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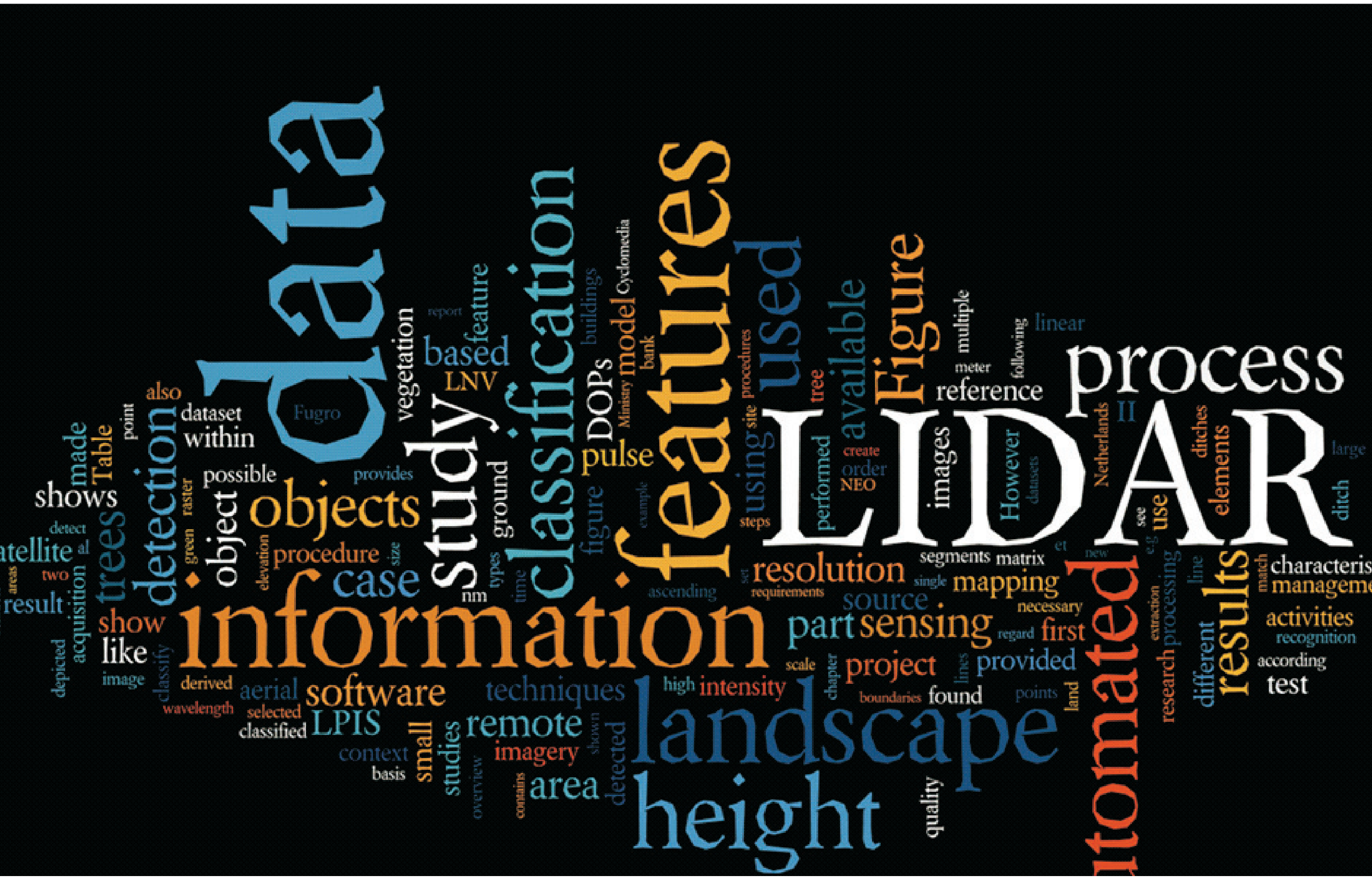

Recording small landscape features by object recognition

Possibilities and limitations of automated procedures to support monitoring in the frame of the GeoCAP

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Arno Krause, Matthijs Danes, Henk Janssen, Henk Kramer and Frans Rip

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The research question itself was registered as HD3133: 'Methodiek voor geautomatiseerde kartering van het landelijk gebied' (Methods for automated mapping of the countryside), project code: BO-01-007-704

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Abstract

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In compliance with EU Common Agricultural Policy (CAP), a digital Land Parcel Information System (LPIS) exists in The Netherlands. However, its content is basically limited to the primarily (net) agricultural area. So far landscape features defined by the CAP EC law were not yet included. In commensurate with the possibility to add distinct landscape features to the area recorded in the LPIS, The Netherlands are seeking to find a digital procedure for their recording.
This study is a reconnaissance of the possibilities for automated recognition of landscape features, using high resolution geo-datasets and aerial photography, including the infrared bands.
The overall conclusion is, that technically it seems well possible to record small landscape features from existing datasets. The study was performed on a spatially limited area in The Netherlands. The results of this study show that several distinct landscape features can be recorded and differentiated in an automatic way to minimize the overall manual procedures for their recording appropriately.
However, the operationalization of the determined procedures (i.e. data availability, storage space, processing capacity) necessary to apply the procedure on a nationwide scale are not subject to this study and will be subject to further investigations.

Keywords: LPIS, small landscape features, object recognition, LIDAR, infrared, aerial photography.

Cover: A word cloud, produced online with www.wordle.net, based on the English main text of this report

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Inhoud

Summary

This report is in response to a question of the Dutch Agricultural Ministry (EL&I) in 2009 for a depiction of the possibilities and limitations of automated detection of landscape features using remote sensing and GIS; also requested was a view on required data sources. The ministry asked for a focus on using datasets that are already available within the ministry.

The background of the question was the need of the ministry to adapt and extend the presently existing Land Parcel Information System (LPIS) in order to comply with developing regulations on the subject of the Common Agricultural Policy of the European Union. In the future, not only agricultural areas need to be in the system, but also adjoining non-agricultural areas, the landscape features.

This report provides an answer to the questions of EL&I, basically by first exploring the nature of the involved matters, and then exploring the technical procedure of automated landscape feature detection.
A first step in the exploration was to find out about which landscape features need to be recognized. From discussions with EL&I, services 'DR' (implementation of regulations) and 'GCC' (GIS Competence Center) it was concluded that there are four types of landscape features that definitely need recording, whereas two others are optional. The four types are: wooded banks, shelterbelts, buildings & paved roads and ditches. The optional types are lines of trees and solitary trees.

The report then tries to define characteristics for each type in order to enable automated recognition. For this, two sources were used, both provided by the ministry: the agricultural parcel digitization manual, and the description of landscape maintenance types. The conclusion is, however, that these descriptions do not contain sufficient criteria. The criteria that can be obtained from the descriptions would need to be more formalized if they were to be used for automated processing.

Next, a compilation and evaluation of software suitable for pattern recognition using LIDAR data was conducted. This results in a selection of three software packages out of a group of seven, that are best suited for the job. A list of 16 literature references was compiled, showing the state of the art regarding object recognition using LIDAR data.

In addition to that, four Dutch companies have been interviewed in the fall of 2009 to determine what aspects of the LIDAR based object recognition state-of-the-art is their strong point. The aspects are: data acquisition, data management, data processing, process management and quality assessment. This action resulted in the conclusion that the firm 'Neo' is relatively strong in process management and quality assessment, whereas the other three firms (Fugro, Imagem, Cyclomedia) have their emphasis with data acquisition, management and processing.

To find out about the value of the ideas so far, case studies would be useful. With regard to the methodology for case studies, three parts are distinguished within the feature recognition process. The first part is Data Acquisition and pre-processing. This results in datasets of satellite images or aerial photographs. The second part consists of segmentation of the data (based on object height) followed by object characterization: a group of pixels becomes a tree or a house. The third part contains Object matching: the aggregation and matching of objects with specific landscape features.

The first case study was about how to use LIDAR data to classify and recognize individual objects (parts two and three of the methodology). To identify objects as any type of feature, the raster based dataset Top10Smart was used. It has a grid cell size of 2.5x2.5 meter. Although in general a feasible processing chain, it turned out that the grid structure of the topographic map was too coarse to always correctly identify objects.

The second case study was about aerial photographs (digital orthophotos, edition 2008, 25 cm resolution, infrared band included) combined with height data based on the LIDAR data. It covers all three parts of the methodology to finally detect landscape features like shelterbelts, lines of trees or ditches. Instead of using the gridded topographic map as a reference, now the reference was manually digitized from various sources. The results of this procedure are very satisfactory as they turned out to be, on average, of a slightly better quality than the reference data.

A third case study was performed as a quick scan in the fall of 2010, focusing on the detection of ditches. It was triggered by the release of version 10 of the ESRI software ArcGIS and its capabilities to process 3D data. This quick scan showed that with LIDAR data it is well possible to detect the course of ditches with sufficient geometric accuracy.

All in all, the study concludes that in principle automated detection of landscape features is possible. However, improvements are necessary in the definitions of landscape features. For nationwide application of the procedure, the availability of LIDAR data and of aerial photography with infra red band included is essential, as well as an adequate computing environment for the huge amounts of data to be processed in a short time.

1 Setting the Scene

According to EU Common Agricultural Policy (CAP) regulations all Member States (MS) are obliged to create and maintain digital reference systems (Land Parcel Identification Systems (LPIS)) since the year 2005. Within that context The Netherlands have created an LPIS based on physical blocks.[1] Among different constraints the regulatory framework requires an adequate correctness of the LPIS in terms of a proper reflection of the current land use. More specific, the LPIS has to be limited to areas which are used for agricultural purposes.

The current modality of the Dutch LPIS does not explicitly take into account geographically areas that are located within or adjoining physical blocks not primarily used for agricultural purposes. That procedure will be changed in the future so that all - also non-agricultural objects (further referred to as landscape features) - will be recorded in a geographical way. As this procedure requires considerable effort especially when conducted in manual processes, EL&I is seeking for solutions that support these processes in automated ways. Thereby use shall be made of digital procedures based on remote sensing techniques and algorithms for pattern recognition.

Moreover EL&I is seeking for automated procedures to record and manage particular objects, in this report referred to as 'landscape features'. A list of these landscape features to be recorded in automated procedures is contained in Appendix 3 of this report.

1 An overview of the current policy framework on the level of the EU can be derived from Table 10 in Appendix 2 of this report.

2 Objectives and structure of the study

Within the context mentioned above EL&I approached Alterra in May 2009 with a research request: The primary objective according to the request was to depict *possibilities and limitations to automatically detect specific objects (landscape features) on the base of remote sensing and GIS-techniques*. Additionally the according and necessary data sources and the future maintenance (mutations) of these landscape features should be represented.

The question formulated by the Ministry consists of several sub-questions:

- Is it possible to develop a methodology for automated mapping of landscape features and subsidy eligible parcels by using high resolution geo-datasets and aerial photography (airborne and/or satellite origin), which complies with the required quality demands (without using Top10-datasets)?
- What is the link (if any) between the developed automated mapping methodology and the Dutch nature conservation information model IMNAB?
- What is the quality of the automated mapping results in relation to field observations?
- Could a (automated) mapping procedure be adequately standardized in the future in order to detect and classify changes (in landscape elements) in the rural area?
- Which long term (societal and technical) developments are of importance in relation to the further development of an automated mapping procedure?
- Could an estimate be given on the costs of a nationwide application of an automated mapping procedure?
- Could an estimate be given of the capacity (calendar time and man power) needed to prepare a nationwide database with landscape features using automated procedures?

The initial request was further elaborated and more detailed in close cooperation between Dienst Regelingen (DR), GIS Competence Centre and Alterra Wageningen UR. On the base of joint discussions, DR specified basically four types of objects to focus on, which are:

- wooded bank (houtwal)
- shelterbelt (houtsingel)
- buildings and paved roads (bebouwing en verharde wegen/paden)
- ditch (sloot)

Optional objects to focus on are:

- line of trees (bomenrij)
- solitary tree (solitaire boom)

The principal expects the study to produce per element a technique for recognition and classification, as well as a process flow in relation to relevant data sources.

Both the research request and some discussions with the principal were at the basis of the project proposal in which the output and content of the study was described. Alterra Wageningen UR offered to perform a study that contains:

- the analysis and compilation of literature and 'state of the art' and
- concept development and concept testing in selected test-areas

Thereby as much as possible focus was made towards possibilities and limitations making use of available data within the Ministry such as digital orthophotos (DOPs) and/or LIDAR, or a combination of these. This prioritization was deliberately made to comply with the wishes on the side of the Ministry to take into account LIDAR data analysis and software necessary for it. This was stressed and asked for by the Ministry in the second project meeting on July, 7th 2009 in Wageningen.

This report provides the agreed output according to the proposal and priorities of the principal. It provides a concise literature analysis towards the current state of the art of comparable projects. On that basis a matrix of available remote sensing platforms and techniques was created that give an overview of their appropriateness for the automated classification of landscape features. Subsequently the result of case studies being conducted at Alterra are introduced and evaluated towards their appropriateness for applicability in the project context. The report closes with a summary of the results of the case studies containing possibilities and limitations as well as recommendations of the selected technologies within the project context.

With regard to the name of the principal, although most of this project took place before the rearrangement of Dutch ministries in October 2010 and their subsequent name changes, in the remainder of this report the principal will be referred to as 'EL&I'.

3 State of the art

This Chapter is the theoretical part of the study. It lays down selected and basic principles, methodologies and comparable studies based on literature. It provides the understanding and hence the frame for the case studies which are described in the subsequent chapters.

3.1 Remote sensing and landscape features: Basic technical framework

As stated in Chapter 1 there is a framework of policies and related documents that determine requirements to resolution and radiometry. These requirements primarily are addressed to the requirements related to the Land Parcel Identification System (LPIS). As landscape features within the project context are used to improve the current state of the LPIS it can be stated that the LPIS minimum requirements are at least the same for the landscape features, too.

Within the 2003 Fischler CAP reform it became evident that LPIS data (and so affiliated data such as landscape features) in general is no longer strictly dedicated to support the aid declaration and subsequent control. In fact the information stored in the LPIS is already broadly used by other external users. This is because the reference parcels, together with the orthophotos and the attribute information on the land use, form the basic set of components, necessary for any decision regarding the land management. In addition, apart from the reference parcels themselves, the LPIS database contains other layers of information (or at least is able to overlay them on-the-fly), which together could be made broadly available through simple Web interface. Only 5 MS out of 27 (IT, NL, IE, Flanders and DE) do not provide LPIS data to external organizations or users.[2] Hence landscape features can be an important part in this database.

The minimum requirements for the assessment of landscape features in the frame of the CAP derive from the requirements of the LPIS. The minimum scale for the cartographic information used to create and update the LPIS is 1:10.000, which corresponds to an orthoimagery of at least 1 meter resolution. However, most of the orthoimages used in the LPIS have a ground sampling distance (GSD) of 50 cm. Half of the MS have orthophotos with GSD in the range of 40 - 60 cm[3]. That shows the tendency in the MS to make use of orthophotos with better resolution than the threshold value.

3.2 Data acquisition modes within the project context

The main source for the production of nation-wide orthoimagery remains the aerial acquisition. Some MS opened already the option for the use of aerial digital cameras (frame or pushbroom). Although the digital technology provides better quality in terms of radiometry and detail, there are some specific limitations, regarding the height of the flight and the processing chain. Also some MS still face difficulties in applying

2 compare. Kay and Milenov, 2006.

3 Germany has orthoimages with broad range of resolution -from 25 cm to 1 m-, as each Bundesland has its own strategy for the orthoimage production as well as for the creation of their LPIS and LPIS data (compare Krause, 2006). In The Netherlands currently a ground resolution of 40 cm is used for LPIS production.

declassification of the raw digital data, as the relevant military authorities in the country requested. Some MS (IT, DE, PL, BG, Flanders and Greece) are using also Very High Resolution (VHR) satellite data together with the aerial orthophotos for part of their countries. Due to flight restrictions, CY is using VHR satellite data only for the LPIS preparation. IE has in addition to the aerial, a complete VHR coverage from 2006.[4]

3.3 Remote Sensing

Remote sensing is a generic term, for a variety of techniques to acquire data. In practice, remote sensing generally concerns the interpretation of satellite images, but other techniques exist. Additionally remote sensing can be subdivided into 'passive' and 'active' techniques. A passive technique only concerns an optical sensor that records incoming radiation with a specific resolution, like the human eye. With active remote sensing radiation is emitted and the reflected energy in combination with the reflectance duration is recorded. Active remote sensing includes techniques like LIDAR and Radar, and are very good for measuring distances. The following section summarizes the different remote sensing techniques.
Some examples of active remote sensing technologies are:
- LIDAR
- Radar

Some examples of passive remote sensing technologies are:
- Low resolution satellite images (e.g. Landsat, Modis, Spot)
- High resolution satellite images (e.g. Quick bird, Ikonos)
- Digital aerial photo

This report investigates the possibilities to use different remote sensing techniques for an automated classification of landscape features. However, since the resolution of radar and low resolution satellite images (LRS) do not meet 1 meter resolution of the European legislation for the Land Parcel Identification System[5], they will be excluded from this research.

High resolution satellite images (HRS) on the other hand, are very detailed and could be suitable for the extraction of landscape feature. However, it is very difficult to acquire cloud free images that cover The Netherlands entirely. Reason for this is the strong competence in data acquisition with nations like Germany and England. This means that most of the time the sensor is not pointed directly to The Netherlands, which reduces its accuracy. Additional problems derive from clouds. The chance that the entire country is cloud free on the moment the satellite passes is very small, which makes satellite images an unreliable source concerning the data acquisition.

For The Netherlands, both LIDAR and Digital aerial photos (DOPs) are being collected. For the AHN project, LIDAR data is acquired. Full coverage of The Netherlands will be available by 2013. No access policy for the original LIDAR for EL&I has been established yet but for test purposes, the data for the province of Zeeland has been made available. The LIDAR data contains information about the height of objects and can be a suitable source of information to create an automated process for the classification of landscape features.

4 Kay and Milenov, 2006.
5 Compare Oesterle and Hahn (2004), Krause (2006).

Almost on a yearly basis, digital aerial photos with a ground resolution better than 50 cm with RGB and Near Infrared spectral bands are collected by companies like Aerodata and Eurosense. For 2006 and 2008, these datasets are available for EL&I as a mosaic for the whole of The Netherlands. The included Near Infrared spectral bands make this dataset a suitable source for the classification of vegetation. With the original photo, stereoscopic image processing can be applied. This makes it possible to extract information about the height of objects.

Since information about heights is crucial for an automated classification of landscape features, and because it's relative reliability in data acquisition, the combined approach of LIDAR and Digital Aerial Photos will be further elaborated during this research.

As a summary the table below provides a matrix that indicates selected characteristics for different kinds of remote sensing techniques being applicable in the project context. They can serve as a basis on which a choice can be made on determining the appropriate technique for the recording of landscape features.

Table 1
Potential remote sensing techniques within the project context.

Criteria	Resolution (meter)	Height information	Data availability	Cost (euro/km^2)	Active/Passive technique
LIDAR	0.3	Yes	+	-	Active
DOP	0.25	No	+	-	Passive
HRS	1-10	No	-	0.95	Passive
LRS	500 - 1.000	No	-	0.12	Passive

The full range of current remote sensing techniques, considered for this case study, is limited by criteria which are basically the availability and ground resolution. They both are determined by the policy framework.
That situation justifies that for the further study only two techniques will be further analyzed, which are LIDAR and DOPs.

3.4 Technical background on LIDAR

LIDAR data stands for *Light Detection and Ranging'*(dit is dubbel accent, dus of accenttekens of cursief) and is used to measure the properties of backscattered light. LIDAR is similar to radar, except that LIDAR uses much shorter wavelengths in the electromagnetic spectrum. Typical LIDAR systems operate in the ultraviolet (10 – 400 nm), visible (400 - 700 nm) or near infrared (700 - 1300 nm) (see Figure 1). Since only objects can be measured that are equal or bigger to the size of the wavelength, smaller wavelength generates more detail (Wikipedia, 29-07-2009).

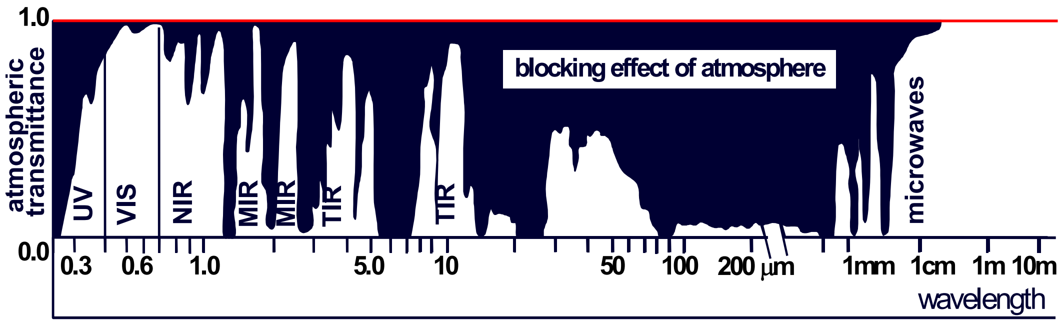

Figure 1

Atmospheric transmittance for radiation as a function of the wavelength. After Lillesand, T.M. and R.W. Kiefer (2000). Remote Sensing and Image Analysis. 4th Ed., John Wiley and Sons, New York.

