
PRI	0.312	0.140	-0.293	
SR8	0.335	-0.214	0.243	-0.188
TGI	-0.339	0.256	0.241	-0.170
		Sept 05		
RDVI		0.467	0.141	0.211
Boochs2	-0.267	0.363		-0.170
CRI3	0.357		-0.340	-0.403
Datt4	-0.304	-0.275	0.275	-0.151
Maccioni	-0.430			
MTCI	-0.416		0.187	
NDVI3	0.176		0.635	-0.557
PSRI	0.358		0.406	
RDVI.1		0.467	0.141	0.211
REP_Li	-0.423			-0.200
SPVI		0.440	0.264	
TCARI2		0.390	-0.277	-0.573
		Sept 13		
Boochs2	0.319	0.178	0.616	0.173
CRI3	-0.394		0.223	-0.665
CRI4	-0.430			-0.238
Datt5		-0.641	0.235	
DD	0.430			-0.180
DWSI4	0.154	0.600		-0.306
Gitelson	0.313	-0.104	-0.673	
MCARI	-0.313	0.420		0.474
PRI	0.391		0.215	-0.329
		Sept 20		
Boochs	0.352	0.313	0.177	0.153
Carter3	-0.394		0.149	-0.219
D1	0.325	-0.345	-0.200	-0.285
Datt	0.347	-0.406		
Datt3	-0.178	-0.431	0.294	0.786
Datt5	-0.272	-0.413	0.125	-0.369
Gitelson2	0.103	-0.210	0.754	-0.292
MCARI2	0.405	-0.117		
Sum_Dr1	0.238	0.400	0.463	
Vogelmann	0.396	-0.207	-0.137	
		Sept 30		
Boochs2	0.288		0.548	0.537
Carter6	0.303	-0.414		-0.198
Datt5	-0.360	-0.325	0.175	
NDVI3	-0.337	-0.307	0.290	-0.197
PRI_norm	-0.306	-0.366		0.246
SPVI	0.328	-0.399		-0.219
SR5	-0.297	-0.351		0.398
Sum_Dr1	0.325	-0.390	0.130	-0.266
TCARI2	0.406	-0.107		0.447
Vogelmann2	-0.146	0.208	0.741	-0.296

It can be seen on the projection (Figure 10), as well as in Figure.3 and 9, Q. *rubra* is well separated from *Q. robur* and *Q. macrocarpa*. At the same time, *Q. robur* and *Q. macrocarpa* are poorly separated by PCA. The good differentiation of *Q. rubra* is associated with its physiological state – soil pH stress, enhanced by drought, that is manifested by leaf chlorosis (Figure 11) (Dmitriev et al., 2022a). Stress may be detected by the configuration of the spectral profiles of oak crowns, which are built using the average values of the reflection coefficient (Figure 12).

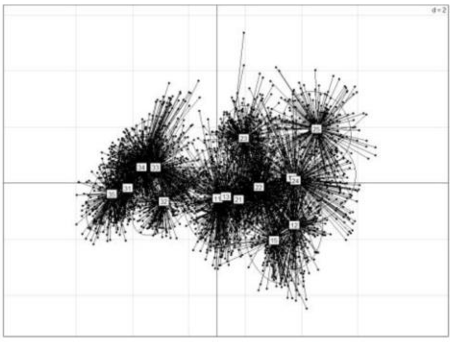

Figure 10. PCA of the values for Boochs2, Carter5, CRI3, Datt, Datt5, DPI, MCARI2, MTVI, PRI, SR8, TGI for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) samples in first shooting time (Aug 22). Numerical designation, bottom digits: the first digit indicates the species; the second is the sample of the species.

Figure 11. Fragments of crowns Q. macrocarpa (1), Q. robur (2), Q. rubra (3). Sept 13

This configuration of the arrangement of objects on the projections persists throughout the period studied (in some cases, the images are inverted mirrorwise about the first or second component).

RF is the next method used to separate species. In total, 500 trees have been analysed. (Figure 13). The number of variables tried at each separation was – 8.

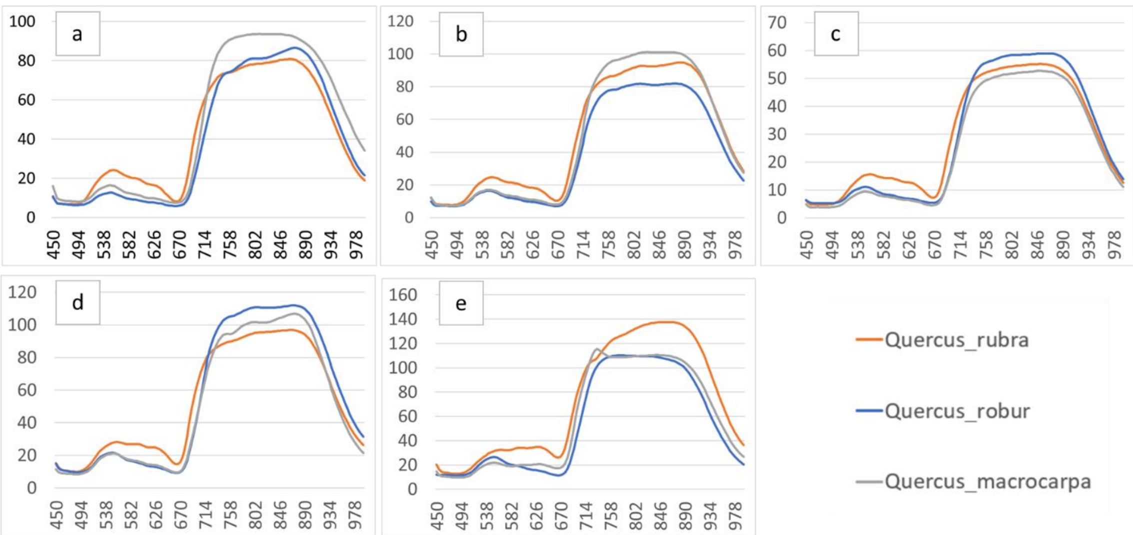

Figure 12. Spectral profiles of crowns of Q. macrocarpa, Q. robur and Q. rubra plants. Dates of the experiments: a – Aug 22, b – Sept 05, c – Sept 13, d – Sept 20, e – Sept 30. Y-scales – reflectance, percent; X-scales – wavelength, nm.

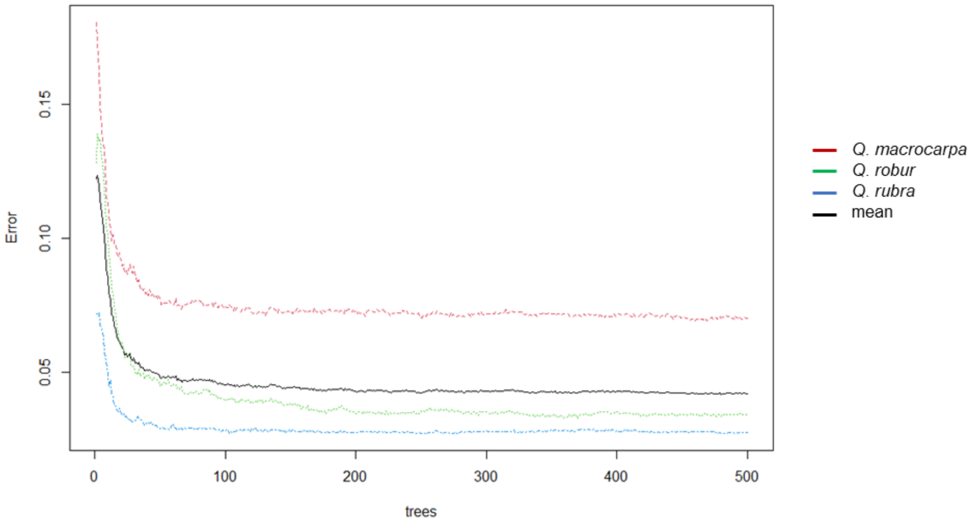

Figure 13. Random forest matrix error depending on the number of trees

OOB estimate of the matrix values error calculated for the 80 VIs of three oak species is low – 4.19%. This indicates a good differentiation of all three oak species by the RF method (Table 6).

The RF method also makes it possible to determine what VIs are the most suitable for species identification. In Figure 14, VIs are arranged depending on their influence on the error value (Mean Decrease Accuracy) and the Gini criterion.

As a result of the RF analysis, it was found that out of 80 VIs, the following VIs have the greatest influence on the accuracy of identification of *Quercus* species and the Gini index:

- D1 D_{730} / D_{706} (Zarco-Tejada et al., 2003)
- Datt3 D_{754} / D_{704} (Datt, 1999)
- DPI $D_{688} \times D_{710} / D^2_{697}$ (Zarco-Tejada et al., 2003)
- Vogelmann R_{740} / R_{720} (Vogelmann et al., 1993),

where Rxxx: Reflectance at the wavelength “xxx”, Dxxx: First derivation of reflectance values at the wavelength “xxx”.

Table 6. Error rates of the matrix of RF values of 80 VIs for *Q. robur*, *Q. macrocarpa*, *Q. rubra*

Species	*Quercusmacrocarpa*	*Quercusrobur*	*Quercusrubra*	class.error
Quercusmacrocarpa	3857	230	61	0.070154
Quercusrobur	110	4610	51	0.033746
Quercusrubra	41	107	5269	0.027321

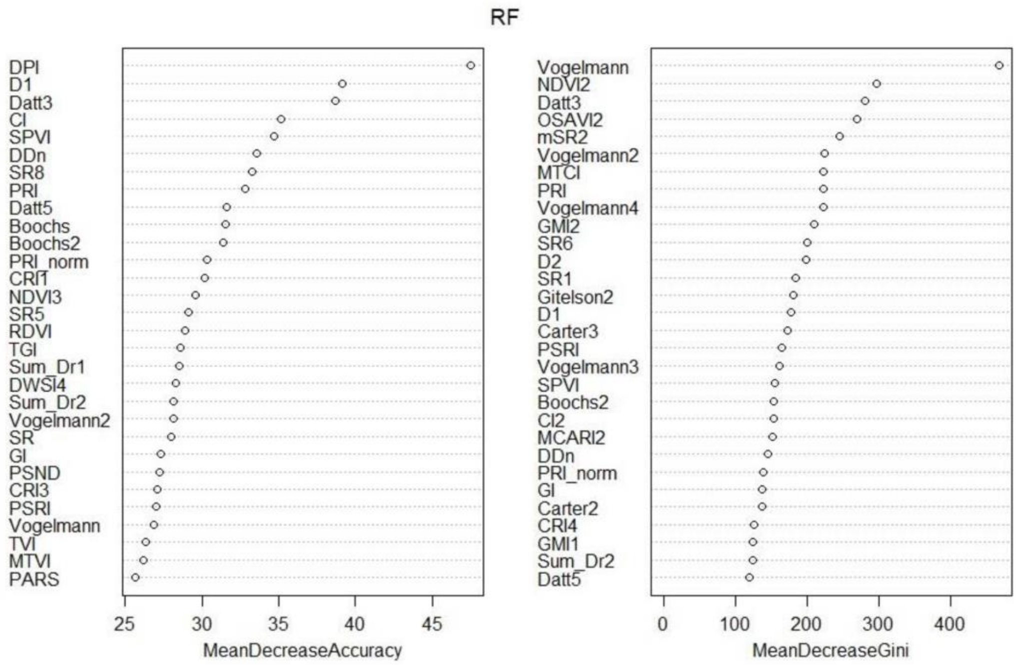

Figure 14. RF: Mean Decrease Accuracy and Mean Decrease Gini calculated for the 80 VIs of Acer species.

These VIs make it possible to separate quite well the stressed *Q. rubra* from *Q. robur* and *Q. macrocarpa*, which are found to be in our region under optimal conditions. At the same time, *Q. robur* and *Q. macrocarpa* are poorly separated. The following wavelengths are used in calculating these VIs: 698 nm,704 nm, 706 nm, 710 nm, 720 nm, 730 nm, 740 nm, 754 nm.

In order to find out how repeatable the result is at different shooting times, the scheme for forming the training and testing samples was as follows:

1. The training sample is the data of 2 (Sept 05), 3 (Sept 13), 4 (Sept 20) and 5 (Sept 30) survey dates. The tested sample – data of the 1st (Aug 22) survey period;
2. The training sample is the data of the 1st, 3rd, 4th, and 5th survey dates. The test sample – data from the 2nd survey period;
3. The training sample is the data of the 1st, 2nd, 4th, and 5th survey dates. The test sample – data from the 3rd survey period;
4. The training sample is the data of the 1st, 2nd, 3rd, and 5th survey dates. The test sample – data of the 4th survey period;
5. The training sample is the data of the 1st, 2nd, 3rd and 4th survey dates. The test sample – data of the 5th survey period.

According to the presented scheme the training sample matrices have a low OOB estimate of error rate (Table 7). Despite the fact that it is not possible to simultaneously identify all three species by VIs values (Table 8), the result obtained should be considered good for field surveys with a hyperspectral camera of tree crowns. *Q. rubra* was well identified in all five terms. *Q. robur* was well identified in the second and third terms of survey, satisfactorily – in the first and fifth and was not identified in the 4th survey. *Q. macrocarpa* was satisfactorily identified only in the second survey period.Good reproducibility of the results (both positive and negative) in terms of timing was obtained, that can be seen from the values of the classification errors of the trained matrices (Table 7) and from the test results (Table 8).The results obtained with the RF method and the PCA method are similar.

Table 7. Error rates of RF matrix of 80 VI values for *Q. robur*, *Q. macrocarpa*, *Q. rubra*, training samples. Number of trees: 500; Number. of variables tried at each split: 8

		Training set 1		
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*	class.error
Q. macrocarpa	3672	157	41	0.051163
Q. robur	84	4256	50	0.030524
Q. rubra	48	98	4884	0.029026
	OOB estimate of error rate			3.60%
		Training set 2		
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*	class.error
Q. macrocarpa	2832	209	35	0.079324
Q. robur	79	3477	24	0.028771
Q. rubra	17	62	3857	0.020071
	OOB estimate of error rate			4.02%
		Training set 3		
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*	class.error
Q. macrocarpa	3096	130	35	0.050598
Q. robur	75	3372	37	0.032147
Q. rubra	23	59	4490	0.017935
	OOB estimate of error rate			3.17%
		Training set 4		
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*	class.error
Q. macrocarpa	3003	194	63	0.078834
Q. robur	66	3562	47	0.030748
Q. rubra	36	94	3544	0.035384
	OOB estimate of error rate			4.71%
		Training set 5		
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*	class.error
Q. macrocarpa	2847	212	66	0.08896
Q. robur	107	3806	42	0.037674
Q. rubra	39	80	4337	0.026706
	OOB estimate of error rate			4.73%

Table 8. Error rates of the matrix of RF values of 80 VIs for *Q. robur*, *Q. macrocarpa*, *Q. rubra*, tested samples

Test sample 1			
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*
Q. macrocarpa	112	156	10
Q. robur	143	219	10
Q. rubra	23	6	367
Test sample 2			
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*
Q. macrocarpa	632	225	133
Q. robur	382	963	405
Q. rubra	58	3	943
Test sample 3			
	Q. macrocarpa	*Q. robur*	*Q. rubra*
Q. macrocarpa	32	1	0
Q. robur	658	1214	184
Q. rubra	197	72	661
Test sample 4			
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*
Q. macrocarpa	422	611	57
Q. robur	122	167	4
Q. rubra	344	318	1682
Test sample 5			
Species	*Q. macrocarpa*	*Q. robur*	*Q. rubra*
Q. macrocarpa	395	146	124
Q. robur	0	464	60
Q. rubra	628	206	777

All methods of the data analysis used in the experiment clearly separate *Q. rubra* from *Q. robur* and *Q. macrocarpa*. This can be associated with a significant difference between the ecological and biological properties of *Q. rubra* and *Q. robur*, *Q. macrocarpa*.When using VI, it is not possible to reliably separate *Q. robur* and *Q. macrocarpa*.These species differ significantly in morphology, but are similar in ecological and biological properties. Most VIs have been developed to quantify the state (primarily the physiological state associated with photosynthetic pigments) of plants (Tucker, 1979; Blackburn 1998; Datt 1999; leMaireetal 2004; Zarco-Tejada et al. 2003; Bolca et al., 2012). Therefore, in a specific period, species that differ significantly in physiology can be successfully separated using VIs. For woody plants that differ in phenology, it is possible to propose a search for VIs with unique seasonal dynamics, by analogy with the NDVI signature.

