The New Cap Gap

Modelling and delineation of Ecological Focus Areas

Dissertation

Ruud Oberndorff

Submitted in part fulfillment of the requirements for the degree of
Master of Science in Geographical Information Systems (UNIGIS)
Faculty of Economics and Business Administration
Vrije Universiteit Amsterdam
The Netherlands
July 2015

Abstract

The New Cap Gap

Modelling and delineation of Ecological Focus Areas

A new Common Agricultural Policy (CAP) of the European Union (EU) aims at greening by implementing Ecological Focus Areas (EFAs), consisting of, amongst others, landscape elements, land laying fallow and nitrogen fixing crops. EU demands an efficient control and monitoring of EFAs, which creates a gap between policy demands and geospatial data availability. This thesis aims at closing this gap by looking for re-use of geospatial data described in Information Models (IMs) or collecting new by using Remote Sensing (RS). Five IMs are explored: BGT/IMGeo, IMLB, IMNa , IMWa and TOP10.

This study poses two central questions: 1. do existing IMs provide relevant information regarding EFAs and 2. is the delineation of landscape elements that are not described in IMs possible using RS.

A Data Specification Cycle is used to assess the fitness for use of IMs. The cycle provides a structural framework and starts with the definition of a use-case that derives the requirements, followed by an as-is and gap analysis and the creation of a Data Specification. As a result trees and tree lines are identified as missing objects. A new IM (IMEfa) is created that serves as a semantical framework by providing definitions of objects that could be used in a RS workflow.

Object Based Image Analysis (OBIA) is used for the delineation of trees and tree lines using very high resolution aerial images and object height derived from stereo true-orthoimages. Results are compared with the use of the Tree Register, an existing dataset derived through laser altimetry. The Tree Register is used in its original form and an updated version. OBIA starts with a segmentation, for which a Segmentation Goodness Evaluation derives the parameters. A subsequent classification is applied to all three datasets and accuracy is assessed, based on thematic and boundary qualities of objects.

Results and subsequent discussion indicate a successful use of the Data Specification Cycle to derive information regarding EFAs from IMs. However, its success depends on the ability to define objects, the usability of an IM and a body of knowledge that helps in defining objects and understanding the content of IMs. This information is successfully used for the delineation of trees and tree lines using RS. However, this success depends on the thoroughness of the definition and the technical capabilities of the used RS techniques to approximate the defined objects. Results indicate that the corrected Tree Register was most accurate in the delineation of trees and tree lines.

Keywords: CAP, Segmentation Goodness Evaluation, GIS, Information Model, Fitness for use, Landscape elements, OBIA, Remote Sensing, Segmentation, Tree Register, EFA

Samenvatting

Het GLB gebrek

Modeleren en detecteren van Ecologische Aandachtsgebieden

Een nieuw Gemeenschappelijk Landbouwbeleid (GLB) van de Europese Unie (EU) streeft vergroening na door het creëren van Ecologische Aandachtsgebieden (EAs), zoals landschapselementen, vlinderbloemigen en braaklegging. De EU vereist een efficiënte controle en monitoring van EAs, wat een gat veroorzaakt tussen beschikbare en benodigde geodata.

Om dit gat te dichten is onderzoek uitgevoerd naar het hergebruik van geodata zoals beschreven in Informatiemodellen (IM) en het inwinnen van nieuwe door middel van Remote Sensing (RS). Vijf IMs zijn in dit onderzoek gebruikt: BGT/IMGeo, IMLB, IMNa , IMWa, TOP10. Twee vragen staan centraal in dit onderzoek: 1. bieden bestaande IMs relevante informatie met betrekking tot EAs en 2. is de inwinning van landschapselementen die niet beschikbaar zijn in IMs mogelijk door middel van RS.

Een Data Specificatie Cyclus is uitgevoerd voor het vaststellen van de geschiktheid van de vijf IMs voor het leveren van informatie over EAs. De cyclus begint met een use-case voor het vaststellen van de databehoefte. Een vergelijking met bestaande datavoorziening (m.n. IMs), maakt de ontbrekende geodata inzichtelijk. In deze studie zijn bomen en boomrijen als ontbrekend objecten aangewezen. Een nieuw IM (IMEfa) dient als een semantisch raamwerk, waarvan de definitie gebruikt kan worden voor de detectie van objecten in een RS toepassing.

Object Based Image Analysis (OBIA) is gebruikt voor het detecteren van bomen en boomrijen uit luchtfoto's van zeer hoge resolutie en object hoogte uit stereoscopie. Het resultaat van OBIA wordt vergeleken met het Bomenregister en een herziene versie hiervan. Het bomenregister is verkregen uit laseraltimetrie en geeft de locatie van bomen weer. OBIA begint met een segmentatie, waarvoor de parameters zijn vastgesteld met behulp van een evaluatie (Segmentation Goodness Evaluation). Een classificatie, die voor alle drie de datasets gelijk was, ging vooraf aan het bepalen van de nauwkeurigheid van de methode. Hierbij is de thematische en object nauwkeurigheid in de drie datasets bepaald.

Uit de resultaten en discussie volgt dat een Data Specificatie Cyclus succesvol gebruikt is voor het vergelijken van IMs en vaststellen van de informatie betreffende EAs. Dit succes is afhankelijk van de mogelijkheid om objecten eenduidig te definiëren en de kennis die nodig is voor interpreteren van de semantische informatie beschreven in IMs. Het is mogelijk om deze informatie te gebruiken voor het detecteren van bomen en boomrijen door middel van RS. De technische mogelijkheden van de gebruikte RS techniek bepalen in hoeverre de gedefinieerde objecten succesvol gedetecteerd en afgebakend kunnen worden. De studie wijst uit dat het gecorrigeerde Bomenregister het meest nauwkeurig was in de detectie van bomen en boomrijen.

Kernwoorden: GLB, Segmentation Goodness Evaluation, GIS, Informatiemodel, Fitness for use, Landschapselementen, OBIA, Remote Sensing, Segmentatie, Bomenregister, EA

Table of contents

List of Figures

List of Tables

List of abbreviations

A	AHN	Actueel Hoogtebestand Nederland, digital elevation dataset
B	BGT	Basisregistratie Grootschalige Topografie
	BRT	Basisregistratie Topografie
C	CAP	Common Agricultural Policy
D	DEM	Digital elevation Model
	DLG	Dienst Landelijk Gebied, government service for land and water management (until January 2015)
	DSM	Digital Surface Model
	DTM	Digital Terrain Model
E	EFA	Ecological Focus Area
	EU	European Union
	EZ	Ministry of Economic Affairs
G	Geonovum	Dutch standardization organization for geo-information
	GIS	Geographical Information System
	GML	Geography Markup Language
I	IM	Information Model (Conceptual Model)
	INSPIRE	Infrastructure for Spatial Information in the European Community
	ISO	International Organization for Standardization
L	LiDAR	Light Detection and Ranging
	LPIS	Land Parcel Identification System
M	MRS	Multi-resolution segmentation
N	NDVI	Normalized Difference Vegetation Index
	NEN	Nederlandse Norm
	NIR	Near-Infrared
	NVWA	Netherlands Food and Consumer Product Safety Authority, Nederlandse Voedsel- en Warenautoriteit
O	OBIA	Object Based Image Analysis
P	PSAN	Provinciale Subsidieregeling Agrarisch Natuurbeheer
R	RS	Remote Sensing
	RVO.nl	Paying Agency of EZ, Rijksdienst voor Ondernemend Nederland
S	SDI	Spatial Data Infrastructure
	SNL	Subsidie Natuur- en Landschapsbeheer
U	UML	Unified Modeling Language
V	VI	Vegetation Index
	VHR	Very High Resolution

Disclaimer

The results presented in this thesis are based on my own research at the Faculty of Economics and Business Administration of the Vrije Universiteit Amsterdam.

All assistance received from other individuals and organisations has been acknowledged and full reference is made to all published and unpublished sources.

This thesis has not been submitted previously for a degree at any institution.

Signed:

Eindhoven, The Netherlands, July 1, 2015

R.L.J. (Ruud) Oberndorff

Acknowledgements

Fortunately I was not completely on my own doing this thesis and I received the help from a lot of people. This is the place to express my gratitude to everyone who helped me throughout this thesis.

Foremost, I want to thank my supervisors for their advice, support and inspiration during this thesis. Rob van de Velde always knew to ask the right questions triggering me to think about my thesis, see the broader picture and keep me on track. Azarakhsh Rafiee for her enthusiasm and for the help regarding Remote Sensing. Also Eduardo Dias, who offered me valuable suggestions at the start of my research.

NEO BV for providing me with the necessary aerial images and other data that made this thesis possible. I want to thank the complete team for letting me do my occasionally work at their office in Amersfoort and I hope that I didn’t cause to much disturbance by “pushing” people away from their computers. A special thanks to Corné van der Sande for his valuable suggestions and advice.

Frans van Diepen, Jaap Kroon, Marc Middendorp, Dirk Vogt and Roelof van der Wal from RVO.nl for their help and advice in constructing the use-cases and developing an Information Model.

Paul Janssen and Hans van Eekelen from Geonovum for sharing their knowledge regarding Information Models and BGT/IMGeo. Informatiehuis Water for answering my emails and providing me the right details to understand the “Informatiemodel Water”.

Furthermore I would like to thank NVWA, my employer, for funding this Master study, for which I am very grateful.

Thank you Heike Gramberg for proofreading my thesis and providing me with the necessary corrections.

A special thanks goes to Stefan Bruehlmann with whom I started UNIGIS in September 2011. Our frequent email and Skype contact where a great support in continuing this study.

1 Introduction

1.1 Setting the scene

With changing policy also the demand for geospatial data changes. Not only for the verification of a correct implementation of regulations, but often also to monitor the environmental or societal effects of a policy change. A recent example is the new Common Agricultural Policy (CAP) of the European Union (EU) that is effectuated in January 2015. An important element of the new CAP is greening, which is partly met by so called Ecological Focus Areas (EFA) consisting of, amongst others, landscape elements, land laying fallow, areas with nitrogen fixing crops, catch crops and flower strips. Farmers should use at least 5% of their arable land for the arrangement of EFAs (EU, 2013b).

To enable effective and efficient control and monitoring of the new CAP, the EU urges member states to create an EFA-layer, showing potential EFAs, as part of a land parcel identification system (EU, 2013b). However, there is a gap between policy demands and the availability of geospatial data and what organizations can do to effectuate this. Many European member states are struggling to complete such a spatial database of EFAs, as illustrated by the following example. England, which selected hedgerows as a possible EFA, is placed for a serious effort to map hedgerows from aerial images, a laborious and costly process (Anon., 2014). English farmers are already warned for a delayed payment of subsidy because of the time needed to monitor farmers applications. To avoid this administrative burden and high costs in information collection regarding landscape elements, the Dutch government didn't select landscape elements in its implementation of the new CAP (EZ, 2014).

This raises the question whether it is really necessary to collect this information from scratch, while re-use could be a feasible alternative. With the rise of internet since the 90s and the exploration and exchange of geospatial data through Spatial Data Infrastructures (SDI), a wealth of information is available. Information which, due to standardization, is described in a consistent manner in an Information Model (IM). An IM is an abstractions of reality and defines objects, attributes, rules and relations that exist in the real world (Geonovum, 2013). IMs or conceptual models, are used for an effective collection, storage, use and exchange of spatial data.

Table 1.1 shows five IMs that describe the rural area, and are relevant as a possible repository for landscape elements and other EFAs.

