Leaf Optical Properties EXperiment 93 (LOPEX93)

Database structure

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Introduction

The estimation of leaf biochemistry and leaf water status with remote sensing data is a challenge for the years to come. It also has an important potential in agriculture to follow crop development and yield predictions. The LOPEX database was established by the JRC in 1993 and has been used by researchers throughout the world for more than a decade. In order to have a wide range of variation of leaf internal structure, pigmentation, water content and biochemical components, plant species with different types of leaves were collected during two separate periods during the summer of 1993. About 70 leaf samples representative of more than 50 species were obtained from trees, crops and plants in the area of the JRC, Ispra, Italy. The biochemical constituents of interest in this experiment were lignin, proteins (nitrogen), cellulose and starch, as well as chlorophyll and foliar water. The major processes involved in the terrestrial ecosystem such as photosynthesis, primary production, or foliar decomposition can be related to these constituents. As leaves are the most important surfaces of a plant canopy, relating their optical properties to these constituents is a priority.
The overall objective of the experiment was to investigate the use of high resolution visible and near infrared reflectance spectroscopy for the retrieval of chlorophylls, water, protein, cellulose, lignin, and starch both on fresh and dry material, on individual leaves and on optically thick samples (stacked leaves and needles or powders). To this end, more than two thousand reflectance and transmittance spectra were measured and analysed in this experiment. The data have since been made available in a compact database along with some auxiliary files which describe the structure and organization of the database. The data are maintained and provided by the SERAC unit of the JRC / IPSC.

This short guide describes the structure of the LOPEX database and is intended to aid in navigating the database. More details on the experiment and the measurement methods are given in the original experiment description file: **Leaf Optical Properties EXperiment 93 (LOPEX93)**

Database structure

The overall structure of the classification system is shown below in Figure 1. The bulk of the data files is constituted by the reflectance and transmittance spectra, generated with the root name **OPEX**. Each file has been radiometrically corrected and is expressed in terms of absolute reflectance (as a fraction of 1). The corresponding wavelengths which are identical for all spectra are contained in the file **OPEX.WVL** and are expressed in nanometres (integer values ranging from 400 to 2500). All auxiliary measurements are contained in a separate sub-directory (**auxmeas**).
The complete list of samples is given in Latin (where possible) and English in Tables 1 and 2 respectively. These names are also contained in the files **SAM_LNAM** and **SAM_ENAM.LST**.

A key element in this classification is the association between the **spectrum number** and the relative **auxiliary measurements.** This is the file **SPEC_AUX.DAT**. An explanation of the code employed in this file is given in Table 3.

The association between the **sample number** and the relative **biochemical analyses** is contained in the file **SAM_BIO.DAT**. This file also contains the code indicating the type of sample in question (i.e. monocotyledon, dicotyledon etc). An explanation of the code employed is given in Table 4.

The association between the **sample number** and the relative **spectra** is contained in the file **SAM_SPEC.DAT**. An explanation of the code employed in this file is given in Table 5.