Conclusion

The ANOVA method applied to the hyperspectral data allows to reveal VI, whose variation significantly depends on the species belonging to the sample.This also confirms the possibility of identifying oak species using VI.PCA and RF methods reliably differentiating *Q. rubra* from *Q. robur* and *Q. macrocarpa*.

The results obtained suggest the possibility that droubt and impact of soil pH, being a factor of environmental stress, may influence the realibility of such an identification. It may be a consequence of a droubt-induced and pH-induced chlorosis that evidently influence leaf pigment composition and, therefore, VIs. It means that changes in the hyperspectral data caused by stress should be considered as a reflectance spectral "signature of stress" and should be an object of attention in the future researches.

Acknowledgements

The project was supported by the Russian Science Foundation under grant No. 22-14-00338 and performed in Southern Federal University (Rostov-on-Don, Russian Federation).

References

Aasen, H., Burkart, A., Bolten, A., Bareth, G., 2015. Generating 3D hyperspectral information with lightweight UAV snapshot cameras for vegetation monitoring: From camera calibration to quality assurance. *ISPRS Journal of Photogrammetry and Remote Sensing* 108: 245–259.

Bareth, G., Aasen, H., Bendig, J., Gnyp, M.L., Bolten, A., Jung, A., Michels, R., Soukkamäki, J., 2015. Low-weight and UAV-based hyperspectral full-frame cameras for monitoring crops: Spectral comparison with portable spectroradiometer measurements. *Photogrammetrie - Fernerkundung - Geoinformation* 1: 69–79.

Blackburn, G.A., 1998. Quantifying Chlorophylls and Caroteniods at Leaf and Canopy Scales: An Evaluation of Some Hyperspectral Approaches. *Remote Sensing of Environment* 66: 273–285.

Bolca, M., Kurucu, Y., Altınbaş, Ü., Esetlili, M.T., Özen, F., 2012. A study on the determination of electromagnetic reflection values of agricultural crop pattern to improve accuracy of land use map by remote sensing technique. *Eurasian Journal of Soil Science* 1(2): 116 - 126.

Cao, J., Leng, W., Liu, K., Liu, L., He, Z., Zhu, Y., 2018. Object-Based mangrove species classification using unmanned aerial vehicle hyperspectral images and digital surface models. *Remote Sensing* 10(1): 89.

Dainelli, R., Toscano, P., Di Gennaro, S.F., Matese, A., 2021. Recent advances in unmanned aerial vehicles forest remote sensing - A systematic review. Part II: Research applications. *Forests* 12(4): 397.

Datt, B., 1999. Visible/near infrared reflectance and chlorophyll content in eucalyptus leaves. *Remote Sensing*. 20: 2741–2759.

Dmitriev, P., Kozlovsky, B., Minkina, T., Rajput, V.D., Dudnikova, T., Barbashev, A., Ignatova, M.A., Kapralova, O.A., Varduni, T.V., Tokhtar, V.K., Tarik, E.P., Akça, İ., Sushkova, S., 2022a. Hyperspectral imaging for small-scale analysis of Hordeum vulgare L. leaves under the benzo[a]pyrene effect. *Environmental Science and Pollution Research*

Dmitriev, P.A., Kozlovsky, B.L., Kupriushkin, D.P., Lysenko, V.S., Rajput, V.D., Ignatova, M.A., Tarik, E.P., Kapralova, O.A., Tokhtar, V.K., Singh, A.K., Minkina, T.M., Varduni, T.V., Sharma, M., Taloor, A.K., Thapliyal, A., 2022b. Identification of species of the genus Acer L. using vegetation indices calculated from the hyperspectral images of leaves. *Remote Sensing Applications: Society and Environment* 25, 100679.

Fassnacht, F.E., Latifi, H., Stereńczak, K., Modzelewska, A., Lefsky, M., Waser, L.T., Straub, C., Ghosh, A., 2016. Review of studies on tree species classification from remotely sensed data. *Remote Sensing of Environment* 186: 64–87.

Kozlovskiy, B.L., Kuropyatnikov, M.V., Fedorinova, O.I., 2016. Results of introduction testing of species of the genus Quercus L. In the botanical garden of the Southern Federal. *Bulletin of the Udmurt University. Series Biology. Earth Sciences* 26(2):53–58.

Kozlovsky, B.L., Ogorodnikova, T.K., Kuropyatnikov, M.V., Fedorinova, O.I., 2009. An assortment of woody plants for green building in the Rostov region. Rostov-on-D.: Publishing House of Southern Federal University. 416p.

Lehnert, L.W., Meyer, H., Obermeier, W.A., Silva, B., Regeling, B., Thies, B., Bendix, J., 2019. Hyperspectral Data Analysis in R: The hsdar Package. *Journal of Statistical Software* 89 (12): 1–23.

Lemaire, C., Kohn, S.C., Brooker, R.A., 2004. The effect of silica activity on the incorporation mechanisms of water in synthetic forsterite: a polarised infrared spectroscopic study. *Contributions to Mineralogy and Petrology* 147: 48–57.

Miyoshi, G.T., Arruda, Md.S., Osco, L.P., Junior, J.M., Gonçalves, D.N., Imai, N.N., Tommaselli, A.M.G., Honkavaara, E., Gonçalves, W.N., 2020b. A novel deep learning method to identify single tree species in UAV-based hyperspectral images. *Remote Sensing* 12(8): 1294.

Miyoshi, G.T., Imai, N.N., Tommaselli, A.M.G., Honkavaara, E., 2020a. Spectral differences of tree species belonging to atlantic forest obtained from UAV hyperspectral images. 2020 IEEE Latin American GRSS & ISPRS Remote Sensing Conference (LAGIRS) pp. 60-65.

Nezami, S., Khoramshahi, E., Nevalainen, O., Pölönen, I., Honkavaara, E., 2020. Tree species classification of drone hyperspectral and RGB imagery with deep learning convolutional neural networks. *Remote Sensing* 12(7): 1070.

Oppelt, N., Mauser, W., 2004. Hyperspectral monitoring of physiological parameters of wheat during a vegetation period using AVIS data. *International Journal of Remote Sensing* 25(1): 145–159.

Ronay, I., Ephrath, J.E., Eizenberg, H., Blumberg, D.G., Maman, S., 2021. Hyperspectral reflectance and indices for characterizing the dynamics of crop–weed competition for water. *Remote Sensing* 13(3): 513.

Saarinen, J., Rogerson, C.M., Hall, C.M., 2017. Geographies of tourism development and planning. *Tourism Geographies* 19(3): 307–3017.

Sothe, C., Dalponte, M., Almeida, C.M., Schimalski, M.B., Lima, C.L., Liesenberg, V., Miyoshi, G.T., Tommaselli, A.M.G., 2019. Tree species classification in a highly diverse subtropical forest integrating UAV-based photogrammetric point cloud and hyperspectral data. *Remote Sensing* 11(11): 1338.

Tucker, C.J., 1979. Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment* 8: 127–150.

Tuominen, S., Balazs, A., Honkavaara, E., Pölönen, I., Saari, H., Hakala, T., Viljanen, N., 2017. Hyperspectral UAV-imagery and photogrammetric canopy height model in estimating forest stand variables. *Silva Fennica* 51(5): 7721.

Vogelmann, J.E., Rock, B.N., Moss, D.M., 1993. Red edge spectral measurements from sugar maple leaves. *International Journal of Remote Sensing* 14: 1563–1575.

Zarco-Tejada, P.J., Pushnik, J.C., Dobrowski, S., Ustin, S.L., 2003. Steady-state chlorophyll a fluorescence detection from canopy derivative reflectance and double-peak red-edge effects. *Remote Sensing of Environment* 84: 283–294.

Zozulin, G.M., 1992. Forests of the Lower Don. Rostov-on-Don: Publishing of Rostov University. 200p.

Supplementary Tables

Supplementary Table 1. Results of a three-way ANOVA of the statistical complex «species-sample-snapshot»