Table 1.1: Information models that inform about landscape elements

Standard	Landscape elements
Basisregistratie Topografie (BRT/TOP10)	Green and blue landscape elements
Basisregistratie Grootschalige Topografie (BGT/IMGeo)	Green and blue landscape elements
IM Landbouw (IMLB)	Green and blue landscape elements
IM Natuur (IMNa)	Green and blue landscape elements
IM Water (IMWa)	Blue landscape elements

A method is needed that allows us to find matching datasets. This process obviously starts with determining the user requirements in terms of needed objects, attributes, temporal aspects and accuracy.

The level of agreement between these requirement and the descriptions of the provided IMs determine the "fitness for purpose" or "fitness for use" (Devillers & Jeansoulin, 2006). A list of requirements is also needed if re-use of geospatial data is not possible and collection is inevitable. Collection of landscape elements and other EFAs is possible using Remote Sensing (RS), a process that benefits from a description provided in an IM. This idea is illustrated in Figure 1.1.

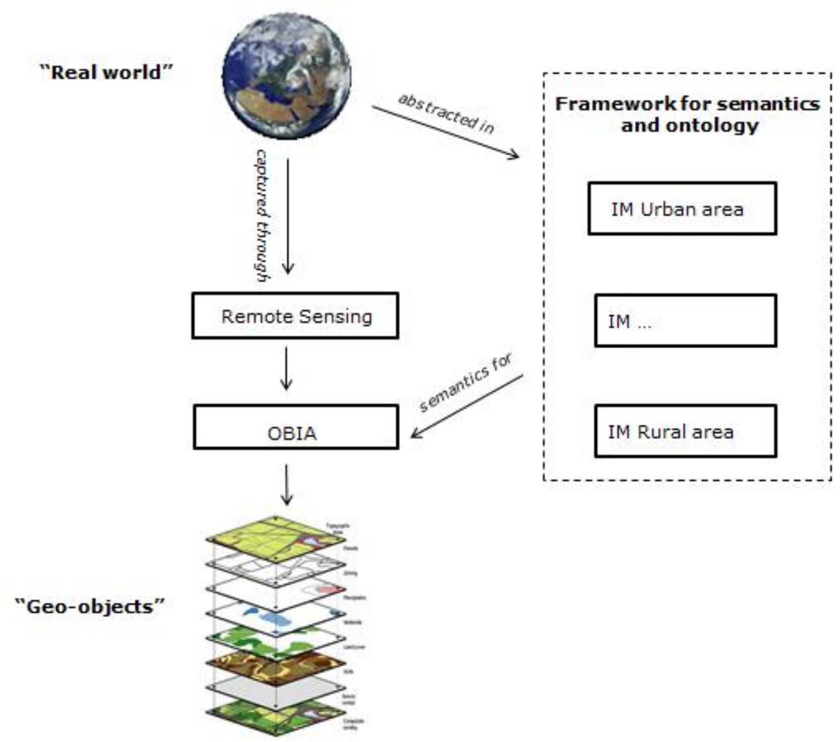


Figure 1.1: Deriving geo-objects by combining models of the world

Blaschke et al. (2014) argue that a descriptive assessment and knowledge is the basis for the translation of spectral characteristics of image objects into real-world features. This "wisdom of the user" or semantics supports the translation from image-objects into real-world objects. Several recent studies use Object Based Image Analysis[1] (OBIA) as a way to collect landscape elements from images, e.g. (Czerepowicz, et al., 2012), (Hellesen & Matikainen, 2013), (Meneguzzo, et al., 2013).

The Tree Register ("Boomregister") is a new and open dataset that claims to "knows every tree" as mentioned by the distributer on the accompanying internet site[2].

[1] Also known as Geographic OBIA (GEOBIA)
[2] www.boomregister.nl

This dataset is derived from laser altimetry, a form of active RS, and demarcates the tree crown boundary (Rip & Bulens, 2013). The use of such a dataset to derive landscape elements that comply to EFA descriptions is also something that needs to be explored which has not been done in recent studies.

1.2 Research aim and questions

The overall aim for this research is to explore what information is contained in IMs and how this can be used for the creation of an EFA-layer, with a special aim for landscape elements. RS is used to collect unavailable EFAs, using a combination of remotely sensed data, e.g. aerial images, and ancillary (GIS)data. Two main research questions with sub-questions are necessary to reach this aim:

1. ***Do existing information models provide the necessary information related to ecological focus areas mentioned in the new CAP?***
   a) How are EFAs currently modelled in information models relevant to the rural area, i.e. IMNa, IMLB, IMWa, BRT, BGT/IMGeo?
   b) What are the differences between EFAs mentioned in the new CAP and information models relevant to the rural area, i.e. IMNa, IMLB, IMWa, BRT, BGT/IMGeo?

2. ***Is it possible to use Remote Sensing to delineate green landscape elements that are not provided through information models?***
   a) Is a pixel-based Remote Sensing technique favorable over OBIA?
   b) What segmentation could be used in an OBIA workflow?
   c) How to delineate green landscape elements and measure accuracy?
   d) Is the delineation of green landscape elements mentioned in the new CAP but not available from information models more accurate by using OBIA or by the use of the Tree Register?

1.3 Research relevance

First, this thesis also contributes in gaining knowledge about EFAs and landscape elements that are part of the new CAP and how they are modelled in IMs used in The Netherlands. This understanding is needed for current registers in The Netherlands. But also the interaction between RS and IMs as an ontological and semantical source of information is relevant. This is one of the challenges indicated in a recent study by (Blaschke, et al., 2014).

Second, this thesis provides relevant information on the detection of landscape elements from aerial images and the use of the Tree Register, as an alternative open dataset for landscape elements. From this member states could learn how databases regarding EFAs and landscape elements could be developed. Such a database is necessary to meet EU regulations, but could also contribute to an European repository regarding the spatial distribution of landscape elements.

This provides a wealth of information for ecologists and biologist for deriving ecological parameters for their research. (Overmars, et al., 2014) indicate this need for information in a recent study.

Third, exploring how an open dataset as the Tree Register could be used for the delineation of landscape elements is also needed.

1.4 Thesis outline

After this introductory first chapter, this thesis continues with defining the theoretical framework in chapter 2. This chapter provides more in depth information regarding IMs and RS. In doing so it also provides a basis for the methods that are described in chapter 3. These methods are used in a two ways. Firstly in a Data Specification Cycle which consists of several stages, including a use-case, to reveal the data need for relevant landscape elements and contrast this with existing IMs. Secondly, in the use of OBIA to detect the relevant landscape elements in aerial pictures in contrast to the use of the Tree Register as a stand-alone open dataset. The results are presented, analyzed and discussed in the following section, chapter 4, ultimately leading to the conclusions and recommendations, provided in last section of this thesis, chapter 5.

Figure 1.2 shows the way this thesis is structured.

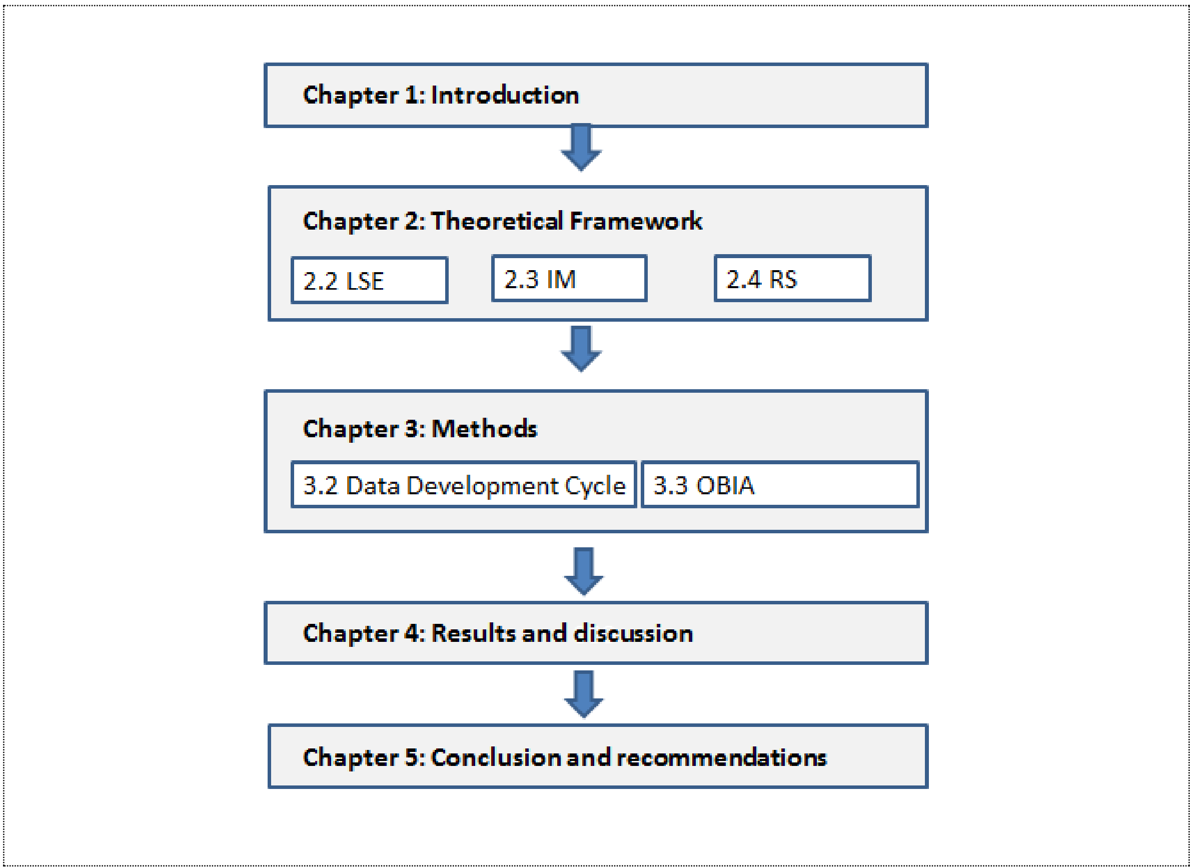


Figure 1.2: Chapter outline

2 Theoretical Framework

2.1 Introduction

This chapter provides an overview of the diverse functions of EFAs with a focus on landscape elements. Not only for policies like the new CAP, but also from an environmental and ecological point of view. It also gives a view how these elements look like in the real world, as this understanding is needed for an appreciation of the modelling options. This improves the understanding and use of RS, which is explored in the last section. The chapter ends by giving an overview of the policy gaps.

2.2 Real world, landscape elements

Antrop (2006) argues that a landscape is a dynamic and complex system. It is not only characterized by the spatial arrangement of patches and elements, but also by their interrelationships, and by natural and human processes that influence their constitution. Part of its complexity is also the subjective nature of appreciation and evaluation of a landscape, which depends on the viewer and the scale in which the phenomena are considered (Antrop, 2006). This indicates that landscapes are spatial in nature, are studied at a different scales, change over time and that appreciation of a landscape is personal and subjective.

Agriculture is a dominant user of land in the Netherlands, more than half of the total land area is used for agriculture (CBS, et al., 2013), which makes the agricultural landscape an important part of the Dutch landscape. The agricultural landscape is not only typified by fields for agricultural production, but also by features that are not used primarily for this goal. These features exist as a result from the effort of farmers to adapt the landscape to the constraints of agricultural production. As such, landscape elements are artefacts of rural cultures and therefore sometimes also referred to as "landscape ghosts", since trees live twice as long as the average farm business (Baudry, et al., 2000). Landscape features consist of linear landscape elements, like field margins, road verges, banks, hedgerows and wooded banks, and patch elements, such as woodlots and ponds (Grashof-Bokdam & Van Langevelde, 2004).