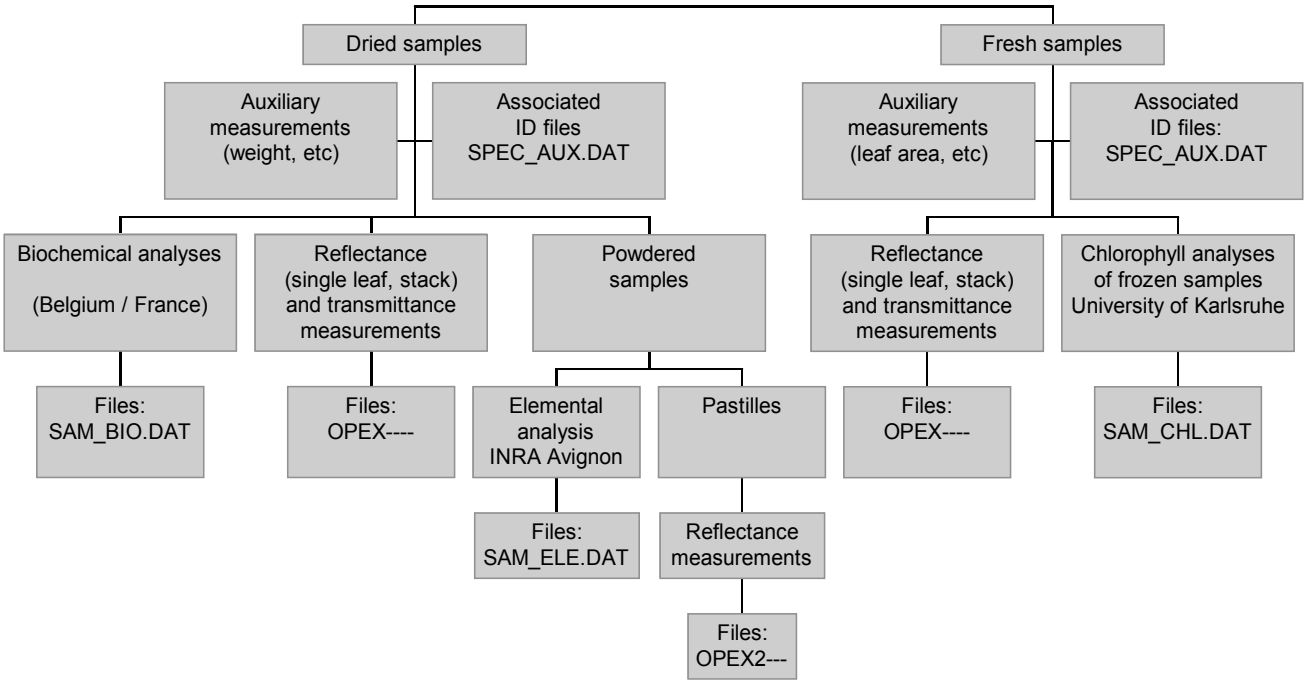
The association between the sample number and the spectrum number can thus be obtained in 2 ways:
1. Indirectly, by means of the spectrum block number in the SAM_BIO and SPEC_AUX files
2. Directly, by means of the SAM_SPEC.DAT file

The results of the chlorophyll and total carotenoids analyses can be found in the file **SAM_PIG.DAT**. An explanation of the code employed in this file is given in Table 6.

The results of the elemental analyses performed at I.N.R.A., Avignon (F) can be found in the file **SAM_ELE.DAT**. An explanation of the code employed in this file is given in Table 7.

The technical specifications and the configuration of the spectrometer are given in Tables 8 and 9.

Fig. 1 Key Elements in LOPEX93



Legal Notice

Conditions of use for LOPEX data

- the LOPEX data will not be used for commercial purposes

- any publication resulting from the use of the LOPEX data will acknowledge the origin of the data set

01	*Trifolium pratense L.*	61	.....
02	*Sorghum halepense*	62	*Corylus avellana L.*
03	*Picea abies*	63	.....
04	*Vitis silvestris*	64	.....
05	*Fraxinus excelsior L.*	65	*Lanugo*
06	*Lactuca sativa*	66	*Amylum solanaceum*
07	*Pseudotsuga menziesii*	67	*Amylum ex oryza*
08	*Prunus laurocerasus*	68	*Amylum ex mays*
09	*Picea abies*	69	*Amylum triticeum*
10	*Populus canadensis*	70	*Furfures triticei*
11	*Medicago sativa L.*	71	*Tilia platyphyllos*
12	*Zea mays L.*	72	*Pinus contorta*
13	*Solanum tuberosum L.*	73	*Populus tremula L.*
14	*Vitis silvestris*	74	*Pseudotsuga menziesii*
15	*Fraxinus excelsior L.*	75	*Quercus pubescens*
16	*Zea mays L.*	76	*Alnus glutinosa*
17	*Pinus contorta*	77	*Zea mays L.*
18	*Psalliota hortensis*	78	*Zea mays L.*
19	*Prunus laurocerasus*	79	*Quercus rubra*
20	*Fagus sylvatica L.*	80	*Zea mays L.*
21	*Laurus nobilis L.*	81	*Zea mays L.*
22	*Robinia pseudoacacia L.*	82	*Quercus rubra*
23	*Quercus pubescens*	83	*Corylus avellana L.*
24	*Helianthus annuus L.*	84	*Castanea sativa*
25	*Tilia platyphyllos*	85	*Acer pseudoplatanus L.*
26	*Zea mays L.*	86	*Salvia officinalis L.*
27	*Juglans regia L.*	87	*Ficus carica L.*
28	*Juglans regia L.*	88	*Bambusa acundinacea*
29	*Populus canadensis*	89	*Chamaerops humilis*
30	*Fagus sylvatica L.*	90	*Phragmites communis*
31	*Laurus nobilis L.*	91	*Bambusa acundinacea*
32	*Robinia pseudoacacia L.*	92	*Armeniaca vulgaris*
33	*Quercus pubescens*	93	*Ulmus glabra*
34	*Zea mays L.*	94	*Hedera helix L.*
35	*Medicago sativa L.*	95	*Zea mays L.*
36	*Beta vulgaris L.*	96	*Picea abies*
37	*Urtica dioica L.*	97	*Robinia pseudoacacia L.*
38	*Picea abies*	98	*Prunus serotina*
39	*Populus canadensis*	99	*Fraxinus excelsior L.*
40	*Oryza sativa*	100	*Brassica oleracea L.*
41	*Phleum pratense L.*	101	*Pinus wallichiana*
42	*Secale cereale*	102	*Iris germanica L.*
43	*Triticum*	103	*Vitis vinifera L.*
44	*Triticum*	104	*Morus alba L.*
45	*Soja hispida*	105	*Salix alba L.*
46	*Beta vulgaris L.*	106	*Vitis vinifera L.*
47	*Triticum*	107	*Musa ensete*
48	*Triticum*	108	*Picea abies*
49	*Secale cereale*	109	*Medicago sativa L.*
50	*Oryza sativa*	110	*Oryza sativa*
51	*Acer pseudoplatanus L.*	111	*Castanea sativa*
52	*Acer pseudoplatanus L.*	112	*Betula alba L.*
53	*Helianthus annuus L.*	113	*Medicago sativa L.*
54	*Armeniaca vulgaris*	114	*Lycopersicum esculentum*
55	*Morus nigra*	115	*Soja hispida*
56	*Platanus acerifolia*	116	*Oryza (foliis siccis)*
57	*Morus nigra*	117	*Oryza (integra-cum glumis)*
58	*Zea mays L.*	118	*Oryza (glumae)*
59	*Castanea sativa*	119	*Oryza (integra)*
60	*Corylus avellana L.*	120	*Oryza (.....)*