In order to register distances, laser pulses are used. Each laser pulse can have a diameter up to 1 meter with a specific pulse length. The pulse length defines the duration between the time the laser is switched on and off. Once the pulse is emitted it is measured how long it takes before the reflected pulse returns to the sensor. The time together with the intensity of the returned signal is stored and provides information about the distance and the material of the measured object.

When measuring 'soft' objects (e.g. trees), one pulse can have multiple returns. In such a case the first return always represents the top of that feature. However, a fraction of the laser-beam might penetrate the outer layer of the 'soft' surface to reflect on the inner structure. In the case of mapping trees, this means that multiple returns can be used to describe the structure inside a canopy. Also with multiple returns, the recorded intensity can be used to map different material characteristics.

The point spacing (or density) is dependent on the pulse frequency (30-KHz means 30.000 pulses per second), the observation distance, the scan angle and sensor speed when the sensor is moving during the measurements. This explains e.g. why the point spacing from a sensor on an airplane differs compared to the point spacing from a similar sensor on a helicopter (FEMA, 29-07-2009).

3.4.1 LIDAR and its range of application

A concise scan of relevant projects comparable to the pattern recognition context of the study at hand shows that there are several application fields in which LIDAR is being used (NOAA, 28-07-2009). Some prominent examples are:

- Shoreline and Beach Volume Changes
- Flood Risk Analysis
- Water-Flow Issues
- Habitat Mapping
- Subsidence Issues
- Riparian Studies
- Forestry Management
- Emergency Response
- Transportation Mapping
- Telecommunication Planning
- Urban Development

Like the latter mentioned examples show, LIDAR data is generally used for its ability to measure distances, but is less famous about its capacities to obtain meteorological information. However, since meteorological information differs from normal distance measurements, other LIDAR systems need to be used. The most prominent systems are:
- Elastic backscatter LIDAR
- Differential absorption LIDAR (DAIL)
- Raman LIDAR
- Doppler LIDAR

The elastic backscatter is based on the intensity of the returned pulse and creates a vertical profile with information about suspended particles. By combining two elastic backscatter devices (DAIL) with different wavelength, even more information can be obtained about the parameters of the suspended particles. Differently than the backscatter and DIAL systems, a Raman system focuses on the wavelength of the return pulse. Because of the characteristics of a medium, the wavelength of the pulse will be transformed slightly. With the amount of transformation, information can be obtained temperature, atmospheric density, water vapor concentration, etc.

A Doppler system works like Raman by measuring the transformation of the wavelength. According to the wind speed, the Doppler effect in-/decreases the wavelength.

3.4.2 Classification of LIDAR data

Like stated before LIDAR returns information about intensity, pulse return, position and height. Before individual objects can be classified, it is first necessary to subdivide the raw LIDAR data into different classes (e.g. vegetation, buildings, roads, etc.). In practice different method can be used to classify raw LIDAR data. Maas published in 1999 about a method to separate buildings and trees by combining the normalized observed height with the ground height. However, it should be emphasized that this article focuses on large trees and normal size buildings. As soon objects become smaller, like cars or scrubs, it becomes impossible to make a proper distinction based on height.

Charaniya et al. (2004) combined the method of Maas (1999) together with height variation, multiple returns, luminance and intensity. According to their findings, the best classification results are observed when intensity is combined with luminance, height variation, and normalized height. Again it should be emphasized that this research does include vegetation objects other than normal size trees.

3.5 Technical background on Digital Orthophotos

Optical Remote Sensing Images acquired by satellite or aircraft have been used for the classification of land cover or land use for many years. One example is the land use database (LGN, Landelijk Grondgebruik Nederland) for The Netherlands which main focus is agricultural land use. The first edition was created in 1986 and its 6th edition was published in 2009. The main source for the LGN database is imagery from the Landsat TM satellite. With a ground resolution of 25 meters and the availability of both Near- and Mid-Infrared spectral bands, this was supposed to be a very suitable source for the classification of land cover (including crops) on a national scale. However, the ground resolution from Landsat TM imagery is to coarse grained to be used for the classification of small landscape elements.

Previous research on using high resolution imagery (HRI) for the detection of small size landscape features is described by Berg (2003), Thunnisen (2000) and Snep (2007). The results show HRI can be used to detect small size landscape features, but is highly influenced by the availability and quality of the source imagery (clouds, shadows, acquisition date (winter or summer)).

3.6 Technical characteristics of landscape features to be recorded

As stated in Chapter 2 of this study the types of features to be recorded are
1. wooded bank (houtwal)
2. shelterbelt (houtsingel)
3. buildings and paved roads (bebouwing en verharde wegen/paden)
4. ditch (sloot)
5. and optional
6. line of trees (bomenrij)
7. solitary tree (solitaire boom)

The differences between these types are predominantly subject-specific driven which often requires the corresponding background knowledge to classify them.

However on the other hand the automated classification and differentiation of landscape features relies basically on clear characteristics that can be interpreted in a machine readable style. Especially the pattern matching between classification results from the remote sensing data with the types of landscape features requires an unambiguous description of the features themselves. Hence within this study the attempt is made to create a machine readable classification matrix. The initial sources for classification criteria are these documents:
- Digitization manual Dutch LPIS (file: Handboek_digitaliseren_AAN_versie1.0.pdf)
- Landscape management types description
  (Index Natuur en Landschap - onderdeel landschapsbeheertypen, file: 2009-07-08 pop definitieve beschrijving landschapsbeheertypen.doc)

They were provided by the principal as background for this study[6]. The documents have different aims in describing the types of features: The digitization manual aims at the detection and classification of landscape features from the aerial image. The landscape management types description aims more or less at classifying landscape features from the perspective of their contribution to the environment with special regard for their maintenance. In that regard it is quite important to state that the distinction made in this document between different types of landscape features cannot be reproduced with remote sensing techniques - at least not in this study - as a quite large number of linear features are quite similar to each other and sometimes only differ in the way they are maintained.

The table below (Table 2) provides a structured compilation of descriptions of the landscape features in this study, combined with criteria derived from the mentioned documents.

[6] An excerpt of the original documents describing the types of landscape features is contained in Appendix 2 of this study.

Table 2
Characteristics of landscape features according to specifications provided by EL&I.

		Criteria according to : 'Handboek_digitaliseren_AAN.pdf'		Criteria according to 2009-07-08 POP DEFINITIEVE BESCHRIJVING LANDSCHAPSBEHEERTYPEN.doc
1	Wooded bank (Houtwal)	Houtwal is not explicitly described in this document. However some specifications are indirectly provided by typeHoutrand in row no. 8 of this table.		Een houtwal of houtsingel is een vrijliggend lijnvorming en aaneengesloten landschapselement, al dan niet groeiend op een aarden wal, met een opgaande begroeiing van inheemse bomen en/of struiken. De begroeiing wordt als hakhout beheerd. De houtwal of houtsingel is maximaal 20 meter breed. Houtwallen en houtsingels worden periodiek, eenmaal in de 6-25 jaar, afgezet met uitzondering van eventueel aanwezige overstaanders. Bij houtwallen wordt het wallichaam in stand gehouden en indien nodig hersteld[7].
2	Shelterbelt (Houtsingel)	'Houtsingel' is not explicitly described in this document. However some specifications are indirectly provided by typeHoutrand in row no 7. of this table		Een houtwal of houtsingel is een vrijliggend lijnvorming en aaneengesloten landschapselement, al dan niet groeiend op een aarden wal, met een opgaande begroeiing van inheemse bomen en/of struiken. De begroeiing wordt als hakhout beheerd. De houtwal of houtsingel is maximaal 20 meter breed. Houtwallen en houtsingels worden periodiek, eenmaal in de 6-25 jaar, afgezet, met uitzondering van eventueel aanwezige overstaanders. idem
3	Buildings and paved roads (Bebouwing en verharde wegen/paden)	Bebouwing	Alle soorten bebouwing dat aard- en nagelvast is, zoals schuren, huizen, stallen - inclusief omliggend erf	Buildings and paved roads ('Bebouwing en verharde wegen/paden') are not mentioned in this document.
		Verharde wegen/paden	Not mentioned in the document	
4	Ditch (Sloot)	Waterlopen gelegen in percelen, tussen percelen en/ of aan de rand van percelen. De sloten hebben een breedte van minimaal 1 meter, gerekend van insteek tot insteek. Sloten breder dan 6 meter staan als vlak in de Top10NL. Sloten die binnen het referentieperceel liggen worden gedigitaliseerd vanaf insteek tot insteek. Als sloten de grens vormen van een referentieperceel wordt gedigitaliseerd ook langs de insteek van de sloot (de insteek is de buitengrens van het referentieperceel).		Ditches ('Sloten') are not mentioned in this document.

7 The source is an EL&I internal working document, of which no English version existed.

		Criteria according to : 'Handboek_digitaliseren_AAN.pdf'	Criteria according to 2009-07-08 POP DEFINITIEVE BESCHRIJVING LANDSCHAPSBEHEERTYPEN.doc
5	Optional: Line of trees (Bomenrij)	Aantal bomen die in een rij staan, waarbij de onderlinge afstand tussen de bomen zodanig is dat de bomenrij tot manshoogte geen zichtbelemmering vormt. Een bomenrij is een vrij liggend lijnvormig landschapselement met opgaande begroeiing van bomen en struiken Minimale lengte voor opname is 100 meter. Er moet wel sprake zijn van een rij: de opgaande bomen staan in een lijn. Struiken of eventueel aanwezig hakhout spelen hierbij geen rol (een aantal rijen bomen die samen een vlak vormen is dus geen bomenrij) Maximaal twee rijen. Bij meer dan twee rijen is er geen sprake meer van een bomenrij, maar van een bos. De bomenrij wordt gedigitaliseerd met een breedte van één meter.	Een bomenrij/solitaire boom is een vrijliggend landschapselement van inheemse loofbomen, niet zijnde houtopstanden, lanen of knotbomen, die kunnen worden gerangschikt onder andere beheertypes van deze index. Bedoeld worden solitaire bomen of bomen in een groep of rij staande op of langs landbouwgrond. De boom staat niet in een ander beheertype waarbij het formaat wordt uitgedrukt in een oppervlakte-eenheid (b.v. houtwal en houtsingel en hakhoutbosje). Een bomenrij bestaat uit minimaal uit 8 bomen per 100 meter. Een solitaire boom is gelijk aan 16 meter bomenrij. Vlakvormige boomweides behoren niet tot dit beheertype.
6	Optional: Solitary tree (Solitaire boom)	Solitary trees ('Solitaire bomen') are not mentioned in this document.	Een bomenrij/solitaire boom is een vrijliggend landschapselement van inheemse loofbomen, niet zijnde houtopstanden, lanen of knotbomen, die kunnen worden gerangschikt onder andere beheertypes van deze index. Bedoeld worden solitaire bomen of bomen in een groep of rij staande op of langs landbouwgrond. De boom staat niet in een ander beheertype waarbij het formaat wordt uitgedrukt in een oppervlakte-eenheid (b.v. houtwal en houtsingel en hakhoutbosje). Een bomenrij bestaat uit minimaal uit 8 bomen per 100 meter. Een solitaire boom is gelijk aan 16 meter bomenrij. Vlakvormige boomweides behoren niet tot dit beheertype.
7	Hedgerow (Heg)	Groene lijn, strak geschoren of hoog en weelderig uitgroeiend, van struikvormende gewassen. Een heg onderscheidt zich van de hagen en houtsingels doordat ze hooguit een paar meter breed zijn en geen bomen bevatten.	Not mentioned in this document.
8	Aggregation of shelterbelt, hedgerow and wooded bank (Houtrand)	Onder Houtrand worden houtsingels, hagen en houtwallen verstaan: terreinen begroeid met loofhout en/of naaldhout, waarvan de inplant van de stammen breder is dan 1 meter. Al dan niet met hoogteverschil. Hoogteverschillen (b.v. Limburg) begroeid met struiken en zo hier en daar een boom, vallen ook onder de categorie Houtrand. De Houtrand wordt gedigitaliseerd aan de hand van de grenzen die op de luchtfoto waarneembaar zijn en heeft een minimale breedte van 1 meter.	Not mentioned in this document.

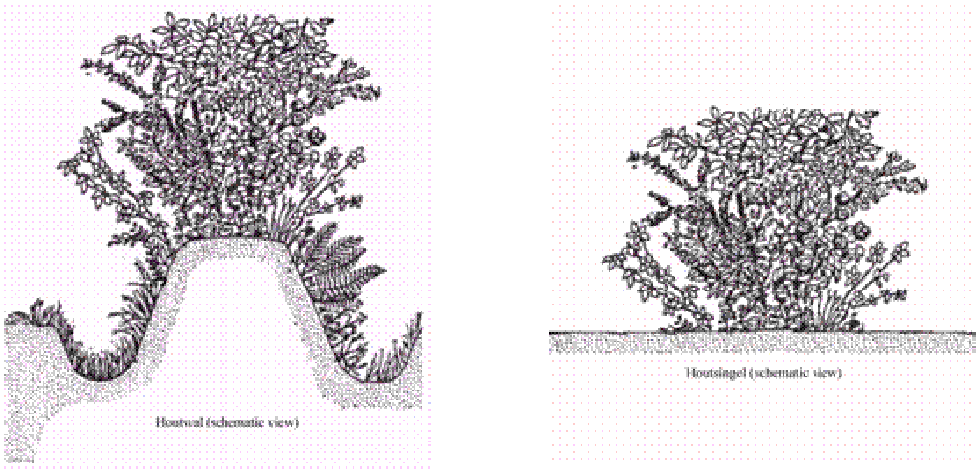

Figure 2
Wooded bank (Houtwal) vs. Shelterbelt (Houtsingel): Schematic view (Holsteiner, 2009, modified).

The information from the documents as represented in the table above is rather descriptive and not fully applicable for automated pattern recognition respectively pattern matching. Especially a differentiation between wooded bank (Houtwal) and shelterbelt (Houtsingel) is quite difficult as the corresponding descriptions are quite similar.

It seems that for this study more differentiation criteria have to be determined that enable distinguishing between the types of landscape features.

Hence, a distinction will be made between wooded bank and shelterbelt based on the underlying bank. In this study only linear features with a bank below will be determined as wooded bank (Houtwal) whereas a linear feature without it will be determined as shelterbelt (Houtsingel). Figure 2 shows the difference.

Moreover the necessity exists to make the descriptions more formal in terms of using the description criteria in the way that they can be interpreted in an automated way.

Table 3 shows the result of an attempt to create a formalized characterization matrix that can support the automated process of pattern matching. The matrix makes no claim to be complete and should rather serve as basis for subsequent refinement by EL&I or further studies.

Table 3
Matrix of object recognition criteria.

	Feature length	Feature width	Feature height	Feature area	Trees available	Extras
Wooded bank (Houtwal)	?	≥ 1m ≤ 20 m	3-6 m	Not used yet	no	Has bank below Has trees (diff. from hedge)
Shelterbelt (Houtsingel)	?	≥ 1m ≤ 20 m	0-3 m	Not used yet	no	Has trees (diff. from hedge)
Buildings and paved roads (Bebouwing en verharde wegen/paden)				Not used yet	no	
Ditch (Sloot)		≥ 1 m		Not used yet		
Line of trees (Bomenrij)	≥ 100 m		> 6m	-	yes	≥ 8 trees/100m Two rows at most. If there are more than two rows the object is seen as a forest. The line of trees will be digitized with a width of one meter
Solitary tree (Solitaire boom)						

3.7 Overview of prominent selected software for pattern recognition

As asked and emphasized by EL&I in the meeting on the 9th of July 2009, EL&I the study performed an inventory of software that is available to analyze LIDAR data.

Actually there is a broad range of software systems available that support users in pattern recognition. In order to support EL&I in its task to select the appropriate tools, a compilation and evaluation of some selected software tools was conducted.

Table 4 summarizes several of the most commonly used software packages. Additionally, it provides information about the type of application and its capability.

Table 4
Available software packages to process LIDAR data.

Company	Software	Application type	Description
Bentley	PowerCivil	Standalone	Landscape development tool, used in designing landscapes
Fugro	FugroViewer	Standalone	Visualizing LIDAR and IFSAR data
Leosphere	EZLIDAR	Standalone	Visualizing and analyzing meteorological information
Overwatch Geospatial Systems	LIDAR Analyst	ArcGIS extension	Point classification, like ground level, vegetation and buildings
QCoherent	LP360	Standalone/ ArcGIS extension	Point classification, like ground level, vegetation and buildings
TerraScan	Terrasolid	Standalone	Point classification, like ground level, vegetation and buildings
USDA Forestry Service	FUSION	Standalone	Designed to obtain canopy characteristics: cover, height, fuel weight and bulk density

Except for FUSION and LIDAR Analyst, the general software is developed to calculate the Digital Elevation Model (DEM) or the Digital Surface Model, which is similar to a DEM but also includes buildings, vegetation, etcetera. However, only few packages are able to recognize individual objects with its characteristics. One can think of tree height, crown width, position of single trees, type of material/vegetation, etc.

Within the objective of this research to classify landscape features, the software packages LIDAR Analyst, LP360 and Terrasolid seem to be the most appropriate to elaborate this capability.

In the case of LIDAR Analyst, it is the only package from which an example is found that concerns vegetation extraction with detailed tree information (see Figure 3). It retrieves the tree height, crown width and stem diameter per tree. Additionally, it can convert the trees into forest areas.

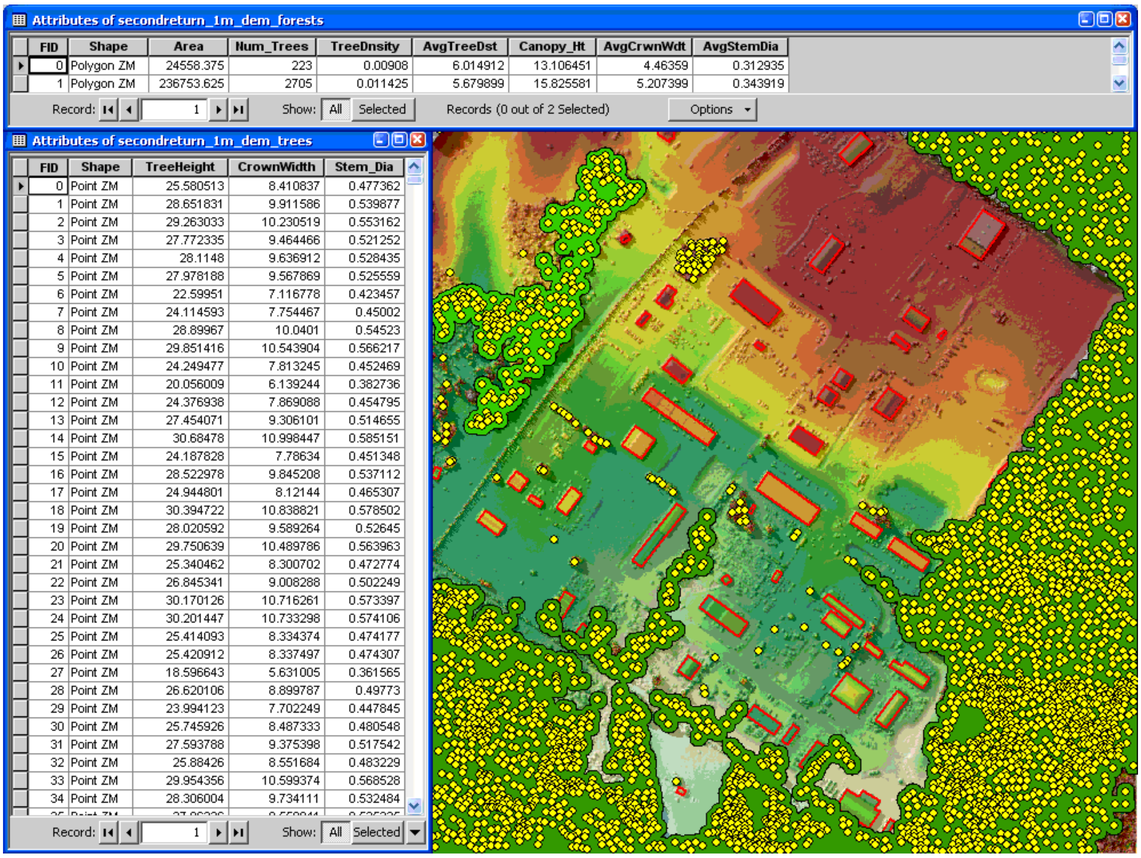

Figure 3

Example of LIDAR Analyst.