ANOVA	date	Df				Sum Sq				Mean Sq				F value			Pr(>F)		
		Species	Sample	Snapshot	Residuals	Species	Sample	Snapshot	Residuals	Species	Sample	Snapshot	Residuals	Species	Sample	Snapshot	Species	Sample	Snapshot
Boochs	Aug 22	2	12	37	3875	2193.00	2014.26	406.36	4524.16	1096.50	167.85	10.98	1.17	939.17	143.77	9.41	0.00	0.00	0.00
Boochs2	Aug 22	2	12	37	3875	9790.69	2787.88	279.72	3021.54	4895.35	232.32	7.56	0.78	6278.07	297.95	9.70	0.00	0.00	0.00
CARI	Aug 22	2	12	37	3875	16285038.71	4233062.50	609240.12	6844569.28	8142519.35	352755.21	16465.95	1766.34	4609.82	199.71	9.32	0.00	0.00	0.00
Carter2	Aug 22	2	12	37	3875	48.24	11.38	1.21	10.10	24.12	0.95	0.03	0.00	9250.81	363.71	12.55	0.00	0.00	0.00
Carter3	Aug 22	2	12	37	3875	11.14	5.25	0.52	4.31	5.57	0.44	0.01	0.00	5004.38	393.01	12.74	0.00	0.00	0.00
Carter4	Aug 22	2	12	37	3875	51.64	12.24	0.82	10.06	25.82	1.02	0.02	0.00	9950.55	393.04	8.53	0.00	0.00	0.00
Carter5	Aug 22	2	12	37	3875	2944.09	462.64	89.75	1681.34	1472.05	38.55	2.43	0.43	3392.63	88.85	5.59	0.00	0.00	0.00
Carter6	Aug 22	2	12	37	3875	57927.56	43888.64	13528.71	69993.91	28963.78	3657.39	365.64	18.06	1603.49	202.48	20.24	0.00	0.00	0.00
CI	Aug 22	2	12	37	3875	38.19	3.67	0.77	16.84	19.10	0.31	0.02	0.00	4395.05	70.48	4.77	0.00	0.00	0.00
CI2	Aug 22	2	12	37	3875	2093.44	827.14	51.91	780.45	1046.72	68.93	1.40	0.20	5197.07	342.24	6.97	0.00	0.00	0.00
ClAInt	Aug 22	2	12	37	3875	55760841.02	51330191.70	18017116.95	103144026.53	27880420.51	4277515.97	486949.11	26617.81	1047.43	160.70	18.29	0.00	0.00	0.00
CRI1	Aug 22	2	12	37	3875	0.05	0.32	0.18	1.58	0.03	0.03	0.00	0.00	67.16	66.29	12.10	0.00	0.00	0.00
CRI2	Aug 22	2	12	37	3875	0.31	1.36	0.48	4.01	0.15	0.11	0.01	0.00	148.61	109.94	12.52	0.00	0.00	0.00
CRI3	Aug 22	2	12	37	3875	6293.42	2744.00	133.20	3175.41	3146.71	228.67	3.60	0.82	3839.97	279.05	4.39	0.00	0.00	0.00
CRI4	Aug 22	2	12	37	3875	2158.92	817.37	44.37	739.89	1079.46	68.11	1.20	0.19	5653.41	356.73	6.28	0.00	0.00	0.00
D1	Aug 22	2	12	37	3875	125.40	50.54	2.08	60.37	62.70	4.21	0.06	0.02	4024.81	270.33	3.61	0.00	0.00	0.00
D2	Aug 22	2	12	37	3875	715.03	235.15	348.60	55820.56	357.51	19.60	9.42	14.41	24.82	1.36	0.65	0.00	0.18	0.95
Datt	Aug 22	2	12	37	3875	48.67	9.00	0.40	8.21	24.33	0.75	0.01	0.00	11490.34	354.21	5.11	0.00	0.00	0.00
Datt2	Aug 22	2	12	37	3875	699.46	233.92	9.31	219.15	349.73	19.49	0.25	0.06	6183.95	344.68	4.45	0.00	0.00	0.00
Datt3	Aug 22	2	12	37	3875	5.07	6.68	1.47	38.09	2.53	0.56	0.04	0.01	257.82	56.60	4.04	0.00	0.00	0.00
Datt4	Aug 22	2	12	37	3875	0.07	0.07	0.00	0.06	0.03	0.01	0.00	0.00	2154.09	380.72	8.23	0.00	0.00	0.00
Datt5	Aug 22	2	12	37	3875	13.89	7.22	1.46	18.14	6.95	0.60	0.04	0.00	1483.64	128.42	8.42	0.00	0.00	0.00
Datt6	Aug 22	2	12	37	3875	26.14	36.48	6.46	48.15	13.07	3.04	0.17	0.01	1051.62	244.63	14.05	0.00	0.00	0.00
DD	Aug 22	2	12	37	3875	673467.61	162326.10	15672.72	153366.25	336733.80	13527.17	423.59	39.58	8508.02	341.78	10.70	0.00	0.00	0.00
DDn	Aug 22	2	12	37	3875	1682277.16	493490.66	82878.48	737351.69	841138.58	41124.22	2239.96	190.28	4420.43	216.12	11.77	0.00	0.00	0.00
DPI	Aug 22	2	12	37	3875	15.69	12.84	1.61	55.71	7.85	1.07	0.04	0.01	545.83	74.42	3.02	0.00	0.00	0.00
DWSI4	Aug 22	2	12	37	3875	7.23	89.98	23.52	223.63	3.62	7.50	0.64	0.06	62.68	129.93	11.01	0.00	0.00	0.00
EGFN	Aug 22	2	12	37	3875	22.43	6.37	0.39	12.83	11.22	0.53	0.01	0.00	3386.58	160.39	3.17	0.00	0.00	0.00
EGFR	Aug 22	2	12	37	3875	4666.65	2072.45	86.27	4298.31	2333.33	172.70	2.33	1.11	2103.53	155.70	2.10	0.00	0.00	0.00
EVI	Aug 22	2	12	37	3875	3301959.86	76119639.64	132664613.35	18873071318.70	1650979.93	6343303.30	3585530.09	4870470.02	0.34	1.30	0.74	0.71	0.21	0.88
GI	Aug 22	2	12	37	3875	69.03	120.46	37.98	341.27	34.51	10.04	1.03	0.09	391.89	113.98	11.66	0.00	0.00	0.00
Gitelson	Aug 22	2	12	37	3875	0.37	0.50	0.14	0.79	0.19	0.04	0.00	0.00	910.58	202.58	18.36	0.00	0.00	0.00
Gitelson2	Aug 22	2	12	37	3875	138.25	1162.95	201.29	3807.58	69.13	96.91	5.44	0.98	70.35	98.63	5.54	0.00	0.00	0.00
GMI1	Aug 22	2	12	37	3875	5570.06	2400.85	128.87	2901.56	2785.03	200.07	3.48	0.75	3719.37	267.19	4.65	0.00	0.00	0.00
GMI2	Aug 22	2	12	37	3875	1953.98	744.20	47.90	709.67	976.99	62.02	1.29	0.18	5334.61	338.63	7.07	0.00	0.00	0.00
Green NDVI	Aug 22	2	12	37	3875	24.49	7.76	0.51	7.11	12.25	0.65	0.01	0.00	6670.78	352.21	7.55	0.00	0.00	0.00
Maccioni	Aug 22	2	12	37	3875	51.04	10.40	0.53	8.10	25.52	0.87	0.01	0.00	12211.40	414.54	6.81	0.00	0.00	0.00
MCARI	Aug 22	2	12	37	3875	9173726.93	1998338.78	196442.24	3667841.75	4586863.47	166528.23	5309.25	946.54	4845.93	175.93	5.61	0.00	0.00	0.00
MCARI2	Aug 22	2	12	37	3875	3691166.89	1319532.30	91721.79	1166900.04	1845583.44	109961.02	2478.97	301.14	6128.75	365.15	8.23	0.00	0.00	0.00
MPRI	Aug 22	2	12	37	3875	8646.65	13605.30	5870.69	29659.57	4323.33	1133.77	158.67	7.65	564.84	148.13	20.73	0.00	0.00	0.00
MSAVI	Aug 22	2	12	37	3875	0.44	0.85	0.22	1.90	0.22	0.07	0.01	0.00	452.27	143.29	11.89	0.00	0.00	0.00
mSR2	Aug 22	2	12	37	3875	1091.50	405.21	21.99	354.92	545.75	33.77	0.59	0.09	5958.57	368.67	6.49	0.00	0.00	0.00
MTCI	Aug 22	2	12	37	3875	811.58	320.44	11.03	251.10	405.79	26.70	0.30	0.06	6262.28	412.09	4.60	0.00	0.00	0.00
MTVI	Aug 22	2	12	37	3875	378600.26	755411.41	205469.61	1624652.50	189300.13	62950.95	5553.23	419.27	451.50	150.15	13.25	0.00	0.00	0.00
NDVI	Aug 22	2	12	37	3875	12.29	5.54	0.90	7.71	6.15	0.46	0.02	0.00	3089.31	232.10	12.17	0.00	0.00	0.00
NDVI2	Aug 22	2	12	37	3875	42.96	10.78	0.73	9.07	21.48	0.90	0.02	0.00	9179.40	383.85	8.41	0.00	0.00	0.00
NDVI3	Aug 22	2	12	37	3875	1.24	6.37	1.44	16.30	0.62	0.53	0.04	0.00	147.12	126.29	9.23	0.00	0.00	0.00
OSAVI	Aug 22	2	12	37	3875	1.62	3.08	0.74	6.82	0.81	0.26	0.02	0.00	460.08	145.90	11.31	0.00	0.00	0.00
OSAVI2	Aug 22	2	12	37	3875	57.61	14.44	0.97	12.13	28.81	1.20	0.03	0.00	9204.31	384.39	8.39	0.00	0.00	0.00
PARS	Aug 22	2	12	37	3875	5120.71	5246.32	534.94	11770.63	2560.36	437.19	14.46	3.04	842.89	143.93	4.76	0.00	0.00	0.00
PRI	Aug 22	2	12	37	3875	4.85	2.79	0.39	4.60	2.43	0.23	0.01	0.00	2042.82	195.81	8.84	0.00	0.00	0.00
PRI_norm	Aug 22	2	12	37	3875	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1722.84	212.29	9.56	0.00	0.00	0.00
PRI*CI2	Aug 22	2	12	37	3875	7.93	11.67	0.91	13.91	3.97	0.97	0.02	0.00	1104.48	270.80	6.82	0.00	0.00	0.00
PSRI	Aug 22	2	12	37	3875	2.48	0.64	0.11	1.24	1.24	0.05	0.00	0.00	3882.80	168.45	9.43	0.00	0.00	0.00
PSSR	Aug 22	2	12	37	3875	22069.13	13615.17	1701.62	26467.92	11034.57	1134.60	45.99	6.83	1615.50	166.11	6.73	0.00	0.00	0.00
PSND	Aug 22	2	12	37	3875	0.14	1.12	0.24	4.14	0.07	0.09	0.01	0.00	66.53	87.52	6.16	0.00	0.00	0.00
RDVI	Aug 22	2	12	37	3875	886.87	965.62	203.02	1822.97	443.44	80.47	5.49	0.47	942.59	171.05	11.66	0.00	0.00	0.00
REP_Li	Aug 22	2	12	37	3875	292006.24	65821.24	5778.70	50166.73	146003.12	5485.10	156.18	12.95	11277.63	423.68	12.06	0.00	0.00	0.00
SAVI	Aug 22	2	12	37	3875	2.76	5.14	1.15	11.12	1.38	0.43	0.03	0.00	480.01	149.25	10.83	0.00	0.00	0.00
SPVI	Aug 22	2	12	37	3875	672661.70	488123.86	105021.17	1083712.39	336330.85	40676.99	2838.41	279.67	1202.61	145.45	10.15	0.00	0.00	0.00
SR	Aug 22	2	12	37	3875	20945.52	9750.46	1697.66	20981.71	10472.76	812.54	45.88	5.41	1934.16	150.06	8.47	0.00	0.00	0.00
SR1	Aug 22	2	12	37	3875	1953.98	744.20	47.90	709.67	976.99	62.02	1.29	0.18	5334.61	338.63	7.07	0.00	0.00	0.00
SR2	Aug 22	2	12	37	3875	8764.54	3181.62	315.10	4123.26	4382.27	265.13	8.52	1.06	4118.42	249.17	8.00	0.00	0.00	0.00
SR3	Aug 22	2	12	37	3875	5570.06	2400.85	128.87	2901.56	2785.03	200.07	3.48	0.75	3719.37	267.19	4.65	0.00	0.00	0.00
SR4	Aug 22	2	12	37	3875	3248.87	915.73	181.32	3088.59	1624.44	76.31	4.90	0.80	2038.05	95.74	6.15	0.00	0.00	0.00
SR5	Aug 22	2	12	37	3875	3.41	2.41	0.47	7.38	1.71	0.20	0.01	0.00	895.52	105.32	6.69	0.00	0.00	0.00
SR6	Aug 22	2	12	37	3875	416.23	155.93	7.63	133.40	208.12	12.99	0.21	0.03	6045.33	377.46	5.99	0.00	0.00	0.00
SR8	Aug 22	2	12	37	3875	11.72	6.03	0.31	9.23	5.86	0.50	0.01	0.00	2460.03	211.05	3.51	0.00	0.00	0.00

Supplementary Table 1. (Continue)

Sum_Dr1	Aug 22	2	12	37	3875	170031.32	300589.34	81413.49	638392.98	85015.66	25049.11	2200.36	164.75	516.04	152.05	13.36	0.00	0.00	0.00
Sum_Dr2	Aug 22	2	12	37	3875	346229.68	249445.24	57355.91	522347.34	173114.84	20787.10	1550.16	134.80	1284.24	154.21	11.50	0.00	0.00	0.00
TCARI	Aug 22	2	12	37	3875	54784.50	306775.46	73268.28	529436.68	27392.25	25564.62	1980.22	136.63	200.49	187.11	14.49	0.00	0.00	0.00
TCARI/OSAVI	Aug 22	2	12	37	3875	84992.63	414303.17	115308.92	703397.81	42496.31	34525.26	3116.46	181.52	234.11	190.20	17.17	0.00	0.00	0.00
TCARI2	Aug 22	2	12	37	3875	307381.33	173483.92	18482.17	256733.96	153690.67	14456.99	499.52	66.25	2319.72	218.21	7.54	0.00	0.00	0.00
TCARI2/OSAVI2	Aug 22	2	12	37	3875	734622.32	978028.74	211345.54	2190815.04	367311.16	81502.39	5712.04	565.37	649.68	144.16	10.10	0.00	0.00	0.00
TGI	Aug 22	2	12	37	3875	510038280.27	202975582.60	42948154.37	240219205.71	255019140.13	16914631.88	1160760.93	61992.05	4113.74	272.85	18.72	0.00	0.00	0.00
TVI	Aug 22	2	12	37	3875	807271016.04	1116504714.24	298690843.08	2260397886.42	403635508.02	93042059.52	8072725.49	583328.49	691.95	159.50	13.84	0.00	0.00	0.00
Vogelmann	Aug 22	2	12	37	3875	54.06	16.34	0.81	13.73	27.03	1.36	0.02	0.00	7626.03	384.29	6.17	0.00	0.00	0.00
Vogelmann2	Aug 22	2	12	37	3875	2.51	0.75	0.03	1.10	1.26	0.06	0.00	0.00	4439.55	219.65	3.12	0.00	0.00	0.00
Vogelmann3	Aug 22	2	12	37	3875	117.16	46.49	2.53	56.15	58.58	3.87	0.07	0.01	4042.91	267.37	4.72	0.00	0.00	0.00
Vogelmann4	Aug 22	2	12	37	3875	3.08	0.99	0.04	1.37	1.54	0.08	0.00	0.00	4345.21	231.55	3.14	0.00	0.00	0.00
Boochs	Sept 05	2	12	17	8368	588.58	22332.75	430.87	8690.64	294.29	1861.06	25.35	1.04	283.37	1791.97	24.40	0.00	0.00	0.00
Boochs2	Sept 05	2	12	17	8368	15597.31	13039.20	155.74	5704.33	7798.66	1086.60	9.16	0.68	11440.28	1593.99	13.44	0.00	0.00	0.00
CARI	Sept 05	2	12	17	8368	18824201.91	39505963.71	281520.83	15120414.53	9412100.96	3292163.64	16560.05	1806.93	5208.88	1821.96	9.16	0.00	0.00	0.00
Carter2	Sept 05	2	12	17	8368	49.69	34.43	0.23	28.69	24.84	2.87	0.01	0.00	7244.85	836.67	3.99	0.00	0.00	0.00
Carter3	Sept 05	2	12	17	8368	18.50	15.42	0.14	13.87	9.25	1.28	0.01	0.00	5580.04	775.24	5.05	0.00	0.00	0.00
Carter4	Sept 05	2	12	17	8368	66.86	36.91	0.30	33.11	33.43	3.08	0.02	0.00	8448.11	777.34	4.42	0.00	0.00	0.00
Carter5	Sept 05	2	12	17	8368	1399.63	835.02	69.75	4152.22	699.82	69.59	4.10	0.50	1410.34	140.24	8.27	0.00	0.00	0.00
Carter6	Sept 05	2	12	17	8368	104365.13	537378.48	6812.02	252252.05	52182.57	44781.54	400.71	30.14	1731.06	1485.55	13.29	0.00	0.00	0.00
CI	Sept 05	2	12	17	8368	13.94	8.42	0.45	36.29	6.97	0.70	0.03	0.00	1606.80	161.70	6.10	0.00	0.00	0.00
CI2	Sept 05	2	12	17	8368	2901.45	1429.45	17.10	2289.64	1450.72	119.12	1.01	0.27	5301.99	435.35	3.68	0.00	0.00	0.00
ClAInt	Sept 05	2	12	17	8368	162071817.41	958283436.21	11725030.84	362775479.47	81035908.71	79856953.02	689707.70	43352.71	1869.22	1842.03	15.91	0.00	0.00	0.00
CRI1	Sept 05	2	12	17	8368	0.06	1.59	0.07	2.86	0.03	0.13	0.00	0.00	84.73	388.11	11.22	0.00	0.00	0.00
CRI2	Sept 05	2	12	17	8368	0.26	4.76	0.14	6.51	0.13	0.40	0.01	0.00	164.58	509.25	10.43	0.00	0.00	0.00
CRI3	Sept 05	2	12	17	8368	8142.25	4503.24	75.26	9190.27	4071.13	375.27	4.43	1.10	3706.88	341.69	4.03	0.00	0.00	0.00
CRI4	Sept 05	2	12	17	8368	2931.99	1347.41	15.28	2194.92	1466.00	112.28	0.90	0.26	5589.01	428.08	3.43	0.00	0.00	0.00
D1	Sept 05	2	12	17	8368	173.58	115.51	1.30	166.99	86.79	9.63	0.08	0.02	4348.97	482.37	3.84	0.00	0.00	0.00
D2	Sept 05	2	12	17	8368	2252.60	2315.05	16.74	6877.34	1126.30	192.92	0.98	0.82	1370.43	234.74	1.20	0.00	0.00	0.26
Datt	Sept 05	2	12	17	8368	47.85	29.38	0.23	26.10	23.92	2.45	0.01	0.00	7670.65	784.93	4.40	0.00	0.00	0.00
Datt2	Sept 05	2	12	17	8368	706.94	437.15	4.40	614.37	353.47	36.43	0.26	0.07	4814.44	496.18	3.53	0.00	0.00	0.00
Datt3	Sept 05	2	12	17	8368	22.29	12.79	0.65	60.45	11.14	1.07	0.04	0.01	1542.50	147.57	5.30	0.00	0.00	0.00
Datt4	Sept 05	2	12	17	8368	0.05	0.11	0.00	0.07	0.02	0.01	0.00	0.00	2993.04	1142.50	6.76	0.00	0.00	0.00
Datt5	Sept 05	2	12	17	8368	6.25	14.18	0.58	60.72	3.13	1.18	0.03	0.01	431.01	162.83	4.68	0.00	0.00	0.00
Datt6	Sept 05	2	12	17	8368	17.06	38.18	0.65	46.82	8.53	3.18	0.04	0.01	1524.57	568.72	6.88	0.00	0.00	0.00
DD	Sept 05	2	12	17	8368	1105377.34	1149439.95	5973.37	601045.98	552688.67	95786.66	351.37	71.83	7694.75	1333.58	4.89	0.00	0.00	0.00
DDn	Sept 05	2	12	17	8368	1880593.74	3552501.67	52204.70	1097081.26	940296.87	296041.81	3070.86	131.10	7172.13	2258.06	23.42	0.00	0.00	0.00
DPI	Sept 05	2	12	17	8368	60.43	17.12	1.30	140.44	30.22	1.43	0.08	0.02	1800.38	84.99	4.55	0.00	0.00	0.00
DWSI4	Sept 05	2	12	17	8368	56.31	214.30	10.59	716.17	28.16	17.86	0.62	0.09	328.99	208.66	7.28	0.00	0.00	0.00
EGFN	Sept 05	2	12	17	8368	26.41	12.88	0.18	33.34	13.20	1.07	0.01	0.00	3314.48	269.46	2.61	0.00	0.00	0.00
EGFR	Sept 05	2	12	17	8368	7121.47	2921.16	36.09	8503.78	3560.74	243.43	2.12	1.02	3503.88	239.54	2.09	0.00	0.00	0.01
EVI	Sept 05	2	12	17	8368	21706773.90	81809408.68	73113515.07	58524901349.89	10853386.95	6817450.72	4300795.00	6993893.56	1.55	0.97	0.61	0.21	0.47	0.88
GI	Sept 05	2	12	17	8368	113.92	280.86	16.24	1164.89	56.96	23.40	0.96	0.14	409.16	168.13	6.86	0.00	0.00	0.00
Gitelson	Sept 05	2	12	17	8368	0.45	1.20	0.02	0.83	0.22	0.10	0.00	0.00	2269.07	1015.43	9.62	0.00	0.00	0.00
Gitelson2	Sept 05	2	12	17	8368	440.15	4933.03	178.34	6446.16	220.07	411.09	10.49	0.77	285.68	533.65	13.62	0.00	0.00	0.00
GMI1	Sept 05	2	12	17	8368	6769.05	4067.21	66.85	8156.58	3384.52	338.93	3.93	0.97	3472.25	347.72	4.03	0.00	0.00	0.00
GMI2	Sept 05	2	12	17	8368	2569.04	1289.68	15.06	2010.55	1284.52	107.47	0.89	0.24	5346.23	447.31	3.69	0.00	0.00	0.00
Green NDVI	Sept 05	2	12	17	8368	23.31	18.32	0.30	22.87	11.66	1.53	0.02	0.00	4265.75	558.51	6.42	0.00	0.00	0.00
Maccioni	Sept 05	2	12	17	8368	63.55	34.22	0.26	27.34	31.77	2.85	0.02	0.00	9724.07	872.81	4.69	0.00	0.00	0.00
MCARI	Sept 05	2	12	17	8368	7714381.83	11040022.16	88953.27	7691461.46	3857190.92	920001.85	5232.55	919.15	4196.47	1000.92	5.69	0.00	0.00	0.00
MCARI2	Sept 05	2	12	17	8368	6397725.80	3408072.37	10086.13	2763762.31	3198862.90	284006.03	593.30	330.28	9685.38	859.90	1.80	0.00	0.00	0.02
MPRI	Sept 05	2	12	17	8368	19362.51	128741.34	3040.06	99877.73	9681.25	10728.44	178.83	11.94	811.12	898.86	14.98	0.00	0.00	0.00
MSAVI	Sept 05	2	12	17	8368	1.47	3.17	0.11	7.77	0.73	0.26	0.01	0.00	790.74	284.67	7.00	0.00	0.00	0.00
mSR2	Sept 05	2	12	17	8368	1509.95	748.04	7.98	1053.01	754.98	62.34	0.47	0.13	5999.60	495.37	3.73	0.00	0.00	0.00
MTCI	Sept 05	2	12	17	8368	1227.66	574.96	5.28	695.14	613.83	47.91	0.31	0.08	7389.22	576.77	3.74	0.00	0.00	0.00
MTVI	Sept 05	2	12	17	8368	485487.16	9807356.78	134203.45	2403161.69	242743.58	817279.73	7894.32	287.18	845.25	2845.83	27.49	0.00	0.00	0.00
NDVI	Sept 05	2	12	17	8368	11.53	14.65	0.25	23.32	5.77	1.22	0.01	0.00	2068.98	438.08	5.17	0.00	0.00	0.00
NDVI2	Sept 05	2	12	17	8368	54.15	28.71	0.24	28.49	27.07	2.39	0.01	0.00	7951.73	702.58	4.10	0.00	0.00	0.00
NDVI3	Sept 05	2	12	17	8368	4.64	12.45	0.41	40.65	2.32	1.04	0.02	0.00	477.22	213.64	4.92	0.00	0.00	0.00
OSAVI	Sept 05	2	12	17	8368	4.96	11.01	0.36	26.52	2.48	0.92	0.02	0.00	783.34	289.65	6.75	0.00	0.00	0.00
OSAVI2	Sept 05	2	12	17	8368	72.63	38.44	0.32	38.16	36.31	3.20	0.02	0.00	7963.69	702.43	4.09	0.00	0.00	0.00
PARS	Sept 05	2	12	17	8368	11612.29	10448.90	505.65	35132.43	5806.14	870.74	29.74	4.20	1382.93	207.40	7.08	0.00	0.00	0.00
PRI	Sept 05	2	12	17	8368	9.55	6.89	0.06	7.59	4.78	0.57	0.00	0.00	5267.86	632.89	3.74	0.00	0.00	0.00
PRI*CI2	Sept 05	2	12	17	8368	12.09	9.00	0.22	27.31	6.04	0.75	0.01	0.00	1851.71	229.91	4.03	0.00	0.00	0.00
PRI_norm	Sept 05	2	12	17	8368	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	3915.89	483.09	2.19	0.00	0.00	0.00
PSND	Sept 05	2	12	17	8368	0.54	2.16	0.36	15.88	0.27	0.18	0.02	0.00	141.68	94.84	11.23	0.00	0.00	0.00
PSRI	Sept 05	2	12	17	8368	1.91	3.00	0.02	2.92	0.95	0.25	0.00	0.00	2733.94	715.79	3.59	0.00	0.00	0.00
PSSR	Sept 05	2	12	17	8368	31728.93	26135.96	472.16	57970.23	15864.47	2178.00	27.77	6.93	2290.04	314.39	4.01	0.00	0.00	0.00
RDVI	Sept 05	2	12	17	8368	1210.09	6589.88	82.78	1652.50	605.04	549.16	4.87	0.20	3063.85	2780.85	24.66	0.00	0.00	0.00
REP_Li	Sept 05	2	12	17	8368	241752.79	200363.29	666.22	121244.60	120876.40	16696.94	39.19	14.49	8342.59	1152.38	2.70	0.00	0.00	0.00
SAVI	Sept 05	2	12	17	8368	8.31	17.77	0.59	43.55	4.15	1.48	0.03	0.01	798.13	284.48	6.68	0.00	0.00	0.00
SPVI	Sept 05	2	12	17	8368	742008.04	5940866.07	92649.04	1237382.85	371004.02	495072.17	5449.94	147.87	2508.97	3348.00	36.86	0.00	0.00	0.00
SR	Sept 05	2	12	17	8368	19771.78	26786.02	704.32	68103.45	9885.89	2232.17	41.43	8.14	1214.70	274.27	5.09	0.00	0.00	0.00
SR1	Sept 05	2	12	17	8368	2569.04	1289.68	15.06	2010.55	1284.52	107.47	0.89	0.24	5346.23	447.31	3.69	0.00	0.00	0.00

