Global Land Cover 2000: Evaluation of the SPOT VEGETATION sensor for land use mapping.

Global Land Cover 2000: Evaluation of the SPOT VEGETATION sensor for land use mapping

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Alterra, Green World Research, Wageningen, 2002

ABSTRACT

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Global Land Cover 2ooo ensues from the Kyoto Protocol in order to monitor the world's land use. This study is performed over Western and Middle Europe with a classification as end product. Cloud free NDVI time series were obtained with the HANTS programme as well as for the red wavelengths for the forest discrimination. Ancillary data are indispensable for classes as urban areas and water bodies.
The validation had CORINE, FAO and PELCOM as a reverence. The overall accuracy with CORINE was 50% while for PELCOM it was 48.5 %. Major improvement compared to NOAA is the better geometry of the objects.

Keywords: SPOT VEGETATION, HANTS, land use mapping, NDVI time series, threshold classification, GLC2000, Global Land Cover 2000

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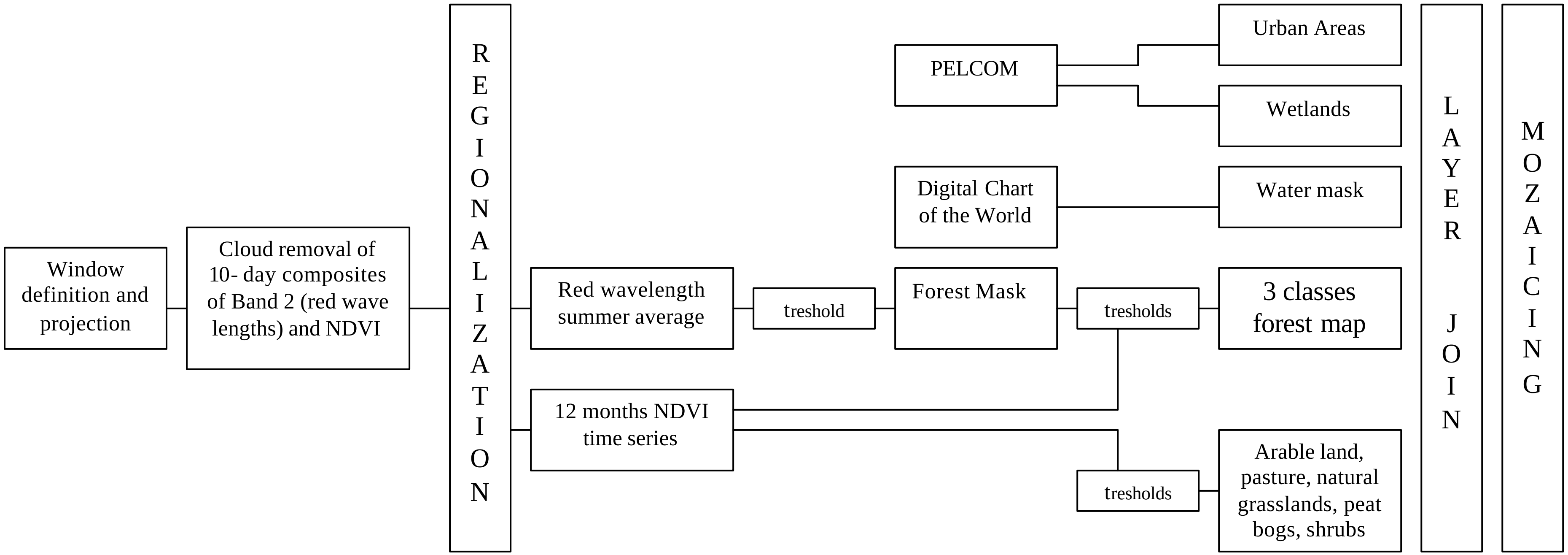
Preface

Within the framework of the GLC2000 project, coordinated by the CEC Joint Research Centre, there was a request to Alterra to implement a part of the Global Classification for the Atlantic zone in Europe.
In the period from March till the beginning of August 2002 I worked at Alterra as a student for my apprenticeship to implement the GLC2000 project for a part of Europe. The work was implemented under the supervision of Sander Mucher, and was largely based on experiences within the PELCOM project.
I would like to express my thanks to the following people for their useful scientific advises and discussions: Sander Mucher, Allard de Wit, Gerbert Roerink and Sytze de Bruin from the Centre of Geo-information and my colleagues Jaap de Kroes and Paco Moral.

Flowchart


Window definition and projection
Cloud removal of 10- day composites of Band 2 (red wave lengths) and NDVI
REGIONALIZATION
Red wavelength summer average
12 months NDVI time series
treshold
PELCOM
Digital Chart of the World
Forest Mask
tresholds
tresholds
Urban Areas
Wetlands
Water mask
3 classes forest map
Arable land, pasture, natural grasslands, peat bogs, shrubs
LAYER JOIN
MOZAICING

1 Introduction

1.1 This Report

This report contains the evaluation of the SPOT VEGETATION sensor for its use as a land cover-mapping instrument at a national, continental and global scale. The report consists of three parts; a summary, the report itself and the annexes.
The first chapter is an introduction on the project where the evaluation is working under and the details about the sensor. The next three chapters are successive steps in the time-schedule of the work. First there is the pre-processing, an evaluation was made of two methods to chance NDVI time series cloud free and eliminate the atmospheric component in the signal.
Then follows the classification methodology. In chapter four the validation discusses the classification results on accuracy and reliability. The conclusion describes the obtained results in a broader perspective. Finally the whole classification process and result is critically reviewed and where possible, improvements are suggested.

1.2 Current classifications: IGBP-DIS and PELCOM

Former classifications on this scale have been produced with NOAA both. The first one in 1992, IGBP-DIS, was based on an unsupervised clustering of monthly NDVI maximum value composites on a continental basis for the entire world. Limitation of this classification is its use of mixed classes and no satisfactorily forest identification (Champeaux *et al*, 1998). The major limitation is its implementation on a continental scale, instead of on a regional scale. In Europe the landscape is heterogeneous and fragmented and requires a stratified approach (www.pik-potsdam.de/igbp-dis/igbp-site/)
PELCOM on the other hand, was based on a supervised classification, only for Europe. PELCOM had a stratified approach and made use of several ancillary data. It was designed for environmental monitoring on a European scale (Mucher *et al*, 2001).

1.3 Global Land Cover and GMES

The general objective is to provide for the year 2000 a harmonized land cover database over the whole globe. The year 2000 is indeed considered as a reference year for environmental assessment in relation to various activities, and in particular the United Nation's Ecosystem-related International Conventions. (www.gvm.sai.jrc.it/glc2000)
GLC is organized as a response to the needs of an environmental assessment, in a context of international conventions. The Kyoto Protocol could be considered as the driving force behind this project. Now GLC is put under the framework of GMES

(Global Monitoring of Environment and Security) where its main aims are: desertification, land cover change and food security.
It should not only serve the scientific community, but also contribute to decision-making on (supra-) national level.
In order to carry out a good-working monitor system, this global classification should be performed each 5 years. SPOT VEGETATION complies the requisites and puts at disposal its data for this assessment.
The project is coordinated by the JRC (Joint Research Centre) in Ispra (I). The production is decentralized so with the knowledge of local experts a reliable map could be obtained. JRC has assigned Alterra to generate the classified map for the window from Ireland to Poland.

1.4 SPOT VEGETATION vs. NOAA-AVHRR

1.4.1 Facts

SPOT VEGETATION is a sensor on board of the SPOT 4 satellite, operational since 24 March of 1998. It is a joint project of the European Commission, OSTC (Belgian Office of Scientific, Technical and Cultural affairs), CNES (Centre National d' Etudes Spatiales), SNSB (Swedish National Space Board) and ASI (Agenzia Spaziale Italiana).
With its daily global coverage and stable spatial resolution, it is a very suitable sensor for global vegetation mapping (table 1).

Table 1: Characteristics of SPOT VEGETATION and NOAA

	NOAA-AVHRR	SPOT VEGETATION
Spatial resolution	1,1 km (nadir)	1 km
Temporal resolution	1/2 day	at least once a day
Swath width	2400 km	2200 km
Altitude	805-870 km	820-830
Scan method	Whisk-broom	Push-broom

The coordination is in hands of VITO (Vlaams Instituut voor Technologisch Onderzoek). The different partners do the production and distribution of the products, which consist in:

Table 2 Product description of SPOT VEGETATION (source: www.vgt.vito.be)

Product	Description
P	Physical product
S	Maximum value composite image, with worldwide land cover with minimum clout cover
S1	Daily synthesis product, consisting of the "calibrated ground reflectance values"
S10	Ten-daily synthesis product, consisting of the "calibrated ground reflectance values"
D10	Bi-directional composite synthesis

Within this project only the S10 product is used, applied by JRC

The 36-decade composites were provided on tape and with a plate carée projection and a 1 by 1 kilometer spatial resolution and acquired during the year 2000. The scene covers Europe entirely. Each image consists of 4 pre-processed bands (table 3). The channels for the visible light and the near and middle infrared are more developed for SPOT, which can enhance the vegetation discrimination compared to NOAA. Although for the NDVI images calculated, the differences are visually small between the two sensors (fig 1 & 2).

Table 3 Channel descriptions

Channel	SPOT VEGETATION	NOAA-AVHRR
1	0.43 - 0.47 µm	0,58-0,68 µm
2	0.61 - 0.68 µm	0,725-1,10 µm
3	0.78 - 0.89 µm	3,55-3,93 µm
4	1.58 - 1.75 µm	10,3-11,3 µm
5		11,5-12,5 µm

The ten-day synthesis (S10) is computed from all the passes on each location acquired during 10-day periods. The periods are defined according to the legal calendar: from 1st to 10th, from 11th to 20th, from 21st to the end of each month. The synthesis between different passes is performed selecting the best measurement of the period defined from the following criteria (www.vgt.vito.be):

- It does not correspond to a blind or interpolated pixel,
- It does not be flagged as cloudy in the status map,
- It does correspond to the highest value of Top of Atmosphere NDVI.