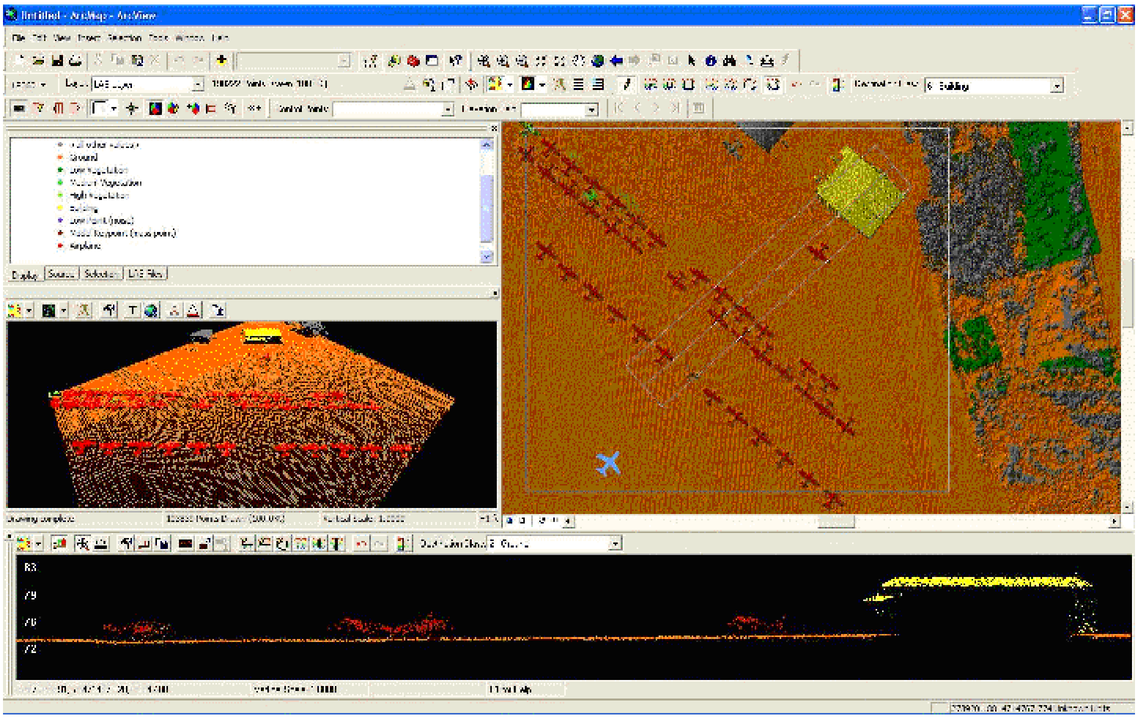

Figure 4

Example LP360.

LP360 (Figure 4) works with different views in order to classify the points. The major advantage of LP360 is that it is not as standardized as LIDAR Analyst. This gives the feeling to be more in control during the classification.

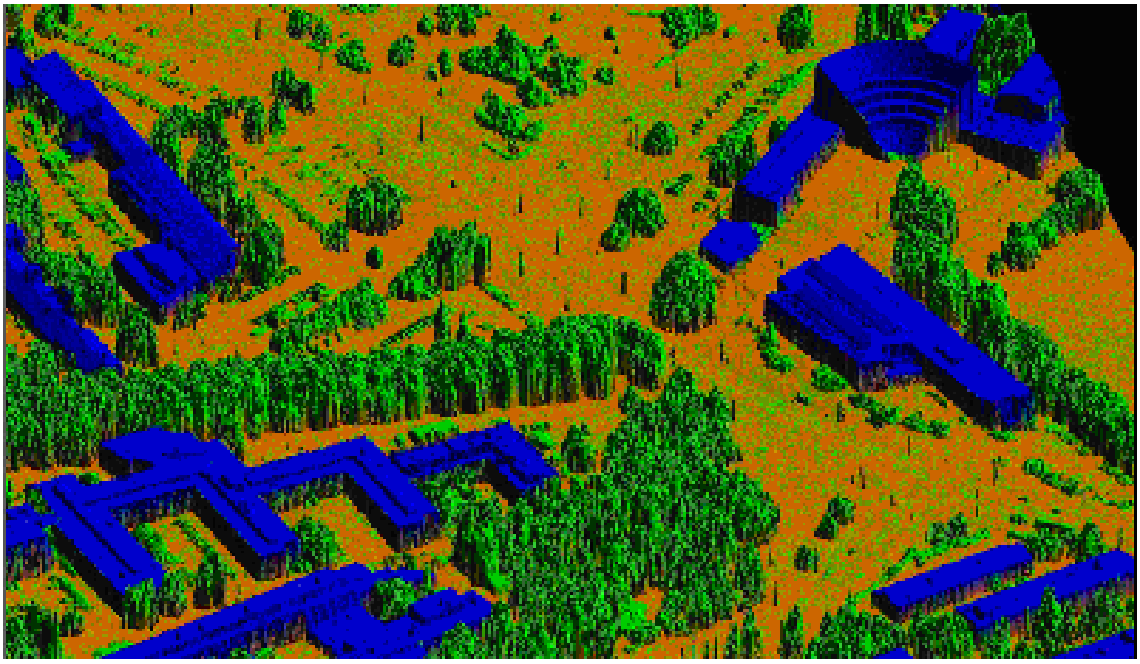

Figure 5
Example Terrasolid.

The last example is taken from TerraScan (see Figure 5). TerraScan is designed to calculate and classify the surface models, but seems less appropriate to retrieve information about the characteristics of single objects.

3.8 Literature review

Reviewing literature reveals several attempts to develop an automated method to obtain new object characteristics. The following table provides 'state of the art' methods to obtain new information based on LIDAR data. Additionally the table shows the kind of input data which are necessary for each method.

Table 5
Literature review of information extraction.

Author	Year	Topic	Content	Used input
Vaze and Teng	2007	DEM	Accuracy	LIDAR, first pulse, 0.3-1 pt./m^2.
Banta et al.	2005	Atmospheric	Air pollution	Doppler LIDAR.
Parrish and Fehsenfeld	2000	Atmospheric	Air pollution	DAIL LIDAR, 248-313 nm.
Wilkerson	2002	Atmospheric	Wind speed and direction	Doppler LIDAR, 355 nm.
Forlani et al.	2006	3D City	Building detection	LIDAR, first and second pulse, 3-5 pt./m^2.
Jochem et al,	2009	3D City	Roof plane detection	LIDAR, first pulse, 1064 nm, 17 pt./ m^2.
Rottensteiner et al.	2005	3D City	Building detection	LIDAR, Infrared wavelength, first and second pulse, Intensity, 0.8 pt./m^2. Additional multi-spectral images.
Rottensteiner and Briese	2002	3D City	Building detection	-
Sohn and Dowman	2006	3D City	Building detection	LIDAR, first pulse and IKONOS imagery.
Zhou et al.	2004	3D City	Building detection and Extraction	LIDAR (525 nm) and Ortho-mage data.
Behera and Roy	2002	Vegetation	Overview of forestry applications	-
Drake et al.	2002	Vegetation	Mean stem diameter, basal area and AGBM	LIDAR, multiple pulses, intensity, 3-9 pt./m^2.
Drake and Weishampel	2000	Vegetation	Canopy height	LIDAR, multiple pulses.
Korpela	2008	Vegetation	Mapping understory lichens	LIDAR, multiple pulses, intensity, 1064 nm, 3-9 pt./m2.
Lefsky et al.	1999	Vegetation	Forest structure	LIDAR, multiple pulses, 1064 nm.
Means et al.	1999	Vegetation	Basal area, AGBM and foliage biomass	LIDAR, multiple pulses and intensity, 1064 nm.
Nelson et al.	1997	Vegetation	Basal area, volume and biomass	LIDAR, first and second return, 532 nm, 2-3 pt./m^2.

4 Interviews and meetings performed

In order to obtain a direct understanding of the current state of the art - especially with regard to the full scope of processes to be performed (see Chapter 5, Figure 6) and operational systems in place - interviews were conducted with a number of selected firms and organizations. Table 6 provides an overview of interviews performed by the authors in the scope of this study.

Table 6
Overview of interviews performed.

Company	Visit date	Persons involved
NEO bv. www.neo.nl	Telephone interview, July 2009	Rob Beck Alterra: Henk Kramer
Fugro www.fugro-nederland.nl	4 September 2009	Luc Amoreus (Research and Development), Alterra: Henk Kramer, Matthijs Danes
Imagem www.imagem.nl	1 September 2009	Henk Kersten, Wim Bozelie, Alterra: Henk Kramer, Matthijs Danes
Cyclomedia www.cyclomedia.nl	2 October 2009	Maurice de Gier, Peter de With, Bart Beers Alterra: Henk Kramer Wageningen University: Lammert Kooistra

Each of the companies were asked how they could contribute to the topic of automated detection of small scale landscape features, either with existing or new techniques and methods. A subdivision into the following activities was made:

a. data acquisition,
b. data management,
c. data processing,
d. process management,
e. quality assessment.

Results from the meetings are reported in the next paragraph.

4.1 NEO

4.1.1 Company profile

NEO is an innovative independent Dutch company, established in 1996. NEO applies satellite imagery in management of infrastructure and environment, as well as in agriculture and forestry. NEO assists both new and experienced users of remote sensing in the supply of satellite imagery and software to process images and especially of knowledge: NEO's most important activity is the interpretation and processing of satellite imagery into useful information. NEO is active on 4 continents.

4.1.2 Activities in relation to this study

One of the core activities of NEO is change detection on the basis of remotely sensed images, both aerial photo's and high resolution satellite images. This activity involves visual interpretation of images with on screen editing and the handling of large datasets. Automated detection of features is not yet a part of this activity. The creation of a precise definition of the object(s) to be identified is an important part of this process. This is also important in the process of automated feature detection. NEO also has particular experience with the operational implementation of the change detection process.

This results in a best match with the activities d) and e).
Current activities of NEO that coincide with the topic of automated detection of small scale landscape features can be found in:
– process management,
– quality assessment.

4.2 Imagem

4.2.1 Company profile

Imagem is the dealer for ERDAS software for The Netherlands. They have experience with image processing, change detection, object based classification, data infrastructural services and data creation.

4.2.2 Activities in relation to this study

Imagem created the 'feature height' (Objecthoogte) data by manually digitizing on stereo photographs. This dataset contains ascending topographic features like buildings and trees (area more than four square meter and height above one meter). With the new software LPS eATE, available since the end of 2009, this process can be automated. A preview of the software is available at http://labs.erdas.com/blog_view.aspx?q=6079 . The video shows an example of the use of LIDAR and Infrared imagery for automated terrain extraction. No examples about automated feature extraction (like trees) are available.

Also, the software product Imagine Objective was demonstrated. With this software it is possible to perform an object based classification of imagery. At this moment, the software can not be used to process LIDAR point cloud data.

As a solution for servicing large image datasets the Erdas Apollo Image Manager software is used. Imagem has experience with the implementation of this software in an operational work process.

This results in a best match with the activities b) and c).

Current activities of IMAGEM that coincide with the topic of automated detection of small scale landscape features can be found in:
– management and accessibility of large datasets,
– knowledge of software that can be used for automated terrain extraction (and possible feature extraction) using stereo photography.

4.3 Fugro Geospatial Services

4.3.1 Company profile

After being part of Fugro-Inpark B.V. for more than eight years, the Aerial Acquisition division (better known as FLI-MAP division) continued as a separate company called Fugro Aerial Mapping B.V. as of January 1st 2008. This new company will be concentrating their services on LIDAR and photogrammetric activities and other surveys from the air.

Fugro Aerial Mapping will become, will become part of an European group of airborne Fugro companies which will strongly work together on research and development, optimal planning of resources and execution of projects.

As one of the earliest and biggest providers of geo-data solutions based on airborne LIDAR data, Fugro is the most obvious survey partner for high quality and high accurate data collection, data management and integration in geo-data infrastructures.

4.3.2 Activities in relation to this study

Fugro is one of the companies that acquires the LIDAR data that is used to create the AHN elevation model. The original LIDAR data includes additional information that is not available from the AHN dataset but can be very useful for the process of automated detection of small scale landscape features. An example can be found in an article by Straatsma and Baptist (2008)[1]. Fugro also has extensive knowledge about the processing of LIDAR data.

This results in a best match with the activities a) and c).
Current activities of Fugro Aerial Mapping will become that coincide with the topic of automated detection of small scale landscape features can be found in:

- data acquisition or supply,
- knowledge of LIDAR data processing.

4.4 Cyclomedia

4.4.1 Company profile

Cyclomedia specializes in the large-scale and systematic visualization of environments based on 360° panoramic photographs (cycloramas). Due to, by Cyclomedia developed recording and process technology, large areas are photographed and entered in an online database. Of each recording location, orientation and time are registered, which makes versatile applications possible, such as 3D measurements and modeling.

Cyclomedia has clients in diverse markets such as central government, municipalities, provinces, estate agents, financial institutions and insurance companies. Cycloramas are used for the sale and taxation of real

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[1] Straatsma, M.W. and M.J. Baptist (2008): Floodplain roughness parameterization using airborne laser scanning and spectral remote sensing. Remote Sensing of Environment 112, pp, 1062-1080.

estate, the assessment of construction applications, the inventory of the environment and the valuation of risks for insurance applications.

4.4.2 Activities in relation to this study

The main product of Cyclomedia are the *Cycloramas* (spherical panoramic images) that give a 360° panoramic view of the environment from street level for the whole of The Netherlands. Cyclomedia also supplies high resolution areal imagery (10 cm detail).

During the interview, several topics of interest were demonstrated:
– real-time change detection on video imagery,
– automated event detection on large database containing surveillance camera's movies (24h registration),
– automated object detection of predefined objects like road signs on cycloramas,
– concept of near-real time change detection on time series of areal imagery,
– fast acquisition of imagery in case of events, change detection with standard imagery.

This results in a best match with the activities a), b) and c).
Current activities of Cyclomedia that coincide with the topic of automated detection of small landscape features can be found in:
– good knowledge of working with large datasets,
– good knowledge of the process of automated object detection/extraction from large datasets (only demonstrated on man-made objects like road signs, trees etc. usually are more difficult to detect automatically).

4.5 Overview

The following table gives an overview of the core activities of the visited firms with regard to the object data extraction process.

Table 7
Core activities of visited firms.

	a) data acquisition	b) data management	c) data processing	d) process management	e) quality assessment
Neo				X	X
Fugro	X		X		
Imagem		X	X		
Cyclomedia	X	X	X		

5 Methodology for case studies to be performed

The automated recognition of landscape features is a complex technical process chain involving various disciplines. In order to shrink down the overall complexity, a subdivision of relevant processes/disciplines was made that structures the overall complex process in constituent parts. At the same time this structure represents the overall work process model for the study at hand. An overview of this process model is given in Figure 6. Process management and quality assessment, as mentioned in Chapter 4, are not explicitly mentioned here. They are, however, an indispensable aspect of the work, and occur in each part of the process.

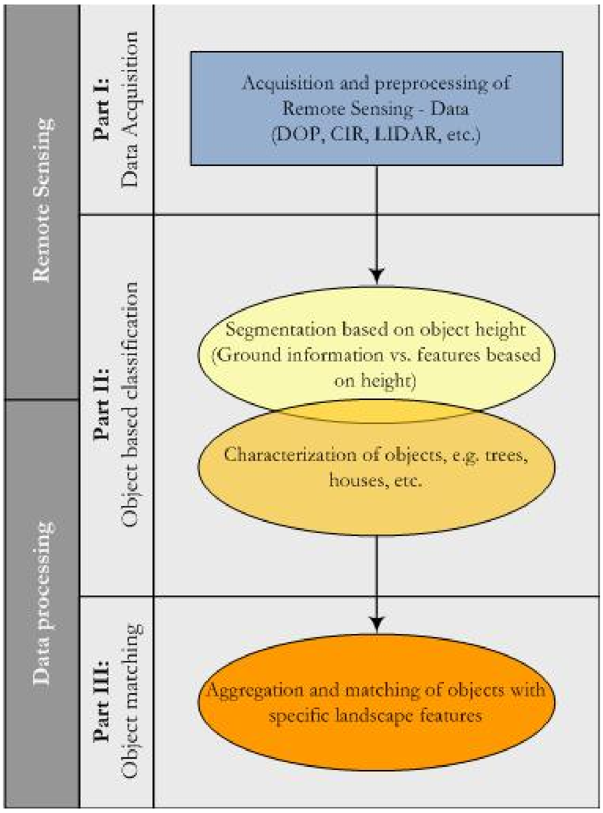


Figure 6
Process model from data acquisition to feature classification.

Part I of the project comprises all work necessary to acquire data by remote sensing techniques. Usually providers are concerned with these tasks and deliver data in a more or less ready-to-use way. The tasks performed to render the data product often remain a black box for the data users. In some cases (e.g. related to the utilization of active remote sensing techniques such as LIDAR, see below) knowledge about these processes in order to explore the full potential of these technologies are an important asset.

Part II of the project comprises all know-how and techniques of image analysis/classification. This part is usually well described and various softwares exist to support this task. The image will be classified and segmented by generally clustering single or multiple picture elements into groups and by characterizing them. This is the part of the process where a group of pixels will be identified as, for instance, 'a tree' or 'a building'.

Part III finally represents the match between the primary objects derived from step II with the landscape features as defined or to be defined within the project context.

5.1 Case studies overview and used methodologies

As identified in Chapter 3 two basic types of data seem to provide the necessary potential within the project context explained in Chapter 2.

Hence in this project two case studies were conducted. Both studies are adjusted to principal methodology depicted in Figure 6. The case studies differ in:

- the data they are based on,
- the geographic region they are conducted in,
- the scope of parts (according to Figure 6) they cover.

Both case studies are not aimed to be in competition or to compare them. Moreover the results of the case studies show that there are justified reasons to assume that both technologies (either in combination or in simultaneous utilization) can complement each other to provide some of the expected results within the project context.

The first case study is exclusively based on LIDAR data. The constraints and priorities, constituted by

- the available data
- the available software, capable of processing the data

are the reason for this case study to focus on parts II and III of the methodology shown in Figure 6.

The literature listed in Table 5 shows that there are many software packages capable to extract individual objects from LIDAR data. However, the information provided during this research does not contain the original information, and lacks information about intensity and pulse number. Today's LIDAR classification software demands information about pulse number and intensity in order to classify and recognize individual objects. Since this information is missing, this case study will focus on classifying the observations into classes (parts II and III of the methodology presented in Figure 7).

Although these priorities had to be made, the report emphasizes the valuable contribution LIDAR data can make, especially with regard to the recording of single objects which could hardly be recorded using the passive remote sensing approach.

The second case study is based on DOPs combined with height information derived from the LIDAR data. The case study is aligned towards the methodological concept explained in Chapter 5, Figure 6. Whereas the first case study was focused on part II of the overall methodological model, this case study operates on all

parts (or levels) of the process model. According to the scope of the project, priorities were made in detecting a selection of landscape features. These concern linear features such as:
- wooded bank (houtwal)
- shelterbelt (houtsingel)
- line of trees (bomenrij)

and non-linear features such as groups of trees and other vegetation.

Figure 7 below depicts how the case studies differ in their focus within the process model. The red ellipse encompasses the process parts on which the case studies are focused on.

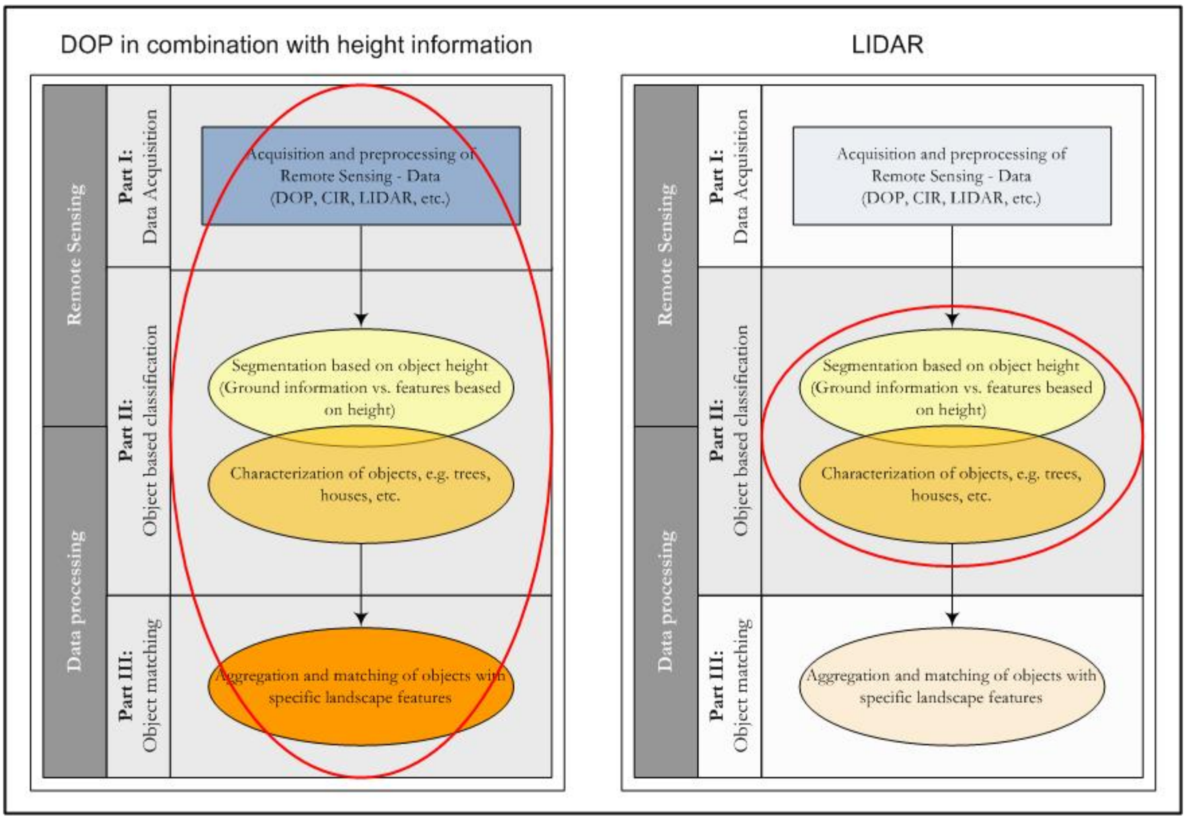


Figure 7
Methodological focus of the case studies.