Changes in farm management and an increase in productivity and mechanization, partly driven by CAP, resulted in a decline of landscape elements in the past decades (Apeldoorn Van , et al., 2013), (Coeur Le, et al., 2002), (Overmars, et al., 2014), (Pe'er, et al., 2014), (Stoate, et al., 2009). Nevertheless, a change of mind refocused the attention to the positive effects that landscape elements have. Some functions of landscape elements[3] are shown in Table 2.1.

The regained interest resulted in a multifunctional view of the rural area, where not only food production is important, but recreation, cultural heritage and preservation of environment are important facets of the rural landscape as well (Stoate, et al., 2009). The "Communication on Green Infrastructure" (EU, 2013d) is an example of this change of mind.

[3] (Marshall & Moonen, 2002) use the term field margins, defined as: whole of the crop edge, any margin strip present and the semi-natural habitat associated with the boundary. Although landscape elements are not always at the boundary of a field, they are field margins.

Green infrastructure is a strategically planned network of natural and semi-natural areas designed to deliver the natural benefits as provided by ecosystems.

Table 2.1: Functions of field margins (Marshall & Moonen, 2003)

Function	**Role**
Agronomy	Land ownership, stock fencing, shelter, windbreak, weed and pest control, game and wood
Environment	Pollution control, eutrophication, pesticides, erosion, snow and water flow, and siltation
Nature Conservation	Species refugia, biodiversity, habitat, feeding, breeding, corridor and movement
Recreation and rural development	Access, walking, driving, hunting, tourism, aesthetics, culture and heritage

These benefits, referred to as ecosystem-services, mitigate climate change effects, improve biodiversity and provide social benefits, to name some important factors. Ideas expressed in the communication also lead to changes in the CAP, as will be further explored later in this section.

Enhanced carbon-sequestration is another important rediscovered feature of landscape elements. FAOs "Climate Smart Agriculture" integrates landscape in a holistic way and not only looks at the role of agriculture for food security, but also the chances in mitigating the effects of climate change (FAO, 2013).

Policies that encompass these new views explicitly look at landscape elements as an important thrust in enabling these effects. Important in this regard are landscape ecology and biodiversity, the new CAP, and Agri-Environmental Measures (AEM), as is further explored in the next sections.

2.2.1 Landscape ecology and biodiversity

Landscape elements are important habitats for species, flora and fauna, and in this way preserve biodiversity in the rural area (Grashof-Bokdam & Van Langevelde, 2004), (Marshall & Moonen, 2002). (Coeur Le, et al., 2002) found that this not only depends landscape elements solely, but also to the diversity of farmers, their farming systems, and land uses. Marshall and Moonen (2003) refer to field margins as a field edge ecotone, indicating a transition zone of ecological change between two different habitats (i.e. field and element). Positive effects of landscape elements on biodiversity are a combined effect of landscape elements, the formulation of networks by interconnecting linear and patch elements, but also of the agricultural fields they border. These combined effects are subject of landscape ecology, defined as a science that studies the structure, function, and dynamics of landscapes to improve the relationship between ecological processes and spatial pattern (Wu, 2013). Maps and imagery always played an important role in landscape ecology (Antrop, 2006) and also the scale of study is an important factor in landscape ecology studies (Wu, 2013).

(Overmars, et al., 2014) made an European assessment of biodiversity, but excluded landscape elements, because of the large scale data (resolution of 1 km grid).

However, on a local or regional scale more detailed data is needed and landscape elements are important factors to derive landscape metrics. A landscape element map could be a useful driver for these studies, and obviate laborious manual collection of data. One of the new aims of CAP aims is to enhance biodiversity, as indicated in the next section.

2.2.2 The new common Agricultural Policy

Agricultural policy, i.e. CAP, is one of the cornerstones of the EU. CAP changed gradually from a price and production driven policy into a land-based approach focusing on food safety, environmental improvement and rural development (EU, 2014c). A new CAP, for which the European Commission approved the basic regulations in December 2013, is effectuated on January 2015 and couples direct payment of subsidy to three greening options (EU, 2013b):

- Crop diversification: farmers need to grow at least 2 or 3 different crops, depending on farm size and crops that already grow on a farm.
- Maintenance of permanent grassland in Natura-2000 areas[4] and optional outside these areas.
- Attributing 5% of arable land for Ecological Focus Areas (EFA) and possible 7% after an evaluation in 2017. One or more of the following are EFAs:
    - Land lying fallow;
    - Terraces;
    - Landscape elements;
    - Buffer strips;
    - Agro-forestry;
    - Strips of eligible hectares along forest edges;
    - Areas with short rotation crops with no use of mineral fertilizer and plant protection products;
    - Afforested areas;
    - Areas with catch crops or green cover;
    - Areas with nitrogen fixing crops.

Since landscape elements are of specific interest in this thesis, the remainder of this section focusses on the role these elements have in the new CAP. To take account of the characteristics of certain types of EFAs and to simplify administration, EU member states are allowed to use conversion and weighting factors. These are shown in Table 2.2 for landscape elements, which demonstrates that, for instance, a wooded bank that is 25 meters in length accounts for 250 m^2 EFA area. To compare, areas with catch crops have a weighting factor of 0.3 meaning that a farmer needs 3 $^1/_3$ ha to attribute 1 ha of EFA.

[4] Natura-2000 is a network of protected areas on land and sea that are part of the EU's Habitat and Bird directives. Their aim is preservation of biodiversity. Circa 160 land based regions with a total area of approximately 360,000 ha belong to Nature-2000 in the Netherlands (www.natura2000.nl)

Table 2.2: Landscape elements conversion and weighting factors (EU, 2014b)

Element		Unit	Conversion factor (unit to m^2)	Weighting factor	EFA area (per unit)
Hedges		Per m	5	2	10 m^2
Wooded bank		Per m	5	2	10 m^2
Trees	Isolated	Per tree	20	1,5	30 m^2
	Line	Per m	5	2	10 m^2
	Group	Per m^2	1	1,5	1,5 m^2
Field margin		Per m	6	1,5	9 m^2
Ponds		Per m^2	1	1,5	1,5 m^2
Watercourse		Per m	3	2	6 m^2
Traditional stone walls		Per m	1	1	1 m^2

There are some requirements that EFAs should comply to (EU, 2013b): EFAs should be situated directly on or at the border of arable land and the use of fertilizers or other chemicals is not allowed. It is also possible to implement EFAs in a collective of up to 10 farmers. EFA measures are based on an annual non-contractual basis. Small farmers and organic farmers are exempted from EFA measures. The Netherlands offers the possibility to exchange landscape elements from agri-environmental measures in the second pillar, described in section 2.2.3, to EFA. Further specific requirements regarding the dimension of landscape element are shown in Table 2.3.

Table 2.3: EFA landscape element dimensions (EU, 2014b)

Element		Measure	Additional requirement
Hedges		≤ 10 m width	
Wooded bank		≤ 10 m width	
Trees	Isolated	≥ 4 m crown diameter[1]	
	Line	≥ 4 m crown diameter[1]	Space between crowns ≤ 5m
	Group	≤ 0.3 ha	Connected by overlapping crown cover
Field margin		≥ 1 and ≤ 20 m width	No agricultural production
Pond		≤ 0.1 ha	Plastic or concrete reservoir not allowed
Watercourse		≤ 6 m width	Concrete walls are not allowed
Traditional stone walls		n.a.	

[1] Crown diameter below 4 m is possible if trees are recognized as valuable landscape features by member states

EU (EU, 2013a) urges member states to include EFAs into a Land Parcel Identification System (LPIS) to enable an effective and efficient control and monitoring of the new CAP. The minimum scale requirement of a LPIS is 1:10,000 changing to 1:5,000 from 2016.

Although the EU doesn't give instructions about the exact implementation of a monitoring routine, a possibility is that farmers map the landscape elements of interest in a Web-GIS application, after which eligibility is checked by the authorities based on aerial images and on-the-spot checks.

England selected hedges as EFA and, as indicated in recent publications (Anon., 2014), there is a fear for the need of extra personnel, additional costs and delayed payments. Especially the need for detailed positional information, and exact measure of width and area is a cause for concern. This is the reason for the Netherlands not to include landscape elements in their EFA implementation. The selected options are shown in Table 2.4. (EZ, 2014), but are subject to change.

Table 2.4: Netherlands EFA implementation (EZ, 2014)

Ecological Focus Area areas are:
Any of the following generic measures:
- Field margin[1]
- Nitrogen fixing crop
- Catch crop
- Coppice wood[2]
Or the following equivalent measures:
➔ 30% of EFA area as:
- Field margin[1], and
➔ Remaining 70% any of the following:
- Watercourse adjacent to wildflower field margin
- Nitrogen fixing crop
- Catch crops
- Landscape elements[3]

[1] Seed mixture of field margin to be determined later
[2] Dutch: wilgenhakhout/griendje
[3] Only landscape elements that are part of Agri-Environmental measures (section 2.2.3)

A recent study by (Pe'er, et al., 2014) criticizes the new CAP and their contribution to greening measures. They ask for an evidence based assessment of the new CAP impact through national monitoring and monitoring biodiversity outcomes. To enable such an evaluation geospatial data is needed.

2.2.3 Agri-environment measures

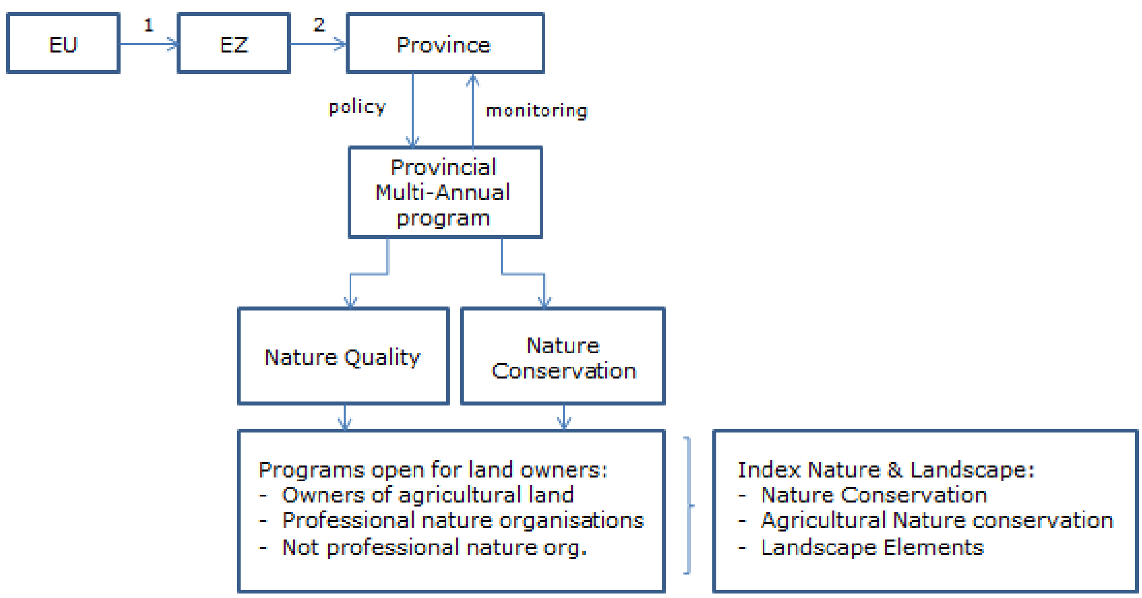
Previous section explored the so called first pillar of the new CAP, especially the greening measures, which consists of a system of direct subsidy payments to farmers. There is also a second pillar, which includes EU rural development policy. An important part of this policy are Agri-environment measures (AEM), offering subsidy to land owners who subscribe to environmental commitments on a voluntary basis for a period of at least five years (EU, 2014d).