Table 1. Latin names of samples

01	Clover	61	Wood shavings
02	*Sorghum halepense*	62	Hazel (2/2)
03	Norway spruce (91)	63	Soy Lecithin
04	Wild vines (1/2)	64	Ecofoam ® (maize)
05	Ash (1/2)	65	Cotton wool
06	Lettuce	66	Potato starch
07	Douglas fir (93)	67	Rice starch
08	Laurel (*ceraso*) old	68	Maize starch
09	Norway spruce (92)	69	Wheat starch
10	Poplar (1/3)	70	Bran
11	Alfalfa	71	Linden
12	Maize (1)	72	Contorta Pine
13	Potato	73	Poplar
14	Wild vines (2/2)	74	Douglas Fir
15	Ash (2/2)	75	Oak
16	Maize 3 (1/2)	76	Alder
17	Contorta Pine	77	Maize (1/2)
18	*Psalliota Hortensis*	78	Maize (dry)
19	Laurel (*ceraso*) young	79	Red oak (1/2)
20	Beech (1/2)	80	Maize (2/2)
21	Laurel (*nobilis*) old (1/2)	81	Maize (half dry)
22	*Pseudo Acacia* (1/2)	82	Red oak (2/2)
23	Oak (1/2)	83	Hazel (2)
24	Sunflower	84	Chestnut (dry)
25	Linden	85	Maple (2)
26	Maize 3 (2/2)	86	Sage
27	Walnut (no stem)	87	Fig
28	Walnut	88	Bamboo (1)
29	Poplar (2/3)	89	Palm
30	Beech (2/2)	90	Lake reeds
31	Laurel (*nobilis*) old (2/2)	91	Bamboo (2)
32	*Pseudo Acacia* (2/2)	92	Apricot (2)
33	Oak (2/2)	93	Elm
34	Maize (stalks)	94	Ivy
35	Alfalfa (stalks)	95	Maize (stalks) (2)
36	Sugar beet (1/2)	96	Norway spruce (93)
37	Nettles	97	*Pseudo Acacia* 2
38	Norway Spruce (93)	98	*Prunus serotina*
39	Poplar (3/3)	99	Ash (2)
40	Rice (1/2)	100	Cabbage
41	*Phleum pratense*	101	Bhutan pine
42	Rye (1/2)	102	Iris
43	Wheat (*salmone*) (1/2)	103	Vine (white)
44	Wheat (*pandas*) (1/2)	104	Mulberry (2)
45	Soy	105	Willow
46	Sugar beet (2/2)	106	Vine (american)
47	Wheat (*pandas*) (2/2)	107	Bananna
48	Wheat (*salmone*) 2/2	108	Norway Spruce (92)
49	Rye (2/2)	109	Alfalfa (stalks) (2)
50	Rice (2/2)	110	Rice (stalks)
51	Maple (1/2)	111	Chestnut (2)
52	Maple (2/2)	112	Birch
53	Sunflower (stalks)	113	Alfalfa (2)
54	Apricot	114	Tomato
55	Mulberry (1/2)	115	Soy (2)
56	Plane (bark)	116	Rice (dry leaves)
57	Mulberry (2/2)	117	Rice (whole grain)
58	Maize (2)	118	Rice (husks)
59	Chestnut	119	Rice (whole grain)
60	Hazel (1/2)	120	Rice (parboiled)