Supplementary Table 1. (Continue)

SR2	Sept 05	2	12	17	8368	9984.10	5980.35	92.03	11777.42	4992.05	498.36	5.41	1.41	3546.91	354.09	3.85	0.00	0.00	0.00
SR3	Sept 05	2	12	17	8368	6769.05	4067.21	66.85	8156.58	3384.52	338.93	3.93	0.97	3472.25	347.72	4.03	0.00	0.00	0.00
SR4	Sept 05	2	12	17	8368	1637.01	1572.51	135.37	7919.73	818.50	131.04	7.96	0.95	864.83	138.46	8.41	0.00	0.00	0.00
SR5	Sept 05	2	12	17	8368	3.26	5.58	0.27	22.05	1.63	0.46	0.02	0.00	617.96	176.37	6.08	0.00	0.00	0.00
SR6	Sept 05	2	12	17	8368	593.85	299.88	2.99	405.53	296.92	24.99	0.18	0.05	6126.98	515.67	3.63	0.00	0.00	0.00
SR8	Sept 05	2	12	17	8368	5.21	6.29	0.26	18.95	2.61	0.52	0.02	0.00	1150.47	231.45	6.66	0.00	0.00	0.00
Sum_Dr1	Sept 05	2	12	17	8368	254695.73	4046985.61	53143.94	887190.47	127347.86	337248.80	3126.11	106.02	1201.15	3180.94	29.49	0.00	0.00	0.00
Sum_Dr2	Sept 05	2	12	17	8368	326174.85	2699617.33	41312.32	612100.65	163087.42	224968.11	2430.14	73.15	2229.56	3075.53	33.22	0.00	0.00	0.00
TCARI	Sept 05	2	12	17	8368	314958.10	2600267.16	37845.61	1500340.97	157479.05	216688.93	2226.21	179.30	878.32	1208.56	12.42	0.00	0.00	0.00
TCARI/OSAVI	Sept 05	2	12	17	8368	596403.18	3695502.12	55775.93	2346231.45	298201.59	307958.51	3280.94	280.38	1063.56	1098.36	11.70	0.00	0.00	0.00
TCARI2	Sept 05	2	12	17	8368	229569.86	997886.29	17583.84	794682.01	114784.93	83157.19	1034.34	94.97	1208.69	875.65	10.89	0.00	0.00	0.00
TCARI2/OSAVI2	Sept 05	2	12	17	8368	1081438.21	8332367.67	221786.83	7950771.87	540719.11	694363.97	13046.28	950.14	569.09	730.80	13.73	0.00	0.00	0.00
TGI	Sept 05	2	12	17	8368	608053573.98	2027738698.66	12833859.91	832733580.37	304026786.99	168978224.89	754932.94	99514.05	3055.11	1698.03	7.59	0.00	0.00	0.00
TVI	Sept 05	2	12	17	8368	593379687.41	13288776732.81	184256273.45	3377877060.50	296689843.71	1107398061.07	10838604.32	403666.00	734.99	2743.35	26.85	0.00	0.00	0.00
Vogelmann	Sept 05	2	12	17	8368	62.95	35.03	0.41	43.36	31.48	2.92	0.02	0.01	6073.99	563.28	4.70	0.00	0.00	0.00
Vogelmann2	Sept 05	2	12	17	8368	1.89	1.33	0.02	2.01	0.94	0.11	0.00	0.00	3919.53	461.21	4.80	0.00	0.00	0.00
Vogelmann3	Sept 05	2	12	17	8368	245.55	110.01	0.99	143.34	122.77	9.17	0.06	0.02	7167.40	535.19	3.39	0.00	0.00	0.00
Vogelmann4	Sept 05	2	12	17	8368	2.42	1.69	0.02	2.59	1.21	0.14	0.00	0.00	3901.08	455.33	4.70	0.00	0.00	0.00
Boochs	Sept 13	2	12	18	7001	341.71	3202.29	23.74	3623.94	170.85	266.86	1.32	0.52	330.07	515.54	2.55	0.00	0.00	0.00
Boochs2	Sept 13	2	12	18	7001	3260.64	4346.08	7.98	2211.15	1630.32	362.17	0.44	0.32	5161.96	1146.72	1.40	0.00	0.00	0.12
CARI	Sept 13	2	12	18	7001	5204848.19	4413204.21	39919.43	5341026.39	2602424.09	367767.02	2217.75	762.89	3411.25	482.07	2.91	0.00	0.00	0.00
Carter2	Sept 13	2	12	18	7001	55.64	26.57	0.15	18.24	27.82	2.21	0.01	0.00	10679.51	849.98	3.22	0.00	0.00	0.00
Carter3	Sept 13	2	12	18	7001	19.90	12.40	0.07	8.54	9.95	1.03	0.00	0.00	8156.16	847.38	3.38	0.00	0.00	0.00
Carter4	Sept 13	2	12	18	7001	52.49	24.79	0.22	19.79	26.24	2.07	0.01	0.00	9281.77	730.52	4.37	0.00	0.00	0.00
Carter5	Sept 13	2	12	18	7001	929.66	1741.12	60.98	3954.13	464.83	145.09	3.39	0.56	823.01	256.90	6.00	0.00	0.00	0.00
Carter6	Sept 13	2	12	18	7001	38353.48	47737.51	544.43	70945.99	19176.74	3978.13	30.25	10.13	1892.37	392.56	2.98	0.00	0.00	0.00
CI	Sept 13	2	12	18	7001	18.29	12.61	0.29	23.17	9.14	1.05	0.02	0.00	2762.91	317.63	4.91	0.00	0.00	0.00
CI2	Sept 13	2	12	18	7001	1836.30	1468.92	20.49	1372.74	918.15	122.41	1.14	0.20	4682.57	624.29	5.80	0.00	0.00	0.00
ClAInt	Sept 13	2	12	18	7001	60620802.47	84700336.82	621845.54	106063204.82	30310401.23	7058361.40	34546.97	15149.72	2000.72	465.91	2.28	0.00	0.00	0.00
CRI1	Sept 13	2	12	18	7001	2.06	1.46	0.17	14.10	1.03	0.12	0.01	0.00	511.03	60.30	4.66	0.00	0.00	0.00
CRI2	Sept 13	2	12	18	7001	4.79	3.54	0.36	31.76	2.39	0.30	0.02	0.00	527.76	65.12	4.46	0.00	0.00	0.00
CRI3	Sept 13	2	12	18	7001	4495.16	3266.51	86.89	6395.14	2247.58	272.21	4.83	0.91	2460.51	298.00	5.28	0.00	0.00	0.00
CRI4	Sept 13	2	12	18	7001	1770.63	1460.06	19.27	1130.65	885.31	121.67	1.07	0.16	5481.88	753.39	6.63	0.00	0.00	0.00
D1	Sept 13	2	12	18	7001	83.47	50.94	1.48	89.76	41.73	4.24	0.08	0.01	3254.90	331.05	6.43	0.00	0.00	0.00
D2	Sept 13	2	12	18	7001	646.90	308.77	6.56	516.84	323.45	25.73	0.36	0.07	4381.43	348.54	4.94	0.00	0.00	0.00
Datt	Sept 13	2	12	18	7001	44.43	16.25	0.25	17.24	22.22	1.35	0.01	0.00	9021.74	550.02	5.57	0.00	0.00	0.00
Datt2	Sept 13	2	12	18	7001	482.98	253.06	6.18	343.49	241.49	21.09	0.34	0.05	4921.97	429.82	7.00	0.00	0.00	0.00
Datt3	Sept 13	2	12	18	7001	1.63	4.83	0.58	48.88	0.82	0.40	0.03	0.01	116.74	57.67	4.62	0.00	0.00	0.00
Datt4	Sept 13	2	12	18	7001	0.05	0.26	0.00	0.28	0.03	0.02	0.00	0.00	645.54	539.80	4.79	0.00	0.00	0.00
Datt5	Sept 13	2	12	18	7001	0.23	40.22	0.47	61.19	0.11	3.35	0.03	0.01	13.13	383.47	2.99	0.00	0.00	0.00
Datt6	Sept 13	2	12	18	7001	27.54	28.90	1.34	118.23	13.77	2.41	0.07	0.02	815.52	142.59	4.39	0.00	0.00	0.00
DD	Sept 13	2	12	18	7001	348711.82	172997.26	1248.64	127628.70	174355.91	14416.44	69.37	18.23	9564.19	790.81	3.81	0.00	0.00	0.00
DDn	Sept 13	2	12	18	7001	432853.59	794814.59	1859.40	640901.42	216426.79	66234.55	103.30	91.54	2364.18	723.52	1.13	0.00	0.00	0.32
DPI	Sept 13	2	12	18	7001	12.66	12.78	0.79	80.34	6.33	1.07	0.04	0.01	551.80	92.83	3.80	0.00	0.00	0.00
DWSI4	Sept 13	2	12	18	7001	32.49	341.48	2.23	413.67	16.25	28.46	0.12	0.06	274.93	481.61	2.10	0.00	0.00	0.00
EGFN	Sept 13	2	12	18	7001	10.03	15.74	0.37	19.44	5.02	1.31	0.02	0.00	1806.98	472.55	7.45	0.00	0.00	0.00
EGFR	Sept 13	2	12	18	7001	2496.65	5139.67	189.85	5527.82	1248.33	428.31	10.55	0.79	1581.01	542.45	13.36	0.00	0.00	0.00
EVI	Sept 13	2	12	18	7001	127706.18	618711.10	301288.22	938588152.30	63853.09	51559.26	16738.23	134064.87	0.48	0.38	0.12	0.62	0.97	1.00
GI	Sept 13	2	12	18	7001	2.88	536.30	3.97	714.67	1.44	44.69	0.22	0.10	14.09	437.80	2.16	0.00	0.00	0.00
Gitelson	Sept 13	2	12	18	7001	0.66	0.90	0.03	2.57	0.33	0.07	0.00	0.00	898.64	204.09	4.16	0.00	0.00	0.00
Gitelson2	Sept 13	2	12	18	7001	378.15	802.25	37.87	4179.91	189.07	66.85	2.10	0.60	316.68	111.98	3.52	0.00	0.00	0.00
GMI1	Sept 13	2	12	18	7001	4212.58	3030.47	81.00	6302.37	2106.29	252.54	4.50	0.90	2339.78	280.53	5.00	0.00	0.00	0.00
GMI2	Sept 13	2	12	18	7001	1706.18	1367.82	17.10	1225.69	853.09	113.98	0.95	0.18	4872.77	651.07	5.43	0.00	0.00	0.00
Green NDVI	Sept 13	2	12	18	7001	20.36	9.98	0.21	16.41	10.18	0.83	0.01	0.00	4342.13	354.68	4.92	0.00	0.00	0.00
Maccioni	Sept 13	2	12	18	7001	48.40	20.10	0.22	16.20	24.20	1.68	0.01	0.00	10454.43	723.78	5.17	0.00	0.00	0.00
MCARI	Sept 13	2	12	18	7001	2046851.95	1969201.35	23113.53	2960860.44	1023425.98	164100.11	1284.09	422.92	2419.91	388.02	3.04	0.00	0.00	0.00
MCARI2	Sept 13	2	12	18	7001	1514925.63	1697780.83	5016.15	773859.74	757462.81	141481.74	278.67	110.54	6852.66	1279.97	2.52	0.00	0.00	0.00
MPRI	Sept 13	2	12	18	7001	7398.78	9453.66	213.50	28329.76	3699.39	787.81	11.86	4.05	914.21	194.69	2.93	0.00	0.00	0.00
MSAVI	Sept 13	2	12	18	7001	2.53	2.77	0.05	5.77	1.27	0.23	0.00	0.00	1535.04	280.05	3.14	0.00	0.00	0.00
mSR2	Sept 13	2	12	18	7001	973.92	721.09	9.35	626.55	486.96	60.09	0.52	0.09	5441.22	671.45	5.81	0.00	0.00	0.00
MTCI	Sept 13	2	12	18	7001	735.17	535.62	8.75	413.11	367.59	44.63	0.49	0.06	6229.51	756.43	8.24	0.00	0.00	0.00
MTVI	Sept 13	2	12	18	7001	100502.32	1277215.82	5881.29	1303815.52	50251.16	106434.65	326.74	186.23	269.83	571.51	1.75	0.00	0.00	0.02
NDVI	Sept 13	2	12	18	7001	18.84	12.52	0.13	16.99	9.42	1.04	0.01	0.00	3880.11	429.88	3.00	0.00	0.00	0.00
NDVI2	Sept 13	2	12	18	7001	43.90	23.54	0.20	17.86	21.95	1.96	0.01	0.00	8607.03	769.27	4.31	0.00	0.00	0.00
NDVI3	Sept 13	2	12	18	7001	6.15	23.65	0.20	31.67	3.07	1.97	0.01	0.00	679.18	435.68	2.43	0.00	0.00	0.00
OSAVI	Sept 13	2	12	18	7001	8.38	9.57	0.16	19.60	4.19	0.80	0.01	0.00	1496.28	284.95	3.26	0.00	0.00	0.00
OSAVI2	Sept 13	2	12	18	7001	58.79	31.55	0.26	23.80	29.39	2.63	0.01	0.00	8647.39	773.36	4.30	0.00	0.00	0.00
PARS	Sept 13	2	12	18	7001	10207.35	7501.06	575.65	38715.72	5103.68	625.09	31.98	5.53	922.90	113.04	5.78	0.00	0.00	0.00
PRI	Sept 13	2	12	18	7001	10.74	9.37	0.06	5.51	5.37	0.78	0.00	0.00	6827.65	992.98	4.11	0.00	0.00	0.00
PRI_norm	Sept 13	2	12	18	7001	0.02	0.02	0.00	0.02	0.01	0.00	0.00	0.00	4935.57	737.90	3.34	0.00	0.00	0.00
PRI*CI2	Sept 13	2	12	18	7001	6.35	19.92	0.28	16.59	3.18	1.66	0.02	0.00	1339.73	700.44	6.53	0.00	0.00	0.00
PSRI	Sept 13	2	12	18	7001	4.57	2.74	0.02	2.38	2.28	0.23	0.00	0.00	6730.77	673.70	2.58	0.00	0.00	0.00
PSSR	Sept 13	2	12	18	7001	23632.90	25370.15	489.14	48130.20	11816.45	2114.18	27.17	6.87	1718.82	307.53	3.95	0.00	0.00	0.00
PSND	Sept 13	2	12	18	7001	1.16	1.74	0.17	11.66	0.58	0.15	0.01	0.00	348.55	87.34	5.56	0.00	0.00	0.00