For each pixel the following additional values are computed:

- The ground surface reflectance in the four spectral bands corresponding to the selected measurement, the atmospheric correction being performed using the annotations of the P corresponding data and SMAC procedure,
- Normalized Difference Vegetation Index,
- Geometric viewing conditions,
- Reference to date and time of selected measurement,
- Information on the composite status map.

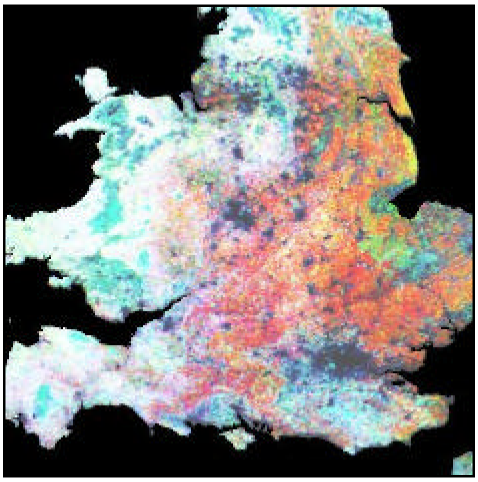


Fig 1 NOAA RGB May-July-September

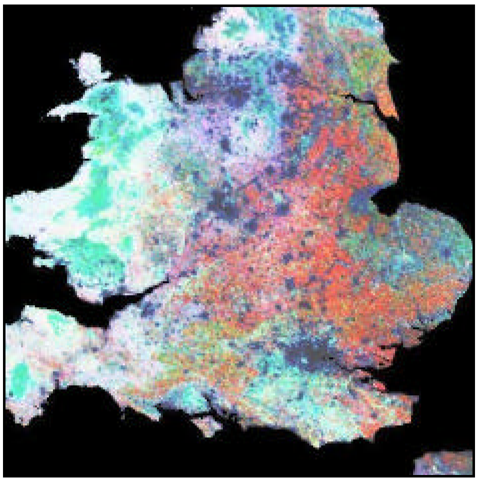


Fig 2 SPOT RGB May-July-Septembre

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1.4.2 Assumptions

What can be expected from this satellite sensor is that it will improve results from former classifications performed on the same scale, like the PELCOM product derived from NOAA data. Especially for the geometric part, because of the push-broom scanner from SPOT does not distort the spatial resolution. Also patterns in the landscape should get clearer.
Also because of the better spectral resolution for the wavelengths that are important for vegetation discrimination better results are expected.

1.5 Data and software

The data delivered by VITO were in HDF format. For the classification they had to be transformed to the ERDAS Imagine format .img. The images had a full cover over Europe. Because of the area to be classified is only a part of the original image, it had to be cut in order to fast up the processing times and lower the storage space. The image is roughly cut to a scene from Ireland to Poland (fig 1). The used method was nearest neighbour and the actual size is now in longitude and latitude coordinates:

- Upper Left: 14 29 54.54 W
  56 55 45.59 N
- Lower Right: 25 16 02.28 E
  49 50 05.13 N

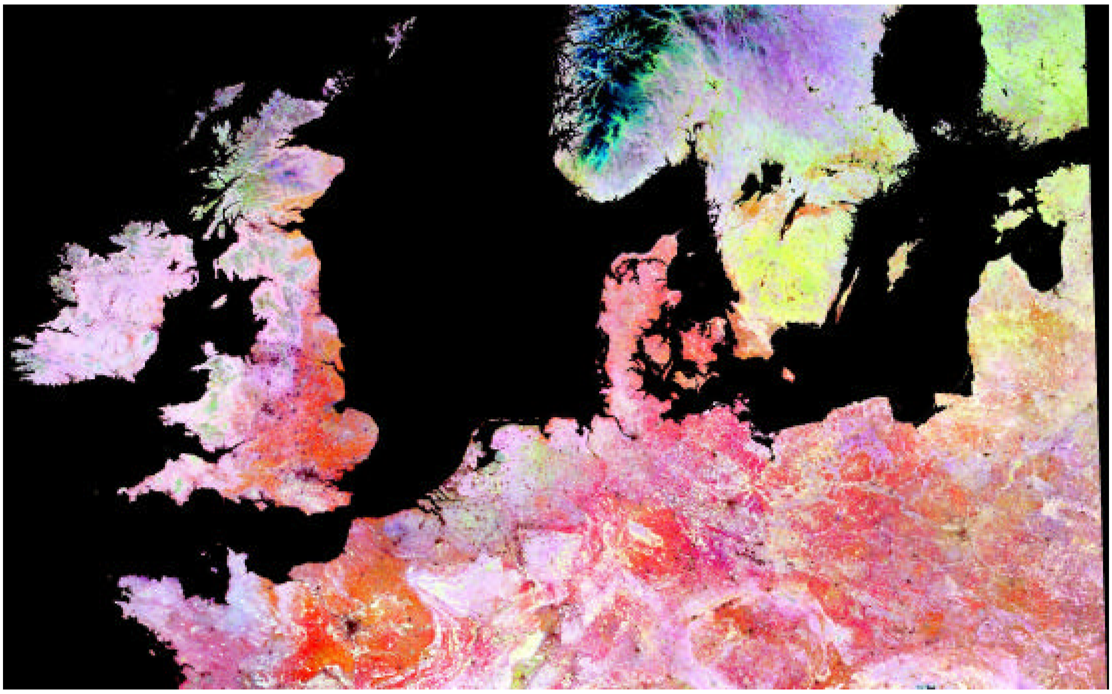


Figure 1 Cloud free NDVI image. Red is May, green is July and blue is September

In order to have the same projection as the ancillary data and the former PELCOM project, there is chosen to reproject the images to Albers Conical Equal Area. As WARP method is triangulation used and as resampling method nearest neighbour. The number of WARP points is on both the X and Y-axis 100. The output size of the images is transformed to 2797 samples by 2444 lines.

Table 4 The projection details

Projection:	Albers Conical Equal Area
Datum:	WGS 72
Latitude Parellel 1:	32:30 N
Latitude Parallel 2:	54:30 N
Longitude Central Meridian:	22:39 E
Latitude Original Projection:	51:24 N
False Easting:	0
False Northing:	0

As ancillary data and reference data, the CORINE database, PELCOM and Digital Chart of the World (DCW) were used. CORINE provides highly detailed land cover information for a large part of Europe. The minimum mapping element is 25 hectares and is performed with high resolution satellite data.
PELCOM is result or a project called: "Development of a consistent methodology to derive land cover information on a European scale from remote sensing for environmental monitoring" (C.A. Mucher, *et al* 2001). This was used as a reference

because of its similarity to GLC2000 and also as a ancillary data source. The DCW provided the water mask.

The initial image treatments and enhancement are done with IDL-ENVI and HANTS (see chapter 2.2.3), for the elaboration of the cloud-free time series, because of both handle easily the generic binary format. ERDAS Imagine in used for the further treatments like classification and validation because of it is user-friendlier and its ability to perform more operations at the time. For the thresholding CART (Salford Systems) was used. The program searches for the optimal division in a set of (overlapping) values that are labelled with two or more denominators. Also is made use of ArcInfo and ArcView for different tasks as well as the Spatial Analyst extension.

2 Image enhancement

2.1 Introduction

The Netherlands is used as a test location for the cloud removal. In order to make a good classification product, the methodology for the PELCOM project is used (C.A. Mucher, *et al.* 2001). This consists of the use of an NDVI time series and a time series for the red light. The last one should be used to discriminate forest from grasslands.
To obtain a good time series, the images should be cloud-free. There are two methods to do so. One is the spline function; the other one is the HANTS algorithm (G.J.Roerink *et al.* 2000). What follows is a comparison between these two methods.

2.2 Methods

2.2.1 Spline function

In order to be able to run the spline function script, a cloud mask should be made.

2.2.1.1 Pre-processing

To determine if a pixel is cloudy or not, a certain threshold is maintained. The threshold values used by VITO are:

- Clear if B0 < 493 or MIR < 180
- Cloudy if B0 > 720 and MIR > 320
- Uncertain in all other cases.

By performing the following band math expression, the pixels are clearly separated between clear and possible cloudy.

(B0 < 493) – (MIR < 180)

From the resulting image a mask can be build, using a threshold of 1000. All the pixels below this value can be determined as cloudy or uncertain. Then, this mask can be applied on the NDVI image or band 2 of that decade.

2.2.1.2 Spline function mechanism

In an NDVI time series with an extreme low value (Graph 2), a new value should be estimated. The spline function does this by using the previous and following points (pixels values). The script (Annex 2) is written in the IDL programming language and the spline function is an available function in the language.

2.2.2 HANTS algorithm

Another way of making your images cloud-free could be obtained by using the Harmonic Analysis of Time Series. One thing is that a major part of the pixels lose their original value. Though the pattern still keeps intact.

2.2.2.1 The HANTS mechanism

This algorithm (G.J.Roerink *et al.* 2000) considers only the most significant frequencies expected to be present in the time profiles, and applies a least squares curve fitting procedure based on harmonic components (sines and cosines). For each frequency the amplitude and phase of the cosine function is determined during an iterative procedure. Input data points that have a large positive or negative deviation from recalculation of the coefficients and the bases of the remaining points, the procedure is repeated until the maximum error is acceptable or the number of remaining points has become too small.

2.2.2.2 Options and possibilities

One of the options of the program is to choose the frequencies of the cosine or sine. HANTS calculates always the zero frequency, which is an average. But also a 12 months or 6 months differences can be emphasized. If the inputs are these three frequencies, the output could be describes by only three Fourier components (three amplitudes and two phases) and from these any cloud-free image (and time series) throughout the year could be generated.
HANTS is steered by five parameters, which can only be set correct after some experience with the program since there are no objective rules. In this particular case the parameters were set at:

Table 5 HANTS parameters and settings

Parameters	Settings	Descriptions
Length of period	36	Amount of input images
Number of frequencies	2	The zero frequency and two more
Periods	36 & 18	HANTS should produce ane image with the year-round differences, and another one with the half-year differences
Fir error tolerance	12	Absolute acceptance error in NDVI units
Degree of over determinedness	11	Minimum amount of images needed for the fit of the curve

2.3 Results

2.3.1 Visual comparison between Spline function and HANTS

Band 3 (March) is used for this comparing test because of it has a relative large cloud covering (fig.2). The resulting image of the HANTS algorithm (fig.3) seems to give a reliable impression. The result of the spline (fig.4) on the other hand, shows high NDVI values, appearing as white smudges, on the places where the cloud mask was applied. Though those noise-looking smudges don't have NDVI values that are too high, comparable with qualitatively high grassland, they do fit in the gap made by the cloud mask (fig.1). After a short spatial analysis (Anex.1) of these data together with a 2 year older classified image (PELCOM), we can put the following (Annex 1):

High NDVI values (>190) took place in 4% of the area without a cloud mask and which was classified as "grassland". Where there do was applied a cloud mask, it was 50%.