In the Netherlands these measures are regulated by the provinces to ensure an integrated and region specific approach in "Subsidiestelsel Natuur- en landschap" (SNL), a rural development policy granting subsidy for nature and landscape.

Figure 2.1 gives a simplified overview of the provincial nature conservation system, showing that EU policies are incorporated into national policies, and subsequently used to determine provincial nature conservation policy. A provincial multi-annual program consists of two corner-stones. The first regulates qualitative aspects of nature conservation, for example by acquiring new areas or change nature in existing areas to a new desired situation. The second regulates the conservation of areas for which SNL funding is used. SNL is divided into three classes:

1. Nature,
2. Landscape elements,
3. Agricultural nature.

These classes are further described in the Index Nature and Landscape[5], which is central to the system and are used to monitor the aforementioned qualitative and quantitative aims, as well as funding.



1: implementation of European Policies into National Policy, e.g. CAP (EAM), Natura-2000

2: implementation of National Policies into Provincial Policy, e.g. Ecological Network (EHS), Vital Countryside

Figure 2.1: Provincial Nature policies (SNL, 2009)

As mentioned, SNL includes landscape elements and the new CAP offers the possibility to use these elements as 'greening equivalent measures' (EZ, 2014), because farmers already adhere to environmental beneficiary practices by implementing strict SNL regulations.

[5] A description of landscape elements according this index is available, in Dutch, from: http://www.portaalnatuurenlandschap.nl/themas/overzicht-typen-natuur-en-landschap/

Double funding, where the same landscape element is funded in SNL subsidy system and as EFA, is an unwanted situation and prohibited.

SNL ends in 2016 and continues as a new program "Agrarisch Natuur- en Landschaps-beheer" (ANLb), Agricultural Nature- and Landscape Conservation. New in this program is an intensified collective approach for nature and landscape policies in which farmers are encouraged to take charge in regional greening as collectives, which is in line with the new CAP regulations.

2.2.4 Policy gap

The previous sections concentrated on the positive effects that landscape elements have on, for instance biodiversity and climate change. This lead to new policies in which landscape elements play an important role. The greening aspirations of a new CAP are implemented through crop diversification, permanent grassland and EFAs (of which landscape elements is a category).

EFAs asks for geospatial data to enable efficient control and monitoring. Each European member state needs to map their potential EFAs, and this geospatial data that is not readily available yet. A gap that needs to be attributed by each member state. This data also helps in evaluating the measures taken by the new CAP.

Another gap is indicated by the need for geospatial data on a local level to monitor the positive effects of landscape elements on biodiversity.

2.3 Modelling the real world, information models

Geographic standards structure and describe geographic data in a standardized manner. This section explores how this is done and explores whether the objects of interest (i.e. landscape elements shown in Table 2.2) are modelled in Dutch geographic standards.

This section starts with a general overview of the nature of geographic data, followed by an explanation of standardization of geographic data. It also offers a more detailed look at specific geographic standards that model the rural area in general and the objects identified in the previous section specifically. This section concludes by indicating modeling gaps.

2.3.1 What is geographic data?

Geographical reality is usually looked at in two ways: as discrete objects or continuous fields (Fonseca, et al., 2003) (Longley, et al., 2011). The former objects have clear boundaries that occupy space and link description to location at a specific time. The latter represent a finite number of values at a specific location. (Hendriks & Ottens, 1997) use five aspects that describe geographic data[6] and also reflect on its special character:

[6] Geographic data is also often referred to as geographic information, geo-information, (geo)spatial data, although strictly taken they mean different things.

- objects or phenomena,
- are at a specific location,
- and have a specific spatial size and form,
- at a certain distance from other objects or phenomena,
- and at a specific time or period.

A process of abstraction is needed before geographic data could be represented in a digital environment. This process specifies the aforementioned five aspects of geographic data and asks questions as: What geographic data should be represented? Who uses this data? At what level of detail? A conceptual framework serves as a guideline in this process of abstraction, whose stages are shown in Figure 2.2.

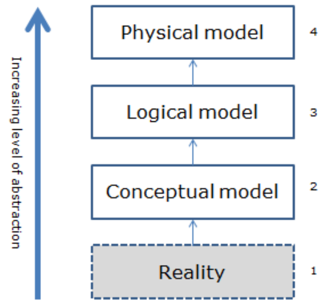


Figure 2.2: Conceptual framework for data modelling (Longley, et al., 2011)

The stages shown in Figure 2.2 comprise (Longley, et al., 2011):

1. **Reality**
   The view of the world depending on the users of a data model, a specific domain, or the purpose of GIS use (e.g. finding answers on the spatial problems related to a specific environmental issue) and is also referred to as universe of discourse.
2. **Conceptual model**
   Defines the spatial objects, their attributes, and spatial relations that are relevant to a particular problem domain.
3. **Logical model**
   Representing a common view of the conceptual model in the form of a schema.
4. **Physical model;**
   Actual implementation of the logical model in a database or GIS.

The abstraction process could deliver different models of the same geographic reality, depending on (Tóth, et al., 2013):

- View: depending on context and point of view, a geographic region could be depicted in different ways,
- Scale: the level of detail that is required, ranging from the level of a building to the level of the planet,
- Time: spatial data changes over time.

(Fonseca, et al., 2003) argues that the conceptual framework shown in Figure 2.2 is typically used in database modelling, which is an approach that uses a specific development paradigm (e.g. object-oriented, or entity-relational) that focusses on the representation of the real world in a digital environment and, as such, concentrates on the development of an information system rather than modelling the special characteristics of geographic data.

(Fonseca, et al., 2003) state the need for a geographic ontology that describes entities, classes and properties that relate to a certain view of the world. It looks at the need for spatial entities and their semantics among user communities.
This is getting more important since data is no longer contained solely in organizational silos, but multiple users and automated systems access, exchange and combine geographic data through the use of internet, SDI and internet services (Kuhn, 2005).

Standards are needed to integrate common views on abstraction, representation and exchange of geographic data. The next section further explains and explores standardization.

2.3.2 Finding a common ground: standardization

An IM[7] describes how geographic data is abstracted and gives a definition of objects, attributes and rules that represent a specific view and as such aims at providing semantics and enhancing interoperability (Geonovum, 2014). Semantics, or the meaning of expressions in language, is implemented in GIS by focusing on the relation between the object and the words or symbols used to represent it (Kuhn, 2005). Interoperability creates the possibility to combine geospatial data and interact with services, without repetitive manual intervention and with a coherent result (Tóth, et al., 2013). Several standards exist and can be grouped in (Geonovum, 2014):

1. Standards for the transfer of information:
   IMs that represent an abstraction of reality and describe the relevant objects, attributes, and their relations as well as the semantics.
2. Standards for the exchange of data:
   Examples are the already mentioned internet services[8], but also Geography Markup Language (GML) and standards that allow the data to be represented in the right coordinate system and projection.
3. Standards for describing metadata.
   Metadata gives information about the information, such as the intended use of the data, representation scale, production date, producer.

2.3.3 NEN-3610

Model NEN-3610 doesn’t contain spatial data itself, but gives rules and guidelines for the modelling, exchange and presentation of spatial data, and is as such a meta-model aiming at enhanced geospatial interoperability (Nederlands Normalisatie Instituut, 2011). The pyramid in Figure 2.3 shows how standardization is organized in The Netherlands.

[7] Conceptual model is also used to refer to an information model. The latter term is used throughout this thesis.
[8] Some examples are WMS (Web Map Service) or WFS (Web Feature Service)

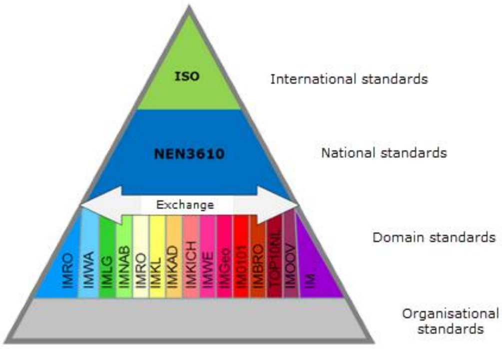


Figure 2.3: Model of geospatial standardization in the Netherlands

Shown in the center of Figure 2.3 is NEN-3610, acting as a bridge between international geospatial standards, like INSPIRE and ISO[9], and Netherlands domain models. The domain models share a common group of stakeholders and model geospatial data that is used within a specific domain, like planning, nature conservation, hydrography and agriculture, based on NEN-3610 concepts. The next sections describe the relevant domain models for landscape elements. NEN-3610 is divided in six different parts, each describing different modelling strategies. Table 2.5 gives an overview of these parts and their meaning.

Table 2.5: NEN-3610 modelling strategies

Model	Description
Basic types	Rules on the modelling of geographic objects, their attributes and constraints, temporal characteristics and versioning
Semantic models	Rules for topographic and thematic meaning of 12 classes of geo-objects: terrain, road, artificial construction, division, 4 area types, water, railway, conduit, building
Aggregate objects	Rules on how geo-objects should be aggregated from other objects
Visualization model	Rules for the portrayal of geo-objects
Network model	Rules on how geometrical and topological relations within networks are modelled
Sensor model	Rules on modelling sensors as geo-objects or include measurements as attributes

NEN-3610 is object-based and models geospatial data as geographic objects, which are an abstraction of real world objects. As such it adheres to the discrete-objects view of geography, that is described in section 2.3.1.

A geographical object has a direct or indirect spatial reference, characteristics (or attributes) and a unique identification. NEN-3610, and all the models based on it, are schematically represented in UML (Unified Modeling Language).

UML gives a schematic overview of the modelling rules by representing geographic objects, their relations and semantic meaning. In other words, an UML model is a formal representation of a conceptual model.

[9] INSPIRE, Infrastructure for Spatial Information in the European Community, is an European directive for an European data infrastructure and ISO is an international organization for standardization

The abstract class "GeoObject" is the basic type for NEN-3610 and other classes inherit their characteristics from it. These characteristics are, for instance, the allowed attributes for an object (for instance identification, dimension, begin- and end date) and are described in the semantic model and domain models.

At a national level geospatial data is collected as part of a basic register of geospatial data. Governmental organizations collect and re-use data (geographic and non-geographic) using a basic register (e-overheid, 2014). The basic registries provide a basis for an e-government service and the data management that goes with it. The system consists of 12 registers containing data related to people, companies, addresses and buildings among others. NEN-3610 provides rules to enable the re-use of objects from these basic registers into sector specific models.

2.3.4 BGT/IMGeo

BGT/IMGeo is part of the basic register and Information Model Geography (IMGeo) describes the standard for an object-oriented topographic map of the Netherlands (Van den Brink, et al., 2013a) (Van den Brink, et al., 2013b). The map is intended for use at large scales, ranging from 1:500 to 1:5,000. The temporal quality of BGT objects ranges from 6 to 18 months. This topographic map is still under development and available as open data from January 2016. BGT is created and maintained by stakeholders. Table 2.6 gives an overview of these stakeholders and the spatial objects they provide.

Table 2.6: BGT Stakeholders (BGT, 2014b)

Organization	Scale	Provides data related to
Waterboards	Regional	Surface water, water management, terrain and roads if managed by waterboards
Municipalities	Local	Objects under responsibility of municipality
Provinces	Regional	Roads, railway, water management, and surface water if managed by Provinces
Prorail (railway infrastructure)	National	Main railways
Ministry of Economic affairs	National	Agricultural parcels
Ministry of Defence	National	Objects situated on military terrain
Ministry of Infrastructure	National	Roads, water management, and surface water if managed by Ministry

IMGeo consists of a mandatory core, BGT (Basisregistratie Grootschalige Topografie), and a facultative part, 'plus'- topography. The latter provides additional objects or additional attribute types for a more detailed description of BGT objects. Figure 2.4 shows that the objects in BGT/IMGeo not only consist of 'real' physical objects, but also legislative areas.