6 Description of case studies performed

6.1 Test sites overview

The locations of the test sites are shown in Figure 8. Both sites are located in the province of Zeeland, on the Walcheren peninsula. Each test case uses its own test site.

Figure 8
Geographic overview of test sites (Source: Google Earth).

6.2 Case study I: LIDAR

6.2.1 Test area I (LIDAR)

During this research only LIDAR data from Middelburg was provided. The exact location of the test site is in the town of Middelburg and is depicted in the figure below. The coordinates of the bounding box are lower left corner; 51°29'56.04"N and 3°36'5.04"E / upper right corner; 51°30'5.76"N and 3°36'21.24"E.

Figure 9
Test site I: Middelburg (Source: EuroSense 2008).

This limited the test area to an urban site. Within it, an area with a lot of 'green' was selected as test-area. The LIDAR data which were provided contained point information with x, y and z coordinates, according to the characteristics of the AHN points dataset. The original information about pulse number and intensity was not included.

6.2.2 Specification of LIDAR data used in the study

The specification of the LIDAR data provided are as follows:
- On average around 10 points per m^2,
- Only information about x, y and z available.

6.3 Classification of LIDAR data

Before the LIDAR data provided can be used to reveal any characteristics of individual objects, it is necessary to separate different land use classes (e.g. roads, water, arable land, etc.). In this chapter a test data-set collected in Middelburg will be classified.

In order to be able to classify the LIDAR data (without information about the return and intensity), the LIDAR data is combined with the topographic classification (from the Top10Smart dataset) and the elevation model (AHN2). The recognized classes and classification rules can be found in Table 8.

Table 8
LIDAR classification.

LIDAR class	Color	TOP10 code	Deviation from elevation model (m)
Buildings	Red	Buildings	>2.0
Bicycle path	Pink	Bicycle path	<= 0.1
Grass	Light green	Pasture, Forest, Remaining, Cemetery	<= 0.1
Infrastructure	Orange	Infrastructure	<= 0.1
Traffic	Black	Infrastructure	>0.3 and <= 2.0
Tree crown	Dark green	Infrastructure, Forest, Pasture, Remaining, Water	>4.0
Tree stem	Brown	Infrastructure, Forest, Pasture, Remaining, Water	> 2.0 and <= 4.0
Water	Blue	Water	<= 0.1

Figure 10a shows the result of the classification. As becomes clear from Figure 10, the used topographic dataset is not detailed enough to distinguish the different classes properly. Top10Smart's raster cell size of 2.5m has a considerable impact on the classification results. For example part of the buildings are classified as vegetation (see Figures 10b I and 10c I) and the other way around (see Figures 10b II and 10c II). Additionally Figure 10d shows that without information about the intensity is difficult to classify 'unexpected' objects. In this case cars are parked on a private property. Fortunately, the majority of the cars are filtered out (10d II), but two cars are classified as a tree stem (10d III) or are recognized as being part of the building (10d I). The same happens with unexpected small sheds (10e I), which are partly classified as tree stems and tree crowns.

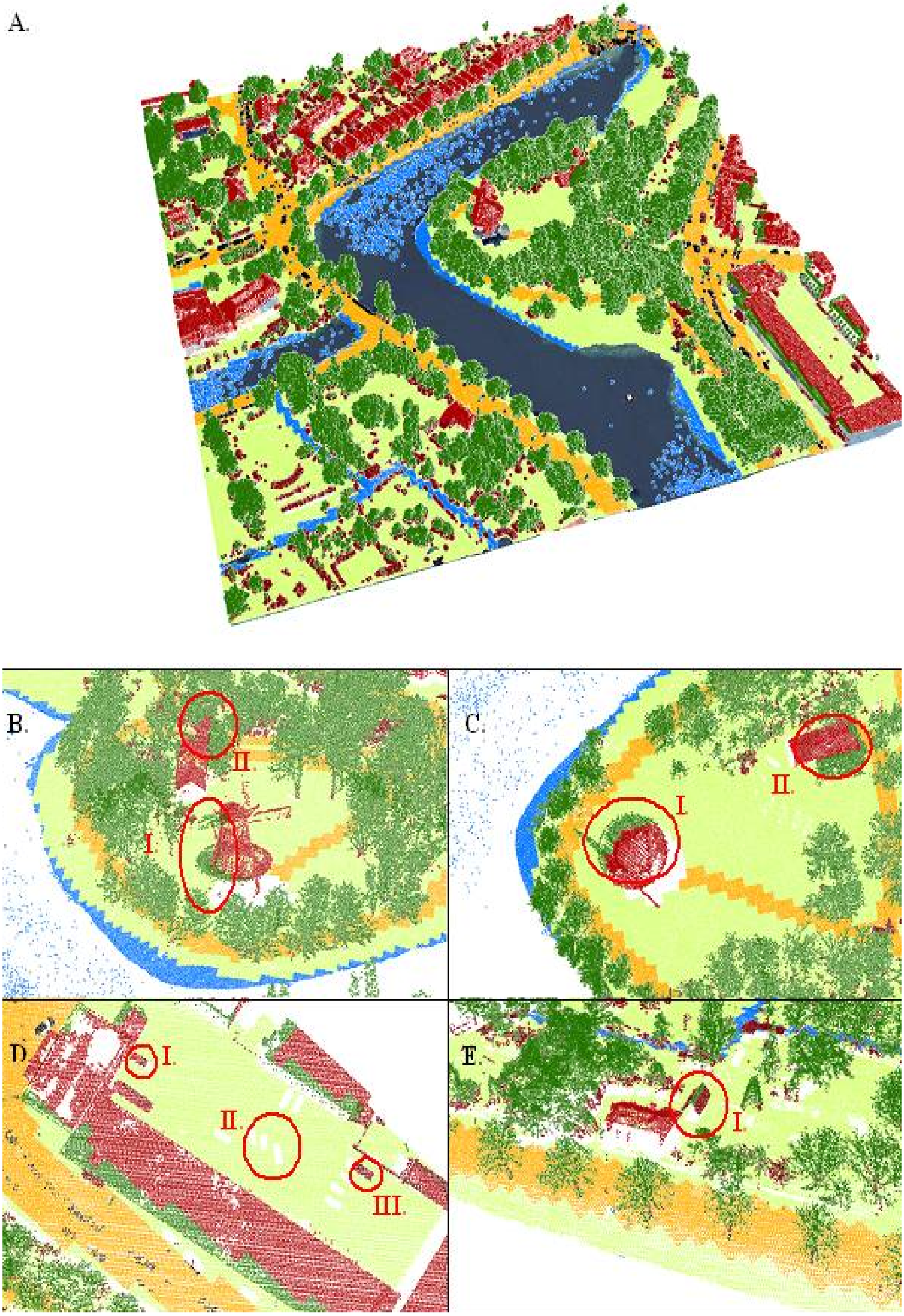


Figure 10

(a) Classified test area. (b/c I/II) misclassified vegetation. (d I/III) misclassified cars. (d II) cars filtered out. (e I) misclassified objects which are not on the topographic map.

6.4 Case study II: DOPs in combination with height information

For this case study the spectral information contained in the DOPs were extended with height information of all ascending features in the study area. Basically there are two data sources which offer the possibility to derive height information which are:

- stereo-images,
- LIDAR data.

For this case study only LIDAR data was available (AHN2 test set) and hence it has been used to derive the height information. After all, the kind of data source of the height information is not an important factor in the classification process, it is the height of the objects that is the important information, no matter how this information is gained.
The steps performed and the results obtained are represented in the following paragraphs.

6.4.1 Test area II

Location of the test site in RD-Coordinates (x-min 26250, y-min 396900, x-max 27250, y-max 397900) as indicated by yellow box. This area is located in the north-eastern part of Walcheren.

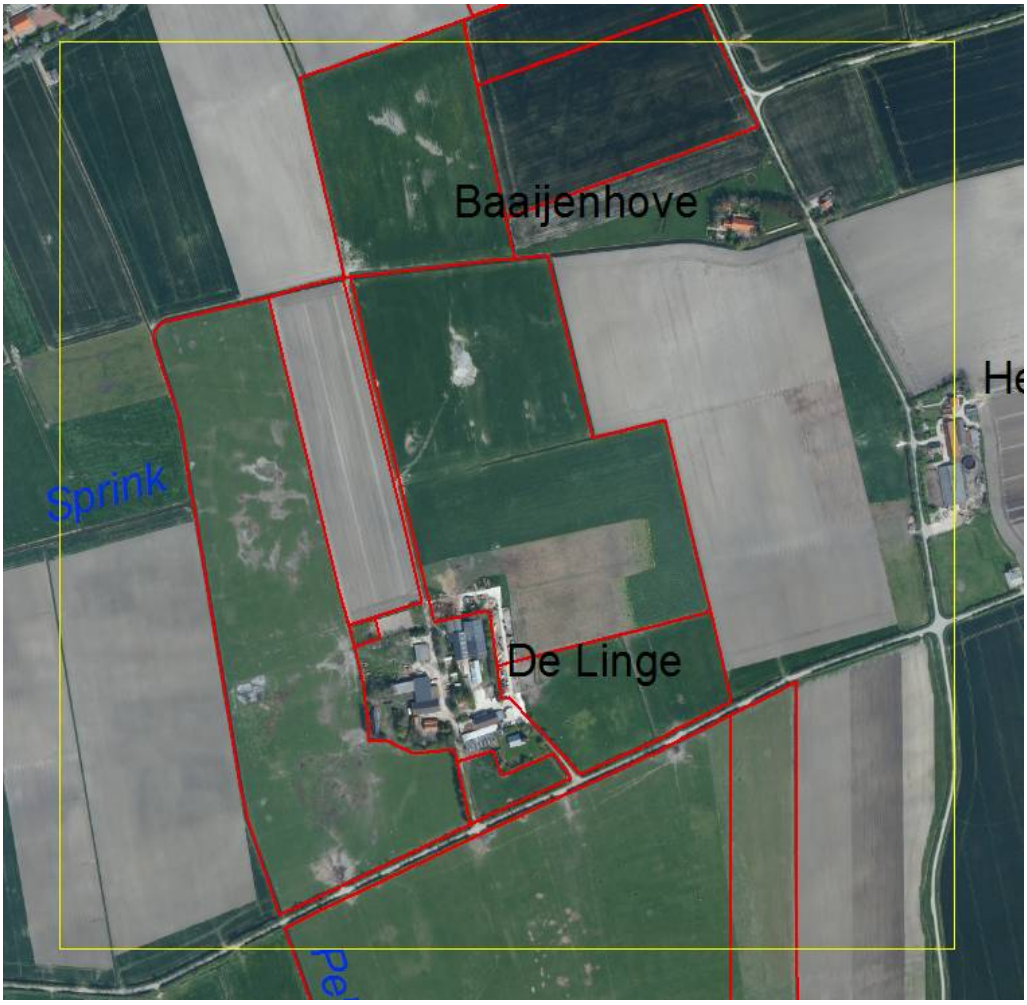


Figure 11
Test site II: Walcheren (source: EuroSense 2008).

This test area was selected because it is part of the selection of parcels from the AAN dataset provided by EL&I-DR. This area contains several elements of interest, small groups of trees and lines of trees in different ways of appearance (short, long, wide and narrow). The extent of the test area is 1 by 1 km. This relatively small size was selected to keep the amount of data to be processed at a workable size.

6.4.2 Specification of data used in the study

Digital orthophotos
The DOPs used for this case study are colour-infrared (CIR) ortho rectified images which are part of the 2008 aerial images campaign. The DOP data contain four spectral bands which are:
– Blue,
– Green,
– Red,
– near infrared (NIR).

The ground resolution is 25 cm. The DOP data for this case study were provided as ortho-rectified images. All distortions caused by the height of objects were corrected so that the DOPs have the same characteristics as a map.
The aerial photo's were acquired by Eurosense, the acquisition date is May 5th 2008. VHR satellite images can also be used instead of DOPS. Images from the IKONOS, Quickbird or other VHR satellites have comparable characteristics.

LIDAR data
For this study, height information is derived from LIDAR data. The LIDAR data from the AHN-2 was derived from the 2007 dataset. This LIDAR dataset contains a point cloud with x, y and z coordinates with a density of at least 10 points per m^{2}.
The LIDAR data for the test site was derived from two flight paths, flown on March 13th 2007.

Reference data
For this study EL&I made available through its GIS Competence Center the AKB data set as a reference base for landscape features. As it turned out, almost no reference features were available in the whole part of Zeeland and hence none in our test site. Hence we were obliged to make use of another set of data which can be used as validation basis for the results of the study. Therefore the dataset 'Core qualities of Dutch National Landscapes'[1] were used as a reference. Green features like single trees, lines of trees and patches of trees were manually digitized on aerial photos from 2006. The data were provided as vector information in *.shp files separated into points, lines and polygon layers.

6.4.3 Process workflow

The overall workflow on the processes performed followed the conceptual model as described in Chapter 5 (and depicted in Figure 6). The individual steps underpinning the parts of the conceptual model are represented on the following process chart.

[1] 'Kernkwaliteiten Nationale landschappen'. This dataset was created by The Netherlands Environmental Assessment Agency (PBL) and Alterra on behalf of the Ministries of EL&I and VROM.

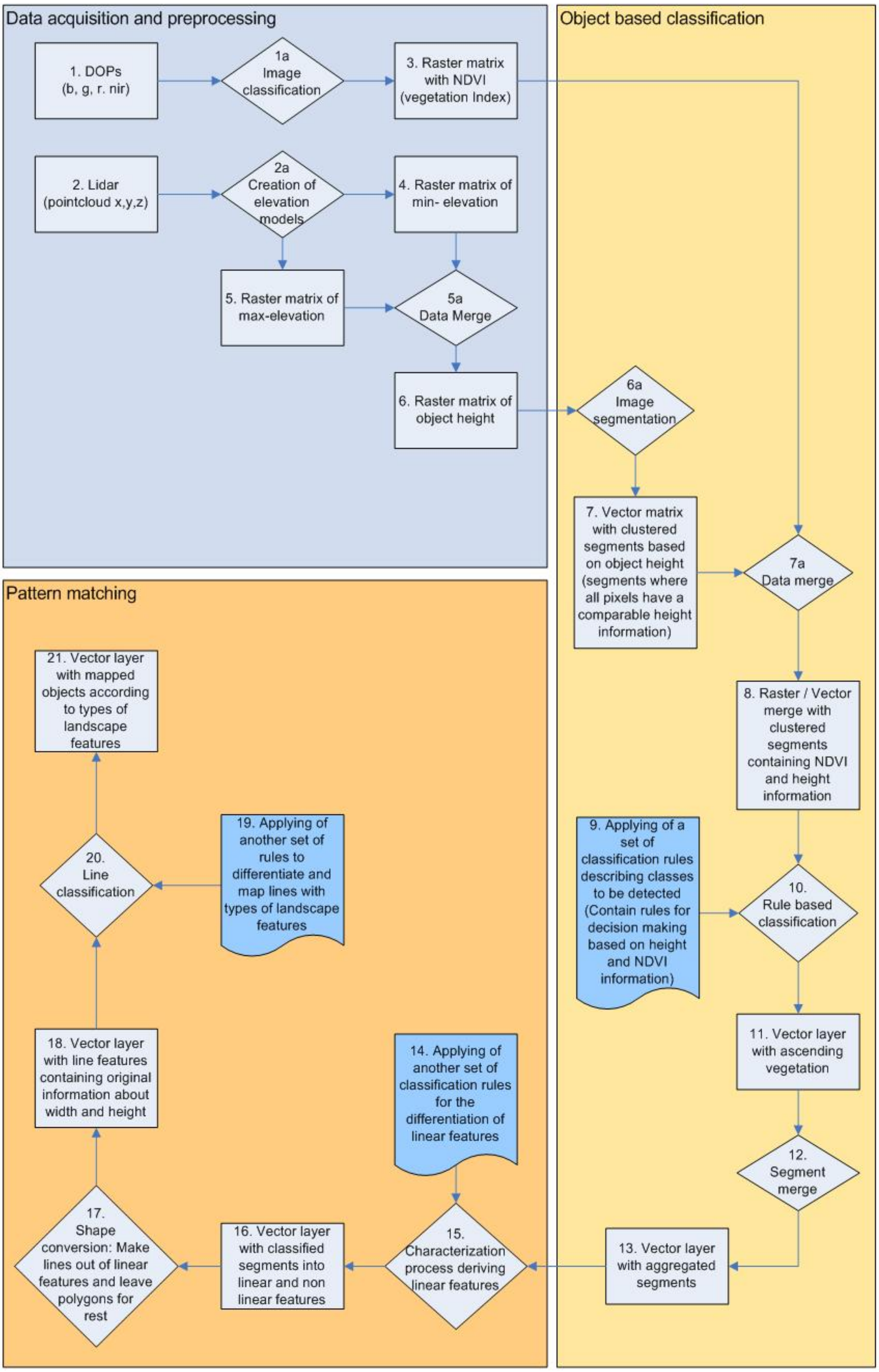


Figure 12
Process overview.

The individual steps performed will be described in more detail in the following sections.

Process description of Part I: Data acquisition and pre-processing

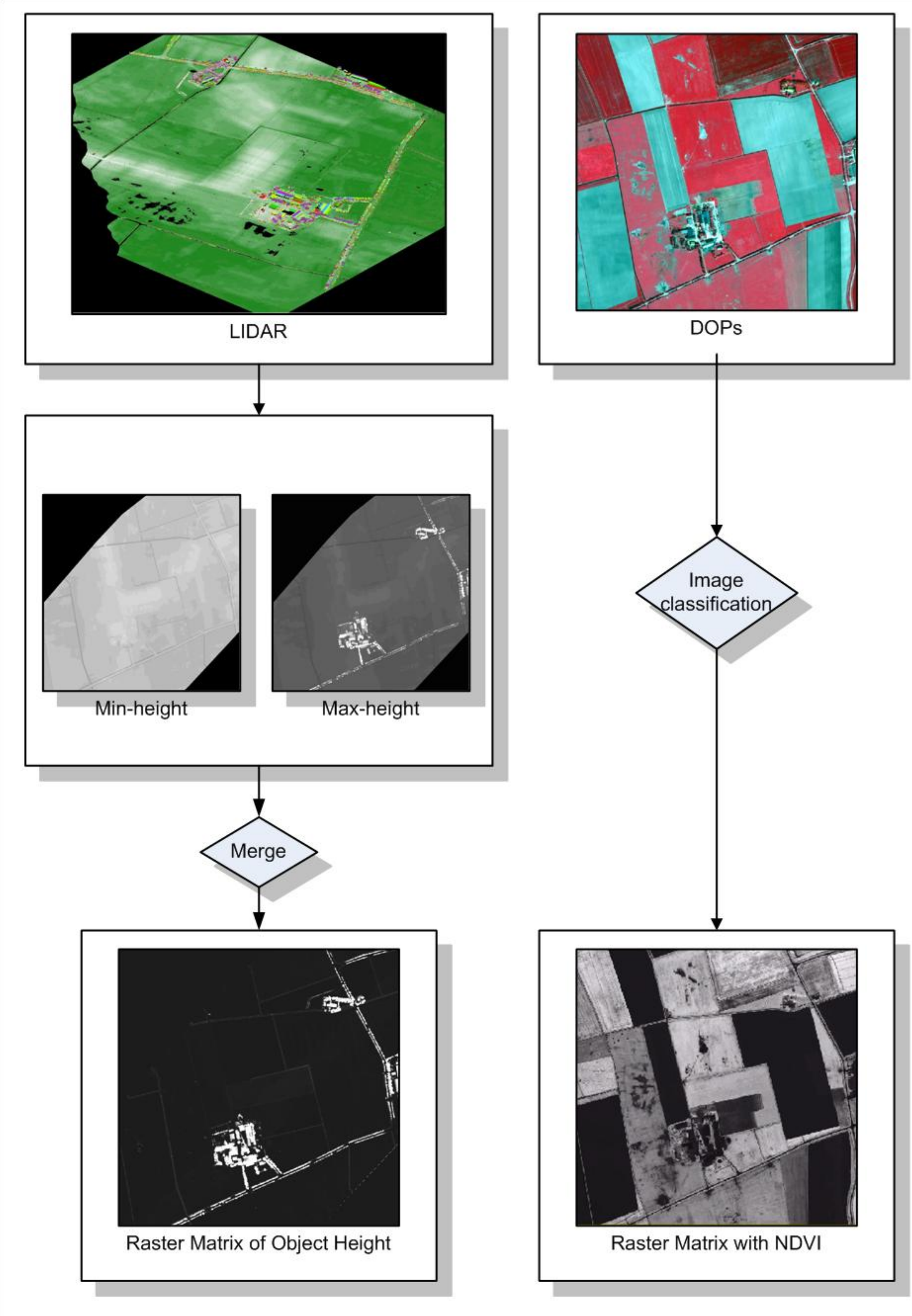


Figure 13
Detailed processes and output of Part I.