Table 2. English names of samples

[1] : Spectrum number: 0001 - 2307
[2] : Spectrum type : 1 = reflectance 2 = transmittance
[3] : State of sample: 0 = fresh 1 = dry
[4] : Type of sample : 1 = single leaf
2 = stack of leaves (eg. 50 leaves)
3 = material in quartz cuvette (eg. needles)
4 = stalks
5 = optically dense material (eg. bark)
6 = pastilles (compressed powder))
[5] : Spectrum block number: 001 - 103
[6] : Average leaf thickness (microns)
or average of averages in the case of leaf stacks
[7] : Fresh weight (grammes)
[8] : Dry weight (grammes)
[9] : Leaf area used in weighing (cm²)

-1 = Measurement not made or not applicable

Extract from data file: SPEC_AUX.DAT

```
0400 1 1 1 004 208.0 -1.0000 -1.0000 -1.00
0401 2 1 1 004 208.0 -1.0000 -1.0000 -1.00
0402 1 1 2 004 208.0 -1.0000 -1.0000 -1.00
0403 1 0 5 033  -1.0  8.5752  6.8440 -1.00
0404 1 0 5 033  -1.0  8.5752  6.8440 -1.00
0405 1 0 5 033  -1.0  8.5752  6.8440 -1.00
0406 1 0 5 033  -1.0  8.5752  6.8440 -1.00
0407 1 0 5 033  -1.0  8.5752  6.8440 -1.00
0410 1 0 1 034 122.0   .0429   .0147  4.10
0411 2 0 1 034 122.0   .0429   .0147  4.10
0412 1 0 1 034 118.0   .0397   .0119  4.10
0413 2 0 1 034 118.0   .0397   .0119  4.10
0414 1 0 1 034 134.0   .0480   .0157  4.10
0415 2 0 1 034 134.0   .0480   .0157  4.10
0416 1 0 1 034  82.0   .0315   .0079  4.10
0417 2 0 1 034  82.0   .0315   .0079  4.10
0418 1 0 1 034 134.0   .0394   .0149  4.10
0419 2 0 1 034 134.0   .0394   .0149  4.10
0420 1 0 2 034 118.0   .4263   .1223 41.00
0421 1 1 1 002  72.0 -1.0000 -1.0000 -1.00
0422 2 1 1 002  72.0 -1.0000 -1.0000 -1.00
0423 1 1 1 002  90.0 -1.0000 -1.0000 -1.00
0424 2 1 1 002  90.0 -1.0000 -1.0000 -1.00
0425 1 1 1 002 104.0 -1.0000 -1.0000 -1.00
```

Table 3. Explanation of code used in Spec. / Aux. meas. file (SPEC_AUX.DAT)

[01] = sample number (001-120)
[02] = type of sample 1: Monocotyledon
2: Dicotyledon
3: Gymnosperm
0: Other
[03] = sample status 1: Single sample
2: Double sample (first occurence)
3: Triple sample (first occurence)
[04] = associated spectrum block number (SPEC_AUX.DAT)
[05] = Nitrogen % dry weight (France)
[06] = Nitrogen % dry weight (Belgium)
[07] = Cellulose % dry weight (France)
[08] = Cellulose % dry weight (Belgium)
[09] = Lignin % dry weight (France)
[10] = Lignin % dry weight (Belgium)
[11] = Starch % dry weight (France)
[12] = Starch % dry weight (Belgium)