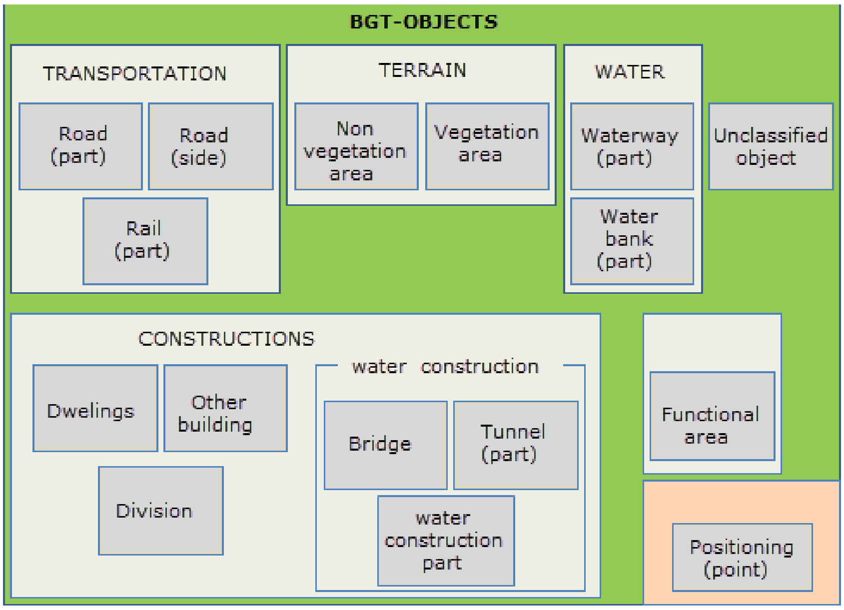


Figure 2.4: Classes in BGT/IMGeo model

Important BGT-objects for deriving information regarding landscape elements relate to terrain and water. The object types, attributes and related domains that can be used to derive further information are:

- Vegetation area ('BegroeidTerreindeel'): smallest functional area covered with vegetation
    - Attribute: physical appearance ('Fysiekvoorkomen') relates to classification of vegetation type.
    - Domain: agricultural parcel, forest (deciduous, coniferous, mixed), wooded bank, hedges.
    - 'plus' - topography: deciduous forest has a sub domain coppice ('Griend en hakhout').
    - Model gives no information on dimensions and delineation of objects.
    - Geometry type: surface.
- Water part ('Waterdeel'): smallest functional area water
    - Attribute: water type ('TypeWater'): specifies the type of water. Available are the types water course ('waterloop'), ditch ('greppel/droge sloot'), water area ('watervlakte'), sea ('zee').
    - Domain: Watercourse ('greppel/droge sloot', containing permanent or periodically water), water area.
    - 'plus' topography is available for the water type water course, and is further specified in the sub domains: River ('Rivier'), Channel ('Kanaal'), Stream ('Beek'), Ditch ('Sloot'), Canal ('Gracht').
    - Model gives sparse information on how to delineate objects.
    - Geometry type: object.

- Water bank ('OndersteunendWaterdeel'): area as part of a water management system and periodically covered completely or partially by water.
    - Attribute: water type ('TypeOndersteunendWaterdeel'): specifies the type of water part and consist of: 'oever', 'slootkant' or 'slik'.
    - Domain: riparian zone (side of a watercourse)

Solitary Vegetation object ('VegetatieObject') is a distinct object which is only available as additional 'plus'-topography and includes vegetation, like solitary trees or hedges, with a limited area. This object is represented as a point, line or polygon. However, these objects are additional and probably only available in urban areas.

2.3.5 BRT/TOP10

BRT (Basic Registry Topography) is also part of the system of basic registers (Kadaster, 2013) and contains a set of topographic maps at different scale levels, of which TOP10NL is the most detailed. This map is intended for use at scales ranging from 1:10,000 to 1:25,000.

There are some differences between the BGT, described in the previous section, and TOP10NL. Firstly, objects in TOP10NL are collected from aerial images, whereas IMGeo/BGT is based on terrestrial surveying. This makes BRT less accurate which explains the coarser scale. Secondly, the Dutch Cadaster is responsible for the production of the BRT map set. Thirdly, the temporal accuracy of TOP10NL is 24 months. Fourthly, the semantics of objects is different. TOP10NL consists of the following object classes:

- Road part: smallest functional road part.
- Railway part: smallest functional railway part.
- Water part: smallest functional water part.
- Building: detached space with a direct or indirect link to the ground. Covered and surrounded completely or partially by walls.
- Terrain: visible confined area that doesn't belong to other classes.
- Functional element ('Inrichtingselement'): small elements that arrange other classes. For instance, park bench, lamppost, traffic light, tree.
- Relief: representation of height.
- Area:
    - Administrative. Area with an administrative unity, like: municipality, provinces.
    - Geographical. Area with a geographical unity, like: names of regions, neighborhood.
    - Functional. Area with a functional unity, like: industrial park, recreation park.

Table 2.7 shows the objects relevant for landscape elements.

Table 2.7: object classes TOP10NL and modelling criteria

Class	Attribute	Criteria	Dutch name
Water part	Watercourse	> 0,5 m - < 6 m (line), > 6 m (area)	Waterloop
	Watercourse (dry)	> 0,5 m (line)	Greppel, droge sloot
	Watercourse (water)	> 0,5 m (line)	Natte sloot
	Pond	> 50 m^2 (area)	Meer, vijver, plas, ven
Terrain	Wooded area	> 50 m length and > 3 m width or > 50 m^2 (area)	Bos, houtwal, houtrand, griend
		> 1,000 m^2 (area)	
	Poplar area	> 1,000 m^2 (area)	Populieren
	Parcel	> 1,000 m^2 (area)	Perceel
Functional element	Tree (single)	Small group of trees represented as point	Boom
	Tree (line)	> 100 m (line)	Bomenrij
	Hedge	Hedge as parcel boundary > 100 m length (line)	Heg, haag

Table 2.7 shows that blue landscape elements (especially waterways) are represented in a possible meaningful way, because attributes are used for a further specification of these objects. This gives more information about object dimensions than BGT (section 2.3.4) For instance, watercourses have an attribute indicating the width of a watercourse (0.5-3, 3-6 and >6 meter) or a minimum width in meters.

Green landscape elements consisting of woody or shrubby vegetation are not that well represented in the model TOP10NL, because they are only available at a rather large thresholds.

Figure 2.5 illustrates the difference between TOP10 and BGT/IMGEO[10] explored in the previous section 2.3.4.

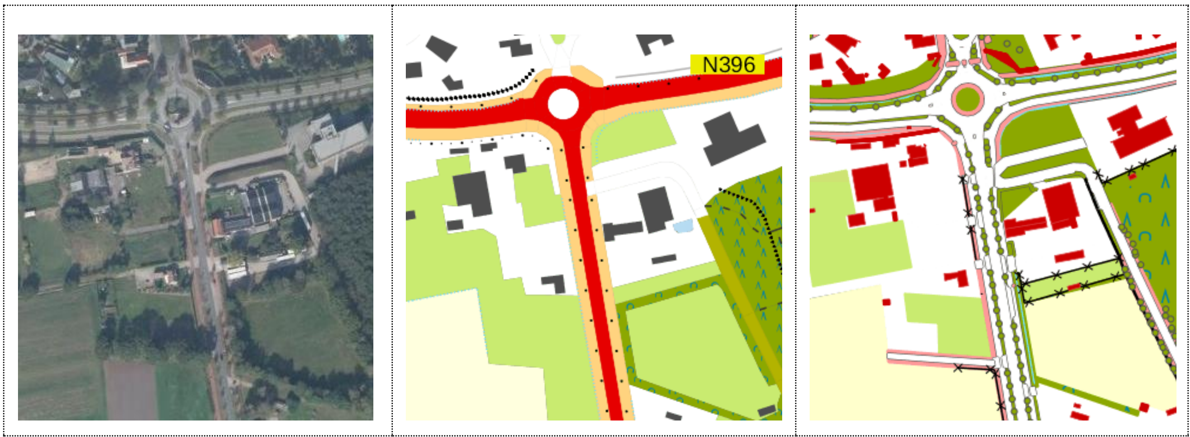


Figure 2.5: Aerial image, TOP10NL and BGT. Area Kluizerdijk, Valkenswaard

Figure 2.5 immediately shows the difference in level of detail between TOP10 (middle) and BGT (right).

[10] Source: http://pdokviewer.pdok.nl/

Also striking is the difference in displaying the vegetation areas and displaying tree lines as points and as vegetation area. From studying the aerial image it is clear that not all green areas or trees are visible in TOP10 and BGT.

2.3.6 IMWa

The current Information Model Water (IMWa) originates from 2010 and focusses on the exchange of geographic data relevant for organizations involved in water management (IHW, 2013a). This concerns the following Dutch organizations: Provinces, Rijkswaterstaat[11] and Waterboards. However, a more detailed model is required for specific European directives, i.e. Water Framework Directive. To encompass these needs, IMWa is further described in a sector specific model, Uitwisselmodel Aquo (UM Aquo, a model for the exchange of water related data), which consists of four parts (IHW, 2013b):

1. Water Framework Directive
2. Sensors related to water
3. Standard database for pollutants
4. Dutch water directive

Important for landscape elements are watercourses and their banks. The UML-model in Figure 2.6 depicts how this is done for landscape elements in IMWa.

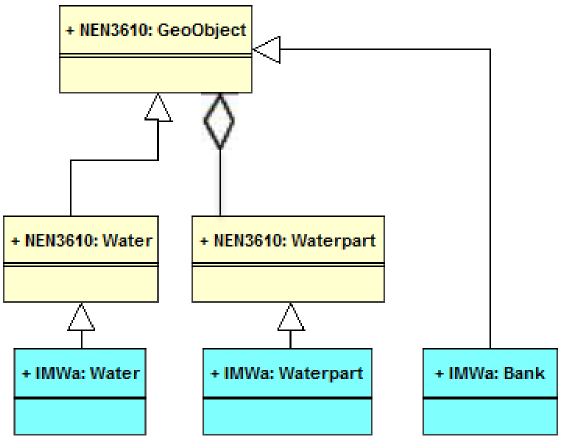


Figure 2.6: Watercourses as landscape elements in IMWa

The object 'water' is used for larger surface water like rivers. The object 'water part' is the smallest functional part of water. This object is important for the new CAP because it models watercourses and pools. The type of water is indicated by the attribute 'surface water quantitative' (Oppervlaktewater kwantitatief). A code list provides fixed values that can be used to indicate the type of water. Some important values are: ditch, watercourse, pool. An attribute 'OmvangWaarde' of object 'water part' provides information regarding watercourse width.

[11] Part of Ministry of Infrastructure and Environment, responsible for design, construction, management and maintenance of roads, waterway network and water systems (http://www.rijkswaterstaat.nl/en/about_us/)

A new version of IMWa, which is only available as a pre-concept, incorporates modelling concepts of BGT/IMGeo (Bakker, 2014).

2.3.7 IMNa

'Digitale Keten Natuur' (DKN)[12], is a collaboration between organizations involved in nature management in the Netherlands and focusses on the exchange of digital data to support daily processes and policy making.