Supplementary Table 1. (Continue)

RDVI	Sept 13	2	12	18	7001	448.03	2375.89	8.32	1882.90	224.02	197.99	0.46	0.27	832.94	736.17	1.72	0.00	0.00	0.03
REP_Li	Sept 13	2	12	18	7001	295797.63	113759.87	565.78	66788.17	147898.82	9479.99	31.43	9.54	15503.34	993.73	3.29	0.00	0.00	0.00
SAVI	Sept 13	2	12	18	7001	13.82	15.94	0.27	31.64	6.91	1.33	0.01	0.00	1528.78	293.85	3.26	0.00	0.00	0.00
SPVI	Sept 13	2	12	18	7001	114725.93	834836.15	3249.36	794730.30	57362.97	69569.68	180.52	113.52	505.33	612.86	1.59	0.00	0.00	0.05
SR	Sept 13	2	12	18	7001	19131.21	20186.48	418.48	50989.63	9565.61	1682.21	23.25	7.28	1313.38	230.97	3.19	0.00	0.00	0.00
SR1	Sept 13	2	12	18	7001	1706.18	1367.82	17.10	1225.69	853.09	113.98	0.95	0.18	4872.77	651.07	5.43	0.00	0.00	0.00
SR2	Sept 13	2	12	18	7001	7207.68	6425.51	68.86	7601.46	3603.84	535.46	3.83	1.09	3319.16	493.16	3.52	0.00	0.00	0.00
SR3	Sept 13	2	12	18	7001	4212.58	3030.47	81.00	6302.37	2106.29	252.54	4.50	0.90	2339.78	280.53	5.00	0.00	0.00	0.00
SR4	Sept 13	2	12	18	7001	1035.18	3091.11	116.07	7678.66	517.59	257.59	6.45	1.10	471.91	234.86	5.88	0.00	0.00	0.00
SR5	Sept 13	2	12	18	7001	2.07	10.34	0.27	21.26	1.03	0.86	0.01	0.00	340.52	283.72	4.93	0.00	0.00	0.00
SR6	Sept 13	2	12	18	7001	370.18	260.84	3.54	235.68	185.09	21.74	0.20	0.03	5498.08	645.70	5.84	0.00	0.00	0.00
SR8	Sept 13	2	12	18	7001	8.27	15.39	0.39	18.70	4.14	1.28	0.02	0.00	1549.19	480.16	8.12	0.00	0.00	0.00
Sum_Dr1	Sept 13	2	12	18	7001	34269.59	511467.39	2336.59	505181.61	17134.80	42622.28	129.81	72.16	237.46	590.68	1.80	0.00	0.00	0.02
Sum_Dr2	Sept 13	2	12	18	7001	71172.44	446055.65	1484.72	393379.92	35586.22	37171.30	82.48	56.19	633.33	661.54	1.47	0.00	0.00	0.09
TCARI	Sept 13	2	12	18	7001	174396.01	250778.89	4182.17	423862.44	87198.01	20898.24	232.34	60.54	1440.26	345.18	3.84	0.00	0.00	0.00
TCARI/OSAVI	Sept 13	2	12	18	7001	301288.91	362239.78	5378.47	597390.46	150644.46	30186.65	298.80	85.33	1765.45	353.77	3.50	0.00	0.00	0.00
TCARI2	Sept 13	2	12	18	7001	179269.02	181648.71	2180.29	249301.91	89634.51	15137.39	121.13	35.61	2517.15	425.09	3.40	0.00	0.00	0.00
TCARI2/OSAVI2	Sept 13	2	12	18	7001	200253.68	1031940.53	20576.04	2385333.30	100126.84	85995.04	1143.11	340.71	293.87	252.40	3.36	0.00	0.00	0.00
TGI	Sept 13	2	12	18	7001	210217683.16	231672136.51	2513182.04	240285856.67	105108841.58	19306011.38	139621.22	34321.65	3062.46	562.50	4.07	0.00	0.00	0.00
TVI	Sept 13	2	12	18	7001	150098347.48	1974985826.02	9294804.47	1857147078.06	75049173.74	164582152.17	516378.03	265268.83	282.92	620.44	1.95	0.00	0.00	0.01
Vogelmann	Sept 13	2	12	18	7001	44.82	26.77	0.41	25.94	22.41	2.23	0.02	0.00	6046.60	601.89	6.21	0.00	0.00	0.00
Vogelmann2	Sept 13	2	12	18	7001	1.77	0.87	0.02	1.41	0.89	0.07	0.00	0.00	4392.65	358.30	4.86	0.00	0.00	0.00
Vogelmann3	Sept 13	2	12	18	7001	106.40	68.49	0.72	83.77	53.20	5.71	0.04	0.01	4445.93	476.97	3.32	0.00	0.00	0.00
Vogelmann4	Sept 13	2	12	18	7001	2.15	1.13	0.02	1.78	1.08	0.09	0.00	0.00	4235.74	370.54	5.28	0.00	0.00	0.00
Boochs	Sept 20	2	12	13	7083	10140.77	5441.77	59.95	4525.05	5070.39	453.48	4.61	0.64	7936.60	709.83	7.22	0.00	0.00	0.00
Boochs2	Sept 20	2	12	13	7083	19980.15	4279.23	34.00	4034.52	9990.08	356.60	2.62	0.57	17538.56	626.05	4.59	0.00	0.00	0.00
CARI	Sept 20	2	12	13	7083	8029116.69	11359679.46	324744.11	18994144.15	4014558.35	946639.96	24980.32	2681.65	1497.05	353.01	9.32	0.00	0.00	0.00
Carter2	Sept 20	2	12	13	7083	119.28	32.14	0.13	22.51	59.64	2.68	0.01	0.00	18769.65	843.00	3.20	0.00	0.00	0.00
Carter3	Sept 20	2	12	13	7083	34.22	14.09	0.07	10.52	17.11	1.17	0.01	0.00	11519.72	790.87	3.82	0.00	0.00	0.00
Carter4	Sept 20	2	12	13	7083	72.70	16.37	0.10	15.89	36.35	1.36	0.01	0.00	16208.75	608.09	3.58	0.00	0.00	0.00
Carter5	Sept 20	2	12	13	7083	3.77	1548.18	46.43	3795.86	1.89	129.02	3.57	0.54	3.52	240.74	6.66	0.03	0.00	0.00
Carter6	Sept 20	2	12	13	7083	69031.46	92121.05	2379.35	172450.68	34515.73	7676.75	183.03	24.35	1417.65	315.30	7.52	0.00	0.00	0.00
CI	Sept 20	2	12	13	7083	19.23	10.08	0.22	18.95	9.62	0.84	0.02	0.00	3594.31	314.09	6.21	0.00	0.00	0.00
CI2	Sept 20	2	12	13	7083	1451.60	438.42	3.08	532.62	725.80	36.53	0.24	0.08	9652.04	485.86	3.15	0.00	0.00	0.00
ClAInt	Sept 20	2	12	13	7083	182300788.67	152754157.89	1109978.03	207006661.23	91150394.33	12729513.16	85382.93	29225.85	3118.83	435.56	2.92	0.00	0.00	0.00
CRI1	Sept 20	2	12	13	7083	0.06	0.13	0.01	0.65	0.03	0.01	0.00	0.00	345.56	120.52	4.25	0.00	0.00	0.00
CRI2	Sept 20	2	12	13	7083	0.23	0.60	0.02	1.99	0.11	0.05	0.00	0.00	405.99	176.85	4.80	0.00	0.00	0.00
CRI3	Sept 20	2	12	13	7083	4987.34	2669.84	36.76	5143.46	2493.67	222.49	2.83	0.73	3434.00	306.38	3.89	0.00	0.00	0.00
CRI4	Sept 20	2	12	13	7083	1446.57	427.38	3.02	501.24	723.28	35.62	0.23	0.07	10220.68	503.28	3.28	0.00	0.00	0.00
D1	Sept 20	2	12	13	7083	115.63	12.97	0.27	44.59	57.81	1.08	0.02	0.01	9183.41	171.67	3.31	0.00	0.00	0.00
D2	Sept 20	2	12	13	7083	5222.80	2211.15	13.21	47797.74	2611.40	184.26	1.02	6.75	386.97	27.31	0.15	0.00	0.00	1.00
Datt	Sept 20	2	12	13	7083	46.67	13.55	0.22	16.83	23.33	1.13	0.02	0.00	9820.01	475.10	7.04	0.00	0.00	0.00
Datt2	Sept 20	2	12	13	7083	359.44	121.68	0.88	129.14	179.72	10.14	0.07	0.02	9856.80	556.11	3.71	0.00	0.00	0.00
Datt3	Sept 20	2	12	13	7083	15.53	7.76	1.60	35.61	7.76	0.65	0.12	0.01	1544.23	128.55	24.50	0.00	0.00	0.00
Datt4	Sept 20	2	12	13	7083	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.00	41.09	278.06	14.28	0.00	0.00	0.00
Datt5	Sept 20	2	12	13	7083	34.49	52.22	2.49	99.06	17.25	4.35	0.19	0.01	1233.13	311.14	13.71	0.00	0.00	0.00
Datt6	Sept 20	2	12	13	7083	4.07	3.61	0.05	6.14	2.04	0.30	0.00	0.00	2347.89	347.18	4.11	0.00	0.00	0.00
DD	Sept 20	2	12	13	7083	1032505.76	300155.35	5205.55	423573.49	516252.88	25012.95	400.43	59.80	8632.79	418.27	6.70	0.00	0.00	0.00
DDn	Sept 20	2	12	13	7083	1967143.09	550071.25	10019.56	772498.76	983571.55	45839.27	770.74	109.06	9018.32	420.30	7.07	0.00	0.00	0.00
DPI	Sept 20	2	12	13	7083	28.94	8.07	1.54	79.37	14.47	0.67	0.12	0.01	1291.29	60.04	10.58	0.00	0.00	0.00
DWSI4	Sept 20	2	12	13	7083	239.12	163.85	2.23	200.52	119.56	13.65	0.17	0.03	4223.20	482.31	6.07	0.00	0.00	0.00
EGFN	Sept 20	2	12	13	7083	5.74	12.76	0.34	23.32	2.87	1.06	0.03	0.00	871.50	322.93	7.98	0.00	0.00	0.00
EGFR	Sept 20	2	12	13	7083	1499.09	2985.74	71.42	6217.48	749.55	248.81	5.49	0.88	853.89	283.45	6.26	0.00	0.00	0.00
EVI	Sept 20	2	12	13	7083	15416094.24	92395213.79	151349235.23	41228880996.79	7708047.12	7699601.15	11642248.86	5820821.83	1.32	1.32	2.00	0.27	0.20	0.02
GI	Sept 20	2	12	13	7083	255.47	252.51	3.90	357.73	127.74	21.04	0.30	0.05	2529.12	416.63	5.93	0.00	0.00	0.00
Gitelson	Sept 20	2	12	13	7083	0.10	0.07	0.00	0.10	0.05	0.01	0.00	0.00	3473.87	392.58	3.45	0.00	0.00	0.00
Gitelson2	Sept 20	2	12	13	7083	589.62	929.98	49.80	2640.59	294.81	77.50	3.83	0.37	790.78	207.88	10.28	0.00	0.00	0.00
GMI1	Sept 20	2	12	13	7083	4826.67	2525.94	33.89	4849.40	2413.34	210.49	2.61	0.68	3524.90	307.45	3.81	0.00	0.00	0.00
GMI2	Sept 20	2	12	13	7083	1428.72	425.90	3.00	503.54	714.36	35.49	0.23	0.07	10048.45	499.23	3.25	0.00	0.00	0.00
Green NDVI	Sept 20	2	12	13	7083	24.17	9.88	0.19	16.40	12.08	0.82	0.01	0.00	5217.89	355.54	6.19	0.00	0.00	0.00
Maccioni	Sept 20	2	12	13	7083	60.85	12.30	0.16	14.46	30.43	1.03	0.01	0.00	14901.92	502.13	5.90	0.00	0.00	0.00
MCARI	Sept 20	2	12	13	7083	1162679.17	7180017.23	223926.90	12653482.05	581339.58	598334.77	17225.15	1786.46	325.41	334.93	9.64	0.00	0.00	0.00
MCARI2	Sept 20	2	12	13	7083	4540426.24	1087785.83	10681.29	1279225.29	2270213.12	90648.82	821.64	180.61	12570.05	501.92	4.55	0.00	0.00	0.00
MPRI	Sept 20	2	12	13	7083	19525.96	23855.20	862.88	83956.03	9762.98	1987.93	66.38	11.85	823.66	167.71	5.60	0.00	0.00	0.00
MSAVI	Sept 20	2	12	13	7083	10.16	6.18	0.14	8.22	5.08	0.52	0.01	0.00	4378.64	444.18	9.29	0.00	0.00	0.00
mSR2	Sept 20	2	12	13	7083	847.02	234.39	1.62	270.54	423.51	19.53	0.12	0.04	11087.97	511.39	3.25	0.00	0.00	0.00
MTCI	Sept 20	2	12	13	7083	532.41	137.76	1.29	167.87	266.21	11.48	0.10	0.02	11232.22	484.38	4.19	0.00	0.00	0.00
MTVI	Sept 20	2	12	13	7083	1223931.79	1046870.91	44801.43	1604666.40	611965.89	87239.24	3446.26	226.55	2701.22	385.07	15.21	0.00	0.00	0.00
NDVI	Sept 20	2	12	13	7083	68.08	23.89	0.15	20.88	34.04	1.99	0.01	0.00	11544.78	675.12	3.86	0.00	0.00	0.00
NDVI2	Sept 20	2	12	13	7083	56.72	13.36	0.08	12.72	28.36	1.11	0.01	0.00	15792.67	619.96	3.42	0.00	0.00	0.00
NDVI3	Sept 20	2	12	13	7083	42.05	25.11	0.40	31.48	21.03	2.09	0.03	0.00	4731.18	470.89	6.99	0.00	0.00	0.00
OSAVI	Sept 20	2	12	13	7083	31.65	17.80	0.34	23.88	15.82	1.48	0.03	0.00	4693.95	440.02	7.68	0.00	0.00	0.00
OSAVI2	Sept 20	2	12	13	7083	76.15	17.93	0.11	17.07	38.08	1.49	0.01	0.00	15803.54	620.15	3.42	0.00	0.00	0.00
PARS	Sept 20	2	12	13	7083	11366.22	5137.63	109.24	17598.04	5683.11	428.14	8.40	2.48	2287.38	172.32	3.38	0.00	0.00	0.00