-1.00 = No analysis or not applicable

Extract from SAM_BIO.DAT

001 2 1 026	31.69	31.35	12.10	15.78	3.04	2.16	0.00	2.43
002 1 1 015	24.21	23.69	24.90	30.01	3.45	3.58	0.00	0.40
003 3 1 009	6.26	7.11	25.20	25.49	12.51	12.29	0.00	2.95
004 2 1 038	10.89	11.86	9.10	11.55	4.28	21.29	9.25	5.13
005 2 1 029	20.64	20.41	11.10	14.79	9.25	22.80	0.35	3.89
006 2 1 024	35.52	35.58	12.40	16.82	3.93	1.60	2.74	2.25
007 3 1 012	7.63	7.94	23.50	27.13	10.68	16.44	0.00	0.00
008 2 1 006	7.37	7.42	14.30	16.66	11.92	22.53	0.00	7.28
009 3 1 010	6.06	7.28	25.10	26.76	12.35	14.46	0.00	0.00
010 2 1 019	18.19	17.69	13.90	15.98	9.82	11.34	0.00	1.61
011 2 1 014	33.05	32.66	2.10	11.34	2.68	3.43	3.02	9.99
012 1 1 013	25.31	26.55	21.80	26.60	2.19	3.03	9.42	0.40
013 2 1 032	31.93	30.33	11.00	14.50	2.62	1.09	1.43	3.66
014 2 2 038	13.70	11.96	8.69	10.61	3.49	17.82	8.67	6.17
015 2 2 029	20.66	19.43	11.50	14.98	6.92	19.12	0.94	4.11
016 1 1 039	25.65	24.09	22.60	25.89	2.39	2.75	0.34	0.00
017 3 1 011	7.90	8.58	29.80	32.51	11.34	13.31	0.00	1.63
018 0 1 042	41.07	40.83	10.90	14.15	10.32	6.82	2.17	6.00
019 2 1 005	9.13	9.83	16.80	19.40	13.17	26.22	3.38	4.01
020 2 1 031	16.99	17.01	22.60	25.56	15.56	16.59	0.70	4.86
021 2 1 006	10.48	11.82	21.90	26.81	20.09	16.80	6.73	2.03
022 2 1 002	25.86	25.13	15.30	18.27	17.36	16.73	2.34	6.52
023 2 1 001	17.02	16.17	23.20	26.29	23.31	18.13	0.12	3.64
024 2 1 017	35.75	34.89	8.30	9.06	3.28	12.49	0.00	0.83

Table 4. Explanation of code used in Sample / Biochemical file (SAM_BIO.DAT)

[1] = sample number (001 - 120)
[2 - 6] = reflectance spectrum number of fresh single leaf (eg. OPEX0306)
[7 - 11] = transmittance spectrum number of fresh single leaf (eg. OPEX0307)
[12] = reflectance spectrum number of fresh leaf stack (eg. OPEX0316)
[13 - 17] = reflectance spectrum number of fresh optically thick material
[18 - 22] = reflectance spectrum number of dry single leaf (eg. OPEX0489)
[23 - 27] = transmittance spectrum number of dry single leaf (eg. OPEX490)
[28] = reflectance spectrum number of dry leaf stack (eg. OPEX0499)
[29 - 33] = reflectance spectrum number of dry optically thick material
[34 - 36] = reflectance spectrum number of pastilles (eg. OPEX2005)

-1 = measurement not made or not applicable

Extract from SAM_SPEC.DAT

001 0306 0308 0310 0312 0314 0307 0309 0311 0313 0315 0316 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 2003 2004 2005
002 0163 0165 0167 0169 0171 0164 0166 0168 0170 0172 0173 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 2006 2007 2008
003 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0111 0112 0113 0114 0115 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0437 0438 0439 0440 0441 -1 -1 -1
004 0522 0524 0526 0528 0530 0523 0525 0527 0529 0531 0532 -1 -1 -1 -1 -1 0768 0770 0772 0774 0776 0769 0771 0773 0775 0777 0778 -1 -1 -1 -1 -1 2013 2014 2015
005 0335 0337 0339 0341 0343 0336 0338 0340 0342 0344 0345 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 2016 2017 2018
006 0288 0290 0292 0294 0296 0289 0291 0293 0295 0297 0298 -1 -1 -1 -1 -1 0489 0491 0493 0495 0497 0490 0492 0494 0496 0498 0499 -1 -1 -1 -1 -1 -1 -1 -1
007 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0134 0135 0136 0137 0138 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0745 0746 0747 0748 0749 2019 2020 2021
008 0073 0075 0077 0079 0081 0074 0076 0078 0080 0082 0084 -1 -1 -1 -1 -1 0454 0456 0458 0460 0462 0455 0457 0459 0461 0463 0464 -1 -1 -1 -1 -1 2022 2023 2024
009 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0117 0118 0119 0120 0121 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 0442 0443 0444 0445 0446 2025 2026 2027