As depicted in Figure 12, this set of activities comprises all necessary steps to create a raster layer of object height information. The combined utilization of DOPs and LIDAR data required a merge of the data. Therefore the LIDAR data was pre-processed to extract the height of objects such as objects and/trees. This was done by calculating two layers of information from the xyz information of the LIDAR data which are:
- the ground elevation,
- the maximum height.

The maximum height minus the ground elevation results in the height of objects which are stored in a raster matrix. The height information gives a good delineation of all ascending elements and this is used as the source information for the segmentations. The pixel matrix had a resolution of $1m^2$. The resulting layers of the first part are:
- a raster Matrix with NDVI and
- a raster matrix of the object height

Figure 13 depicts the steps performed in a graphical way using screenshots of real data.

The first process comprises all necessary step to provide an according data situation. Starting point for this set of activities was comprised by a set of LIDAR data and DOPS as described in paragraphs 3.4 and 3.5.

As stated in paragraph 3.4, the LIDAR data available for this study we already pre-processed. For each pixel the minimum and maximum height information was calculated from the LIDAR data. Thereby information was made available towards the ground height of a pixel. The approximate point spacing within the LIDAR datasets is 30cm (11 points per m^2). The minimum and maximum elevation matrixes are calculated from the original LIDAR data. The points with the lowest and highest z-value within a m^2 are assigned to the raster cells.

The object height matrix is calculated using the formula (maximum elevation minus minimum elevation). The minimum object height is 0 (the ground, shown in black), the maximum object height is 21 meters (shown in white).

DOPs were classified by calculating the Normalized Difference Vegetation Index (NDVI). The NDVI is a simple numerical indicator that can be used to analyze remote sensing measurements, and assess whether the target being observed contains live green vegetation or not. Live green plants appear relatively bright in the near-infrared.

Hence the output of the first process consists of two sets of raster data matrixes providing information for
- Object height information,
- NDVI-indicators.

Process description of Part II: Object based classification

The overall process overview with original screenshots of the data retrieved is depicted in Figure 14:

The starting point for the second part is provided by the output of Part 1:
- Object height information and
- NDVI-indicators.

The object height layer derived from LIDAR data was segmented using the *Definiens Developer Software*. The result of this segmentation process are image segments that primarily do not correspond to real natural features. The screen shot below illustrates the result of the segmentation process. To show the non-conformity with real elements the segmentation result is superimposed to the DOP (Figure 15).

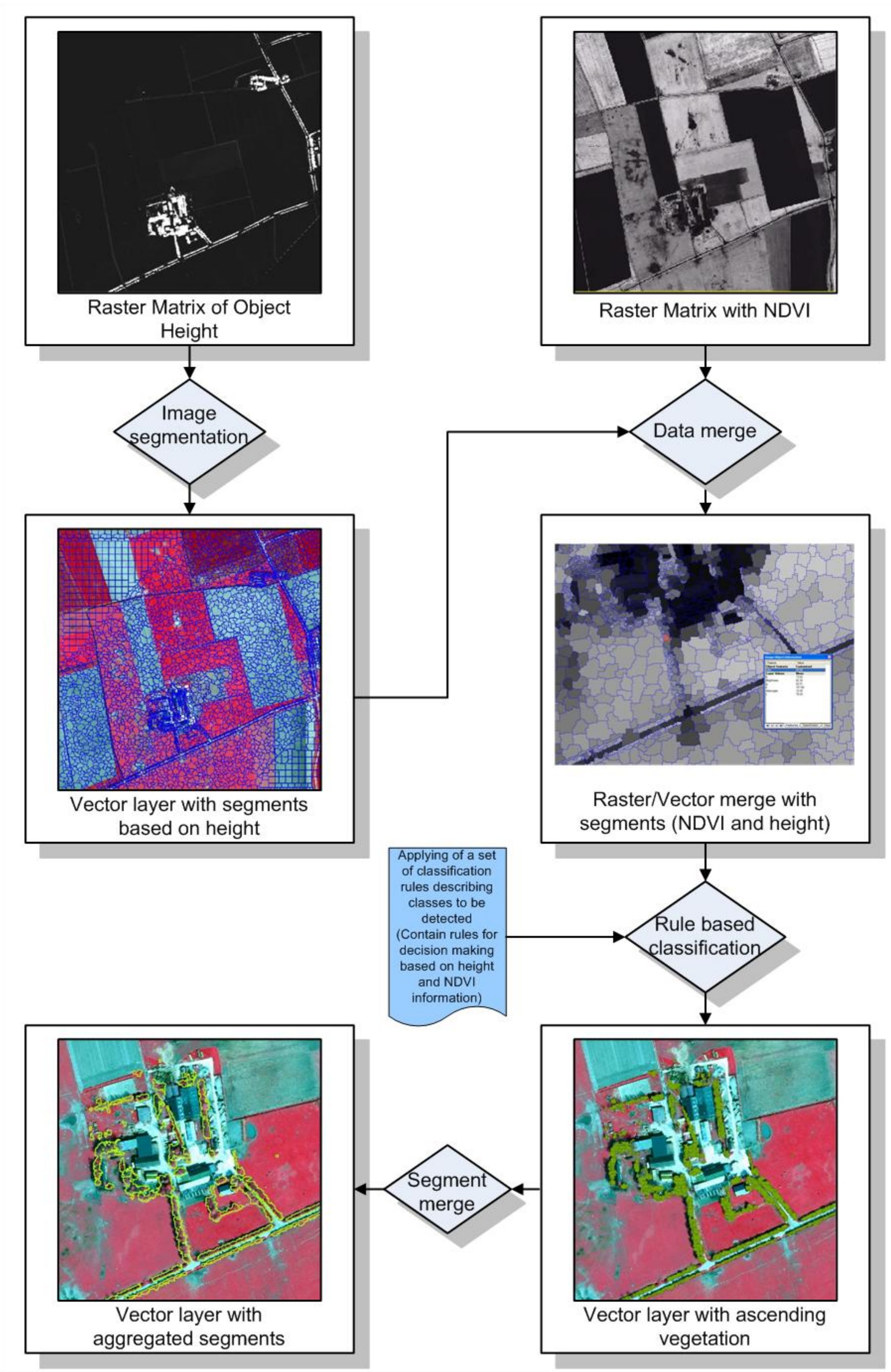


Figure 14
Detailed process overview of Part II.

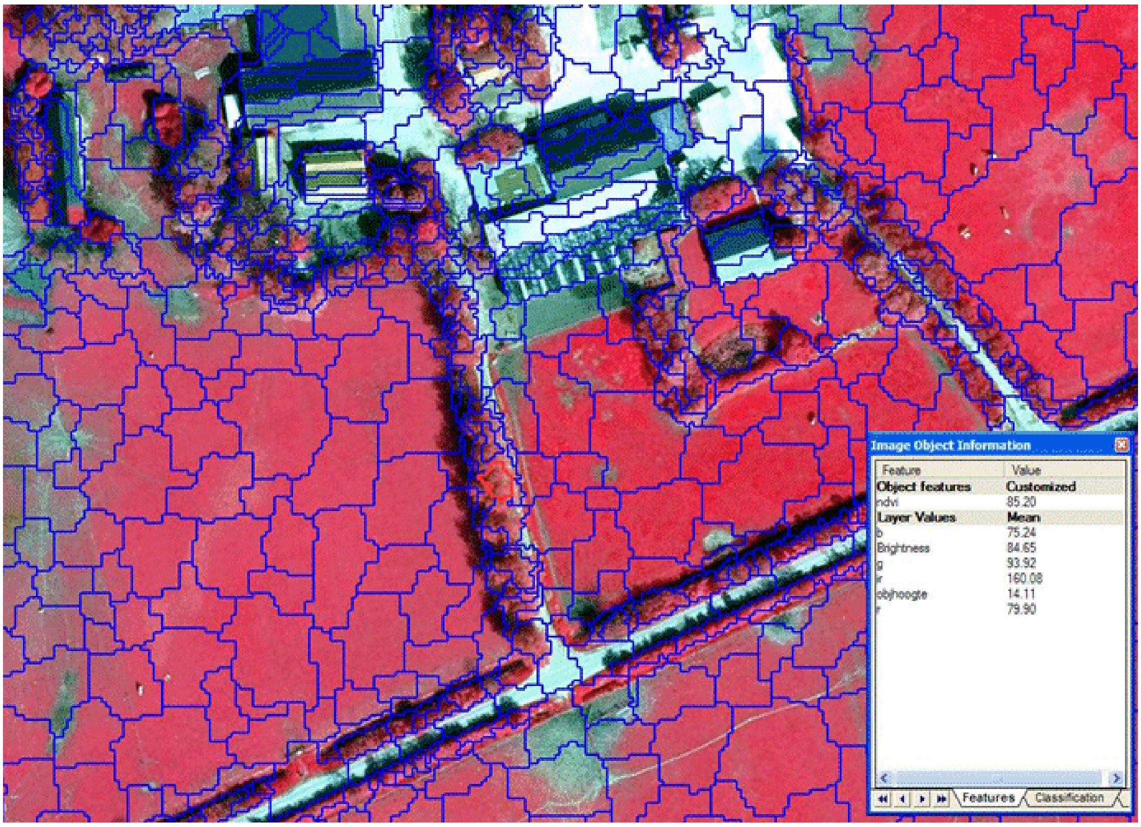


Figure 15
Image segmentation based on object height.

The image segments are basically raster clusters, delineated by a vector boundary. Thus it is possible to click on such a vector boundary to obtain statistic information about the segment derived from the pixels (such as the mean height and/or the mean values for each of the spectral bands of the DOP (see highlighted polygon in the figure above)).

The blue lines show the boundaries of the created segments. Each segment represents an area with a homogeneous height. For ascending feature like trees and buildings and also descending features like ditches small segments are created. Segments that coincide with the earth surface are relatively large.

The vector layer with the segments will then be merged with the NDVI raster matrix which results in an raster/vector merge with segments containing NDVI and height information.

Subsequently this data stack will be classified according interpretation rules in a classification procedure. The first step in the classification is the creation of the class 'ascending elements'. These are all segments with a height >0.75 m. This is done purely on the basis of height information.

In a next step the segment information are combined with the information from DOP in order to create the class 'ascending green elements'. To be able to do this, the vegetation index (NDVI) for each segment will be used.

All segments that belong to the class 'ascending elements' with an NDVI value >80 are assigned to the class 'ascending vegetation elements'.

The result of this process is depicted in Figure 16. It is a raster matrix containing only ascending vegetation. However, the classification does not contain information on the kind of green element it belongs to, e.g. a single tree, a line of trees or a group of trees.

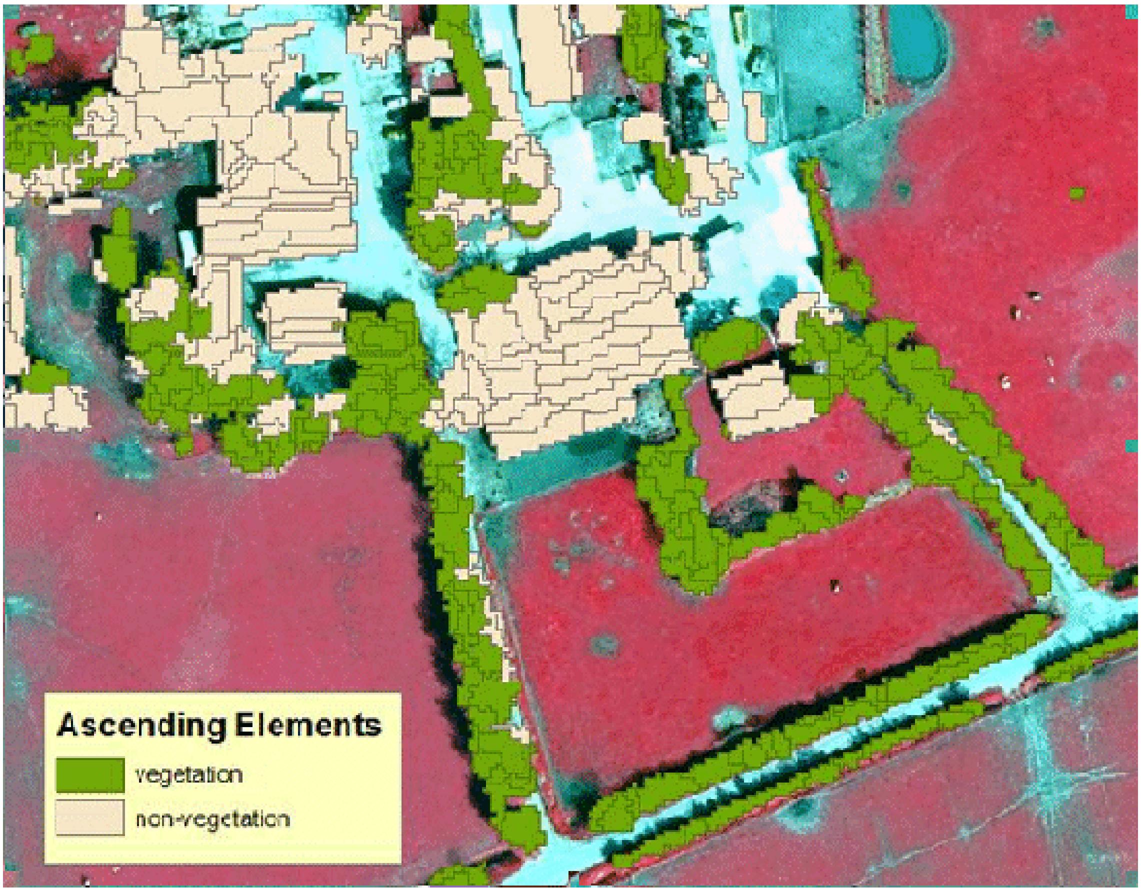


Figure 16
Object classification.

This differentiation can be made, based on shape features of the classification result. For that purpose, all segments of the class 'ascending vegetation' which are adjoining each other will be merged to one single

object. The result of this process is the output of the part II (Object based classification) and depicted as an example in Figure 17.

Figure 17
Vector layer with aggregated segments.

Process description of Part III: Pattern matching
The overall process overview with original screenshots of the data retrieved is depicted in Figure 18.

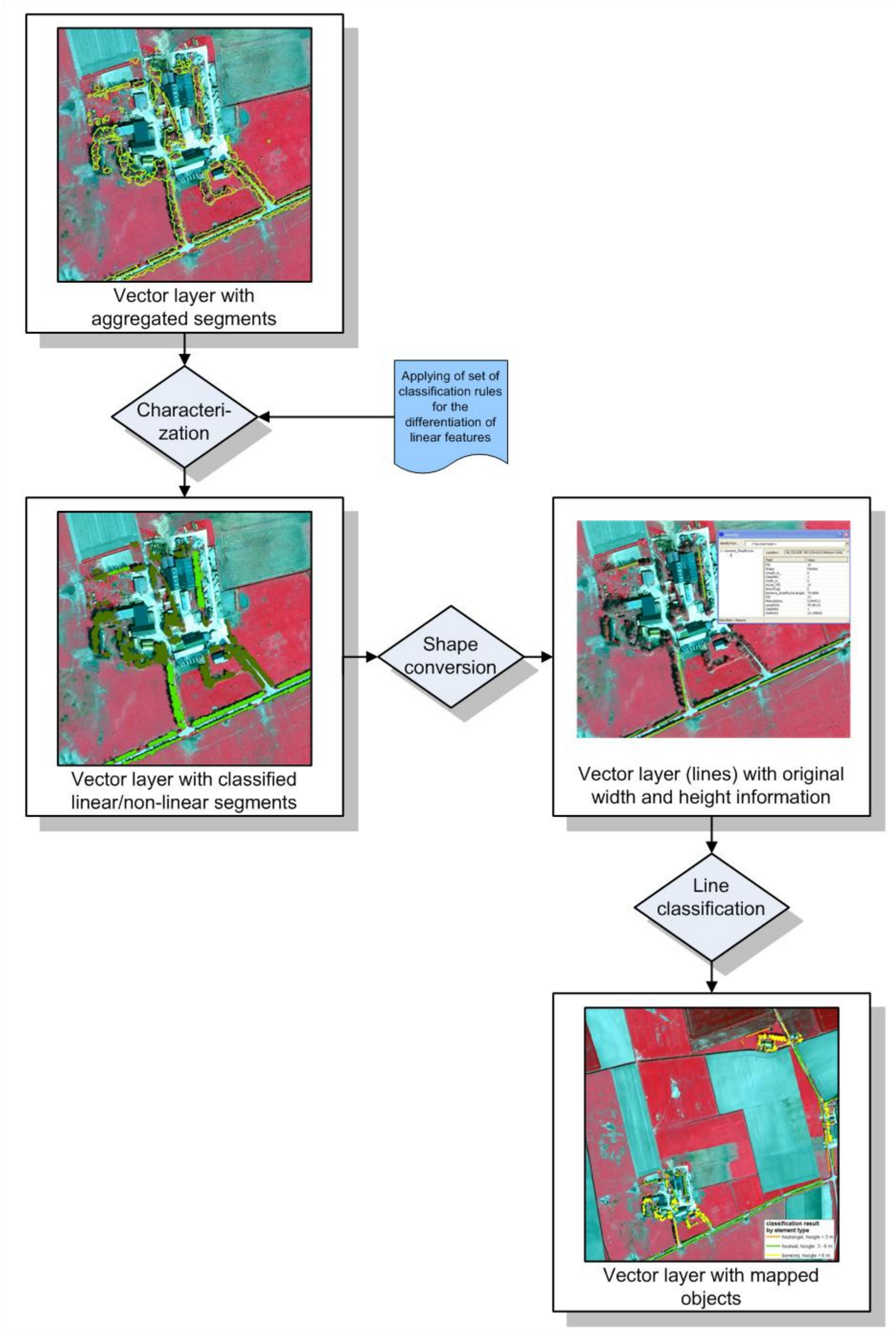


Figure 18
Detailed process overview of Part III.

The input for this part is the output from part II, which is a vector layer with aggregated segments.
For each new constructed segment, the length/width index is calculated which is equal to the length divided by the width of an object. This calculation enables a differentiation between linear and non-linear features. The processing of that index is part of the *Definiens Developer Software*'.

Thereby all segments with a length/width index >5 are assigned to the class 'linear features'.
These were primarily stored as polygons and then subsequently further processed to lines. The lines follow the main shape of the polygon and are converted to single line objects using the *simplify operation* (which is performed as standard operation in ArcGIS). The line objects still contain the information about the mean width and mean height of the line of trees object.

The final result for this classification is shown in Figure 19.

Figure 19
Pattern matching.

This figure also shows line of tree elements, taken from the Small landscape features baseline measurement dataset ('Nulmeting KLE', from EL&I/PBL) in purple. This shows that almost all elements from this dataset were detected by this classification approach.

In the final steps of the process the lines are classified according to their height into three height classes:
- Class 1: <3m,
- Class 2: 3-6,
- Class 3: >6m.

6.4.4 Results and validation

To show the results of this study we compared the landscape features as they were provided as vector elements from EL&I with the features we detected in the process as depicted above.
The quantitative analysis is represented in the Table 9 below.

Table 9
Quantitative analysis of study results.

	Reference data (manual digitalization)	Results (features detected in automated process)
Amount of lines	29	35
Total length of lines	3469	2524
Amount of polygons	2	68
Total area of polygons	1603 m^2	11251 m^2

The tables shows that more (or more fragmented) features were found in the classification than in the data provided.

More information about the results are given in a qualitative approach which is underpinned by the following figures. The left figure below shows the reference data as provided by EL&I. The right figure shows the landscape features as detected in the classification process.

Figure 20
Qualitative results of the study.

The following figure shows the classification results by superimposing the results with the reference data.

Figure 21
Object recognition in relation to reference data.

The figures above show that almost all features that are available in the reference data are found by the classification process. The only feature which was only partly detected is a small group of trees which can be seen in the figure below. It is an enlarged area of the test site.