IMNa 2.0 describes the spatial data used in DKN by modelling their objects, their attributes and constraints, and describes how information is exchanged (IMNa, 2012). The organizations involved include nature conservation organizations, policy makers, provinces and national government (RVO.nl, NVWA and DLG, all part of Ministry of Economic Affairs). The model integrates four concepts:

- Policy information. Integrates (inter)national policies that relate to nature management and conservation with this information for the determination of its area in the Netherlands. Policies include the Dutch implementation of European Habitat- and Bird-directive. This part also includes information about areas with existing policies and virtual areas where a policy could be feasible.
- Current regimes. Translates the policy information into areas that are (or will be) acquired or are currently under conservation.
- Contracts. Information regarding the contracts that underlie the current areas under development.
- Monitoring and evaluation of above concepts, which outcomes are used to adjust policy and related areas.

These concepts are modelled to create several maps that depict information related to one of the concepts. The UML-model in Figure 2.7 depicts the basis of IMNa and gives an overview of how above concepts are integrated into IMNa.

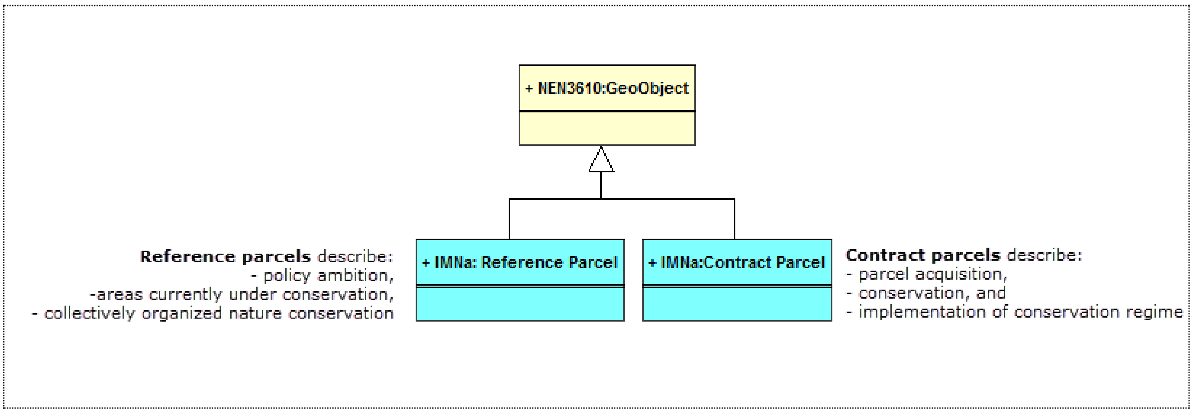


Figure 2.7: IMNa basics

The classes "Reference parcel" and "Contract parcel" are "borrowed" from IMLB, which is described in the next section. Objects from IMNa are instances of these super-classes.

[12] http://www.portaalnatuurenlandschap.nl/themas/digitale-keten-natuur/overzicht-digitale-keten-natuur/

Information regarding landscape elements are modelled as reference parcels and describe information according to SNL (section 2.2.3).
Temporal aspects are very important to IMNa, because it describes several layers of information. It provides current parcels, as well as their history. It also describes future interests, because contracts have a specific end date and it describes ambition of nature to future prospects.

IMNa looks interesting for the provision of information related to the so called 'equivalent practices' (section 2.2.2) that includes landscape elements that are already subsidized in SNL (section 2.2.3).

2.3.8 IMLB

IMLB (Kaper, 2012) (IMLB, 2012) is a semantic standard aiming at interoperability and exchange of data within the agricultural domain. The model looks for a close semantic relation to BGT/IMGeo. The model intends to exchange data between several actors within the primary agricultural sector and government. Main actor, however is the Paying Agency (RVO.nl, Rijksdienst voor Ondernemend Nederland) of EZ and the data they need for an efficient monitoring of regulations.

IMLB distinguishes objects that exist in the real world and virtual objects. Virtual objects are used to test whether certain regulations apply and are intended for the monitoring of regulations, there are five:

- Reference parcel ('Referentieperceel') is used to check if certain demands for specific regulations are met. The obligatory LPIS (see section 2.2.2) is indicated as a reference parcel. In the Netherlands called: agricultural area (Agrarisch Areaal Nederland, AAN)
- Regulation parcel ('Regelingsperceel') indicates whether a regulation applies to a parcel. This indicates for instance if SNL (section 2.2.3) applies to a parcel.
- Crop parcel ('Gewasperceel') specifies what crop grows on the parcel in a specific period.
- Activity parcel ('Activiteitenperceel'), indicates whether an activity is planned on the parcel.

Figure 2.8 show how the different objects relate to each other. Indicated are that physical, real world, objects consist of the object 'Unbuilt area' ('OnbebouwdFysiekGebied') and contains two sub-types: agricultural parcel ('Landbouwperceel') and small landscape element ('KleinLandschapselement'). It is not clear what information is conveyed in this object, but they are probably included to allow for the creation of a relation between the objects of BGT/IMGeo (vegetation area, water part, water bank, solitary vegetation object).

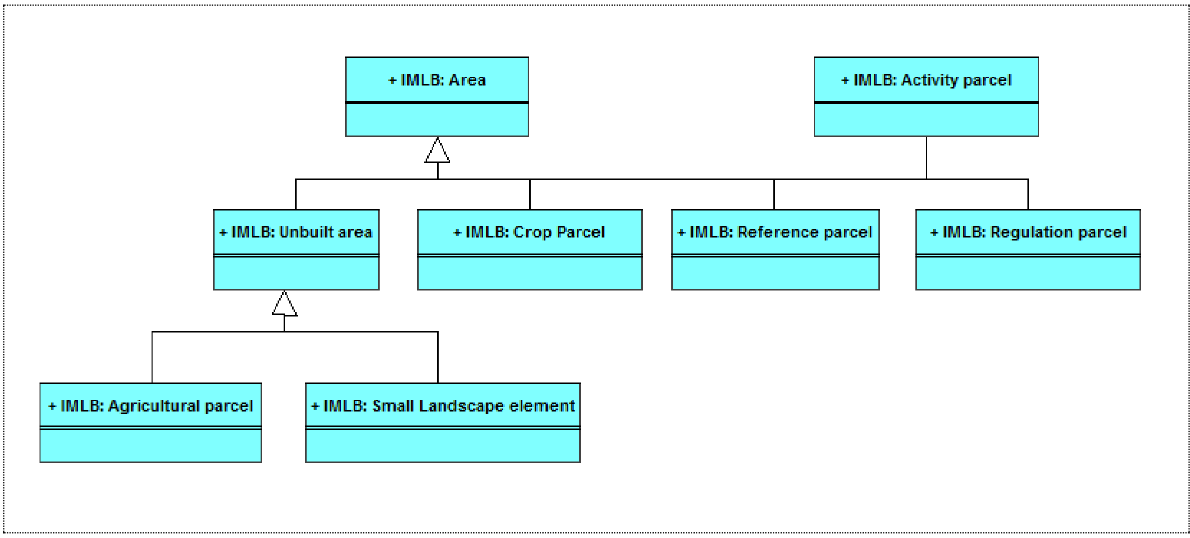


Figure 2.8: Relation between use-case, theme and sub-model in IMLB

2.3.9 Information model gap

The previous sections focussed on how standards are used to convey the semantics of geospatial data and enhance interoperability. Several IMs are explored that describe the rural area and are useful to derive relevant information regarding landscape elements. This indicated several gaps related to IMs. Table 2.8 is a summary of this information.

Table 2.8 shows that IMWa only provides information regarding water and in this respect is only important for blue landscape elements. This partial information provision is also the case for IMNa, which focusses on specific SNL landscape elements, hence the orange color. The two topographic maps (BGT/IMGeo and TOP10) provide information regarding both blue and green landscape elements. Single trees are not modelled in TOP10, a gap indicated in red. However, the exact gaps can only be indicated once the exact definition and dimensions of EFAs are known enabling a structured compare with IMs, hence the orange color for most landscape elements.

Another gap which impedes the use of BGT/IMGeo is that it provides only scarce or no information at all about the dimension of objects and their delineation. Also, IMs are regularly updated and not always available or only available in concept versions. This makes it difficult to interpret.

Lastly, to assess the fitness for use regarding EFAs, user requirements need to be collected and contrasted to available geospatial data. There is the need for a method to enable a structured way of doing this.

Table 2.8: Overview of the Information models[13]

Object		BGT/IMGeo	IMLB	IMWa	IMNa	TOP10
Version | year (model status)		1.1.1/2.1.1 | 2013 (final)	0.9 | 2012 (draft)	5.0 | 2013 (final)	2.0 | 2012 (draft)	2.1 | 2013 (final)
Sector		Government	RVO.nl, NVWA, Primary agri sector	Province, Waterboard, Rijkswaterstaat	RVO.nl, NVWA Province	Government
Owner		Stakeholders (SVB-BGT)	RVO.nl	Informatiehuis water	IPO/BIJ12	Cadaster
Related to IM[14]		IMLB (new versions of several domain IMs)	BGT/IMGeo, IMNa	TOP10, (IMRO, IMKL, UMAqua)	TOP10, IMLB, (IMRO, IMKICH)	IMWa, IMNa
Remarks		No information regarding minimum object size	Adheres BGT standard. Not clear what information small landscape elements provide	New model looks for relation with BGT	Boundary of objects is based on TOP10	Coarse scale, large minimum dimension
Exchange format		CityGML 2.0	GML 3.2.1	GML	GML 3.1.1	GML 3.1
Reference system		RD	RD	RD	RD	RD
Scale		1:500 – 1:5,000	1:500 – 1:5,000	1:10,000	1:10,000	1:10,000-1:25,000
Blue landscape elements	Watercourse	Water part	n.a.	Water part	Only SNL objects	Water part (0.5-6m)
	Pond	Water part	n.a.	Water part	Only SNL objects	Water part (> 50 m^2)
	Bank	Water bank	n.a.	Water bank	Only SNL objects	Water bank
Green landscape elements	Hedges	Vegetation area	Small landscape elements	n.a.	Only SNL objects	> 100 meter
	Wooded bank	Vegetation area	Small landscape elements	n.a.	Only SNL objects	> 50 m length and > 3 m width
	Tree single	'plus' topography	Small landscape elements	n.a.	Only SNL objects	Not modelled
	Tree line	Vegetation area or single trees ('plus´ topography)	Small landscape elements	n.a.	Only SNL objects	> 100 meter or wooded area (>3 m width and 50 m length)
	Tree group	Vegetation area	Small landscape elements	n.a.	Only SNL objects	> 1,000 m^2

[13] Red: information not available; Orange: information available but meets the requirements partially; Green: information available and meets the requirements
[14] Information models that are no part of this thesis are shown between brackets. All models implement NEN-3610, therefore not shown in the table

2.4 Harvesting objects from images, remote sensing

IMs have a twofold role in this thesis. On one hand they determine objects that are not available but will be collected using RS. And on the other hand they serve as a semantic framework that provides a definition for these objects. There are several ways to collect missing geospatial data regarding landscape elements. For instance, "Monitoring Kleine Landschaps Elementen" (MKLE, Monitoring Small Landscape Elements) is a system for the manual collection of information regarding landscape elements in The Netherlands (Oosterbaan & Pels, 2007). The use of local volunteers in the MKLE study reduced costs, nonetheless it is a laborious method that is only applicable to small areas. Manual interpretation and digitization of remotely sensed data is also an alternative to collect landscape elements. However, this is also a time intensive way of collecting information. The purpose of this section lies in exploring other options to collect green landscape elements using RS.

First, the use of RS for the delineation of landscape elements is explored in section 2.4.1. This is followed by describing segmentation in section 2.4.2, a first and essential step in an OBIA. A new and open data source known as Tree Register, derived from laser altimetry, could also provide information regarding green landscape elements and is evaluated in section 2.4.3. This section also describes how height is derived using true-orthorectified aerial images. Section 2.4.4 concludes by determining gaps in the use of RS for the detection of landscape elements.