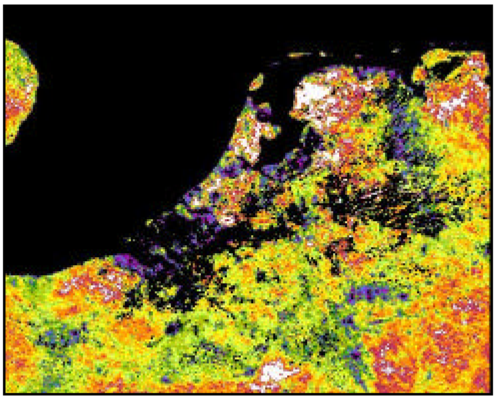


Figure 2 Original image with cloud-mask in band 3 (March)

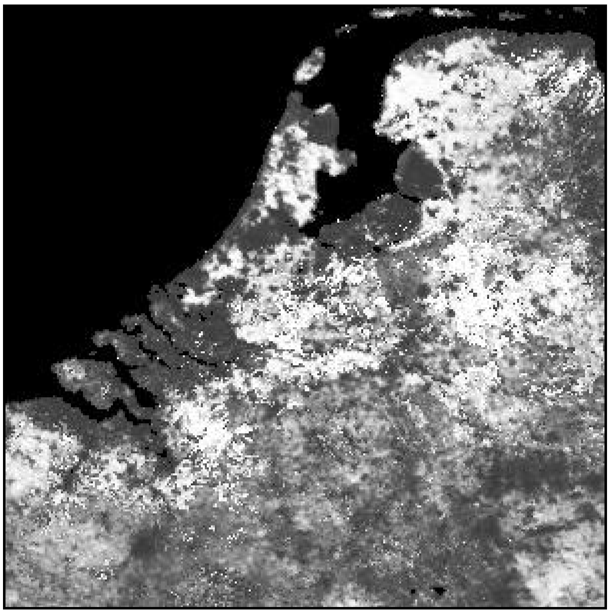


Fig 3 Spine: Band 3 (March). The white smudges are noise caused by the interpolation with the spline function

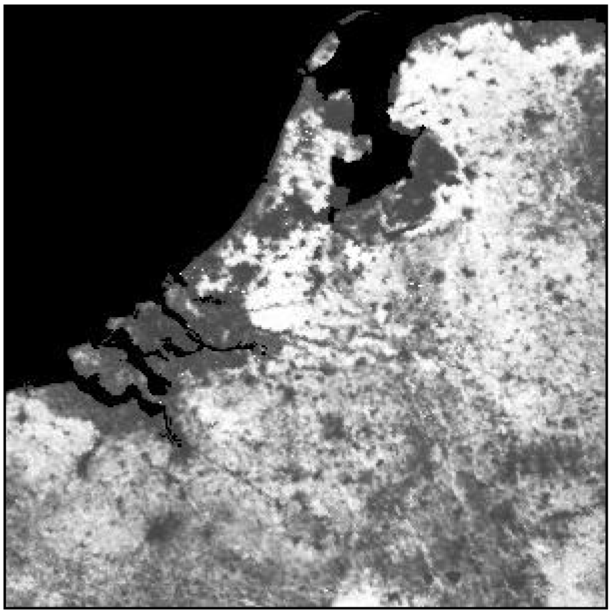


Fig 4 HANTS: Band 3 (March).

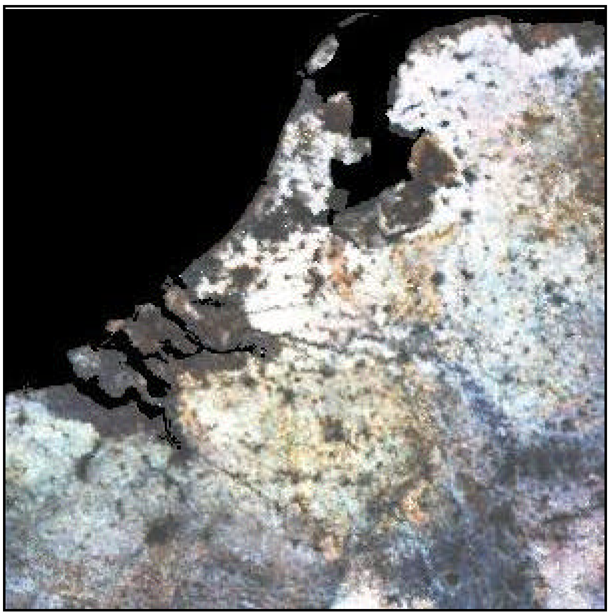


Fig 5 HANTS: red=January, green=February blue=March

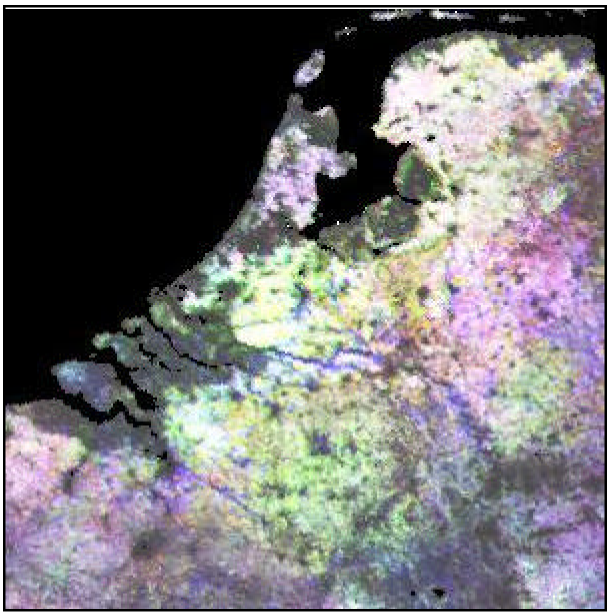


Fig 6 Spline: red=January, green=February, blue=March

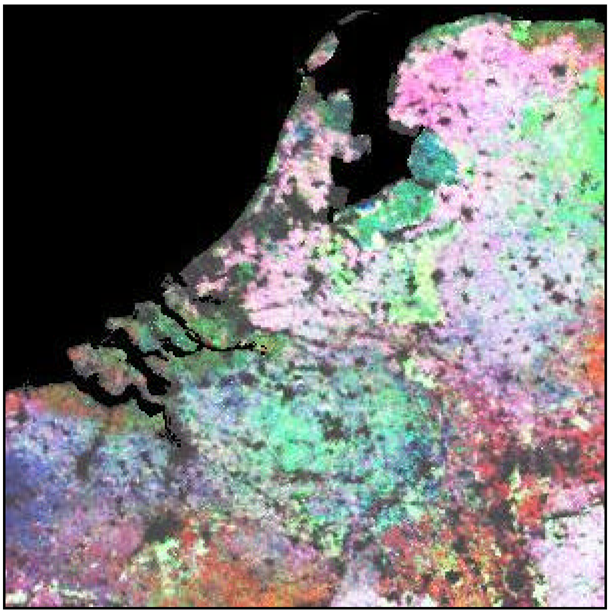


Fig 7 HANTS: red=May, green=July, blue=September Woodland (Veluwe) in the centre can be clearly distinguished

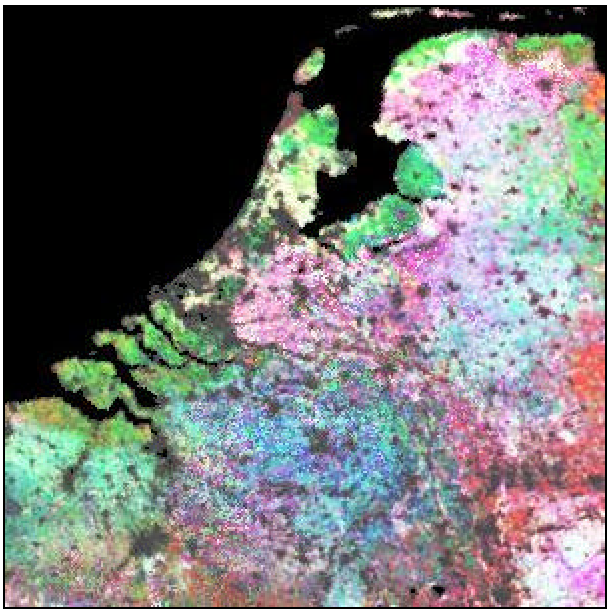


Fig 8 Spline: red=May, green=July, blue=September Some noise can be observed east of the Delta

2.3.2 Pixel comparison between Spline function and HANTS

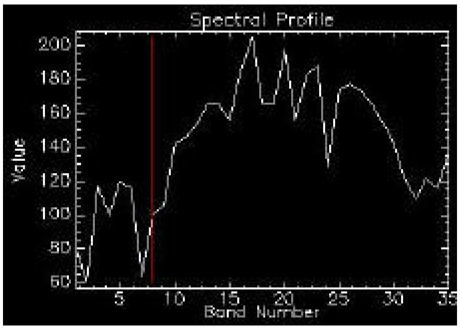
Some points were compared, where for sure a spline function or a HANTS algorithm was employed. Each point is four times represented on a time scale on the X-axis and its value on the Y-axis. The points from the original image consist out of 35 units throughout the year. The other ones consist out of 12. The Y-axis can have a quite different scale between the images because of the extreme pikes plotted.