Supplementary Table 1. (Continue)

PRI	Sept 20	2	12	13	7083	15.85	7.76	0.07	6.41	7.93	0.65	0.01	0.00	8752.54	713.77	5.69	0.00	0.00	0.00
PRI_norm	Sept 20	2	12	13	7083	0.02	0.02	0.00	0.01	0.01	0.00	0.00	0.00	5744.44	699.99	21.30	0.00	0.00	0.00
PRI*CI2	Sept 20	2	12	13	7083	8.11	5.36	0.07	10.12	4.05	0.45	0.01	0.00	2836.15	312.19	3.83	0.00	0.00	0.00
PSRI	Sept 20	2	12	13	7083	20.84	11.69	0.08	7.05	10.42	0.97	0.01	0.00	10469.71	978.65	6.57	0.00	0.00	0.00
PSSR	Sept 20	2	12	13	7083	43164.70	16674.60	169.57	33939.73	21582.35	1389.55	13.04	4.79	4504.10	289.99	2.72	0.00	0.00	0.00
PSND	Sept 20	2	12	13	7083	2.33	1.88	0.12	11.63	1.16	0.16	0.01	0.00	708.90	95.22	5.61	0.00	0.00	0.00
RDVI	Sept 20	2	12	13	7083	3799.27	1334.33	40.54	1678.77	1899.63	111.19	3.12	0.24	8014.84	469.14	13.16	0.00	0.00	0.00
REP_Li	Sept 20	2	12	13	7083	1267269.57	425400.41	1846.85	279475.60	633634.78	35450.03	142.07	39.46	16058.77	898.44	3.60	0.00	0.00	0.00
SAVI	Sept 20	2	12	13	7083	52.72	29.49	0.56	39.51	26.36	2.46	0.04	0.01	4725.31	440.48	7.71	0.00	0.00	0.00
SPVI	Sept 20	2	12	13	7083	1150265.20	388029.67	13082.17	662658.95	575132.60	32335.81	1006.32	93.56	6147.45	345.63	10.76	0.00	0.00	0.00
SR	Sept 20	2	12	13	7083	25737.48	8929.11	53.08	14885.78	12868.74	744.09	4.08	2.10	6123.25	354.06	1.94	0.00	0.00	0.02
SR1	Sept 20	2	12	13	7083	1428.72	425.90	3.00	503.54	714.36	35.49	0.23	0.07	10048.45	499.23	3.25	0.00	0.00	0.00
SR2	Sept 20	2	12	13	7083	6037.78	2027.97	12.51	2550.76	3018.89	169.00	0.96	0.36	8382.91	469.27	2.67	0.00	0.00	0.00
SR3	Sept 20	2	12	13	7083	4826.67	2525.94	33.89	4849.40	2413.34	210.49	2.61	0.68	3524.90	307.45	3.81	0.00	0.00	0.00
SR4	Sept 20	2	12	13	7083	343.02	2507.23	71.98	6253.54	171.51	208.94	5.54	0.88	194.26	236.65	6.27	0.00	0.00	0.00
SR5	Sept 20	2	12	13	7083	5.51	9.50	0.29	19.31	2.75	0.79	0.02	0.00	1010.19	290.41	8.07	0.00	0.00	0.00
SR6	Sept 20	2	12	13	7083	306.91	81.89	0.56	95.83	153.45	6.82	0.04	0.01	11341.80	504.40	3.20	0.00	0.00	0.00
SR8	Sept 20	2	12	13	7083	1.39	4.44	0.25	16.81	0.70	0.37	0.02	0.00	293.80	155.94	8.24	0.00	0.00	0.00
Sum_Dr1	Sept 20	2	12	13	7083	261562.05	289941.05	12602.45	525997.53	130781.02	24161.75	969.42	74.26	1761.08	325.36	13.05	0.00	0.00	0.00
Sum_Dr2	Sept 20	2	12	13	7083	1052457.50	348589.65	5920.17	355350.11	526228.75	29049.14	455.40	50.17	10489.03	579.02	9.08	0.00	0.00	0.00
TCARI	Sept 20	2	12	13	7083	364017.71	719820.07	18023.62	1569172.22	182008.86	59985.01	1386.43	221.54	821.56	270.76	6.26	0.00	0.00	0.00
TCARI/OSAVI	Sept 20	2	12	13	7083	1168010.81	1624606.20	19027.76	2442807.06	584005.40	135383.85	1463.67	344.88	1693.34	392.55	4.24	0.00	0.00	0.00
TCARI2	Sept 20	2	12	13	7083	2356153.91	553763.83	3485.52	345074.39	1178076.96	46146.99	268.12	48.72	24181.22	947.21	5.50	0.00	0.00	0.00
TCARI2/OSAVI2	Sept 20	2	12	13	7083	11508981.30	9551785.06	28326.06	9175077.28	5754490.65	795982.09	2178.93	1295.37	4442.37	614.48	1.68	0.00	0.00	0.06
TGI	Sept 20	2	12	13	7083	185651654.87	457038424.73	22358919.45	762632748.10	92825827.43	38086535.39	1719916.88	107670.87	862.13	353.73	15.97	0.00	0.00	0.00
TVI	Sept 20	2	12	13	7083	1947880637.93	1725764970.75	59222353.13	2341229121.16	973940318.97	143813747.56	4555565.63	330542.02	2946.49	435.08	13.78	0.00	0.00	0.00
Vogelmann	Sept 20	2	12	13	7083	44.28	9.21	0.06	9.94	22.14	0.77	0.00	0.00	15778.70	546.88	3.03	0.00	0.00	0.00
Vogelmann2	Sept 20	2	12	13	7083	1.14	0.32	0.00	0.48	0.57	0.03	0.00	0.00	8313.74	396.20	3.24	0.00	0.00	0.00
Vogelmann3	Sept 20	2	12	13	7083	140.67	38.96	1.12	78.63	70.33	3.25	0.09	0.01	6335.44	292.44	7.75	0.00	0.00	0.00
Vogelmann4	Sept 20	2	12	13	7083	1.31	0.39	0.00	0.57	0.66	0.03	0.00	0.00	8162.96	401.59	3.12	0.00	0.00	0.00
Boochs	Sept 30	2	12	14	6641	9853.51	48597.14	1234.53	5725.00	4926.76	4049.76	88.18	0.86	5715.04	4697.73	102.29	0.00	0.00	0.00
Boochs2	Sept 30	2	12	14	6641	452.71	12556.79	796.12	5173.31	226.35	1046.40	56.87	0.78	290.57	1343.27	73.00	0.00	0.00	0.00
CARI	Sept 30	2	12	14	6640	77230682.42	113295496.40	1589870.30	20901423.12	38615341.21	9441291.37	113562.16	3147.80	12267.39	2999.33	36.08	0.00	0.00	0.00
Carter2	Sept 30	2	12	14	6640	61.86	30.55	0.51	33.76	30.93	2.55	0.04	0.01	6083.87	500.79	7.11	0.00	0.00	0.00
Carter3	Sept 30	2	12	14	6640	13.00	12.90	0.28	15.65	6.50	1.07	0.02	0.00	2757.92	455.82	8.45	0.00	0.00	0.00
Carter4	Sept 30	2	12	14	6640	50.52	18.55	0.35	22.66	25.26	1.55	0.02	0.00	7402.28	452.92	7.26	0.00	0.00	0.00
Carter5	Sept 30	2	12	14	6640	248.23	2653.40	76.45	4309.62	124.12	221.12	5.46	0.65	191.23	340.68	8.41	0.00	0.00	0.00
Carter6	Sept 30	2	12	14	6641	577561.61	849171.57	15769.85	253759.18	288780.80	70764.30	1126.42	38.21	7557.53	1851.94	29.48	0.00	0.00	0.00
CI	Sept 30	2	12	14	6640	18.93	7.88	0.27	28.67	9.46	0.66	0.02	0.00	2192.36	152.09	4.53	0.00	0.00	0.00
CI2	Sept 30	2	12	14	6640	1344.02	697.56	14.81	609.06	672.01	58.13	1.06	0.09	7326.31	633.74	11.54	0.00	0.00	0.00
ClAInt	Sept 30	2	12	14	6641	1876414580.28	1803351580.23	21333103.67	461216678.32	938207290.14	150279298.35	1523793.12	69449.88	13509.13	2163.85	21.94	0.00	0.00	0.00
CRI1	Sept 30	2	12	14	6640	19.02	60.41	4.28	261.74	9.51	5.03	0.31	0.04	241.28	127.72	7.75	0.00	0.00	0.00
CRI2	Sept 30	2	12	14	6640	36.65	142.03	6.32	308.41	18.33	11.84	0.45	0.05	394.57	254.82	9.72	0.00	0.00	0.00
CRI3	Sept 30	2	12	14	6640	681.90	3217.57	211.23	5416.02	340.95	268.13	15.09	0.82	418.00	328.73	18.50	0.00	0.00	0.00
CRI4	Sept 30	2	12	14	6640	854.91	298.48	19.60	638.70	427.46	24.87	1.40	0.10	4443.87	258.58	14.56	0.00	0.00	0.00
D1	Sept 30	2	12	14	6640	68.41	118.50	2.64	162.80	34.20	9.87	0.19	0.02	1395.12	402.77	7.69	0.00	0.00	0.00
D2	Sept 30	2	12	14	6640	15508.19	52121.00	8905.77	23052209.99	7754.09	4343.42	636.13	3471.72	2.23	1.25	0.18	0.11	0.24	1.00
Datt	Sept 30	2	12	14	6640	62.76	12.57	1.05	33.62	31.38	1.05	0.07	0.01	6196.76	206.85	14.78	0.00	0.00	0.00
Datt2	Sept 30	2	12	14	6640	242.96	83.39	6.43	162.80	121.48	6.95	0.46	0.02	4954.61	283.44	18.74	0.00	0.00	0.00
Datt3	Sept 30	2	12	14	6640	414.52	65.97	4.99	144.34	207.26	5.50	0.36	0.02	9534.40	252.91	16.39	0.00	0.00	0.00
Datt4	Sept 30	2	12	14	6640	0.23	1.82	0.08	0.68	0.12	0.15	0.01	0.00	1127.21	1472.83	54.85	0.00	0.00	0.00
Datt5	Sept 30	2	12	14	6640	323.51	324.00	5.17	225.22	161.76	27.00	0.37	0.03	4768.85	796.02	10.89	0.00	0.00	0.00
Datt6	Sept 30	2	12	14	6640	110.72	399.05	8.56	133.85	55.36	33.25	0.61	0.02	2746.33	1649.65	30.33	0.00	0.00	0.00
DD	Sept 30	2	12	14	6641	1123462.24	1303548.35	10623.27	376266.56	561731.12	108629.03	758.80	56.66	9914.40	1917.27	13.39	0.00	0.00	0.00
DDn	Sept 30	2	12	14	6641	6125111.30	6841598.81	172983.79	1282826.45	3062555.65	570133.23	12355.98	193.17	15854.39	2951.49	63.97	0.00	0.00	0.00
DPI	Sept 30	2	12	14	6640	66.97	132.59	3.96	341.30	33.48	11.05	0.28	0.05	651.41	214.96	5.50	0.00	0.00	0.00
DWSI4	Sept 30	2	12	14	6640	1086.23	433.45	13.53	299.11	543.11	36.12	0.97	0.05	12056.65	801.85	21.46	0.00	0.00	0.00
EGFN	Sept 30	2	12	14	6640	32.13	9.76	1.83	27.45	16.06	0.81	0.13	0.00	3885.63	196.81	31.57	0.00	0.00	0.00
EGFR	Sept 30	2	12	14	6640	8363.66	3451.02	383.39	7884.13	4181.83	287.59	27.38	1.19	3521.93	242.20	23.06	0.00	0.00	0.00
EVI	Sept 30	2	12	14	6641	180347.66	2324671.11	5392491.41	2099469161.69	90173.83	193722.59	385177.96	316137.50	0.29	0.61	1.22	0.75	0.83	0.25
GI	Sept 30	2	12	14	6640	1421.88	692.52	19.45	585.81	710.94	57.71	1.39	0.09	8058.37	654.14	15.75	0.00	0.00	0.00
Gitelson	Sept 30	2	12	14	6640	10.03	20.88	0.74	3.24	5.01	1.74	0.05	0.00	10284.27	3569.57	108.89	0.00	0.00	0.00
Gitelson2	Sept 30	2	12	14	6640	81438.65	44660.93	2187.96	28533.52	40719.33	3721.74	156.28	4.30	9475.74	866.08	36.37	0.00	0.00	0.00
GMI1	Sept 30	2	12	14	6640	1706.00	4095.50	174.17	5976.15	853.00	341.29	12.44	0.90	947.75	379.20	13.82	0.00	0.00	0.00
GMI2	Sept 30	2	12	14	6640	1251.97	688.15	13.29	580.90	625.98	57.35	0.95	0.09	7155.38	655.50	10.85	0.00	0.00	0.00
Green NDVI	Sept 30	2	12	14	6640	1.76	12.48	0.85	20.70	0.88	1.04	0.06	0.00	281.84	333.62	19.46	0.00	0.00	0.00
Maccioni	Sept 30	2	12	14	6640	57.88	14.08	0.47	27.70	28.94	1.17	0.03	0.00	6936.76	281.22	8.04	0.00	0.00	0.00
MCARI	Sept 30	2	12	14	6640	16371961.33	41731768.89	696512.14	8779402.00	8185980.66	3477647.41	49750.87	1322.20	6191.19	2630.20	37.63	0.00	0.00	0.00
MCARI2	Sept 30	2	12	14	6640	363231.03	1347439.08	68919.71	384265.59	181615.52	112286.59	4922.84	57.87	3138.26	1940.28	85.07	0.00	0.00	0.00
MPRI	Sept 30	2	12	14	6640	211775.21	246302.47	4724.11	101526.83	105887.61	20525.21	337.44	15.29	6925.20	1342.38	22.07	0.00	0.00	0.00
MSAVI	Sept 30	2	12	14	6640	9.76	14.51	0.19	16.26	4.88	1.21	0.01	0.00	1992.28	493.67	5.55	0.00	0.00	0.00
mSR2	Sept 30	2	12	14	6640	726.25	384.71	5.96	315.42	363.13	32.06	0.43	0.05	7644.25	674.89	8.96	0.00	0.00	0.00
MTCI	Sept 30	2	12	14	6640	465.49	220.68	3.07	206.74	232.74	18.39	0.22	0.03	7474.97	590.63	7.04	0.00	0.00	0.00
MTVI	Sept 30	2	12	14	6640	12795954.57	24646406.29	596811.16	3337074.35	6397977.29	2053867.19	42629.37	502.57	12730.48	4086.72	84.82	0.00	0.00	0.00