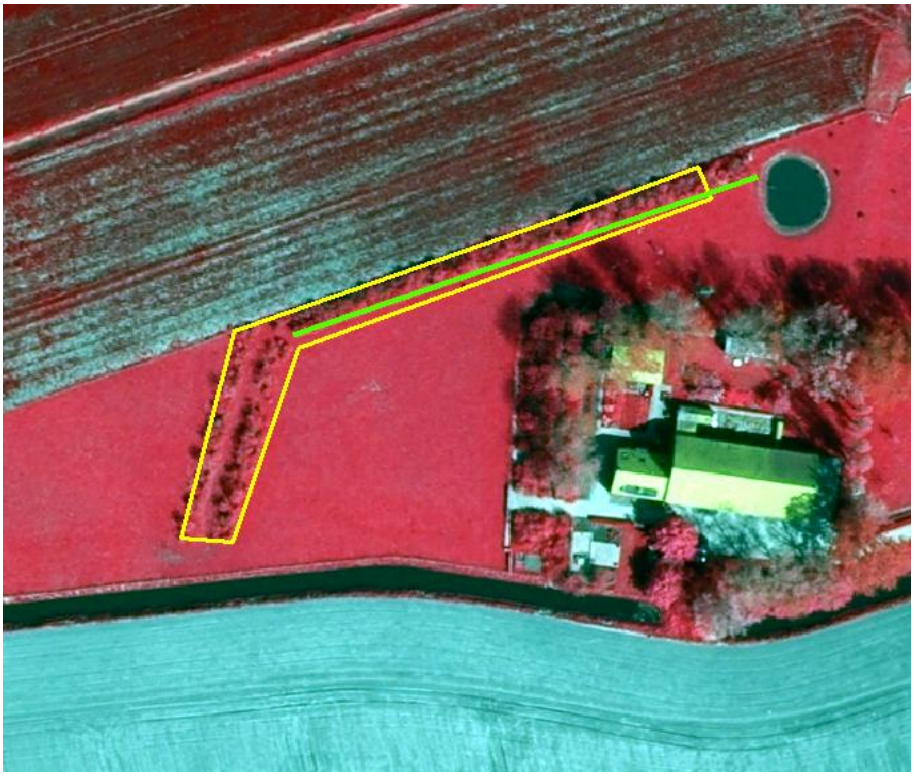


Figure 22
Detailed view of classification results.

The green line represents the classification result whereas the yellow polygon shows the feature as digitized in the reference data.

The figures show that results are detected for all linear reference data. The classification covers all reference features, however not with the same appearance. The classification result is more fragmented which explains that more linear features have been detected than were present in the data provided.

On some locations pixel clusters were classified as polygon features, whereas the reference data indicated linear features.

Figure 23
Results and validation of the classification process.

Figure 23 Above shows the results of the classification.

A: The spots marked with 'A' show places where landscape features are detected, that are not in the reference data. On these locations trees are visible on the DOPs.

B: The spots marked with 'B' indicate places where, according to reference data, landscape features are present that were not detected by the object recognition process.

C: The spots marked with 'C' indicate places with gaps in linear features, where the reference data show a continuous element.

6.5 Detection of ditches, quick scan 2010

During the execution of the project in 2009, the detection of ditches as a landscape feature was only briefly investigated. A visual assessment of the DOPs and the LIDAR data showed that ditches could be recognized but an actual process workflow could not be developed because of the lack of functionality of the available software at that time.

However, this changed with the release of ArcGIS 10 in September 2010. The capabilities of this software to process 3D data make it possible to create a workflow for detecting ditches. Because of the importance of the detection of this landscape feature, it was decided to carry out a quick scan to explore what could be done with it.

Although only a small area is processed, the results of this quick scan clearly show possibilities for the automated detection of ditches and their boundaries from LIDAR data.

In this paragraph results are shown in combination with the DOPS and the DEM to address the uncertainties that are involved with the detection of ditch boundaries.

The study area is a subset of the test area II, its location is shown in Figure 24.

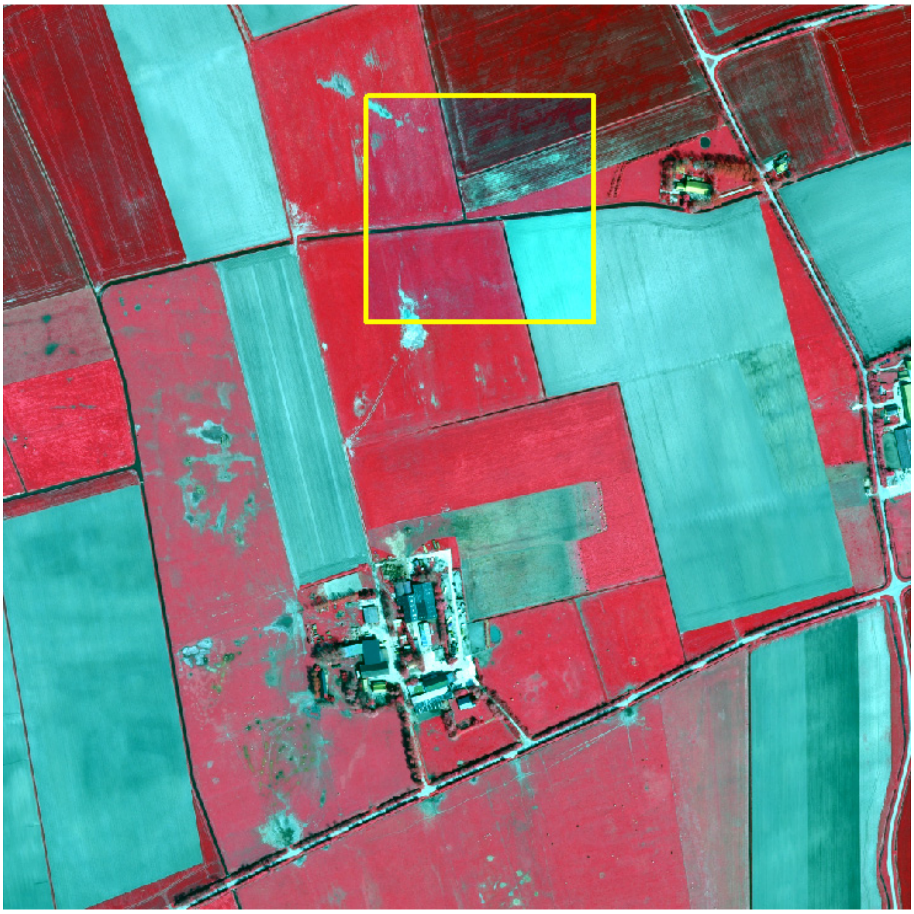
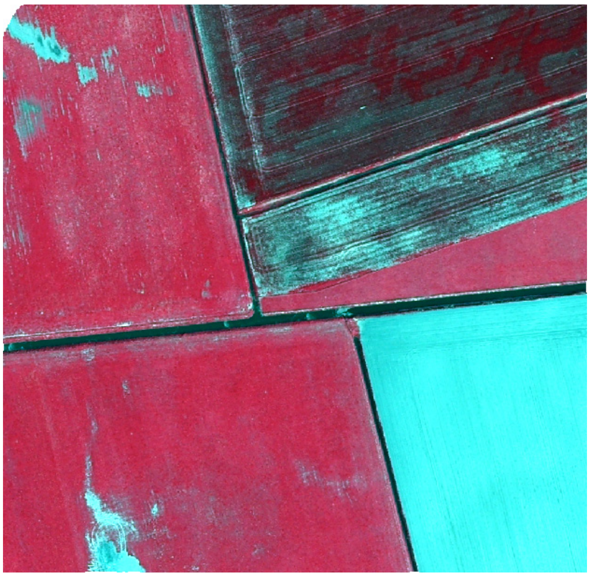
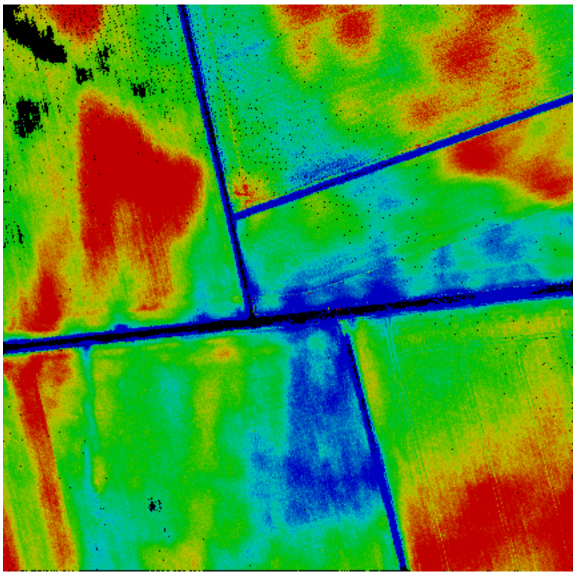


Figure 24
The yellow box indicates the location of the test area for the detection of ditches.

The source data for this process is the LIDAR dataset. Figure 25 shows both the false-color photo and the LIDAR data. The false-color aerial photo is only used as a visual reference.



False color aerial photo



LIDAR elevation points, colors based on height

Figure 25
Source data.

The ditches can be distinguished in the false-color areal photo based on the linear shape and dark color. But anomalies can also be seen within the contours of the ditches, some bright blue area's are visible. These are obstacles within the ditch. The LIDAR data show with a color scale based on the height of the points, this ranges from low (dark blue) to high (red). The black color represents missing data. These are most likely areas with water, as the LIDAR pulse is not reflected by water, which results in areas without data.

The first step in the process is to derive a DEM with a grid size of 50 cm from the LIDAR points. The result is shown in Figure 26. ArcGIS 10 has the capabilities to perform this step in the course of which the missing data areas are processed in meaningful manner. A workable result for the missing data areas is an essential condition for the next process steps.

The height information in the calculated DEM is used to classify the ditches, the classification result is used to detect the ditch boundaries. These are shown in Figure 27.

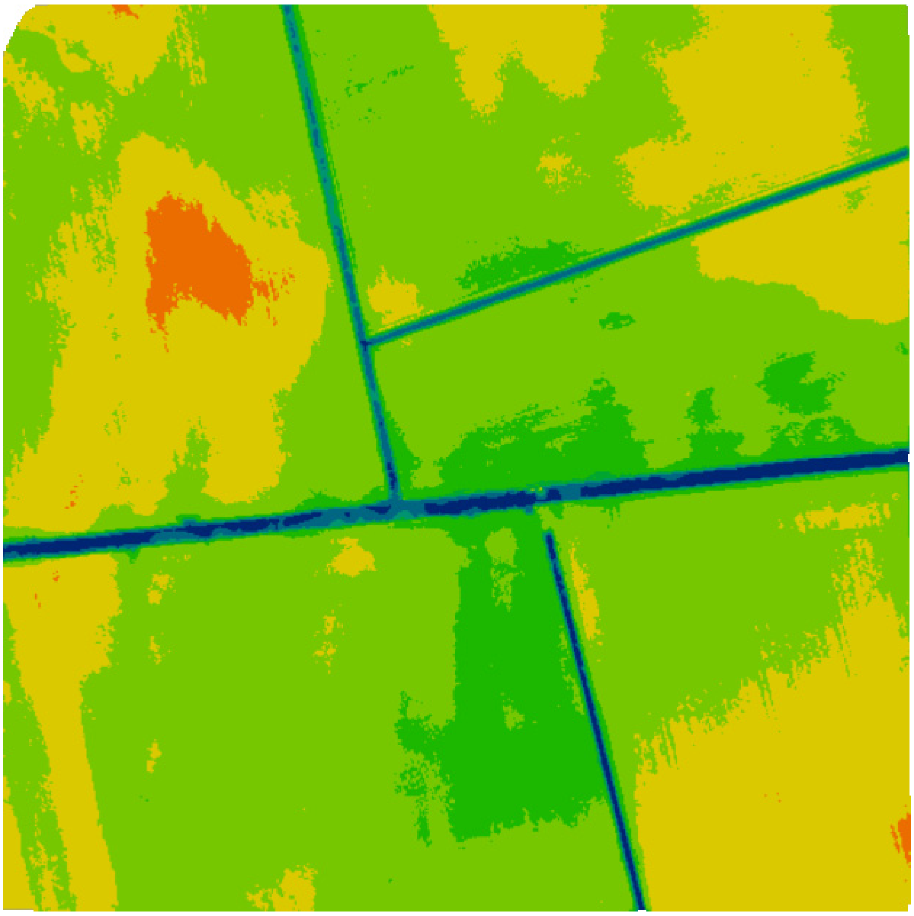
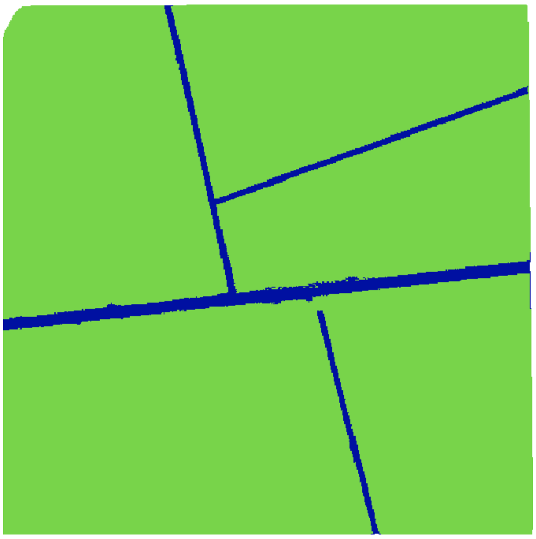
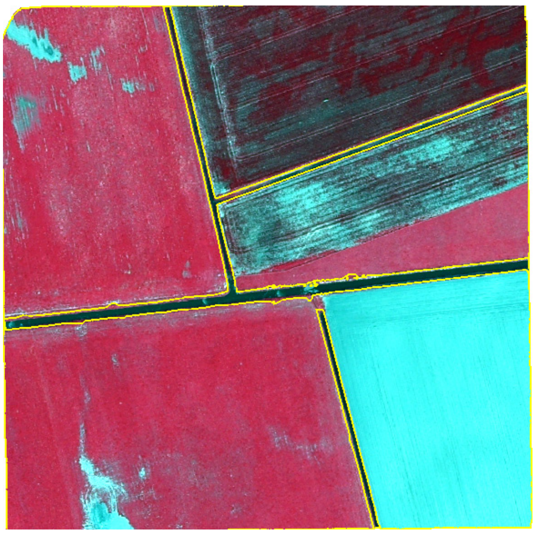


Figure 26
DEM derived from LIDAR points.



Blue: ditches
Green: other



Yellow lines: ditch boundaries

Figure 27
Ditch classification result (left) and derived ditch boundaries imposed upon false-color areal photo (right).

The detected ditch boundaries do match the visible outlines of the ditches on the areal photo when shown from a distance (Figure 27, right). Irregularities in ditch boundaries can be seen in a close-up view.

The left image in Figure 28 does show the ditch boundary as a straight line but the location seems not to be on the visible edge of the ditch. The maximum distance between the detected edge and the visible edge is about one meter. As the geometric accuracy of the source DEM is 50 cm's, it can be concluded that the accuracy of the automated detected edge is acceptable. The edge in the right image in Figure 28 does show some irregularities. These are also within a distance of one meter.

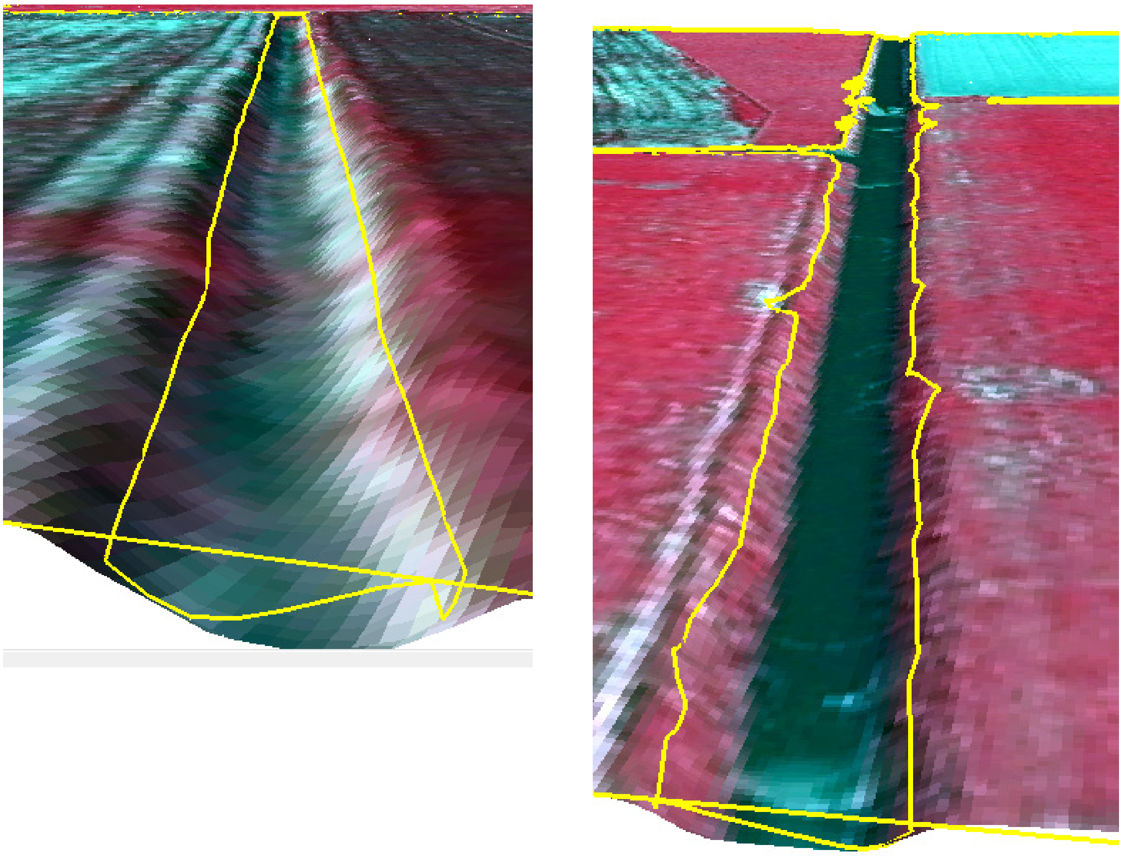


Figure 28
Perspective view of detected ditch edges (yellow) superimposed on the false-color areal photo with DEM.

Conclusion
The results of the quick scan show that it is possible to detect ditch edges from LIDAR data. The results might be improved by using additional processing steps that have not been used in this quick scan:
- Enhanced edge detection
- Line generalization

7 Conclusions and recommendations

7.1 Research Question

The primary objective according to the research request of the Ministry of EL&I was to depict:

Possibilities and limitations to automatically detect (mutation in) specific objects (landscape features) on the base of remote sensing and GIS-techniques

7.2 Conclusions

This study provided answers to this research request by addressing the sub-questions as described by the Ministry:
Q: Is it possible to develop a methodology for *automated* mapping of landscape features and subsidy eligible parcels by using high resolution geo-datasets and aerial photography (airborne and/or satellite origin), which complies with the required quality demands (without using Top10-datasets)?

A: The study reveals that linear features can be detected using DOPs in combination with height information derived by LIDAR. Results show a complete match for linear features between the real life *location* and the recognized objects from the designed process.

However, the exact delineation of a landscape feature with regard to the functional needs of the LPIS requirements would in the majority part require an additional manual control. In that regard the depicted automated process can be indicative for the quality of the manual digitalization process and therefore be used as an audit trigger to conduct the parcel digitization process in a more effective way.

Q: What is the link (if any) between the developed automated mapping methodology and the information model IMNAB?

A: A standardized and harmonized information model is a pre-requisite for efficiently collecting, storing, using and exchanging data on landscape features on a national (and international) scale. The different users of the datasets need to develop and use a common definition of the relevant landscape features, in order to be able to use the data in their internal process flows (e.g. European subsidy claims, …) and automated systems. An information model contains the definitions of the relevant objects, their characteristics, the procedures for collecting, storing and using them (metadata) together with the interrelation between the defined objects. The definitions contained in these model need to be based on physically recognizable object parameters (height, width, …). Only these parameters can be used in automated procedures. Properties like the type of management scheme of a landscape feature cannot be detected using earth observation techniques.

IMNAB (InformatieModel NatuurBeheerplannen) is an example of an information model, but this model does not cover the complete domain of the Ministry concerning landscape features. Based on this observation, the Ministry started the development of IMLG (see helpdesk question 'InformatieModel voor het Landelijk Gebied', IMLG). Both IMNAB and IMLG are under construction and it is foreseen that new versions of IMNAB and IMLG will be linked to cover the entire domain of the Ministry.

Q: What is the quality of the automated mapping results in relation to field observations?

A: In this project, we used visual observation of DOPs as an equivalent for field observations. Landscape features that can be seen on DOPs, can be detected by using the automated mapping procedure. The results show a good match between classified objects and visible features.

Q: Can a (automated) mapping procedure be adequately standardized in the future in order to detect and classify changes (in landscape elements) in the rural area?

A: The study shows that initial detection and classification of landscape features highly depends on landscape feature definitions. Current definitions are designed for manual detection and classification, whereas digitized procedures need machine measurable properties like height, width, color, etc. The results show that certain steps in the procedure - especially detections of objects - can be fully automated. Pattern matching however, is more difficult, and needs more designing and testing. Therefore we suggest to develop a procedure with both automated and manual components.

According to the answers above, a fully automated mapping of landscape features will hardly be possible. However it seems realistic that it will be possible to automate a procedure that creates object suggestions that match to a high degree the real shape of features. These 'feature suggestions' would only have to be verified or adjusted and users could be prompted automatically to these objects (by raising an alert to an human operator).