2.3.2.1 Arable land and Pasture

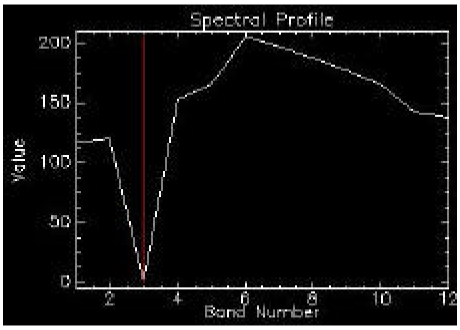
The first sample is for arable land. Clouds covered this particular pixel in March. Both the spline function and the HANTS algorithm can cope with it easily.

Also for the pixel located in pasture, there doesn't seem to be a problem for none of the two methods applied.

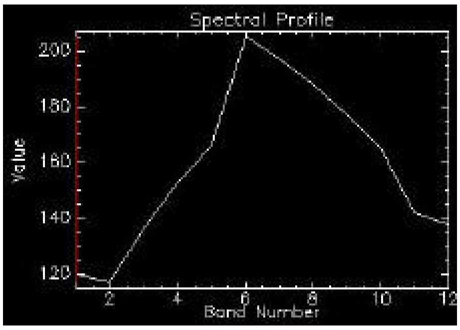
Arable Land



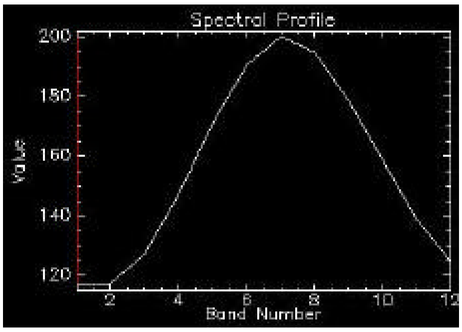
Graph 1 Original



Graph 2 Month composite with cloud mask in Band 3

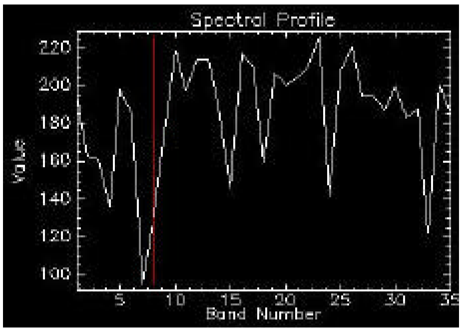


Graph 3 Spline

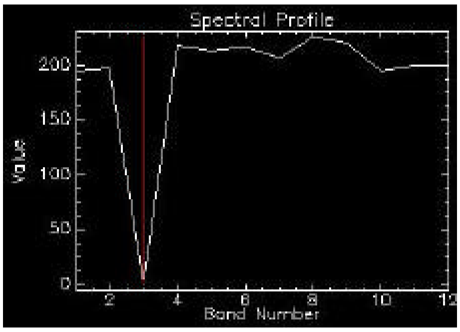


Graph 4 HANTS

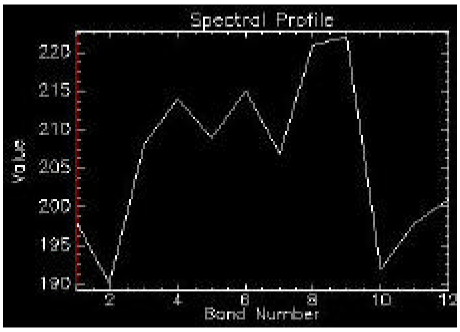
Pasture



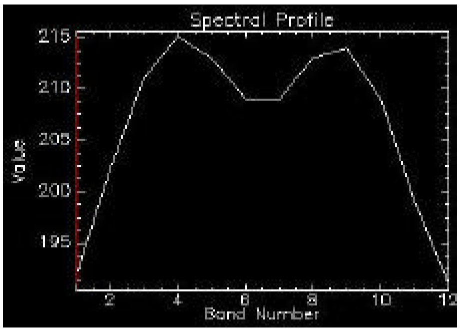
Graph 5 Original



Graph 6 Month composite with cloud mask in Band 3



Graph 7 Spline



Graph 8 HANTS

2.3.2.2 Erroneous Pixels in the Spline Images

In the subset made for this test, the Netherlands, some bands have after the spline operation pixels with values that are extremely high or even negative (Table 5), while the given data are within the range of 0 to 255 (Table 6). Also are given the data ranges of the images after the HANTS operation in order to make a comparison with the spline method (Table 7).

Table 6 Band ranges for all months after applying the spline function

Band	Min.	Max.	Mean	Stan. Dev.
1	0	756	104,2	71,6
2	0	1334	101,7	69,8
3	-219	478	99,6	68,7
4	-119	311	122,7	82,3
5	0	657	131,6	86,5
6	0	255	139,6	90,7
7	-224	255	129,2	85,1
8	-114	255	135,2	88,8
9	-178	255	134,4	88,5
10	-437	713	114,5	76
11	-437	713	111,6	74,4
12	-437	713	110,8	75,1

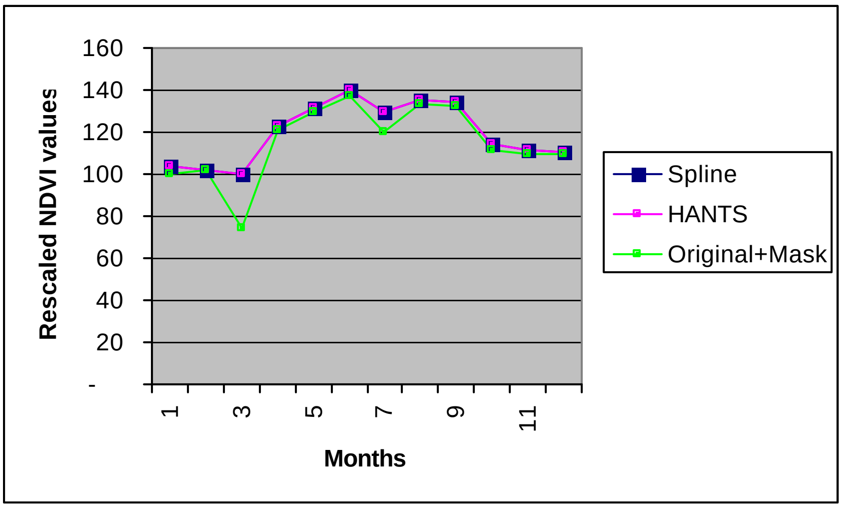
Table 7 Data ranges for all months with cloud mask

Band	Min.	Max	Mean	Stan. Dev.
1	0	255	100,4	69,9
2	0	255	102,4	72,6
3	0	255	74,1	71,2
4	0	255	120,8	83,2
5	0	255	129,3	86,7
6	0	255	137,5	90,8
7	0	255	120,4	87,9
8	0	255	133,3	89,4
9	0	255	132,3	89,3
10	0	255	111,2	77,5
11	0	255	109,8	75,1
12	0	255	75,2	75,2

Table 8 band ranges for all months after applying the HANTS algorithm

Band	Min.	Max.	Mean	Stan. Dev.
1	0	252	102,3	69,1
2	0	252	104,5	71,5
3	0	173	110,5	74,8
4	0	260	120,6	79,7
5	0	252	1306	84,5
6	0	262	137,4	88
7	0	296	139,2	89,7
8	0	296	136,4	88,2
9	0	174	130,2	84,6
10	0	252	122	79,8
11	0	26	113,4	74,6
12	0	239	103,1	70,4

What in both methods happens is that for a to be interpolated point, a new value is estimated. Due to the mathematical function some points can get a higher value than the original value limit. This phenomenon can be observed in HANTS in an acceptable way, though with the spline function, some deviations are extreme. But those extreme points are not of influence on the mean (Graph 9). The reason why the original image, with the cloud mask applied on it, has some lower mean values is because of the cloud mask. The clearest example is showed in band 3, which is used because of the above-mentioned reason in this comparison.



Graph 9 Mean NDVI values in the Netherlands.

Focusing on these extreme pixels, one statement can be made. They are all located along the coast or in mountainous areas. The distribution of these erroneous pixels is comparable along the whole European coast, with more negative than extreme positive pixels. A higher density occurs in high mountains like the Alps, or in Scandinavia

2.4 Conclusion

Here can be put that by using the spline function and its pervious processes, a very large part of the imagery can be made cloud free. This is mainly due to the elaborating of maximum NDVI composites. The remaining gaps, that are filled up by the spline function, seem to give higher values than expected for many pixels and a small part of those interpolated pixels show strong deviations into either the negative way, either the extreme positive way. This is because of too few or absent values in wintertime, where had to be extrapolated as being both the beginning and the end of the cycle. The cloud threshold does not guaranty that all the clouds are masked. Good thing about this method is that the majority of the pixels preserve their original value.

The HANTS algorithm gives a proper looking time series, were the different land cover types can be distinguished clearly. Also thanks because of the amplitude images temporal differences can be visualized. This gives opportunities to distinguish better for example crops with an annual cycle, forest from grassland and shows when harvesting starts.
A characteristic that is less desired is that HANTS modifies all the original pixel values, though the pattern remains the same. Another inconvenience is that there are no objective rules to set the parameters. But besides these two lesser problems, the HANTS result looks a lot better than the result of the spline function. HANTS makes possible to produce a smooth and cloud-free NDVI time series.

3 Classification

3.1 Nomenclature

The nomenclature proposed by the FAO and UNEP is the Land Cover Classification System (LCCS) (A. Di Gregorio, L.J.M.. Jansen, 2000). The worldwide classes can be consulted in Annex#.
For this part of Europe the nomenclature (Table 9) is set at 10 classes. It was decided not to use mixed classes. Although a mixed class would have increased the accuracy (CORINE contains a mixed class), it stays difficult to define a mixed class. Since there is no overall similarity between the different types of mixed classes, is chosen to divide only pasture and arable land in the cultivated areas. Another problem is that mixed classes are difficult to apply later. For example what is a "complex cultivation pattern"? Environmental and climate models and other user have difficulties to handle this class. Pixels with this corse resolution are many times mixed, though still it can be assigned to the class that is dominant within that pixel.