2.4.1 Remote sensing of landscape elements

There are a lot of definitions of RS. One definition states that RS is the science of obtaining information about objects or area's from a distance[15]. This broad definition also includes visual interpretation with our eyes as well as microscopic study of an object. (Campbell, 2007) narrows this definition by mentioning that devices are used to derive this information. These devices, usually sensors mounted on airborne or satellites platforms are able to capture reflected or emitted electromagnetic radiation. Sunlight is an important natural source of electromagnetic radiation and provides an energy source used in passive RS, in contrast to active RS where sensors produce their own radiation, for instance radar or laser.

The measured radiation is captured on analog or digital images. The former records reflectance on a film's emulsion, which is a light sensitive layer. By using different films and filters specific wavelengths are captured in the visible and nonvisible portions of the electromagnetic spectrum (Paine & Kiser, 2003). Digital images, acquired by aerial or satellite platforms, record for each pixel the reflectance as brightness value or digital number. Both analog and digital images can collect information simultaneously over several bands (Campbell, 2007).

This thesis concentrates on landscape elements. There is a large variation in size and shape of landscape elements, ranging from a single tree to a group of trees or shelterbelt and within one image these objects are present at different scale levels. This puts constraints on the use of remotely sensed data due to spatial and spectral resolution of an image.

[15] http://oceanservice.noaa.gov/facts/remotesensing.html

There are no clear rules for the desired spatial resolution, normally expressed as pixel size, in a RS application. (Hengl, 2006) gives a rule of thumb by stating that for the detection of the smallest objects four pixels are needed, and at least two pixels for the narrowest objects. This rule indicates that, for instance, the use of a pixel size of 1 meter enables the detection of a tree crown with a diameter of 2 meter. Although difficult to give a general rule, most studies aiming at the detection of landscape elements use very high resolution (VHR) images, ranging from 0.25 to 1 meter and use Red, Green, Blue and Near-Infrared bands ((Meneguzzo, et al., 2013) (Czerepowicz, et al., 2012) (Sheeren, et al., 2009) (Thornton, et al., 2007) (Krause, et al., 2010).

Most studies prefer images during leaf-on season to make a better distinction possible between vegetated and non-vegetated areas and within the first category between tree and non-tree areas. To enhance this distinction some studies use vegetation indices (VI) to allow for a better distinction between areas with or without vegetation. VIs measure biomass or vegetative vigor by combining spectral values in an equation to yield a single value (Campbell, 2007). A widely used index is NDVI (Normalized Difference Vegetation Index) which calculates a ratio of brightness values of the red (R) and infrared (IR) bands.

NDVI doesn’t make a distinction in vegetation type, a deficit that can be avoided by using texture (Aksoy, et al., 2010) (Sheeren, et al., 2009) (Tansey, et al., 2009). Texture refers to a quasi-repeating pattern in images describing surface characteristics, such as smoothness, coarseness or irregularity (Richards, 2013). Standard deviation is a measure for texture, where a low standard deviation represents a homogenous surface and a heterogeneous surface is represented by a high standard deviation (Wiseman, et al., 2009).

Another popular way to differentiate between vegetation is the use of height in the classification process. (Hellesen & Matikainen, 2013) include height data derived from Airborne Laser Scanning (ALS, also known as LiDAR, Light Detection and Ranging). They used a LiDAR point cloud to derive a height model of above ground objects (or normalized Digital Surface Model, nDSM). Their method gave significant better results, compared to a second method without the height data.

Several (semi)-automated delineation strategies for images exist. Computer assisted image interpretation, as contrast to manual interpretation, derives useful information from an image. (Lillesand, et al., 2008) indicate that the “possible forms of digital image manipulation are literally infinite”. Several methods are available to classify images, grouped according to their characteristics. It is beyond the scope of this section to describe all of these methods in detail, but two methods are interesting to explore: pixel-based classification and OBIA.

A pixel-based method is based on the spectral characteristics of an individual pixel. Several statistical approaches are used to group pixels into distinct classes. This method works well if the objects of interest are smaller or similar of size compared to the spatial resolution (Blaschke, et al., 2014). However, pixel-based methods underperform when used for the detection of landscape elements solely. This is mostly because of the use of VHR-images in the detection of landscape elements and the increased spectral variation within landscape features, which potentially causes a decrease in classification accuracy (Blaschke, et al., 2014).

Furthermore, and this is explored in more depth later in this section, pixel-based methods only use spectral characteristics, which is normally not enough for the detection of landscape elements.

In an OBIA method first segments are created, consisting of similar groups of pixels (Campbell, 2007). These segments are classified, instead of pixels. There are several advantages in the use of OBIA over a pixel-based classification:

- Object-based classification is closer to human visual interpretation of images (Blaschke & Strobl, 2001),
- Image objects are created at various scales (Meneguzzo, et al., 2013), which is particularly important in the case of landscape elements, since they are present at different scales.
- OBIA uses not only spectral characteristics, but also contextual and texture information (Blaschke, et al., 2014),
- Better accuracy in detecting landscape elements (Meneguzzo, et al., 2013) (Sheeren, et al., 2009),
- The output of an OBIA is presented as vector files, which can be immediately used in a GIS (Tansey, et al., 2009),
- Object based classification alleviates the pepper-and-salt effect encountered in pixel-based classification (Meneguzzo, et al., 2013).

Unfortunately, there are also some obvious disadvantages to the use of OBIA that need to be mentioned. Sheeren et al. (2009) mentions the creation of image segments as a critical task, because several user-defined parameters are needed to be specified. Also the lack of an OBIA accuracy assessment is often mentioned as a disadvantage.

Image objects are the main basis for classification. Therefore, segmentation is crucial since it directly influences classification and accuracy of the remote sensing process. A remote sensing method is not complete without accuracy assessment. Frequently the thematic accuracy is assessed using a confusion matrix and determines the reliability of classification, or user accuracy, and the correctly identified area, or producer accuracy (Congalton & Green, 2009). An object based accuracy assessment is not complete if the geometric accuracy of an object is not determined (Albrecht, 2008). The next section explores segmentation as the critical first step in the use of OBIA.

2.4.2 Segmentation

Image segmentation is the process of subdividing an image into regions consisting of pixels with similar properties (Happ, et al., 2010). The goal of segmentation in RS is the creation of image objects that resemble real world objects like trees, parcels or buildings. Segmentation thus mimics the process of a human interpreter by using image semantics to 'read' an image, and as (Baatz & Schäpe, 2000) explain, the ”semantic information to understand an image is not represented in single pixels but in meaningful image objects and their mutual relations”. (Dey, et al., 2013) mentions that hundreds of different segmentation techniques are available which are all very different.

They are based on two distinct criteria that describe the relationship a pixel has with its surrounding pixels: discontinuity (e.g. edge-based) or similarity (e.g. region-based). Region-based techniques use similarity measures to determine suitable regions, whereas discontinuity measures determine the edge of regions (Räsänen, et al., 2013).

Other categorizations are possible and distinguish segmentation in bottom-up and top-down approaches (Trimble, 2014). Bottom-up describes a process of region growth, that starts with a pixel or object which gradually grows into larger objects. A top-down approach splits an images into smaller segments based on heterogeneity criteria.
Other possible categorizations are indicated by (Dey, et al., 2013) and depend on the point of action (pixel based, edge based, region based or hybrid) or on the assumptions and processes a segmentation model uses and are based on mathematical or conceptual models. The former are probability or statistics based (e.g. artificial neural network) and the latter use some kind of fuzzy logic (e.g. watershed, multi-scale).

Despite the large number of segmentation techniques and their arbitrary categorization it is important to know how to use them and what to expect from them. (Dey, et al., 2013) sum up several factors that are important in choosing a segmentation. These choices consider the interpretation elements for images (e.g. tone, color, size, shape and texture). Depending on the aim of segmentation some of these elements are suitable to incorporate in a segmentation based on expert knowledge. In the case of landscape elements those interpretation elements are, for instance, color (i.e. NDVI or height) and texture. Also more practical considerations are important and relate to the available software, the ease of use and the segmentation techniques that are provided by that software, to name some. Table 2.9 gives an overview of these factors and contrasts this with issues in this thesis.

Table 2.9: Factors influencing segmentation techniques (Dey et al., 2013)

Criteria	Examples	Thesis use
Concept based	• Image interpretation elements: spectral, spatial, texture, shape, size, context, shadow, connectivity, association • Scale • Segmentation technique (e.g. top-down, bottom-up)	NDVI and/or height are needed for distinction between tree and other vegetation
Implementation and use based	• Usage and parameter complexity, which is related to the used software	eCognition is used as software. Only proprietary segmentation available
Evaluation factor	• Segmentation quality assessment	Object based accuracy

Table 2.9 shows three criteria that influence the choice of segmentation techniques. Concepts based criteria refer to the type of segmentation technique and the inherent homogeneity measure. For this thesis a combination of height and NDVI is considered. This means that a segmentation technique needs to be capable of segmenting two datasets. eCognition, software that is available for this thesis, contains several segmentation techniques. Figure 2.9 shows the effect of different proprietary eCognition segmentation techniques using the UNIGS logo.

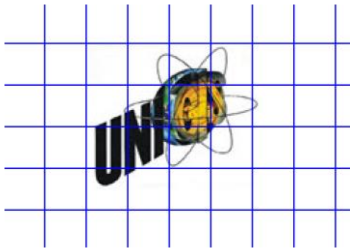
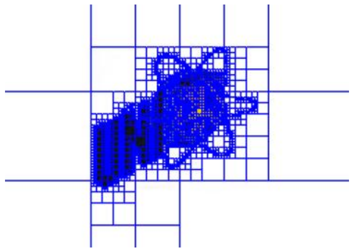
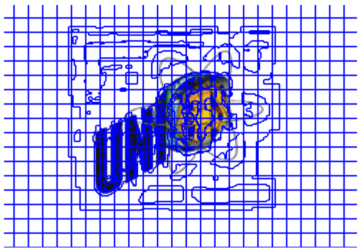
Segmentation type	Description	Example
Chessboard	Divides an image into an equal grid of squares (Object size 30)	
Quadtree	Creates squares of differing sizes depending on object homogeneity (scale 70)	
Multi-resolution segmentation	Creates objects by aggregating pixels until user defined criteria for homogeneity and shape are met (scale 30 shape 0.1 comp. 0.5)	
Contrast filter	For initial segmentation and filters pixels based on contrast and classified according user defined settings. (default settings and scale 8)	
Contrast split	Segments the scene into dark and bright objects based on a threshold. Logo is split into three objects. (120/253 as min/max threshold)	
Spectral difference	Merges image objects if the difference in spectral values does not exceed a user defined threshold	

Figure 2.9: Some proprietary segmentation algorithms of eCognition

Figure 2.9 demonstrates that some of the available techniques (e.g. chessboard and quadtree) are for initial segmentation, because they quickly divide an image in segments. Several studies indicate a good performance of Multi Resolution Segmentation (MRS) compared to other segmentations (Marpu, et al., 2010) (Räsänen, et al., 2013). As mentioned in section 2.2, a landscape is a complex system that is represented at different scales. MRS is available in eCognition and creates segments that are directly recognizable and works at several scale levels.

There are also some disadvantages in the use of MRS: it is heavy on resources and segmenting at low scale levels requires long computing times. Also the assessment of several parameters takes considerable amount of exploratory work. Figure 2.9 doesn't show Multi-threshold segmentation, because this segmentation is comparable to contrast split segmentation (Trimble, 2014).

2.4.3 Object height

Two sources for object height are used in this thesis. The first uses stereo images, the second is a dataset called Tree Register. This section gives a short description of both sources.