Supplementary Table 1. (Continue)

NDVI	Sept 30	2	12	14	6640	37.25	30.43	0.54	33.56	18.63	2.54	0.04	0.01	3684.96	501.74	7.61	0.00	0.00	0.00
NDVI2	Sept 30	2	12	14	6640	37.77	17.44	0.24	16.02	18.89	1.45	0.02	0.00	7827.93	602.21	7.08	0.00	0.00	0.00
NDVI3	Sept 30	2	12	14	6640	154.70	72.07	1.88	42.92	77.35	6.01	0.13	0.01	11965.41	929.03	20.78	0.00	0.00	0.00
OSAVI	Sept 30	2	12	14	6640	26.64	37.55	0.65	42.78	13.32	3.13	0.05	0.01	2066.88	485.63	7.25	0.00	0.00	0.00
OSAVI2	Sept 30	2	12	14	6640	50.00	22.94	0.32	21.34	25.00	1.91	0.02	0.00	7778.17	594.83	7.16	0.00	0.00	0.00
PARS	Sept 30	2	12	14	6639	9547.95	14054.63	767.50	31617.97	4773.98	1171.22	54.82	4.76	1002.42	245.93	11.51	0.00	0.00	0.00
PRI	Sept 30	2	12	14	6639	14.50	7.94	0.19	8.04	7.25	0.66	0.01	0.00	5985.82	546.66	11.44	0.00	0.00	0.00
PRI_norm	Sept 30	2	12	14	6639	0.05	0.08	0.00	0.05	0.02	0.01	0.00	0.00	3107.85	858.02	9.19	0.00	0.00	0.00
PRI*CI2	Sept 30	2	12	14	6639	9.84	15.37	0.35	18.78	4.92	1.28	0.02	0.00	1739.19	452.78	8.83	0.00	0.00	0.00
PSRI	Sept 30	2	12	14	6639	21.93	16.74	0.26	9.27	10.96	1.40	0.02	0.00	7854.23	999.62	13.28	0.00	0.00	0.00
PSSR	Sept 30	2	12	14	6639	19673.41	22382.38	1130.06	28044.96	9836.70	1865.20	80.72	4.22	2328.61	441.54	19.11	0.00	0.00	0.00
PSND	Sept 30	2	12	14	6639	0.08	4.67	0.38	14.11	0.04	0.39	0.03	0.00	18.93	183.22	12.86	0.00	0.00	0.00
RDVI	Sept 30	2	12	14	6639	11326.21	24994.63	877.40	2168.06	5663.11	2082.89	62.67	0.33	17341.49	6378.19	191.91	0.00	0.00	0.00
REP_Li	Sept 30	2	12	14	6639	265738.63	131930.69	1919.70	317092.54	132869.31	10994.22	137.12	47.76	2781.90	230.19	2.87	0.00	0.00	0.00
SAVI	Sept 30	2	12	14	6639	39.51	61.13	1.20	69.48	19.75	5.09	0.09	0.01	1887.49	486.70	8.22	0.00	0.00	0.00
SPVI	Sept 30	2	12	14	6639	10084591.18	15585576.69	364172.04	1927776.37	5042295.59	1298798.06	26012.29	290.37	17364.98	4472.88	89.58	0.00	0.00	0.00
SR	Sept 30	2	12	14	6639	22179.79	18668.98	572.28	20234.69	11089.90	1555.75	40.88	3.05	3638.59	510.44	13.41	0.00	0.00	0.00
SR1	Sept 30	2	12	14	6639	1248.40	684.18	13.10	577.26	624.20	57.02	0.94	0.09	7178.91	655.73	10.76	0.00	0.00	0.00
SR2	Sept 30	2	12	14	6639	5754.30	3566.67	103.10	3397.74	2877.15	297.22	7.36	0.51	5621.79	580.76	14.39	0.00	0.00	0.00
SR3	Sept 30	2	12	14	6639	1710.79	4072.57	173.65	5942.70	855.39	339.38	12.40	0.90	955.62	379.15	13.86	0.00	0.00	0.00
SR4	Sept 30	2	12	14	6639	1009.84	4806.80	146.50	7621.00	504.92	400.57	10.46	1.15	439.86	348.95	9.12	0.00	0.00	0.00
SR5	Sept 30	2	12	14	6639	14.94	28.40	0.36	26.93	7.47	2.37	0.03	0.00	1841.74	583.47	6.31	0.00	0.00	0.00
SR6	Sept 30	2	12	14	6639	270.69	141.75	2.20	117.62	135.35	11.81	0.16	0.02	7639.55	666.75	8.85	0.00	0.00	0.00
SR8	Sept 30	2	12	14	6639	3.17	11.16	0.26	18.68	1.59	0.93	0.02	0.00	564.01	330.46	6.72	0.00	0.00	0.00
Sum_Dr1	Sept 30	2	12	14	6639	5927009.38	9697362.85	256841.09	1402258.25	2963504.69	808113.57	18345.79	211.22	14030.73	3826.02	86.86	0.00	0.00	0.00
Sum_Dr2	Sept 30	2	12	14	6639	3589447.99	6734517.00	167789.13	661540.69	1794724.00	561209.75	11984.94	99.64	18011.25	5632.11	120.28	0.00	0.00	0.00
TCARI	Sept 30	2	12	14	6639	1925079.98	2820026.13	43213.95	2027091.91	962539.99	235002.18	3086.71	305.33	3152.45	769.66	10.11	0.00	0.00	0.00
TCARI/OSAVI	Sept 30	2	12	14	6639	3829097.82	5382640.25	46713.44	3549515.49	1914548.91	448553.35	3336.67	534.65	3580.96	838.97	6.24	0.00	0.00	0.00
TCARI2	Sept 30	2	12	14	6639	231814.82	1351391.30	45166.43	386082.49	115907.41	112615.94	3226.17	58.15	1993.12	1936.52	55.48	0.00	0.00	0.00
TCARI2/OSAVI2	Sept 30	2	12	14	6639	5573196.69	18237286.44	589483.11	19916473.51	2786598.35	1519773.87	42105.94	2999.92	928.89	506.60	14.04	0.00	0.00	0.00
TGI	Sept 30	2	12	14	6639	984393027.60	2852603562.57	60855938.56	873517904.49	492196513.80	237716963.55	4346852.75	131573.72	3740.84	1806.72	33.04	0.00	0.00	0.00
TVI	Sept 30	2	12	14	6639	12794442412.98	31390104790.64	710763336.72	3167684374.16	6397221206.49	2615842065.89	50768809.77	477132.76	13407.63	5482.42	106.40	0.00	0.00	0.00
Vogelmann	Sept 30	2	12	14	6639	30.69	17.97	0.24	17.05	15.34	1.50	0.02	0.00	5975.81	583.31	6.66	0.00	0.00	0.00
Vogelmann2	Sept 30	2	12	14	6639	7.82	0.83	0.03	1.07	3.91	0.07	0.00	0.00	24263.99	428.37	12.42	0.00	0.00	0.00
Vogelmann3	Sept 30	2	12	14	6639	113.86	139.32	2.24	136.40	56.93	11.61	0.16	0.02	2770.91	565.10	7.77	0.00	0.00	0.00
Vogelmann4	Sept 30	2	12	14	6639	8.74	0.95	0.03	1.19	4.37	0.08	0.00	0.00	24294.49	441.18	11.97	0.00	0.00	0.00

Supplementary Table 2. VI factor loads on significant components for *Q. robur*, *Q. macrocarpa*, *Q. rubra*

VI	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8	Comp.9
				Sept 05					
Boochs		0.202	0.126					-	-
Boochs2		0.233			0.134			-	-
CARI	0.124		0.119	0.156				-	-
Carter2	0.140							-	-
Carter3	0.138				-0.137			-	-
Carter4	0.144							-	-
Carter5		-0.169	0.243		0.145	0.113		-	-
Carter6	0.127	0.119			-0.159			-	-
CI		0.112		-0.101	-0.182	-0.309		-	-
CI2	-0.142							-	-
ClAInt	0.123	0.129		0.135				-	-
CRI1	-0.102	-0.133		0.162		-0.107		-	-
CRI2	-0.108	-0.128		0.187				-	-
CRI3	0.133			-0.181				-	-
CRI4	0.141							-	-
D1	-0.133				-0.114			-	-
D2				0.152	-0.127	0.150		-	-
Datt	-0.142							-	-
Datt2	-0.143							-	-
Datt3				0.134		-0.132		-	-
Datt4	-0.114		-0.177		-0.100			-	-
Datt5		0.109	-0.292	0.122	0.104			-	-
Datt6	-0.127			0.170	-0.146			-	-
DD	-0.136			-0.143				-	-
DDn		-0.278						-	-
DPI					0.232	0.208		-	-
DWSI4			0.260	-0.189	-0.243			-	-
EGFN	-0.102	0.115		0.155				-	-
EGFR	-0.103			0.180				-	-
EVI							-0.990	-	-
GI			0.283	-0.136	-0.168			-	-
Gitelson	-0.131				-0.191			-	-
Gitelson2		0.176			0.206	-0.106		-	-
GMI1	-0.134			0.174				-	-
GMI2	-0.142				-0.104			-	-
Green NDVI	-0.140				0.156			-	-
Maccioni	-0.142							-	-
MCARI	0.113		0.176	0.139		0.120		-	-
MCARI2	-0.109	0.181						-	-
MPRI	0.123	0.140			-0.133			-	-
MSAVI	-0.119		0.182		0.105			-	-
mSR2	-0.143							-	-
MTCI	-0.140							-	-
MTVI		0.215	0.122					-	-
NDVI	-0.134		0.133					-	-
NDVI2	-0.144							-	-
NDVI3			-0.238	0.224	0.259			-	-
OSAVI	-0.121		0.181					-	-
OSAVI2	-0.144							-	-
PARS	-0.121		0.102	0.210				-	-
PRI	-0.114			-0.177		0.346		-	-
PRI_norm	0.108			0.177		-0.38		-	-
PRI*CI2					-0.168	0.573		-	-
PSRI	0.106			0.254				-	-
PSSR	-0.135			0.126				-	-
PSND			0.177	0.193	0.140			-	-
RDVI		0.238	0.162					-	-
REP_Li	-0.133			-0.141				-	-
SAVI	-0.120		0.183		0.101			-	-
SPVI		0.245		0.114				-	-
SR	-0.131		0.118	0.106				-	-
SR1	-0.142				-0.104			-	-
SR2	-0.140				-0.126			-	-
SR3	-0.134			0.174				-	-
SR4		-0.159	0.260		0.129			-	-
SR5		0.149	-0.277		-0.101			-	-
SR6	-0.143							-	-
SR8			-0.234	-0.115		0.226		-	-
Sum_Dr1		0.215	0.105	0.110				-	-
Sum_Dr2		0.250	0.111					-	-
TCARI	0.124	0.130			-0.179			-	-
TCARI/OSAVI	0.125	0.118			-0.188			-	-
TCARI2		0.198		-0.259	0.169			-	-
TCARI2/OSAVI2	0.114	0.132						-	-
TGI	0.126		0.107		-0.171			-	-
TVI		0.221	0.123					-	-
Vogelmann	-0.143				-0.104			-	-
Vogelmann2	0.138				0.157			-	-
Vogelmann3	-0.133							-	-
Vogelmann4	0.138				0.165			-	-

Supplementary Table 2. (Continue)