Table 5. Explanation of code used in Sample / Spectrum file (SAM_SPEC.DAT)

Note: Special case is sample no.56 (plane bark)
[2-6] = reflectance of inner side of fresh bark
[13-17] = reflectance of outer side of fresh bark
[29-33] = reflectance of outer side of dry bark

[1] = sample number
[2] = type of sample 1: fresh leaf (flmr / flmt / flmri --> 66 spectra)
2: dry leaf (dlmr / dlmt / dlmri --> 60 spectra)
3: fresh needle (fnmr --> 10 spectra)
4: dry needle (dnmr --> 10 spectra)
5: fresh stalk (fsmr --> 12 spectra)
6: dry stalk (dsmr --> 7 spectra)
7: powder (pwmr --> 11 spectra)
[3] = type of plant (1: Monocotyledon 2: Dicotyledon 3: Gymnosperm)
[4-5] = Chlorophyll a content per fresh weight (mg / g)
[6] = average value
[7-8] = Chlorophyll b content per fresh weight (mg / g)
[9] = average value
[10-11] = Carotenoids content per fresh weight (mg / g)
[12] = average value
[13-14] = Chlorophyll a content per dry weight (mg / g)
[15] = average value
[16-17] = Chlorophyll b content per dry weight (mg / g)
[18] = average value
[19-20] = Carotenoids content per dry weight (mg / g)
[21] = average value

-1 = measurement not made or not applicable

Extract from SAM_PIG..DAT

_____

001 1 1 2 2.61 2.97 2.79 0.94 1.00 0.97 0.51 0.56 0.54 10.01 11.40 10.71
3.61 3.86 3.74 1.94 2.15 2.05
002 1 2 1 2.42 2.32 2.37 0.55 0.52 0.54 0.68 0.69 0.69 9.59 9.20 9.40
2.19 2.05 2.12 2.72 2.74 2.73
003 3 1 3 0.67 0.64 0.66 0.27 0.23 0.25 0.22 0.21 0.22 0.82 0.77 0.80
0.32 0.29 0.31 0.26 0.25 0.26
003 4 1 3 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
-1 -1 -1
004 1 3 2 0.88 0.89 0.89 0.24 0.25 0.25 0.34 0.35 0.35 2.95 2.97 2.96
0.81 0.84 0.83 1.14 1.16 1.15
004 2 1 2 1.34 1.41 1.38 0.22 0.18 0.20 0.19 0.21 0.20 3.67 3.87 3.77
0.61 0.48 0.54 0.53 0.58 0.55
005 1 4 2 3.35 3.31 3.33 1.05 1.03 1.04 0.83 0.83 0.83 8.72 8.61 8.66
2.74 2.69 2.72 2.16 2.15 2.16
006 1 5 2 1.17 1.02 1.10 0.40 0.36 0.38 0.36 0.31 0.34 11.50 10.04 10.77
3.92 3.54 3.73 3.51 3.05 3.28
006 2 2 2 3.12 3.20 3.16 0.44 0.40 0.42 0.35 0.37 0.36 3.47 3.56 3.52
0.48 0.45 0.47 0.39 0.41 0.40

Table 6. Explanation of code used in Sample / Pigments file (SAM_PIG.DAT)

[1] = sample number
[2-4] = Carbon (% dry matter)
[5] = Carbon (average value)
[6-8] = Hydrogen (% dry matter)
[9] = Hydrogen (average value)
[10-12] = Oxygen (% dry matter)
[13] = Oxygen (average value)
[14-16] = Nitrogen (% dry matter)
[17] = Nitrogen (average value)