Table 9 The classes used in the classification with their description

Class	Label	Description
Pasture	9	Land that have introduced grass species and has been improved for grazing
Arable Land	14	Cultivated crops for which the land is tilled
Natural Grassland	10	Natural lands with herbaceous types of cover
Needle leafed forest	3	Lands dominated by coniferous trees and shrubs
Deciduous forest	2	Lands dominated by deciduous trees and shrubs
Mixed forest	5	Lands dominated by coniferus and deciduous trees and shrubs
Shrubland	8	Lands with woody natural vegetation less than 2 m tall.
Wetlands	12	Lands with a permanent mixture of water and herbaceous or woody vegetation, either in salt, brackish, or fresh water
Urban Areas	17	Land covered by buildings and other man-made structures
Water bodies and Sea	19	Oceans, seas, lakes, reservoirs and rivers

The thresholds for each class vary for the different blocks (Annex 3) any times. The aim was to find a classification as close as possible to the reality and to CORINE.

3.2 Regions

The studied area can actually be divided in two biogeographically regions: the Atlantic and the Central European one. So the regions would still be quite large. Divisions along the national borders are too unequal so eleven blocks (figure 9) have been cut out of the original image to do the classification on. Successive classification

of different strata enables improvement of the discrimination process on difficult classes and reduces the number of misclassifications due to spectral confusion. (Thunnissen *et al.* 1993). The total area is about 8849200 ha, without sea and large water bodies.

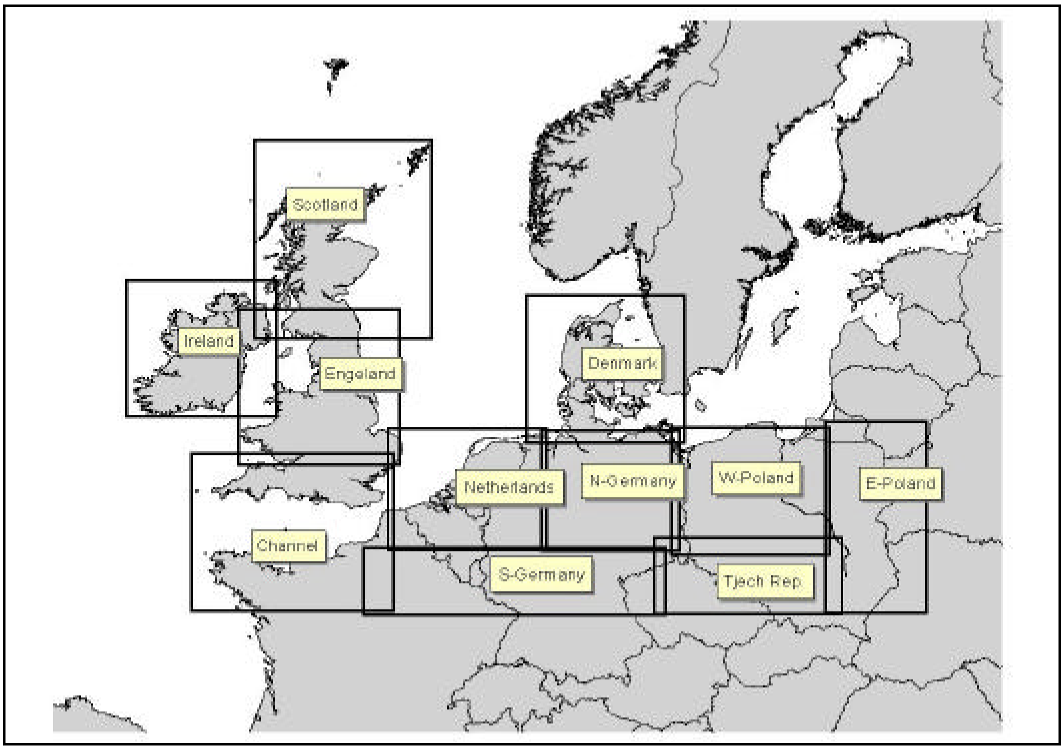


Figure 9 The total window with its division in blocks

3.3 Masks and Ancillary data sources

3.3.1 Introduction

Before the classification on NDVI time series started, some masks have been made. The forest map is based on a SPOT VEGETATION time series for the red wavelengths, water bodies and urban areas on ancillary data sources. Spectral overlap causes confusion and decreases the accuracy.

3.3.2 Urban mask

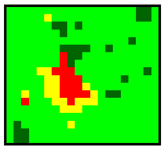


Figure 10 City located in grassland, with recent extension classified as arable land

It seemed to be impossible to derive a good classification for the urban areas with the SPOT VEGETATION data because of their spectral overlap with other classes such as arable land or even forest. Ancillary data are common sense in classification of remotely sensed images (Brown *et al* 1993). Because there are no up to date urban maps on European scale available, a choice had to be made between CORINE, PELCOM and Digital Chart of the World. DCW contains only the major cities and the CORINE database is only for a part of Europe and geometrically just not good. So finally is chosen for the same urban mask as in PELCOM, which is obtained as en integration between various

ancillary sources, such as DCW and CORINE. Although many cities have incremented in size (fig 10), it was not possible to add those newly built-up areas to the urban mask.

3.3.3 Water mask

For the water mask it is about the same story as the urban mask. The geometry of CORINE was not good compared to the DCW. The only thing with the DCW was that some few major lakes were absent and had to be added manually.

3.3.4 Forest map

Because of the difficulties of discriminating forest from grasslands with an NDVI time series (Champeaux *et al.* 1995; Mücher *et al.* 2001), is chosen for forest discrimination using their photosynthetic absorption in the blue and the red wavelengths.

First a composite of the two first bands (blue and red) is elaborated with HANTS, an average of the months of June, July, August and September. This time of the year forest absorbs more of the blue and red wavelengths than any other kind of vegetation or land use type, except for water.

In order to evaluate the utility of these two bands, 50 labelled as forest were compared with 50 not-forest pixels for each of the two bands for a test region (Benelux). Then based on tree-growing (CART, Salford Systems) the most probable threshold was derived. So the produced forest maps could be compared with the PELCOM map. (table 10)

Table 10 Comparison between red and blue light for forest discrimination

PELCOM	Band1(blue)	Band2(red)	Pixelcount
Forest	Forest	Forest	7152
Forest	Forest	Not-Forest	688
Forest	Not-Forest	Forest	922
Forest	Not-Forest	Not-Forest	3040
Not-Forest	Forest	Forest	4768
Not-Forest	Forest	Not-Forest	3456
Not-Forest	Not-Forest	Forest	2880
Not-Forest	Not-Forest	Not-Forest	150288

The differences are smaller when the forest from PELCOM and forest from band 2 carry the same label than the forest from PELCOM and forest from band 1. PELCOM doesn’t have the perfect forest map, but did serve as a useful indication to pick the samples.

Also is known than the blue wavelengths are scattered (Rayleigh scattering) in the atmosphere (Lillesand and Kiefer, 1994) what gives less reliable pixels values.

Thresholds are determined for each region in the same way as explained before for the red wavelengths (table 11).

Table 11 Thresholds for the different blocks

Region	Threshold B2
Netherlands	104,4
North Germany	105,4
West Poland	100,4
East Poland	97,4
South Germany	105,4
Denmark	94,4
North France	103,9
Channel	96,1
England	94,1
Scotland	76,5
Ireland	94,1

Differences between the blocks are small. Less forested areas, like Ireland or Scotland, have lower thresholds due to the spectral signature of mixed pixels. Forests there are scattered and small.
To discriminate the different forest types (deciduous, coniferous and mixed forest), NDVI thresholds from July have been determined on the basis of CORINE. The thresholding is performed by CART, and with more or less 50 samples for each class.

3.3.5 Wetlands

Wetlands are difficult to discriminate in a consistent way. Under wetlands can be seen peat bogs, reed, partially open water and marshland. Mostly their distribution is very scattered and patches are often small. Only the major peat bogs at the west coast of Ireland could be classified from the SPOT VEGETATION images, all the rest is applied as a mask from PELCOM (the 50 % majority criterion was applied after merging CORINE themes 35 through 37). (Mücher *et al.* 2001)

3.4 SPOT VEGETATION CLASSIFICATION

The two conventional methods for classification are based on different statistical methods for spectral separation between the classes. One is supervised, the other un-supervised. This means that for the supervised method one should collect training samples for each class, which will be extended to the entire image within the statistical limits for each class. The unsupervised method creates “natural classes” from the feature space, within the user’s limits.
The disadvantage of unsupervised classification is that for a time series not always the classes are created that the used desires, as well as the problem with the mixed classes, that are inevitable here. For supervised classification, maybe the desired classes can be obtained, but there is no statistical prove on the separability. Just one training sample can make a difference.

So to overcome the disadvantages of both previously named methods, there is chosen here for a threshold-based supervised method by treegrowing. Over an amount of labelled values optimal thresholds are searched with its probability. Samples are collected at random within the class with CORINE as the reference.
This classification is based on thresholding with CART, which are different for each region. Not all regions have the same classes. This classification of NDVI time series has approved to be successful for classifying large areas.
For the Benelux, the best separation could be found between grasslands and arable land by dividing them on the NDVI values of February. Arable land shows low NDVI values in winter because of the ploughing. The samples were taken on the basis of 50 pure CORINE pixels for each of the two classes. It was decided for not using a mixed class. Although a mixed class would have increased the accuracy, it stays difficult to define a mixed class. Mixed classes also seemed to be difficult to apply in environmental and climate models, because of their uncertain definition and variability throughout Europe. Since there is no overall similarity between the different types of mixed classes, is chosen to divide only pasture for arable land in the cultivated areas. This method works fairly well for the continental part of the window, but for the British Isles some classes had to be added. They have large areas of natural vegetation, which cannot be classified as forest, such as natural grasslands and shrubs.
As input was made use of the 12 cloud free NDVI images of the year 2000 produced by HANTS. For each geographical block thresholds (Annex 4) were generated.