				Sept 13					
Boochs		0.247			0.126				-
Boochs2		0.190							-
CARI	0.117		0.136	-0.141					-
Carter2	0.148			-0.104					-
Carter3	0.144				-0.134	-0.120			-
Carter4	0.151								-
Carter5			0.265			0.159			-
Carter6	0.116	0.155			-0.148				-
CI				0.107		-0.306		0.285	-
CI2	-0.149				-0.100				-
ClAInt	0.116	0.149		-0.171					-
CRI1		-0.156	0.173			-0.144			-
CRI2		-0.177	0.136	-0.116					-
CRI3	0.143			0.185					-
CRI4	0.146				0.105				-
D1	-0.133							-0.137	-
D2	0.132			-0.101	-0.106			0.106	-
Datt	-0.144				0.106				-
Datt2	-0.149								-
Datt3				-0.195		-0.226		-0.692	-
Datt4		-0.158	-0.165						-
Datt5			-0.269	-0.12	0.180				-
Datt6	-0.117	-0.135		-0.125					-
DD	-0.145			0.101					-
DDn		-0.222							-
DPI						0.286		-0.249	-
DWSI4			0.220	0.184	-0.164	-0.197			-
EGFN	-0.111			-0.234				0.249	-
EGFR	-0.112			-0.246		0.116		0.218	-
EVI							-0.998		-
GI			0.259	0.151	-0.153	-0.134			-
Gitelson	-0.117	-0.148			-0.145				-
Gitelson2		0.112			0.274				-
GMI1	-0.143			-0.177				0.114	-
GMI2	-0.149				-0.101				-
Green NDVI	-0.145				0.202				-
Maccioni	-0.148								-
MCARI			0.191	-0.109		0.146			-
MCARI2	-0.125	0.137							-
MPRI		0.165			-0.148				-
MSAVI	-0.115		0.182						-
mSR2	-0.150								-
MTCI	-0.144								-
MTVI		0.251		-0.101					-
NDVI	-0.137		0.116						-
NDVI2	-0.151								-
NDVI3		-0.102	-0.188	-0.211	0.172	0.215			-
OSAVI	-0.116		0.185						-
OSAVI2	-0.151								-
PARS	-0.108		0.167	-0.198	0.109				-
PRI	-0.126			0.156	-0.160	0.255			-
PRI_norm	0.121			-0.154	0.194	-0.300			-
PRI*CI2					-0.390	0.350			-
PSRI	0.124			-0.259					-
PSSR	-0.138			-0.11				0.101	-
PSND			0.226	-0.165	0.105				-
RDVI		0.236		-0.1					-
REP_Li	-0.141			0.177	0.158				-
SAVI	-0.115		0.185						-
SPVI		0.248		-0.142	0.132				-
SR	-0.131		0.130			-0.122			-
SR1	-0.149				-0.101				-
SR2	-0.147								-
SR3	-0.143			-0.177				0.114	-
SR4			0.274			0.130			-
SR5			-0.285					-0.102	-
SR6	-0.150								-
SR8			-0.249	0.105		0.181			-
Sum_Dr1		0.247		-0.151					-
Sum_Dr2		0.252							-
TCARI	0.104	0.159			-0.131	-0.172			-
TCARI/OSAVI	0.113	0.132			-0.145	-0.182			-
TCARI2		0.210		0.219	0.233				-
TCARI2/OSAVI2		0.193		0.131					-
TGI	0.116	0.122			-0.195				-
TVI		0.253							-
Vogelmann	-0.149								-
Vogelmann2	0.143								-
Vogelmann3	-0.138							-0.135	-
Vogelmann4	0.143								-

Supplementary Table 2. (Continue)

				Sept 20					
Boochs	0.104	0.167						-	-
Boochs2	0.134							-	-
CARI		0.204	-0.102	0.168				-	-
Carter2	-0.142							-	-
Carter3	-0.138							-	-
Carter4	-0.141							-	-
Carter5		0.168	-0.269					-	-
Carter6	-0.103	0.137	0.158		-0.111	-0.154		-	-
CI	0.105		0.186			-0.119		-	-
CI2	0.141							-	-
ClAInt	-0.121		0.124	0.170	-0.128			-	-
CRI1			-0.248		-0.220	-0.123		-	-
CRI2		-0.106	-0.239		-0.121			-	-
CRI3	-0.126			-0.147				-	-
CRI4	-0.140							-	-
D1	0.110			-0.108				-	-
D2				0.182		-0.152		-	-
Datt	0.123	-0.105		-0.107	-0.102			-	-
Datt2	0.135							-	-
Datt3		-0.123			-0.297	0.172		-	-
Datt4		-0.293						-	-
Datt5		-0.210		0.118				-	-
Datt6	0.118	-0.128				-0.123		-	-
DD	0.132			-0.102				-	-
DDn	-0.108		-0.209		0.130			-	-
DPI						0.415		-	-
DWSI4	0.112	0.149		-0.148		-0.122		-	-
EGFN		-0.141		0.373	0.138			-	-
EGFR		-0.141		0.371	0.130			-	-
EVI							0.995	-	-
GI	0.101	0.177		-0.154				-	-
Gitelson	0.127	-0.106				-0.107		-	-
Gitelson2			0.163		-0.359	0.407		-	-
GMI1	0.127			0.147				-	-
GMI2	0.141							-	-
Green NDVI	0.130			0.103		0.130		-	-
Maccioni	0.134							-	-
MCARI		0.238	-0.165	0.121				-	-
MCARI2	0.138							-	-
MPRI			0.215			-0.104		-	-
MSAVI	0.122	0.110	-0.104		0.102			-	-
mSR2	0.141							-	-
MTCI	0.137							-	-
MTVI		0.223	0.119	0.138				-	-
NDVI	0.139							-	-
NDVI2	0.142							-	-
NDVI3	-0.113	-0.141		0.170		0.130		-	-
OSAVI	0.125	0.103	-0.105					-	-
OSAVI2	0.142							-	-
PARS	0.121		-0.144	0.101	-0.148			-	-
PRI	0.129				0.166			-	-
PRI_norm	-0.116	-0.116			-0.276			-	-
PRI*CI2	0.115			0.147		-0.247		-	-
PSRI	-0.126				-0.194			-	-
PSSR	0.134					-0.114		-	-
PSND			-0.230		-0.231			-	-
RDVI	0.117	0.155		0.121				-	-
REP_Li	0.131			-0.163		0.130		-	-
SAVI	0.126	0.104	-0.104					-	-
SPVI		0.127	0.136	0.234				-	-
SR	0.139					-0.121		-	-
SR1	0.141							-	-
SR2	0.140					-0.122		-	-
SR3	0.127			0.147				-	-
SR4		0.158	-0.249					-	-
SR5		-0.163	0.180					-	-
SR6	0.140							-	-
SR8		-0.132	0.188	0.133	0.416	0.149		-	-
Sum_Dr1		0.203	0.132	0.262	-0.130			-	-
Sum_Dr2	0.112	0.139	0.120	0.114				-	-
TCARI			0.239			-0.200		-	-
TCARI/OSAVI	-0.102		0.213		-0.130	-0.206		-	-
TCARI2	0.125		0.118			0.112		-	-
TCARI2/OSAVI2		0.138		-0.246		0.163		-	-
TGI		0.226			-0.174	-0.159		-	-
TVI		0.222	0.114	0.152				-	-
Vogelmann	0.138							-	-
Vogelmann2	-0.131				0.112			-	-
Vogelmann3	0.127							-	-
Vogelmann4	-0.131				0.110			-	-

Supplementary Table 2. (Continue)

				Sept 30					
Boochs		0.195							
Boochs2		0.106	0.103		0.306		0.173		
CARI		0.166							
Carter2	0.163								
Carter3	0.147		-0.144						
Carter4	0.155		0.130						
Carter5			0.208		-0.213	-0.171			
Carter6	0.103	0.174				0.129			
CI				-0.167	0.242	0.298	0.214		
CI2	-0.166								
ClAInt	0.127	0.138				0.152			
CRI1	-0.108				-0.258	0.205	0.239		
CRI2	-0.115				-0.245	0.206	0.210		
CRI3			-0.100	-0.309	-0.154				
CRI4	0.133		0.109		-0.147		0.150		
D1	-0.110						0.281		
D2								0.219	-0.947
Datt			-0.255	0.186		-0.140			
Datt2	-0.121		-0.200	0.145					
Datt3			-0.231	0.212		-0.131			
Datt4		-0.140			-0.128	0.144	0.124		
Datt5		-0.142		0.170					
Datt6	-0.134				-0.206	0.208			
DD	-0.123	-0.129			0.103	-0.135			
DDn		-0.170							
DPI			-0.122	0.108			-0.288	0.208	0.159
DWSI4	-0.121	0.135		-0.151					
EGFN			0.179	0.167	0.246	0.182	-0.133		
EGFR			0.159	0.180	0.250	0.189	-0.151		
EVI								-0.901	-0.188
GI	-0.116	0.139		-0.124	-0.111				
Gitelson	-0.137				-0.220	0.191			
Gitelson2		0.139	-0.114	0.127					
GMI1			0.137	0.255	0.111				
GMI2	-0.170								
Green NDVI				0.322					
Maccioni	-0.106		-0.235	0.120		-0.105			
MCARI		0.175							
MCARI2		0.173			0.228		0.136		
MPRI	0.110	0.159				0.153			
MSAVI	-0.123	0.122	0.126			-0.134			
mSR2	-0.171								
MTCI	-0.149		-0.180						
MTVI		0.194							
NDVI	-0.149	0.108							
NDVI2	-0.172								
NDVI3	0.112	-0.137		0.198					
OSAVI	-0.126	0.123	0.122			-0.133			
OSAVI2	-0.171								
PARS	-0.111		0.179	0.174			0.230		
PRI	-0.139			-0.145		0.105	-0.169		
PRI_norm	0.107	-0.108	-0.135				0.311		
PRI*CI2	-0.131				-0.101	0.250	-0.231		
PSRI	0.122	-0.117		0.143					
PSSR	-0.158								
PSND			0.130	0.235	-0.120	-0.142	0.110		
RDVI		0.194							
REP_Li	-0.134		-0.139		0.130	-0.148	0.169		
SAVI	-0.121	0.128	0.125			-0.142			
SPVI		0.184							
SR	-0.162								
SR1	-0.170								
SR2	-0.169					0.119			
SR3			0.137	0.255	0.111				
SR4			0.205		-0.186	-0.142			
SR5		-0.108	-0.221						
SR6	-0.169								
SR8		-0.111	-0.144		0.192		-0.316		
Sum_Dr1		0.179				0.101			
Sum_Dr2		0.192							
TCARI	0.103	0.140				0.207			
TCARI/OSAVI	0.115	0.112	-0.112			0.240			
TCARI2		0.190			0.172		0.194		
TCARI2/OSAVI2		0.189					0.185		
TGI		0.197							
TVI		0.195							
Vogelmann	-0.170								
Vogelmann2		-0.111	0.245	-0.137					
Vogelmann3	-0.129								
Vogelmann4		-0.109	0.246	-0.134					

Supplementary Table 3. Projections of VI values for *Q. robur, Q. macrocarpa, Q. rubra*

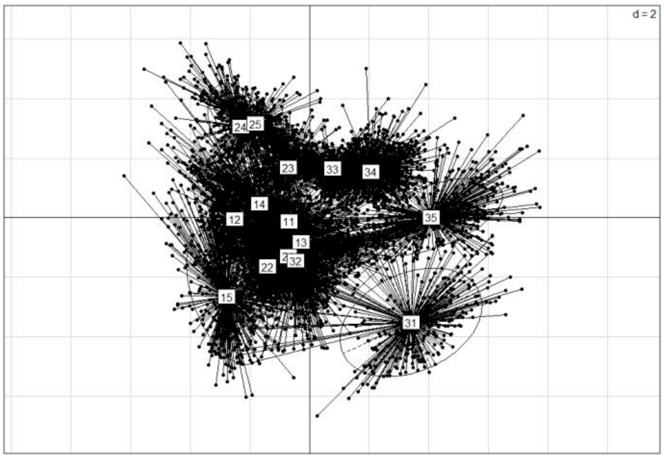

Figure 1. Projections of VI values for Boochs2, CRI3, Datt4, Maccioni, MTCI, NDVI3, PSRI, RDVI, RDVI, REP_Li, SPVI, TCARI2 for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) samples (Sept 05). Numerical designation on the projection: the first digit indicates the view; the second is the sample of the species

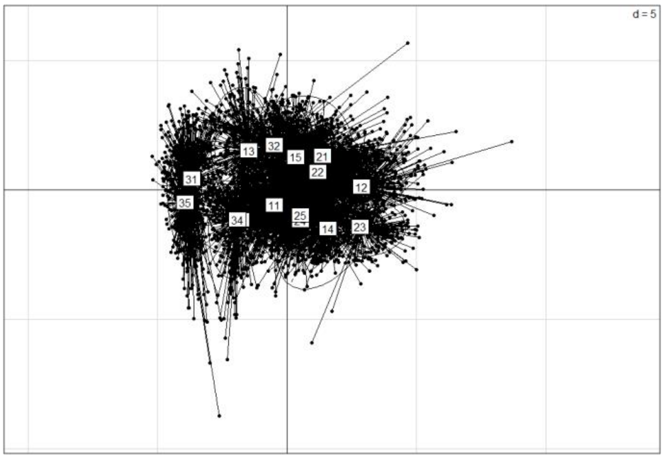

Figure 2. Projections of VI values for Boochs2, CRI3, CRI4, Datt5, DD, DWSI4, Gitelson, MCARI, PRI for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) samples (Sept 13). Numerical designation on the projection: the first digit indicates the view; the second is the sample of the species

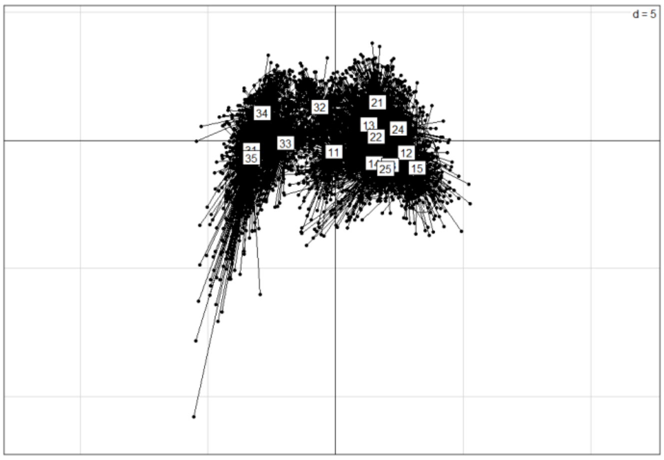

Figure 3. Projections of VI values for Boochs, Carter3, D1, Datt, Datt3, Datt5, Gitelson2, MCARI2, Sum_Dr1, Vogelmann for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) samples (Sept 20). Numerical designation on the projection: the first digit indicates the view; the second is the sample of the species

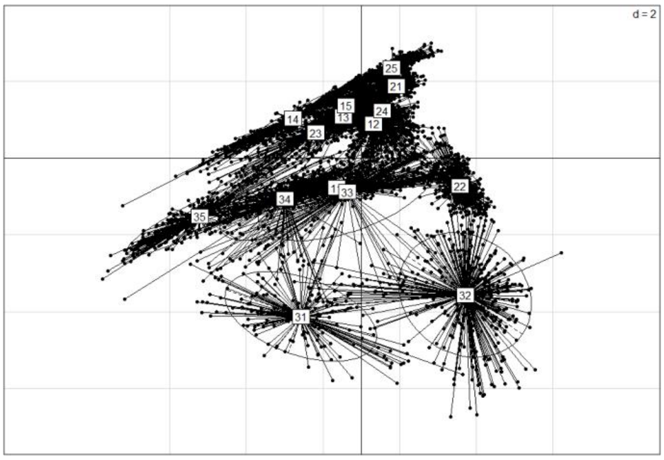

Figure 4. Projections of VI values for Boochs2, Carter6, Datt5, NDVI3, PRI_norm, SPVI, SR5, Sum_Dr1, TCARI2, Vogelmann2 for Q. macrocarpa (1), Q. robur (2), Q. rubra (3) samples (Sept 30). Numerical designation on the projection: the first digit indicates the view; the second is the sample of the species