-1 = measurement not made or not applicable

Extract from SAM_ELE.DAT

_____

001 46.30 46.96 -1.00 46.63 6.13 6.23 -1.00 6.18 36.82 37.96 -1.00 37.39 5.22 5.06 -1.00 5.14
002 47.32 46.50 47.26 47.03 6.19 6.13 6.63 6.31 36.76 40.71 39.57 39.02 3.32 3.30 3.30 3.31
003 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00
004 46.14 45.82 46.02 45.99 5.56 5.85 5.56 5.65 44.09 43.68 -1.00 43.88 2.00 1.87 -1.00 1.94
005 45.82 46.08 45.95 45.96 5.94 -1.00 -1.00 5.95 37.83 39.83 39.30 38.99 3.32 3.16 -1.00 3.24
006 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00
007 50.46 50.73 50.57 50.59 6.61 6.83 7.04 6.83 40.60 41.28 -1.00 40.94 1.43 1.22 1.10 1.25
008 49.07 48.67 47.75 48.50 6.26 6.23 5.99 6.16 39.66 40.32 -1.00 39.99 1.41 1.17 -1.00 1.29
009 51.93 51.83 51.76 51.84 7.51 7.53 7.00 7.35 38.91 40.92 39.34 39.72 1.66 1.28 -1.00 1.47
010 47.32 46.77 47.01 47.03 6.93 6.89 5.69 6.50 38.54 37.02 -1.00 37.78 2.94 2.72 -1.00 2.83
011 46.21 46.86 46.96 46.68 6.13 6.43 -1.00 6.28 36.52 37.33 -1.00 36.93 5.09 5.26 5.11 5.15
012 46.96 47.06 47.08 47.03 7.35 6.43 6.11 6.63 37.32 37.66 -1.00 37.49 4.31 4.41 -1.00 4.36
013 42.82 43.66 43.83 43.44 5.68 5.26 5.89 5.61 37.53 39.03 -1.00 38.28 4.88 4.98 -1.00 4.93
014 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00
015 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00 -1.00
016 46.22 46.78 45.97 46.32 7.18 5.84 6.00 6.34 38.37 38.31 -1.00 38.34 3.74 3.56 -1.00 3.65
017 50.20 50.06 49.49 49.92 7.89 6.14 6.74 6.92 42.21 42.93 -1.00 42.57 1.27 1.51 -1.00 1.39

Table 7. Explanation of code used in Sample / Elements file (SAM_ELE.DAT)

Principle of operation	Double-beam, double-monochromator spectrometer
Spectral range	UV / Vis / NIR (175 - 3200 nm)
Instrument control	External PC (COMPAQ 386 Deskpro)
Optics	2 monochromators in series, each with 2 gratings
Gratings	UV/Vis: Holographic grating with 1440 lines/mm NIR: Ruled grating with 360 lines/mm Automatic grating change during monochromator slewing
Filters	Programmed optical filters with automatic filter change during monochromator slewing
Light sources	UV: Deuterium lamp Vis/NIR: Tungsten-halogen lamp Automatic source change during monochromator slewing
Beam incidence angle	8°
Detectors	UV/Vis : Side window photomultiplier NIR: PbS Automatic detector change during monochromator slewing
Dimensions	845 * 250 * 610 mm
λ accuracy	UV/Vis: ± 0.15 nm NIR: ± 0.6 nm
λ repeatability	UV/Vis: better than 0.02 nm NIR: better than 0.08 nm
λ resolution	UV/Vis: 0.05 to 5.0 nm NIR: 0.2 to 20 nm
Stray radiation	< 0.00008% at 220, 340 and 370 nm < 0.002% at 1690 nm
Photometric accuracy	± 0.08% T at 1A ± 0.05% T at 0.05A
Baseline flatness	UV/Vis: ± 0.001 A NIR: ± 0.002 A
Scan speed	0.9 - 960 nm/min.
Integrating sphere	BaSo4 coating

Table 8. Technical specifications of the Perkin Elmer λ19 spectrophotometer

Ordinate limits / mode	0 - 100 / reflectance
Abscissa range (170 - 3200 nm)	400 - 2500 nm
Data interval (0.01 - 100 nm)	1.00 nm
Slit width UV/Vis (0.05 - 5 nm)	2.00 nm (fixed)
NIR servo (1-8)	3
Lamps	D2 off / Tungsten (W) on
Detector	Auto (detector change at 860.8 nm)
Instrument speed	480 nm/min
Smoothing	2 nm
Cycles / Time	1 / Auto

Table 9. Configuration of the Perkin Elmer λ19 spectrophotometer during LOPEX93

Reference: Hosgood B., Jacquemoud S., Andreoli G., Verdebout J., Pedrini A., Schmuck G., (1994) "Leaf Optical Properties EXperiment 93 (LOPEX93)", *Report EUR 16095 EN*