An overall conclusion is that it is possible to develop an adequately standardized automated mapping procedure to detect and classify changes (in landscape elements) in the rural area.

Q: Which long term (societal and technical) developments are of importance in relation to the further development of an automated mapping procedure?

A: An automated mapping procedure needs:
– The availability of up-to-date, high resolution earth observation datasets (like AHN2, DOPs), with DOPs including the infra-red bands. To enable detection of change on a yearly basis, the most recent DOPs as well of those of the previous year should be available.
– Good processing environment for huge amounts of data in a short time.

Q: Can an estimate be given on the costs of a nationwide application of an automated mapping procedure?

A: The report reveals that remote sensing based detection of landscape features making use of height information offers much more results than the traditional 2D approach.

The scope of this research study as well as the quality of the data that was available, could only provide a first glance of the full capacity of this approach. It can be assumed that an enlarged test site and improved data sets will provide qualitatively better results, which can be used to extrapolate to the whole area of The Netherlands.

For that we need the final AHN2 products as validated ground layer which was not available for this study. Moreover we need a complete set of LIDAR raw data including multiple returns and intensity which also were not provided for this study. That would render the classification accuracy much higher and could improve the capability for the automation of the processes.

Together with the ministerial process specialists and data producers, we could define an operational process, which will be the base for the business case calculations.

Q: Can an estimate be given of the capacity (calendar time and man power) needed to prepare a nation wide database with landscape features using automated procedures?

A: See previous question and answer.

7.3 Recommendations

The study made clear that operationalization of the object recognition processes requires an integrated understanding of the functional context of the GeoCAP, as well as an in depth understanding of remote sensing techniques. At present there is a (geo)gap between functional requirements of the LPIS and the update procedures and the existing base technologies to be applied in that context.

Another point is about data availability: infrared DOPs and LIDAR height data should be available nationwide and on a regular basis.

The current study was conducted with a relatively small subset of data. If the results were to be applied operationally, then huge amounts of data will have to be processed and stored. This requires the management of mass data processing including the specific issues related to that. Those are not mentioned here.

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Appendix 1 Abbreviations

	Abbreviations	
A	AAN	Agricultural Area Netherlands
	AHN, AHN2	Actual Height model of The Netherlands *(Actueel Hoogtebestand Nederland, a detailed elevation model of the whole country using Airborne Laser Altimetry)*
	AKB	Application to process GIS-data of accepted subsidy requests *(Aanvraag Kaart Behandelsysteem)*
B	BG	Bulgaria
C	CAP	Common Agricultural Policy
	CIR	Colour-infrared
	CY	Cyprus
D	DE	Germany *(Deutschland)*
	DEM	Digital Elevation Model
	DOP	Digital Orthophoto
	DR	Dienst Regelingen *(agency of the Ministry of EL&I for the implementation of regulations)*
	EL&I	Dutch Ministry of Economic Affairs, Agriculture and Innovation. *(Min. Economische Zaken, Landbouw en Innovatie. Exists as off October 14, 2010. Before that, see under "LNV")*
E	EU	European Union
G	GSD	Ground sampling distance
H	HRI	High Resolution Imagery
	HRS	High Resolution Satellite
I	IE	Republic of Ireland
	IMNAB	Dutch nature conservation information model *(Informatiemodel Natuurbeheer)*
	IT	Italy
	KLE	Small landscape features *(Kleine Landschaps Elementen)*
L	LIDAR	Light Detection and Ranging *(optical remote sensing technology to measure properties of scattered finding range and/or other information of a distant target)*
	LGN	Land use database of The Netherlands *(Landelijk Grondgebruik Nederland)*
	LNV	Dutch Ministry of Agriculture, Nature Conservation and Food Quality *(Ministerie van Landbouw, Natuur en Voedselveiligheid. Existed until October 14, 2010)*
M	LPIS	Land Parcel Identification System
	MS	Member State
	LRS	Low resolution satellite
N	NDVI	Normalized Differenced Vegetation Index
	NOAA	National Oceanic and Atmospheric Administration
	NIR	Near infrared
	NL	The Netherlands
P	PBL	The Dutch Environmental Assessment Agency *(Planbureau voor de Leefomgeving)*
	PL	Poland
R	Radar	Radio Detection and Ranging
V	VHR	Very High Resolution
	VROM	Dutch Ministry of Spatial Planning, Housing and the Environment *(Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer)*

Appendix 2 Compilation of policy framework

Table 10
Overview of policy framework in context to this study (no claim to completeness).

No.	Short name	Full name	Type	Remarks
1	Reg. (EC) 73/2009	COUNCIL REGULATION (EC) No 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers, amending Regulations (EC) No 1290/2005, (EC) No 247/2006, (EC) No 378/2007 and repealing Regulation (EC) No 1782/2003	Council Regulation	Replaced Reg. (EC) 1782/2003 in January 2009
2	Reg. (EC) 796/2004	COMMISSION REGULATION (EC) No 796/2004 of 21 april 2004 laying down detailed rules for the implement-tation of cross-compliance, modulation and the integrated administration and control system provided for in of Council Regulation (EC) No 1782/2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers	COMMISSION REGULATION	Article 30 provides some basic framework for LPIS creation and landscape features
3	2580DiscLPISv1.4	Discussion document "Land Parcel Identification Systems in the frame of Regulation (EC) 1593/2000", document reference OL/I04/M2580/01	Discussion Paper	Available online: http://mars.jrc.it/mars/Bulletins-Publications/Discussion-Paper-Land-Parcel-Identification-Systems-in-the-frame-of-Regulation-EC-1593-2000-archive-document-2001
4	IACS_ Implementatioı 1187v2-2-1.pdf	Implementation of IACS-GIS, Reg. 1593/00 and 2419/01 (archive document, 2002)	Discussion Paper	Available online: http://mars.jrc.it/mars/content/download/990/6087/file/IACS_Implementation1187v2-2-1.pdf
5	IACS_Implementation 1187v2-2-1.pdf	Implementation of IACS-GIS, Reg. 1782/03 and 796/2004	Discussion Paper	Available online: http://mars.jrc.it/mars/content/download/989/6082/file/2575v3-3.pdf

Appendix 3 Landscape features

Description of landscape features according to LNV specifications

The following descriptions stem from the document '2009-07-08 POP DEFINITIEVE BESCHRIJVING LANDSCHAPSBEHEERTYPEN.doc:'
The illustrations are taken from the document: 'Index natuur en landschap onderdeel landschapsbeheertypen.pdf'

Index Natuur en Landschap, Onderdeel landschapsbeheertypen
(Definitieve versie voor POP -aanvraag d.d. 8 juli 2009)

L01 Groen blauwe landschapselementen

L01.02 Beheertype houtwal en houtsingel
L01.03 Beheertype elzensingel
L01.04 Beheertype bossingel en bosje
L01.05 Beheertype knip- of scheerheg
L01.06 Beheertype struweelhaag
L01.07 Beheertype laan
L01.08 Beheertype knotboom
L01.09 Beheertype hoogstamboomgaard
L01.10 Beheertype struweelrand
L01.11 Beheertype hakhoutbosje
L01.12 Beheertype griendje
L01.13 Beheertype bomenrij en solitaire boom
L01.14 Beheertype rietzoom en klein rietperceel
L01.15 Beheertype natuurvriendelijke oever

L04 Recreatieve Landschapselementen

L04.01 Beheertype wandelpad over boerenland

L01.02 Beheertype Houtwal en houtsingel

Afbakening

Een houtwal of houtsingel is een vrijliggend lijnvormig en aaneengesloten landschapselement, al dan niet groeiend op een aarden wal, met een opgaande begroeiing van inheemse bomen en/of struiken. De begroeiing wordt als hakhout beheerd.
De houtwal of houtsingel is minimaal 25 meter lang en maximaal 20 meter breed.
Elzensingels bestaande uit een enkele rij horen niet tot dit beheertype, maar tot het beheertype L01.03 Elzensingel.
Windsingels om boomgaarden en kwekerijen horen niet tot dit beheertype.

Beheervoorschriften

Voorwaarden en eisen

Tenminste 75% van de oppervlakte van het element wordt als hakhout beheerd en periodiek afgezet;
Snoeihout mag op stapels of rillen in het element verwerkt worden voor zover het de ondergroei en/of de stoven niet schaadt;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element en als snoeihout versnipperd wordt mogen de snippers niet verwerkt worden in het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden;
Het wallichaam wordt in stand gehouden als het element daarvan is voorzien;
Het element mag niet betreden en/of beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Het afzetten van het element wordt alleen verricht in de periode tussen 1 oktober en 15 maart.
Overhangende takken kunnen gedurende het gehele jaar worden teruggesnoeid.

Beheerpakketten

L01.02.01 Houtsingel en houtwal

Het element wordt periodiek afgezet in een cyclus van éénmaal per 6-15 jaar.

L01.02.02 Hoge houtwal

Het element wordt periodiek afgezet in een cyclus van éénmaal per 21-25 jaar. Tussentijds mogen overhangende takken gesnoeid worden;
Het wallichaam is minimaal 0,8 meter hoog en de kruidachtige vegetatie van de steile walkanten wordt gemaaid;
Aan de voet van het wallichaam ligt een greppel die in stand wordt gehouden.

L01.02.03 Holle weg en graft

Het element is gelegen op het talud van een holle weg of graft in Zuid-Limburg;
Het element wordt periodiek afgezet in een cyclus van minimaal éénmaal per 15 jaar;

L01.03 Beheertype Elzensingel

Afbakening

Een elzensingel is een vrijliggend lijnvormig en aaneengesloten éénrijig landschapselement dat grotendeels bestaat uit Zwarte els en als hakhout wordt beheerd.
Een elzensingel is minimaal 25 meter lang.
Losse bomenrijen horen niet tot dit beheertype, maar tot het beheertype L01.13 Bomenrij/solitaire boom.
Windsingels om boomgaarden en kwekerijen horen niet tot dit beheertype.

Beheervoorschriften

Voorwaarden en eisen

75% van lengte van het element wordt als hakhout beheerd;
Het hakhout wordt periodiek afgezet in een cyclus van éénmaal per 6-21 jaar. Tussentijds mogen overhangende takken worden gesnoeid;
Het snoeihout mag niet in het element verwerkt worden;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element en als snoeihout versnipperd wordt mogen de snippers niet verwerkt worden in het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden;
Het element mag niet betreden en/of beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Het afzetten van het element wordt alleen verricht in de periode tussen 1 oktober en 15 maart.

Beheerpakketten

L01.03.01 Elzensingel bedekking 30-50%
L01.03.02 Elzensingel bedekking 50%-75%
L01.03.03 Elzensingel bedekking > 75%

L01.04 Beheertype Bossingel en bosje

Afbakening

Een bossingel is een vrijliggend lijnvormig en aaneengesloten landschapselement met een opgaande begroeiing van inheemse bomen en struiken.
Een bossingel is minimaal 25 meter lang en maximaal 20 meter breed.
Een bosje is een vrijliggend vlakvormig en aaneengesloten landschapselement met een opgaande begroeiing van inheemse bomen en struiken.
Een bosje is minimaal 2,0 are en maximaal 1 hectare groot.

Beheervoorschriften

Voorwaarden en eisen

Het element wordt als bos met hoog opgaande bomen beheerd;
Het element wordt periodiek gedund en overhangende takken kunnen het gehele jaar worden gesnoeid;
Randen van het element kunnen als hakhout beheerd worden;

Snoeihout mag op stapels of rillen in het element verwerkt worden voor zover het de ondergroei en/of de stoven niet schaadt;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element, en als snoeihout versnipperd wordt mogen de snippers niet verwerkt worden in het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden;
Het element mag niet betreden en/of beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Dunningswerkzaamheden en het eventueel terugzetten van hakhout worden alleen verricht in de periode tussen 1 oktober en 15 maart.

Beheerpakket
L01.04.01 Bossingel en bosje

L01.05 Beheertype Knip- of scheerheg

Afbakening
Een knip- of scheerheg is een vrijliggend lijnvormig landschapselement, met een aaneengesloten begroeiing van inheemse bomen en/of struiken, dat wordt geknipt of geschoren.
Een knip- of scheerheg is minimaal 25 meter lang.
Een knip- of scheerheg kan periodiek gevlochten worden.
Windsingels om boomgaarden en kwekerijen horen niet tot dit beheertype.

Beheervoorschriften

Voorwaarden en eisen
Snoeimateriaal mag blijven liggen voor zover dat het element of de ondergroei niet schaadt;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden;
Het element mag niet betreden en/of beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Snoeiwerkzaamheden worden alleen verricht in de periode tussen 15 juni en 15 maart.

Beheerpakketten
L01.05.01 Knip- en scheerheg jaarlijkse cyclus
De heg wordt eenmaal per jaar geknipt of geschoren . Na het knippen/scheren heeft de heg een hoogte van minimaal 0,8 meter.

L01.05.02 Knip- en scheerheg 2-3 jaarlijkse cyclus
De heg bestaat voor meer dan 50% uit meidoorn en wordt om de 2-3 jaar geknipt of geschoren. Na het knippen/scheren heeft de heg een hoogte van minimaal 1,0 meter en een breedte van minimaal 0,8 meter.

L01.06 Beheertype Struweelhaag

Afbakening

Een struweelhaag is een vrijliggend lijnvormig landschapselement met een aaneengesloten opgaande begroeiing van inheemse, overwegend doornachtige, struiken.
Een struweelhaag is minimaal 25 meter lang.
Hagen die minimaal eenmaal per 3 jaar worden gesnoeid horen tot het beheertype L01.05 Knip- of scheerheg.

Beheervoorschriften

Voorwaarden en eisen

Het snoeien kan gecombineerd worden met het vlechten van de haag;
Het snoeihout mag niet in het element verwerkt worden, behoudens bij het vlechten van de haag;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element, en als snoeihout versnipperd wordt mogen de snippers niet verwerkt worden in het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden;
Het element mag niet betreden en/of beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Het afzetten van het element wordt alleen verricht in de periode tussen 1 oktober en 15 maart.
Overhangende takken kunnen gedurende het gehele jaar worden teruggesnoeid;
Indien snoeiwerkzaamheden machinaal worden uitgevoerd, wordt geen klepelmaaier gebruikt.

Beheerpakketten

L01.06.01 Struweelhaag snoeicyclus 5-7 jaar

Het element kan vrij uitgroeien en wordt periodiek in een cyclus van éénmaal per 5 - 7 jaar aan drie zijden gesnoeid. Na het snoeien heeft de haag een hoogte van minimaal 1,0 meter en een breedte van minimaal 0,8 meter.

L01.06.02 Struweelhaag snoeicyclus > 12 jaar

Het element kan vrij uitgroeien en wordt periodiek in een cyclus van éénmaal per 12 - 25 jaar afgezet.

L01.07 Beheertype Laan

Afbakening

Een laan is een weg of pad, die aan beide zijden met een of meerdere rijen bomen is beplant en is bedoeld en aangelegd als laan.
Bij een laan gaat het meestal om bomen van dezelfde soort en leeftijd en er is sprake van een herkenbaar en regelmatig plantverband.
Onder dit beheertype vallen ook dijken met een weg, bovenop de kruin van de dijk, die aan beide zijden met bomen is beplant.
Een laan is minimaal 50 meter lang.
Losse bomenrijen horen niet tot dit beheertype, maar tot het beheertype L01.13 Bomenrij/solitaire boom.

Beheervoorschriften

Voorwaarden en eisen
De bomen worden periodiek gesnoeid;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden;
De bomen mogen niet beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Snoeiwerkzaamheden worden alleen verricht in de periode tussen 15 juli en 15 maart.

Beheerpakketten
L01.07.01 Laan stamdiameter < 20 cm
L01.07.02 Laan stamdiameter 20-60 cm
L01.07.03 Laan stamdiameter > 60 cm

De diameter van de stammen wordt op 1,0 meter boven het maaiveld bepaald en element wordt als geheel in een van de diameterklassen ingedeeld op basis van de gemiddelde diameter van de bomen van het element.

L01.08 Beheertype Knotboom

Afbakening
Een knotboom is een inheemse loofboom, waarvan de stam periodiek op een hoogte van minimaal 1,0 meter boven maaiveld wordt afgezet (geknot).
Knotbomen worden aangetroffen als solitaire boom, in rijen of in kleine groepen. Een kleine groep bestaat uit maximaal 20 bomen.
Vlakvormige elementen met knotbomen, behoudens kleine groepen, horen niet tot dit beheertype maar kunnen mogelijk gerangschikt worden onder het beheertype L01.12 Hakhoutbosje of L01.13 Griendje mits voldaan wordt aan de eisen van deze beheertypen.

Beheervoorschriften

Voorwaarden en eisen
Knotwilgen, -elzen, -essen en -populieren –worden in een cyclus van éénmaal per 3-8 jaar geknot. Knoteiken en -haagbeuken worden geknot in een cyclus van minimaal eenmaal per 15 jaar;
Er mag geen snoeihout verbrandt worden in de directe omgeving van de knotboom;
De boom mag niet beschadigd worden door vee.
Knotwerkzaamheden worden alleen verricht in de periode tussen 1 oktober en 15 maart.

Beheerpakketten
L01.08.01 Knotboom stamdiameter < 20 cm
L01.08.02 Knotboom stamdiameter 20-60 cm
L01.08.03 Knotboom stamdiameter > 60 cm

De diameter van de stammen wordt op 1,0 meter boven het maaiveld bepaald en als het element uit meerdere knotbomen bestaat wordt het element als geheel in een van de diameterklassen ingedeeld op basis van de gemiddelde diameter van de bomen van het element.

L01.09 Beheertype Hoogstamboomgaard

Afbakening

Een hoogstamboomgaard is een verzameling van fruitbomen, met een stam van minimaal 1,50 meter hoog en waarvan de onderbegroeiing bestaat uit een grazige vegetatie.
Een hoogstamboomgaard bestaat uit minimaal 10 fruitbomen en heeft een dichtheid van minimaal 50 en maximaal 150 bomen per hectare.
Maximaal 10% van de fruitbomen bestaat uit walnoten.
Een hoogstamboomgaard is vaak in een cluster geplant en duidelijk afgescheiden van de omgeving.

Beheervoorschriften

Voorwaarden en eisen

Indien het appel of peer betreft wordt de boom tenminste éénmaal per 2 jaar gesnoeid. Andere soorten enkel vormsnoei indien nodig;
De grasvegetatie wordt jaarlijks gemaaid en het maaisel wordt afgevoerd of de grasvegetatie wordt beweid;
Er mag geen snoeihout verbrand worden in de directe omgeving van de bomen of versnipperd hout verwerkt worden in de boomgaard;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en de pleksgewijze bestrijding van Akkerdistel, Ridderzuring en Brandnetel in het element gebruikt worden;
De hoogstamfruitboom mag niet beschadigd worden door vee. Jonge bomen zijn voorzien van een boomkorf;
Bemesten en bekalken van de boomgaard is toegestaan. Bij bemesten van de boomgaard worden de fruitbomen en wortels niet beschadigd;
Snoeiwerkzaamheden kunnen gedurende het gehele jaar worden verricht.

Beheerpakket

L01.09.01 Hoogstamboomgaard

L01.10 Beheertype Struweelrand

Afbakening

Een struweelrand is een aaneengesloten rand met een mozaïek van struweel (bramen en/of andere inheemse bomen of struiken) en een kruidachtige begroeiing van inheemse grassen en kruiden die zich spontaan kan ontwikkelen.
De rand is minimaal 25 meter lang en maximaal 20 meter breed.
Maximaal 50% van de oppervlakte van de rand wordt ingenomen door inheemse bomen en/of struiken.
De struweelrand kan langs een bosrand of een landschapselement liggen maar ook vrij in het veld, bijvoorbeeld langs een perceelsrand.

Beheervoorschriften

Voorwaarden en eisen

Periodiek wordt de begroeiing gemaaid en/of afgezet;
50% van de oppervlakte van de rand bestaande uit een kruidachtige begroeiing van inheemse grassen en kruiden mag periodiek gemaaid worden met een cyclus van maximaal éénmaal per 5 jaar. Het maaisel wordt afgevoerd;

Snoeihout mag op stapels of rillen in het element verwerkt worden voor zover het de ondergroei en/of de stoven niet schaadt;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element, en als snoeihout versnipperd wordt mogen de snippers niet verwerkt worden in het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling en de pleksgewijze bestrijding van Akkerdistel, Ridderzuring en Brandnetel, en meststoffen in het element gebruikt worden.
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Het element mag niet betreden en/of beschadigd worden door vee;
Maaiwerkzaamheden worden uitgevoerd tussen 15 juli en 15 maart en het afzetten van struweel wordt alleen verricht in de periode tussen 1 november en 15 maart.

Beheerpakket
L01.10.01 Struweelrand

L01.11 Beheertype Hakhoutbosje

Afbakening
Een hakhoutbosje is een vrijliggend vlakvormig landschapselement, met inheemse bomen en/of struiken dat als hakhout wordt beheerd.
Een hakhoutbosje is minimaal 1,0 are en maximaal 1,0 hectare groot.
Kleine vrijliggende bosjes zonder hakhoutbeheer of met enkel hakhoutbeheer aan de randen horen tot het beheertype L01.04 Bossingel en Bosje.