3.5 Focus points

3.5.1 Western Europe

For Western Europe, where a lot of regions are classified as a mixed class of pasture and arable land (Bretagne, Kempen), the result for the CART tree was:

Table 12 The mixed class problem

Class	Arable land	mixed	Pasture
NDVI	<141	142-169	>170

Because of this mixed class problem, the class is just divided into two, what makes that the threshold between pasture and arable land is set at 155. For Eastern Europe (Poland), it isn't possible to use the NDVI values for February because of the snow cover. This is why is chosen to do the CART separation in august, just after harvesting. Here a threshold of 186 is maintained.

3.5.2 British Isles

For the British Isles, the different land use and vegetation types are more complicated to distinguish by tree growing. For Ireland there are the following classes with their separation thresholds. The peat bogs, mainly situated in the west, have lower NDVI values than other classes in spring (table 13).

Table 13 Peat bogs in Ireland

Class	Month	NDVI
Arable land-Pasture	September	176
Peat bogs-Other	May	175

In Britain, it is not the peat bogs, which can be distinguished as another class, but the moors and natural grasslands. Natural grasslands (fig.10 and fig.11) are characterized by their low NDVI values throughout the year, moors also, but with higher values in late summer. Eventually it seemed that in May a good separation could be made for the four classes (pasture, natural pasture, arable land and shrubs) at the time (table 14).

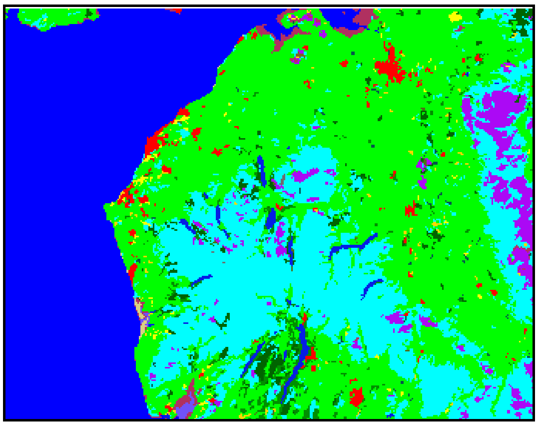


Figure 10 Corine: Cyan is natural grassland, Violet are shrubs.

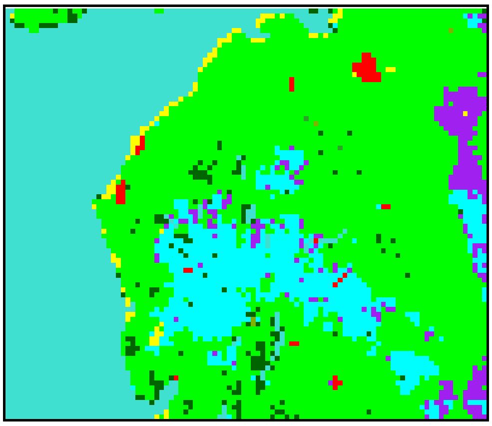


Figure 11 GLC2000, colours the same in Figure 10.

Table 14 Shrubs and natural grass-Lands Britain

Class	NDVI
Pasture	> 205
Arable Land	176-204
Shrubs	156-175
Natural Grassland	<156

In the overall classification all the blocks are put together (mozaicing) and a part of south Sweden is taken out because of different land use there which would have required other thresholds for e.g. forests.

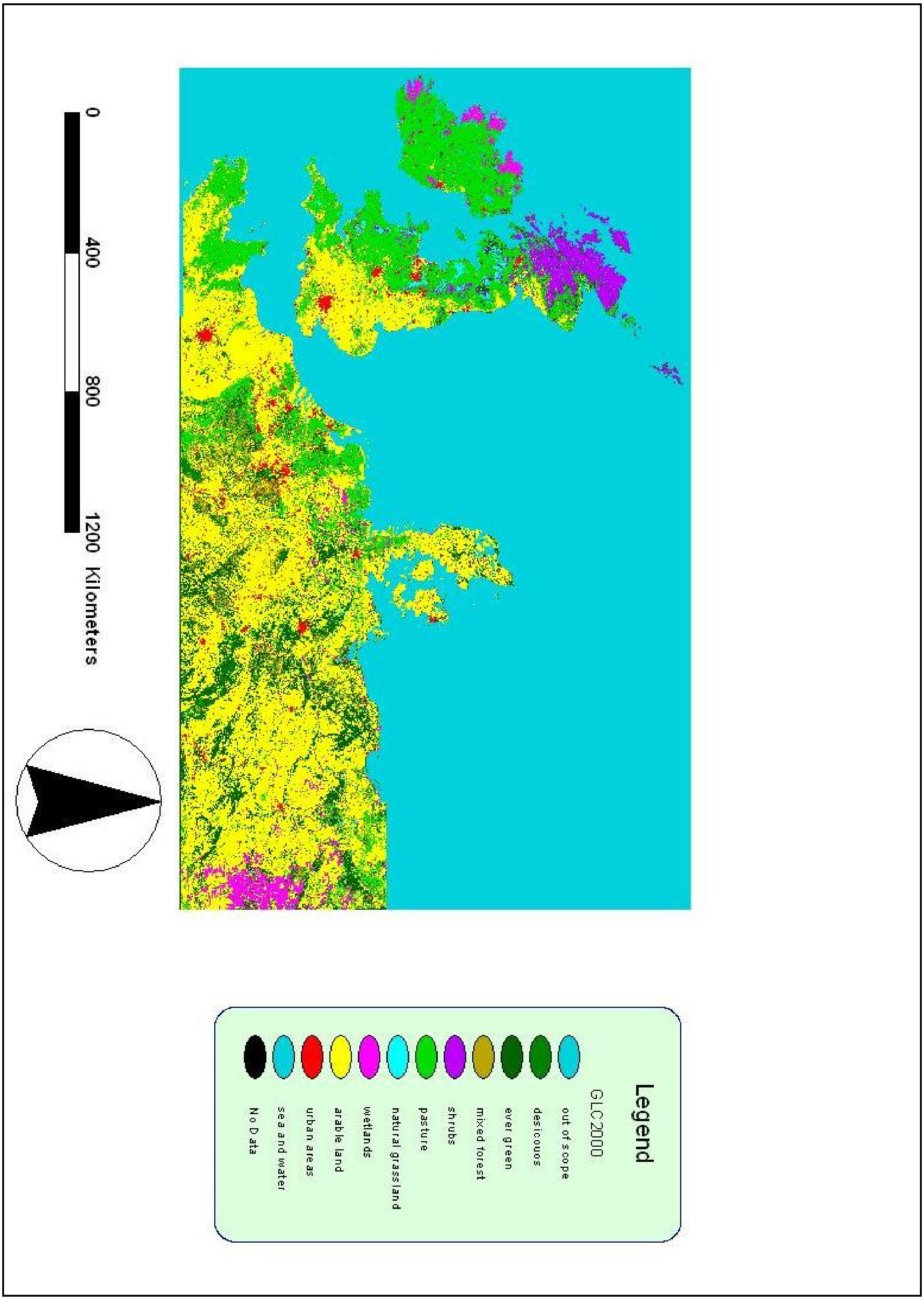


Figure 12 The overall classification result

4 Validation

The classification was performed along the guidelines of the PELCOM project(C. A. Mücher *et al*, 2001). PELCOM used similar images (NOAA-AVHRR) as SPOT VEGETATION, but is less accurate.
So by comparing both classifications, something could be said about the preference of SPOT VEGETATION over NOAA-AVHRR. Next to CORINE the FAO statistics are being used for validation. They do not show the geometric patterns, but the land surface for each (generalized) class.
Both reference data source are not really up to date and geometrically not always so good (CORINE), but they are the only ones that have coverage on a European scale and that are freely available.

4.1 Pixel-wise (CORINE)

The CORINE database is produced for different countries, that handled their own criteria's and projections, so geometrically not everything is like it should, caused by reprojecting and mosaicing of the different maps.
The total accuracy for GLC is **50.0%** and for PELCOM **48.5%**. These are low values; it depends on the validation method. In the PELCOM report (C.A. Mucher *et al*,2001) an accuracy of 69.2% was reached. The difference is in the reference map. For the PELCOM project CORINE was resampled to pixels of the same size and an equal amount of classes.
CORINE has mixed classes, which is non-information for the validation of this product. Nearly every pixel is on a 1 kilometre scale is mixed, but for this product is opted for a simplification to restricted classes. Comparing the accuracies and reliabilities between PELCOM-CORINE and GLC-CORINE, one can observe a little improvement for most of the classes, except for the accuracy of the deciduous forest (table 15). For the different countries separated the same matrix is calculated (table16).

Table 15. Accuracy and Reliability matrix for the entire region compared with PELCOM

Class	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	78,0	78,8	45,0	55,6
Pasture	54,5	58,7	38,9	49,7
Nat-grassland		15,4		64,0
Deciduous	25,4	17,1	21,1	27,7
Evergreen	43,5	45,6	15,5	38,0
Mixed	15,1	17,1	7,8	15,1
Shrubs	49,9	57,2	50,4	59,6
Wetlands	37,3	44,7	9,5	15,2
Total Forest	52,0	55,3	23,6	53,9

The percentages are low because of the CORINE database was not resampled to the spatial resolution of the classification products of the 1 km imagery nor were merged the classes to those ones put in table 15.
Some remarks on these data. The accuracy of arable land is very high, just because of its large surface. For pasture, the reliability has improved quite some comparing to PELCOM. This has also to do with the new class, which is Natural Grasslands, absent in PELCOM. Certainly not all natural grasslands could be identified, but the reliability was high. This is because natural grassland is only identified in England, because of its large abundance there. For other regions the patches of natural grassland are too small to give a good classification result.
Also here (www.gvm.sai.jrc.it/glc2000/march2002/pps_files/champeaux_map.pps) not such a good result for the forest types discrimination could be obtained. The discrimination of forest with the channel 2 of SPOT VEGETATION gives good results, considering the accuracy and reliability of "total forest".
Shrubs are also only classified for Britain, with its moors and Scottish highland bushes. The improvement is considerable comparing to PELCOM.
For the wetlands, the same mask is used as the one for PELCOM. The difference in accuracy and reliability is entirely due to the classification performed for Ireland, where the peat bogs are large and relatively easy to discriminate from the rest of the land.
Urban areas and water are let out because of their irrelevance.
In order to improve the classification, and put clear where the difficulties are for the different regions, the accuracy and reliability for all the blocks are given (table 16).