Beheervoorschriften

Voorwaarden en eisen
Minimaal 80% van de oppervlakte van het bosje wordt als hakhout beheerd;
Het element wordt periodiek afgezet in een cyclus van éénmaal per 6 - 25 jaar;
Snoeihout mag op stapels of rillen in het element verwerkt worden voor zover het de ondergroei en/of de stoven niet schaadt;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element, en als snoeihout versnipperd wordt mogen de snippers niet verwerkt worden in het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden ;
Het element mag niet betreden en/of beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Slootmaaisel of bagger mag niet verwerkt worden in het element.
Het afzetten van het element wordt alleen verricht in de periode tussen 1 oktober en 15 maart.
Overhangende takken kunnen gedurende het gehele jaar worden teruggesnoeid.

Beheerpakketten
L01.11.01 Hakhoutbosje met dominantie van langzaamgroeiende boomsoorten (zomereik, wintereik, berk, haagbeuk)

L01.11.02 Hakhoutbosje met dominantie van snelgroeiende boomsoorten (zwarte els, gewone es)

L01.12 Beheertype Griendje

Afbakening
Een griendje is een vrijliggend vlakvormig landschapselement met inheemse wilgensoorten dat als hakhout wordt beheerd.
Het griendje is minimaal 1,0 are en maximaal 1,0 hectare groot.
Grienden die machinaal gemaaid worden behoren niet tot dit beheertype.

Beheervoorschriften

Voorwaarden en eisen
Het element bestaat uit inheemse wilgensoorten en wordt geheel als hakhout beheerd en afgezet in een cyclus van tenminste éénmaal per 5 jaar;
Snoeihout mag op stapels of rillen in het element verwerkt worden voor zover het de ondergroei en/of de stoven niet schaadt;
Er mag geen snoeihout verbrand worden in of in de directe omgeving van het element, en als snoeihout versnipperd wordt mogen de snippers niet verwerkt worden in het element;
Er mogen geen gewasbeschermingsmiddelen, behalve bij bestrijding van ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) middels een stobbenbehandeling, en meststoffen in het element gebruikt worden;
Het element mag niet betreden en/of beschadigd worden door vee. Indien het element is uitgerasterd moet het raster op een zodanige afstand staan dat vraat aan stammen wordt voorkomen;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Het afzetten van het element wordt alleen verricht in de periode tussen 1 oktober en 15 maart.
Overhangende takken kunnen gedurende het gehele jaar worden teruggesnoeid.

Beheerpakket
L01.12.01 Griendje

L01.13 Beheertype Bomenrij en solitaire boom

Afbakening
Een bomenrij/solitaire boom is een vrijliggend landschapselement van inheemse loofbomen dat niet kan worden gerangschikt onder andere beheertypes van deze index.
Bedoeld worden solitaire bomen of bomen in een groep of rij staande op of langs landbouwgrond.
Bomen die een onderdeel vormen van een ander beheertype van deze index of deel uitmaken van een bomenrij als bedoeld in dit beheertype kunnen niet als solitaire boom of verzameling van solitaire bomen aangevraagd worden.
De bomenrij is minimaal 50 meter lang en bestaat uit minimaal 8 bomen per 100 meter.
Vlakvormige boomweides behoren niet tot dit beheertype.
Solitaire knotbomen of een rij knotbomen behoren tot het beheertype L01.08 Knotboom.
Windsingels om boomgaarden en kwekerijen horen niet tot dit beheertype

Beheervoorschriften

Voorwaarden en eisen
De bomen worden periodiek gesnoeid. Jonge bomen gemiddeld eenmaal per 5 jaar en oudere bomen gemiddeld eenmaal per 10 jaar. Bij oudere bomen kan het snoeien zich beperken tot het verwijderen van dood hout;

Na het snoeien beslaat de blijvende kroon altijd minimaal tweederde deel beslaat van de totale lengte van de boom;
Er mag geen snoeihout verbrand worden in de directe omgeving van het element;
Ongewenste houtsoorten (Amerikaanse vogelkers, Amerikaanse eik, Robinia en Ratelpopulier) in het element mogen middels een stobbenbehandeling bestreden worden;
De bomen mogen niet beschadigd worden door vee. Jonge bomen in een weiland (boomdijk) zijn voorzien van een boomkorf of zijn uitgerasterd;
Snoeiwerkzaamheden worden alleen verricht in de periode tussen 15 juli en 15 maart.

Beheerpakketten

L01.13.01	Bomenrij en solitaire boom stamdiameter < 20 cm
L01.13.02	Bomenrij en solitaire boom stamdiameter 20-60 cm
L01.13.03	Bomenrij en solitaire boom stamdiameter > 60 cm

De diameter van de stammen wordt op 1,0 meter boven het maaiveld bepaald en als het element uit meerdere bomen bestaat wordt het element als geheel in een van de diameterklassen ingedeeld op basis van de gemiddelde diameter van de bomen van het element.

L01.14 Beheertype Rietzoom en klein rietperceel

Afbakening
Een rietzoom bevindt zich langs een waterloop en bestaat uit riet-, biezen en/of zeggevegetaties met een dominantie van riet (bedekking riet > 50%).
De rietzoom heeft een breedte van minimaal 2 meter en is minimaal 25 meter lang.
Een klein rietperceel is een vlakvormig element met een vegetatie die overwegend uit riet bestaat. De maaibare oppervlakte van een klein rietperceel is maximaal 0,5 ha.

Beheervoorschriften

Voorwaarden en eisen
Maximaal 20% van de oppervlakte van het element bestaat uit struweel;
Het element wordt periodiek gemaaid in een cyclus van éénmaal per 2-4 jaar en het maaisel wordt afgevoerd;
Er mogen geen gewasbeschermingsmiddelen en meststoffen in het element gebruikt worden;
Het element mag niet betreden en/of beschadigd worden door vee;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Maaiwerkzaamheden worden verricht in de periode tussen 1 oktober en 1 maart.

Beheerpakketten

L01.14.01	Smalle rietzoom (2- 5 meter)
L01.14.02	Brede rietzoom (> 5 meter) en klein rietperceel

L01.15 Beheertype Natuurvriendelijke oever

Afbakening
Een natuurvriendelijke oever is een aaneengesloten oever langs een bestaande waterloop, in de vorm van een plas- of drasberm of flauw talud (flauw talud minimaal 1: 3) met een begroeiing van inheemse planten.
De oever heeft een breedte van minimaal 3 en maximaal 10 meter en is minimaal 25 meter lang.

Beheervoorschriften

Voorwaarden en eisen
Het element wordt periodiek gemaaid in een cyclus van minimaal éénmaal per 2 jaar en maximaal éénmaal per jaar. Het maaisel wordt afgevoerd;
Er mogen geen gewasbeschermingsmiddelen en meststoffen in het element gebruikt worden;
Het element mag niet betreden en/of beschadigd worden door vee;
Slootmaaisel of bagger mag niet verwerkt worden in het element;
Maaiwerkzaamheden worden verricht in de periode tussen 15 juli en 1 maart.

Beheerpakket
L01.15.01 Natuurvriendelijke oever

L04.01 Beheertype Wandelpad over boerenland

Afbakening.
Een wandelpad over boerenland bestaat in beginsel uit een onverhard pad. Kleine gedeelten verhard pad over particuliere gronden kunnen meegenomen worden als dit noodzakelijk is voor de wandelpadenstructuur.
Het wandelpad heeft een breedte van maximaal 3 meter.
De paden zijn duidelijk gemarkeerd en zijn geschikt voor wandelaars met een normale conditie.
Het wandelpad vormt een onderdeel van een doorgaande en/of openbare wandelstructuur.

Beheervoorschriften

Voorwaarden en eisen
Het wandelpad wordt zodanig beheerd dat een goede begaanbaarheid gewaarborgd is;
De voorzieningen die een onderdeel vormen van het wandelpad zoals bruggetjes, klaphekjes e.d. worden in goede staat van onderhoud gehouden;
Het wandelpad is opengesteld van zonsopgang tot zonsondergang en jaarrond toegankelijk.

Beheerpakket
L04.01.01 Wandelpad over boerenland

Appendix 4 Excerpt: Handboek_digitaliseren_AAN_versie1.0.doc

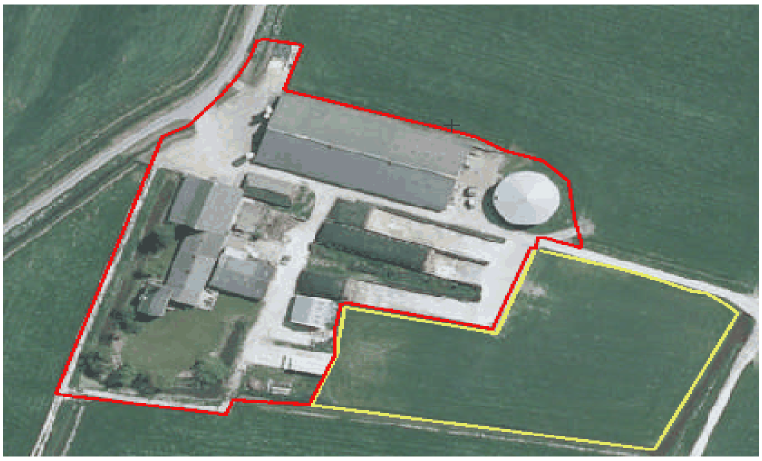
The following descriptions stem from the document “Handboek_digitaliseren_AAN_versie1.0.doc”, which describes how to digitize agricultural parcels and comply with subsidy regulations.

De Landschapselementen
Hieronder is de lijst van landschapselementen opgenomen waarvan de oppervlakten uitgesloten moeten worden van de oppervlakte van het nieuwe referentieperceel. Ter verduidelijking zijn voorbeelden op de luchtfoto toegevoegd.

Bebouwing
Gebouw
Kassencomplex/Losse kassen, schuren
Molen / windturbine
Terrein
Riet
Gaswinning / fakkeltoren
Sport- en recreatieterrein
Moestuin
Opslag
Kuilvoer
Mest
Grond, zand, afval)
Paardenbak
(onverharde) paden
Begroeiing
Bomenrij
Houtrand (houtwal/houtsingel, haag)
Heg
Water
Sloot
Waterdelen
Ven, plas, dras, poel

Bebouwing

Bebouwing (huizen, schuren, inclusief erf)



Beschrijving:
Alle soorten bebouwing dat aard- en nagelvast is, zoals schuren, huizen, stallen - inclusief omliggend erf

Kassen

Losse schuren, kassen binnen het perceel

Voornamelijk uit glas of plastic opgebouwde overbouwing van de grond.

Omliggend verhard oppervlak hoort ook bij het object.

Molen/windturbine

Beschrijving:
Werktuig (met of zonder gebouw) dat bewegingsenergie van de wind omzet in bewegingsenergie die wordt gebruikt om elektriciteit (groene stroom) op te wekken, of om graan te malen.

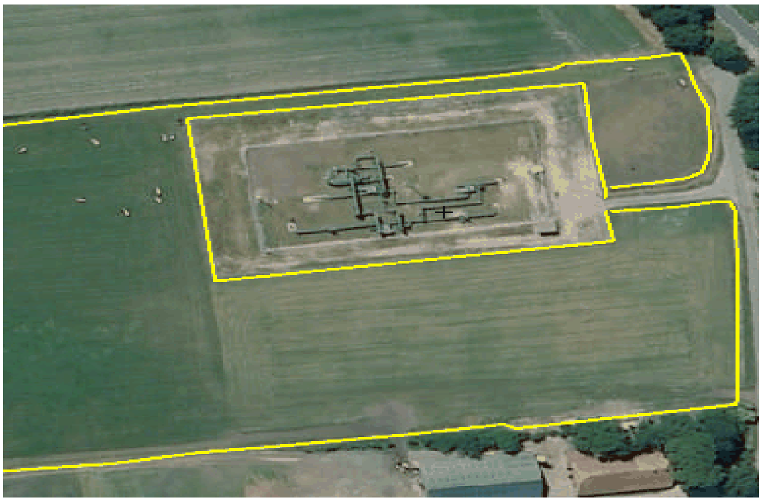
Omliggend verhard oppervlak valt hier ook onder.

Terrein

Rietzoom/klein rietperceel

Beschrijving:
Lange grasachtige vegetatie die vaak langs waterkanten te vinden is. De grens waar het netto perceel begint wordt met de gele lijn weergegeven.

Gaswinninglocatie/fakkeltoren



Beschrijving:
De eventuele aanwezige omheining bepaalt de grenzen van het totale oppervlak. Omliggend verhard oppervlak hoort er ook bij.

Weg/pad

Beschrijving:
Alle paden/wegen die zich binnen de grenzen van het perceel bevinden, zoals een toegangsweg, ongeacht de verharding. De verharding kan bestaan uit grint, stenen, beton. Maar ook onverharde paden, van zand, modder (kleipad) en paden die zijn ontstaan door bandensporen en permanent worden gebruikt als toegangsweg.

Bomenrij

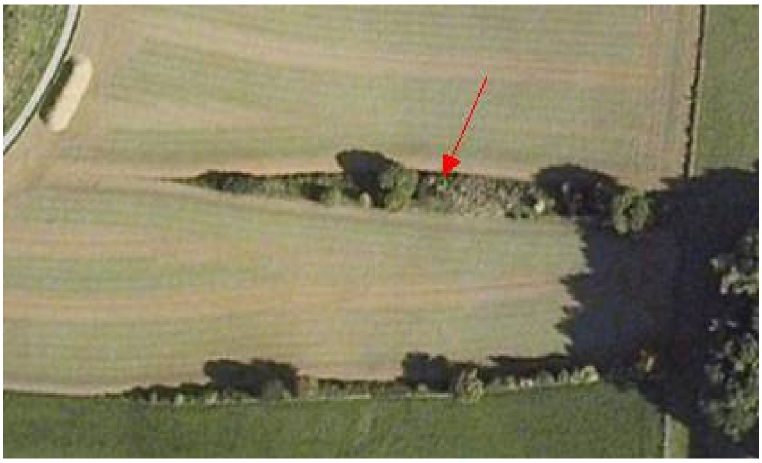
Beschrijving:
Aantal bomen die in een rij staan, waarbij de onderlinge afstand tussen de bomen zodanig is dat de bomenrij tot manshoogte geen zichtbelemmering vormt. Een bomenrij is een vrij liggend lijnvormig landschapselement met opgaande begroeiing van bomen en struiken

Minimale lengte voor opname is 100 meter. Er moet wel sprake zijn van een rij: de opgaande bomen staan in een lijn. Struiken of eventueel aanwezig hakhout spelen hierbij geen rol (een aantal rijen bomen die samen een vlak vormen is dus geen bomenrij)

Maximaal 2 rijen. Bij meer dan 2 rijen is er geen sprake meer van een bomenrij, maar van een bos.

De bomenrij wordt gedigitaliseerd met een breedte van 1 meter.

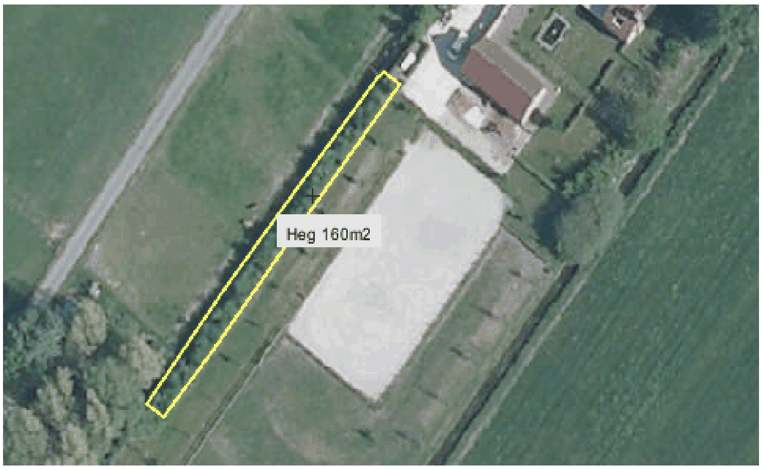
Houtrand



Beschrijving:
Onder houtrand worden houtsingels, hagen en houtwallen verstaan: terreinen begroeid met loofhout en/of naaldhout, waarvan de inplant van de stammen breder is dan 1 meter. Al dan niet met hoogteverschil. Hoogteverschillen (b.v. Limburg) begroeid met struiken en zo hier en daar een boom, vallen ook onder de categorie Houtrand.

De houtrand wordt gedigitaliseerd aan de hand van de grenzen die op de luchtfoto waarneembaar zijn en heeft een minimale breedte van 1 meter.

Heg



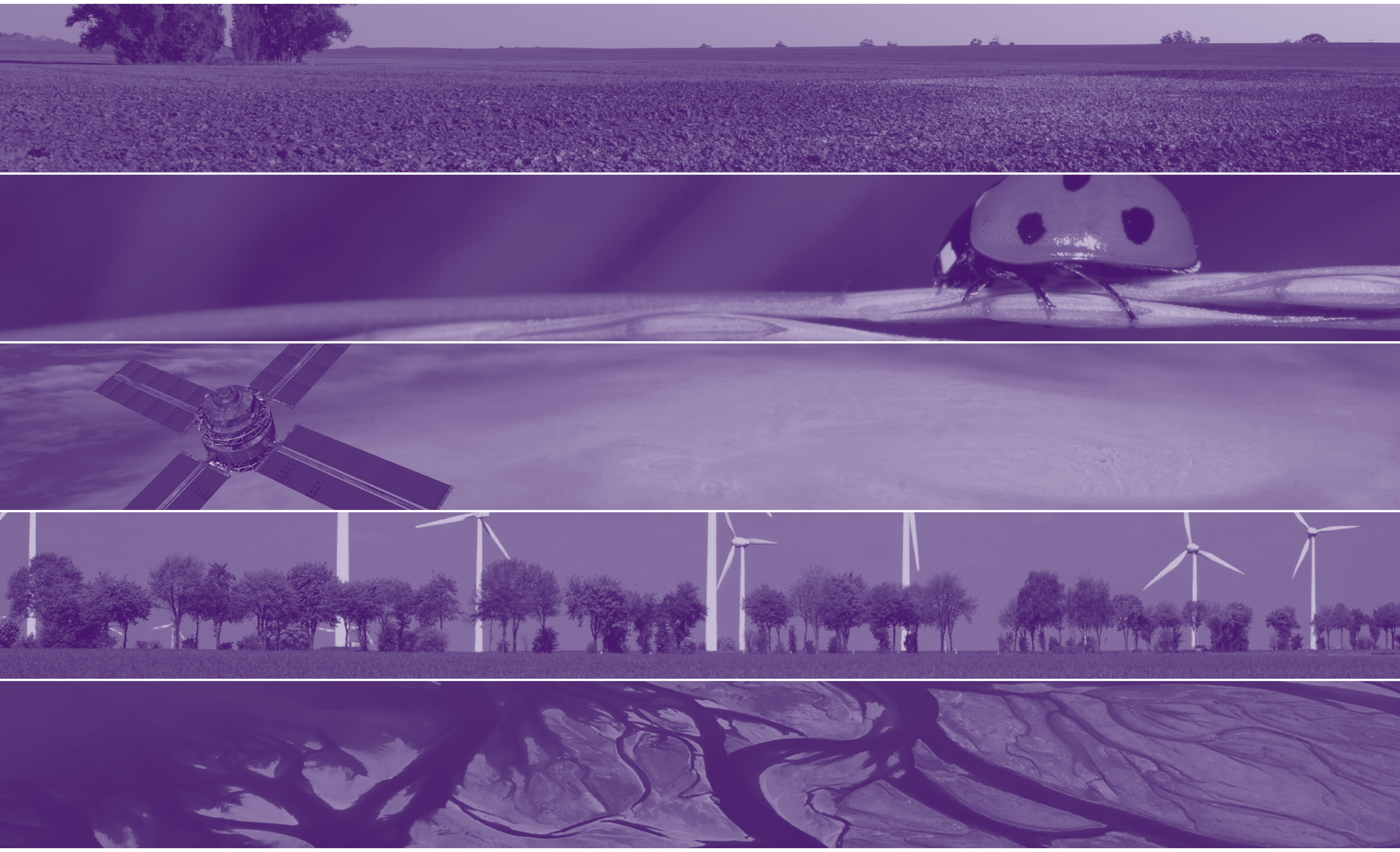
Beschrijving:
Groene lijn, strak geschoren of hoog en weelderig uitgroeiend, van struikvormende gewassen. Een heg onderscheidt zich van de hagen en houtsingels doordat ze hooguit een paar meter breed zijn en geen bomen bevatten.

De heg wordt gedigitaliseerd zoals vanaf de bovenkant is te zien. De minimale breedte van het vlak is 1 meter.

Sloten

Beschrijving:
Waterlopen gelegen in percelen, tussen percelen en/ of aan de rand van percelen.

De sloten hebben een breedte van minimaal 1 meter, gerekend van insteek tot insteek. Sloten breder dan 6 meter staan als vlak in de Top10NL.



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