Table 16 Accuracy and reliability for the different blocks, a comparison between PELCOM (pel) and GLC2000 (glc).

Benelux	acc-pel	acc-glc	rel-pel	rel-glc	UK	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	79,0	74,5	40,1	45,1	Arable land	78,0	77,5	57,5	58,8
Pasture	68,3	71,2	46,7	43,5	Pasture	64,3	71,4	57,9	57,5
Nat-grassland					Nat-grassland		18,9		63,8
Deciduous	25,4	27,8	18,3	42,7	Deciduous	7,5	1,0	8,3	21,4
Evergreen	27,9	41,2	34,0	24,8	Evergreen	27,5	28,0	25,1	30,3
Mixed	18,8	28,1	27,9	29,5	Mixed	4,1	1,5	0,2	0,7
Shrubs					Shrubs	61,2	69,6	50,7	60,5
Wetlands					Wetlands	7,5	12,7	36,4	50,5
Total Forest					Total Forest				

Ireland	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	12,4	12,3	13,9	35,3
Pasture	91,1	95,0	70,8	69,1
Nat-grassland				
Deciduous	0,1	0,7	1,2	2,1
Evergreen	12,9	11,8	17,1	18,0
Mixed	1,7	1,2	0,2	1,1
Shrubs				
Wetlands	49,3	57,2	50,0	53,7
Total Forest				

Denmark	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	87,1	81,8	67,6	70,5
Pasture	4,2	6,2	34,8	4,9
Nat-grassland				
Deciduous	24,0	0,9	4,8	3,2
Evergreen	17,3	52,0	41,9	19,0
Mixed	14,3	10,4	17,9	23,1
Shrubs				
Wetlands	11,8	12,0	5,2	5,7
Total Forest				

Germany	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	75,3	77,2	59,0	60,5
Pasture	32,5	28,9	44,0	34,8
Nat-grassland				
Deciduous	31,6	20,3	27,6	25,3
Evergreen	42,6	45,1	48,4	46,2
Mixed	18,7	23,6	14,4	18,2
Shrubs				
Wetlands				
Total Forest	57,0	63,6	45,1	36,1

France	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	82,2	85,3	53,3	57,2
Pasture	50,5	59,3	49,2	37,5
Nat-grassland				
Deciduous	38,6	25,3	41,4	69,4
Evergreen	9,5	6,3	9,4	12,2
Mixed	9,1	8,5	3,3	3,5
Shrubs				
Wetlands				
Total Forest				

Tsjec Rep.	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	78,0	70,1	55,1	62,5
Pasture	0,1	4,2	0,7	4,6
Nat-grassland				
Deciduous	8,8	15,1	6,5	4,4
Evergreen	36,0	52,2	39,8	36,6
Mixed	13,3	8,4	10,4	10,5
Shrubs				
Wetlands				
Total Forest				

Poland	acc-pel	acc-glc	rel-pel	rel-glc
Arable land	79,6	82,4	56,5	56,8
Pasture	5,6	6,2	24,8	22,6
Nat-grassland				
Deciduous	8,8	5,3	20,2	13,2
Evergreen	54,0	48,9	45,5	45,0
Mixed	11,9	10,9	14,9	14,0
Shrubs				
Wetlands				
Total Forest	54,1	54,0	54,5	58,8

4.2 Country-wise (FAO)

The other way of comparing the results is with land use statistics of the Food and Agricultural Organisation (FAO) (apps.fao.org/lim500/nph-wrap.pl?LandUse&Domain=LUI). The values are in 100 Ha and PELCOM and

CORINE are also put to serve as a reference (table 17). It is only possible to show these 4 countries, because of all other countries in the window only appear partially. That would make it impossible to compare the results. Arable land for CORINE consists in a join of "Arable Land" and "Principally occupied by arable land". Pasture is a join of "Grasslands" and "Natural Grasslands".

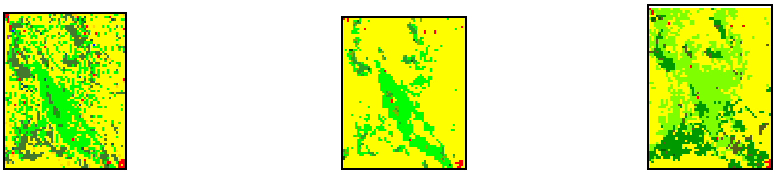
Table 17 Comparison of the FOA statistics with classified images

Region	Class	FAO94	PELCOM	Glc2000	CORINE
Benelux	Wood	10430	10172	11005	10118
	Arable land	17140	32226	24718	18122
	Pasture	17390	25105	25659	16040
UK	Wood	23900	26947	1541	33460
	Arable land	59020	79159	69710	54445
	Pasture	110970	89783	99993	104514
Denmark	Wood	4170	5321	6112	3965
	Arable land	23650	36287	29702	29106
	Pasture	3170	90	856	955
Ireland	Wood	5700	5484	1998	3145
	Arable land	13140	3329	1187	6919
	Pasture	30740	51341	55149	42632

Wood has high errors in all regions, while out of CORINE the overall accuracy was better; here for the different countries values are low. But the few forest present in the British Isles and Denmark can explain this. Their surface cover is also low (and scattered) comparing to the Benelux, which has a smaller area than Britain.

4.3 Visual

In the two former validation methods, no detailed locations of interest can be highlighted. This is important as a way to show geometric similarities and differences. Again PELCOM and CORINE will serve as a reference. Some features are impossible to distinguish at a level of 1 km², so both in PELCOM as in this classification the result will not correspond 100% with CORINE.

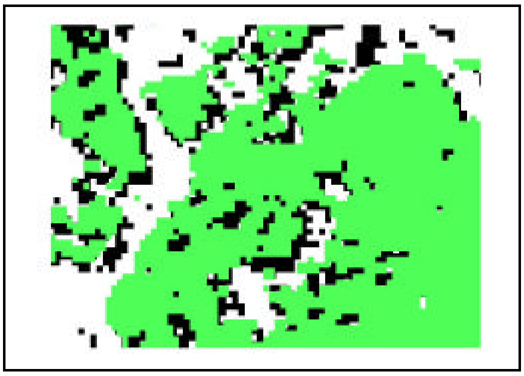


CORINE SPOT NOAA

Figure 13 Visual comparisons for a small area in northern France.

The NOAA-AVHRR images are somehow distorted so that a shift occurs. In the examples follow (fig14) it gets clear. Black is forest classified with NOAA, and grey is forest classified with SPOT VEGETATION. The features have more or less the

same shape, but NOAA shows a shift towards the southeast, perpendicular to the nadir.


Spot Vegetation laid over NOAA

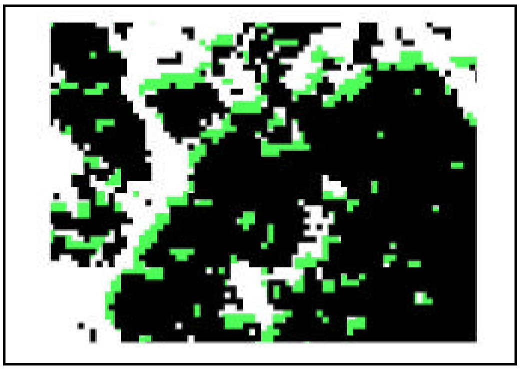

NOAA laid over Spot Vegetation

Figure 14 A visual comparison between SPOT and NOAA forest in Poland .

5 Conclusions

The conclusion for this study consists of three parts. The first one is about the pre-processing. The HANTS algorithm can be considered as the best way to obtain a cloud free NDVI time series for this purpose. Regional patterns in the time come out clear, but individual pixels values mostly don't preserve their original value. The other method tested, the spline function, does preserve most of the original values, but the result is unsatisfactory for this purpose.

The conclusion for the classification is twofold. The classification product has only a 1.5% higher accuracy than a former product, PELCOM. This is lower than expected, possible reasons will be commented in the discussion. One thing is clear; SPOT VEGETATION has better geometrical properties than NOAA-AVHRR. In Eastern Europe, there is a shift of the objects in south-eastern direction. SPOT VEGETATION has a more stabile sensor than NOAA and HANTS can produce a very nice time series out of it. The classification results are so similar because of the small differences between the two sensors (fig1&2).

The entire classification process is performed with thresholds. No trainings samples are used nor unsupervised classification. The advantage consists in the fact that it is a more reliable method in terms of quantification of the probability that a pixel belongs really to that class. With the tree-growing in CART, the program gives the threshold between two (or more) classes with a probability. Only with a probability higher than 80% the threshold was accepted.
The disadvantage is that lots of pixel values have to be collected to obtain good results.

6 Discussion

Most difficulties were found in determining the different types of forest, especially in areas with low forest densities. Other classes with a low accuracy, like natural grassland, might be due to its small area and heterogeneous composition. A possible improvement could be obtained by using the Mid Infra Red band. This band could have been made cloud-free easily with HANTS, against expectations. It follows the same spectral pattern as the Red band. Thought was that the signal would not follow the yearly fluctuation of the vegetation so clearly, what is necessary for a reliable HANTS output. But this was concluded is and advanced stadium of the classification.
Using the CART for the classification has one disadvantage: collecting the 50 samples for each class and for each block is work intensive.

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WebPages:

www.gvm.sai.jrc.it/glc2000
www.fao.org
free.vgt.vito.be
www.spot.com
www.vito.be

Annex 1

The spline function gives too high values for grassland in the Netherlands

Description	id	#PIXELS	Size corr.
Grassland without mask	107	18848	18848
Grassland with mask	275	3584	3584
>190 without mask	87	791	719
Normal NDVI without mask	183	68674	62431
>190 with mask	255	2628	2389
Error or sea without mask	292	18	16
Normal NDVI with mask	351	15049	13681
Error or sea with mask	460	47714	43376
>190 in grassland	20	2397	2397
Normal NDVI in grassland	116	15472	15472
Error or sea in grassland	225	4	4
>190 without mask in grassland	194	603	603
Normal NDVI without mask in grassland	290	13601	13601
>190 with mask in grassland	530	1786	1786
Normal NDVI with mask in grassland	326	1788	1788
Error or sea with mask in grassland	735	4	4
>190 in mask of total >190	70%		
Sea land ratio	17%		
Total >190	3108		
% >190 in total grassland	13%		
% >190 in total grassland with mask	50%		
% >190 in total grassland without mask	4%		

Annex 2

The script for the spline function in IDL

```
function spline_ndvi2, b1

	datasize=size(b1)
	nrcols=datasize[1]
	nrrows=datasize[2]
	nrlayers=datasize[3]
	print, nrcols, nrrows, nrlayers
	result=intarr(nrcols, nrrows, nrlayers)
	xrange=indgen(nrlayers)
	for i=0,nrcols-1 do begin
		for j=0,nrrows-1 do begin
			tseries=b1[i,j,*]
			baddata=where(tseries eq 0)
			gooddata=where(tseries gt 0)
			if (baddata[0] ne -1) and (gooddata[0] ne -1) $
			  and (n_elements(gooddata) gt 6) then begin
				x=xrange[gooddata]
				y=tseries[gooddata]
				t=xrange[baddata]
				r=spline(x,y,t)
				tseries[baddata]=r[baddata]
				result[i,j,*]=tseries
			endif
			if (baddata[0] eq -1) then result[i,j,*]=tseries
		endfor
	endfor

  return, result
```

Annex 3

The LCCS global legend

Domain	I. Aggregation Global Classes **(mandatory)**		II. Suggestion for regional & sub-regional classes **(additional classes may be added if consistently achievable)**		<< corresponding LCCS codes & classifiers ***(examples - not exhaustive)***	***(IGBP correspondence)*** • **General comments**
Forest types	**6.1**	Tree Cover, broadleaved, evergreen ***(LCCS >15% tree cover, tree height >3m)***	1.1	-closed ***> 40% tree cover*** ***(LCCS >65% and >40-65% r)***	**2*& A3, A10,A11+A12, D1, E1,**	***(Evergreen Broadleaved Forest)*** • **GLC forest definition overlaps in terms of definition partly with IGBP Woody Savannas & Savannas** • **GLC Forest is close to FAO definitions, recommended by Definitions workshop also for 'Kyoto forests'**
			1.2	-. open ***15-40% tree cover***	**2*& A3, A11+A13, D1, E1**	
	6.2	Tree Cover, broadleaved, deciduous	2.1	- closed	**2*& A3, A10,A11+A12, D1, E2**	***(Deciduous Broadleaved Forest)***
			2.2	- open	**2*& A3, A11+A13, D1, E2**	
	6.3	Tree Cover, needle-leaved, evergreen	3.1	- closed	**2*& A3, A10,A11+A12, D2, E1**	***(Evergreen Needleleaved Forest)***
			3.2	- open	**2*& A3, A11+A13, D2, E1**	
Flooded & inundated forest types	**6.4**	Tree Cover, needle-leaved, deciduous	4.1	- closed	**2*& A3, A10,A11+A12, D2, E2**	***(Deciduous Needleleaved Forest)***
			4.2	- open	**2*& A3, A11+A13, D2, E2**	
	6.5	Tree Cover, mixed phenology or leaf type	5.1	- closed	**2*& A3, A10,A11+A12, D1+// D2** or **E1//E2**	***(Mixed Forests)***
			5.2	- open	**2*& A3, A11+A13, D1//D2** or **E1//E2**	
	6.6	Tree Cover, regularly flooded: Mangrove	6	Tree Cover, regularly flooded: Mangrove	**4*& A3, A12-13-14-15** and **R3**	***(Propose to evergreen broadleaved)***
		>>>>-flooded forest types other than mangrove (swamp, peat swamp, ..) are not displayed at the global level but grouped under class (1)<<<<	1.3	Tree Cover, other, regularly flooded, closed	**4*& A3, A12,A13+14**	***(propose to evergreen broadleaved)***
			1.4	Tree Cover, other, regularly flooded, open	**4*& A3, A13+15**	
Shrubland type& Shrub-Tree Savannas types	**6.7**	Shrub Cover, closed-open, evergreen (with or without sparse tree layer)	7.	**- minimum same as global** **optional: > 7.1 without, 7.2 with sparse tree layer**	**2*& A4, D1-2, E1 and optional F2,F5**	***(Shrubland - Open- closed)***
	6.8	Shrub Cover, closed-open, deciduous (with or without sparse tree layer)	8.	**- minimum same as global** **optional: > 8.1 without, 8.2 with sparse tree layer**	**2*& A4, D1-2, E2 and optional F2,F5**	***(Savannas)***
Grassland, Savannas ,Heath ***Pasture***	**6.9**	Herbaceous Cover, closed-open	9.1	Herbaceous Cover, closed-open 9.11 natural; 9.12 pasture[1]	**2*& A2-5-6, A10-11-12-13** **2*& A6, A10-11-12-13** + user-label 'pasture'	***(Grasslands)*** • **The global 'target legend' would consist of the 21 classes listed above - assuming that they can be consistently formed from the original LCCS classes.** • **At the (sub-) regional level the**
Tree Savanna type			9.2	Herbaceous Cover, closed-open with sparse trees or shrubs (> sub-classes)	**2*& A2-5-6, F2, F5-6** **2*& A3, A14-15-16** or **4*& A3, A16-17-18**	

Steppe types	**6.10**	Sparse Herbaceous or sparse shrub cover	10	**- minimum same as global-**	**2*& A2-5-6, A14-15-16** or **2*& A4, A14-15-16**	**legends would be as detailed as consistently possible and as discussed in the regional GLC2000 groups. It is required that the classes can be integrated into the global scheme. Some sub-classes generally desired at this level are displayed above, however the regional working group may add others. If sub-classes cannot be formed consistently for a sub-region or region one would fall back to the global categories.**
Tundra types	**6.11**	Lichens & Mosses	11	**- minimum same as global-**	**2*& A7-8-9**	
Wetland types	**6.12**	Regularly flooded shrub and/or herbaceous cover	12	**- minimum same as global-**	**4*& A4, D1-2, E1-2, F2,F5**	***(Persistent Wetlands)*** • **The original LCCS classes are built in each sub-region, region or data set independently and following the LCCS criteria and philosophy: original land cover classes are described to the detail possible. The 'target' legend above would be the result of aggregation of the original classes.**
Bog type	**6.13**	Regularly flooded cover of mosses (and lichens)	13	**- minimum same as global-**	**4*& A2-5-6-8-9** or **4*&A7-10-11**	
Cropland	**6.14**	Cultivated and managed areas	14.1	- terrestrial	**0*& A11,**	***(Croplands)*** 1. **If 'cultivated grassland' = 'pasture' cannot be distinguished from natural grassland, it will be included in the natural class**
				14.11 Tree & shrub cover (perennial) (***orchards, vineyards)***	**1*& A1-A2**	
				14.12 Herbaceous crops (annual), non-irrigated	**1*& A3-4-5 (&D1)**	
				14.13 Herbaceous crops (annual), irrigated	**1*& A3-4-5 & D3**	
			14.2	- aquatic ***(flooded during cultivation period)***	**0*& A23**	
Mosaic types ***Each component =20% and =80%*** ***First component dominant***	**6.15**	Tree cover / Other natural vegetation	15	**- minimum same as global-**	**2*& A3 and A2-4-5-6** or **C2, F2, F4-6 / 0004** or **4*& A3, A2-4-5-6-8-9 / 0004**	***(most probably to Shrubland)***
	6.16	Cropland / Tree Cover	16	**- minimum same as global-**	**0*/ 2*& A3** or **0*/ 4*& A3**	***(Cropland / Other Vegetation Mosaic)***
	6.17	Cropland / Other natural vegetation (non-trees)	17	**- minimum same as global-**	**0*/ 2*& A2, 4-9** or **0*/ 4*& A2-11**	
Barren & Desert	**6.18**	Bare Areas	18	**- minimum same as global-**	**6***	***(Barren or sparsely vegetated)***
Water & Snow & Ice	**6.19**	Water Bodies (natural & artificial)	19	**- minimum same as global-**	**8*& A1** or **0*& B27**	***(Water)***
	6.20	Snow and Ice (natural & artificial)	20	**- minimum same as global-**	**8*& A2-3**	***(Snow & Ice)***
Urban	**6.21**	Artificial surfaces and associated areas	21	**- minimum same as global-**	**0*& B15**	***(Urban and built-up areas)***

Annex 4

Threshold for all the classes in all the blocks

Block	bos (b2)	naald	loof	gemengd	akker	wei	Shrubs	Nat. Grassland	wetlands
Netherlands	>104 (b2)	>160(feb)	<146(feb)	<160 & >140	<141(feb)	>141(feb)			
Denmark	94,4	>165(feb)	<150(feb)	<165 & >150	<141(feb)	>141(feb)			
N-Germany	105,4	>165(feb)	<150(feb)	<165 & >150	<141(feb)	>141(feb)			
Tsjec Rep.	105,4	<217(aug)	>230(aug)	<230 & >217	<186 (sep)	>186(sep)			
W-Poland	100,4	<217(aug)	>230(aug)	<230 & >217	<186 (sep)	>186(sep)			
E-Poland	97,4	<217(aug)	>230(aug)	<230 & >217	<186 (sep)	>186(sep)			
N-France	103,9	<217(aug)	>230(aug)	<230 & >217	<186 (sep)	>186(sep)			
Channel	96,1	<214(aug)	>235(aug)	<235 & >214	<205 & >176(may)	>205(may)		<157(may)	
England	94,1	<214(aug)	>235(aug)	<235 & >216	<205 & >176(may)	>205(may)	<176 & >157(may)	<157(may)	
Scotland	76,5	<212(aug)	>230(aug)	<230 & >212	<175(sep)	>175(sep)	<180(may)		
Ireland	94,1	<221(aug)	>226(aug)	<226 & >221	<176(sep)	>176(sep)			<176(may)