Figure 2.10 shows a screenshot from the Tree Register internet site around the VU campus. The Tree Register, an open dataset, shows the boundary of tree canopy perimeters with an claimed completeness of 60 percent (Rip & Bulens, 2013). Attributes of the Tree Register give information regarding the mean and maximum tree height of tree canopies. The Tree Register originates from a point cloud derived from laser altimetry (LiDAR). The AHN -2 (Actueel Hoogtebestand Nederland) is a height model of the Netherlands derived through LiDAR. AHN-2 consists of several products: a LiDAR point cloud, a Digital Terrain Model (DTM) and a Digital Surface Model (DSM). A DTM shows the surface without the objects on it, and a DSM shows the surface including the objects on it. As explained by (Benthem, 2013), tree crowns are extracted as follows: the DTM and DSM are subtracted to create a normalized height raster, showing object height. Moreover, to decrease the search area two masks are applied: a 'buildings mask' derived from TOP10. This mask also contains no data areas of the DTM. A 'no tree' mask is created by applying a standard deviation filter on the DSM. Trees show, as a result of their texture, a high standard deviation. Tree crowns are filtered by aggregating the two masks and object height. Tree crowns in the Tree Register typically consist of one or more trees.

A second source derives height from stereoscopy (Krause, et al., 2010). This could provide a viable alternative to the use of LiDAR. (Paine & Kiser, 2003) explain that the use of overlapping aerial images, or a stereoscopic pair, makes it possible to view an object from two different viewing points. This enables the calculation of object height, by using a principle called absolute parallax, or the difference in displacement between two points (Paine & Kiser, 2003). True orthoimages, or perfect vertical images, thus corrected for topographic displacement are needed for height calculation. Calculation of height is made possible by using specialized software.

There are no studies on the use of height derived from stereoscopy for the detection of green landscape elements. Other studies related to forestry show promising results.

For instance, Hobi and Ginzlr (2012) compared DSMs generated from aerial and satellite stereo-images with a LiDAR (Light Detection and Ranging) generated DSM and concluded that a DSM derived from stereo-images are a valuable alternative to LiDAR derived DSMs.

White et al. (2013) compared Digital Elevation Models (DEM) derived from LiDAR with stereo-imaging for forest parameters (i.e. height, basal area, volume) and concluded that stereo-imaging is an alternative to LiDAR. However, LiDAR was more accurate.

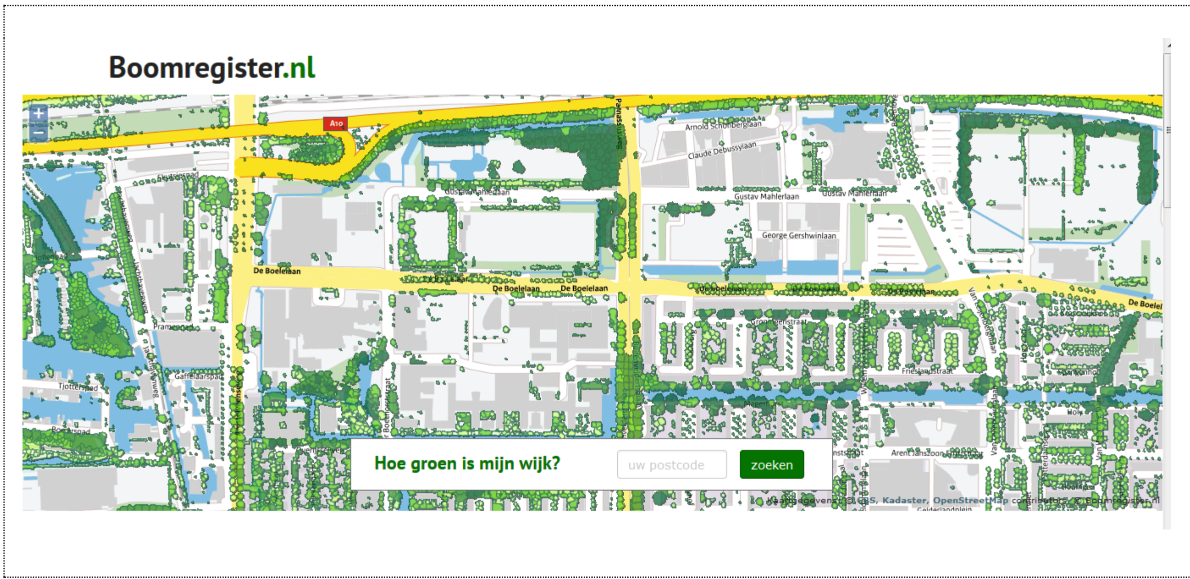


Figure 2.10: Tree Register, VU Campus area (boomregister.nl)

2.4.4 RS gap

The previous sections described how RS is used for the detection of landscape elements with a special aim on OBIA. In doing so several gaps regarding RS are identified that in the course of this thesis need attention.

Several studies indicate that using height greatly helps in the identification of landscape elements. The use of stereoscopic images as a height source is not used for the detection of landscape images. Closing this knowledge gap could provide interesting information regarding the usability for an accurate delineation of landscape elements. Also the use of an open dataset (Tree Register) is a gap that needs to be explored.

Segmentation parameters are normally determined by trial-and-error. This approach uses a subjective visual assessment of the segmentation result. A more objective method is needed to evaluate the segmentation goodness in an OBIA workflow. This is also the case for validation of the end result for which an accuracy assessment is needed.

Finally the use of IMs as a source for semantics is not mentioned in recent studies.

2.5 Concluding remarks chapter 2

Previous sections indicated several gaps on different areas: policy, IMs and RS. Starting with the questions asked by policy makers and ecologist that need geospatial data regarding landscape elements or organizations aiming at monitoring and evaluation of the role of EFAs in the new CAP.

Several sources for this data are conceivable and matching data could be found in existing sources that are described in IMs. A match regarding IMs could be determined by means of a use-case or data specification cycle.

Another option is to start from scratch and collect the relevant data through the use of RS (OBIA or Tree Register) guided by the semantic description of an IM. However, using RS is not without difficulties and choices regarding segmentation, segmentation parameters and classification are needed. Also accuracy assessment of the collected information is needed for a final evaluation. The next chapter describes the methods that are used in trying to close these gaps.

3 Methodology

3.1 Introduction

Chapter 3 describes how the research is conducted and clarifies its design. It gives an overview of the methods used in this thesis. As a quick reminder, the main research questions that this thesis tries to address are:

1. *Do existing information models provide the necessary information related to Ecological Focus Areas mentioned in the new CAP?*
2. *Is it possible to use Remote Sensing to delineate green landscape elements that are not provided through information models?*

Although both research questions seem unrelated at first sight, there is a connecting element. The semantics derived through the first question serve as input for the second question, meaning that the semantics of the objects of interest bridges both research questions. Figure 3.1 gives an overview of the design of the methodology, showing that "real world" objects that are of interest for this research, or universe of discourse, are described through a data specification method. This method results in a semantical and conceptual framework that is used in an OBIA to derive objects through remote sensing. Ultimately, the derived objects can be integrated in a GIS.

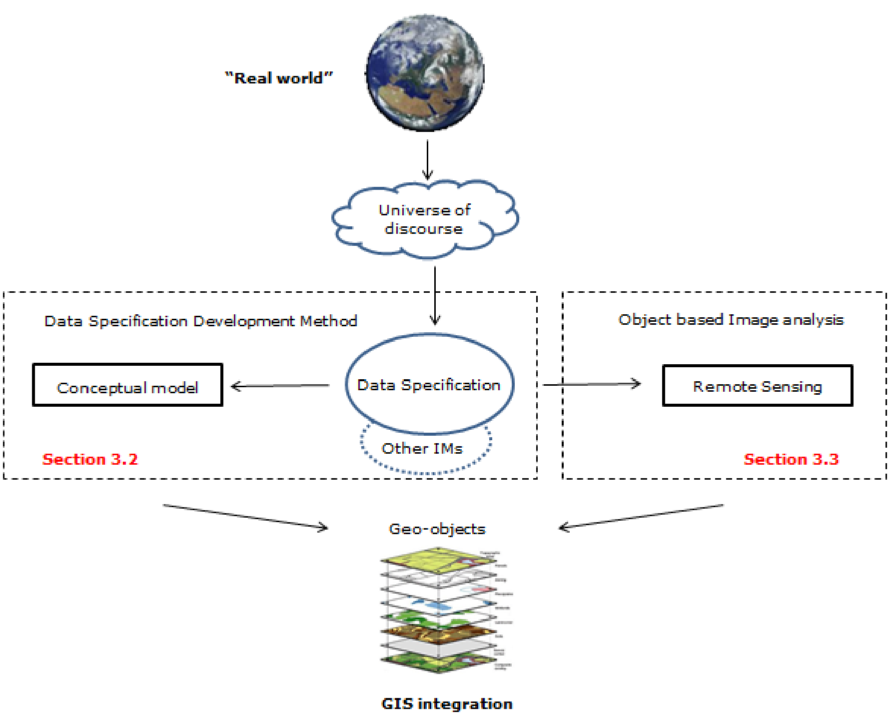


Figure 3.1: Research design

The next section explains the Data Development Method and its use as a means to derive an IM. The final section of this chapter, section 3.3, explains OBIA and its use to delineate the landscape elements of interest.

3.2 Developing information models: Data Specification Cycle

The Data Specification Development method is originally used for the development of INSPIRE spatial data themes. The method is created as a framework to guide the process of defining and harmonizing consistent spatial data themes among several different organizations (Tóth, et al., 2013). This method is also used for the development of IMs that are used in the Netherlands.

It builds on international standards (i.e. ISO 19131) and borrows elements from information technology (i.e. use case), thus is based on a large theoretical framework which builds on a predictable and repeatable process. Because this method is used as a default in the development of (inter)national IMs, it sets a good basis for the first research question by determining the needed objects and comparing this to already existing IMs. The method involves several stages (INSPIRE, 2008) (Tóth, et al., 2013):

1. <u>Use-case development</u>: A use-case is a goal-oriented sequence of interactions between actors and the desired system. 'Monitor application for EU subsidy for farmers' is an example of such a use-case. In this case, the desired system monitors the legitimate subsidy. An actor is a user or any other system that uses the system described in the use-case. Actors in this example are, for instance, a farmer that receives subsidy, a paying agency that monitors the subsidy, but also a reference layer that is used to enable a correct monitoring. Use-cases help to understand the requirements of the users and define the essential data to fulfil them.
2. <u>Identification of user requirements and spatial object types</u>: A candidate list of spatial object types, draft definitions and descriptions is derived based on the use-case. Attributes, data consistency, temporal aspects, level of detail and data quality are some other important aspects regarding user requirements. This serves as a 'first-cut' data specification, describing the universe of discourse. In the previous example, information regarding the agricultural parcels is needed to enable a good check, but also a reference layer to check whether a declared parcel is eligible for subsidy.
3. <u>As-is analysis</u>: Compares the data requirement from the use-cases with the existing (as-is) situation. This stage reveals whether the requested geographic data is available using other IMs.
4. <u>Gap analysis</u>: Identifies gaps, by comparing the user requirements with the available IMs.
5. <u>Data specification development</u>: Creation of a data specification according to the results of the 'as-is' and gap analysis. Technical and financial feasibility should be considered in this stage as well.
6. <u>Collect missing data using OBIA and validate its results</u>: The data from the identified gaps is collected through the use of OBIA or Tree Register. This stage, and the validation of the results, is described in section 3.3.

Figure 3.2 gives an overview of the Data Specification Method. Use-cases are the key element of this method. It is therefore worthwhile to explore this stage in more depth which is done in the next section.

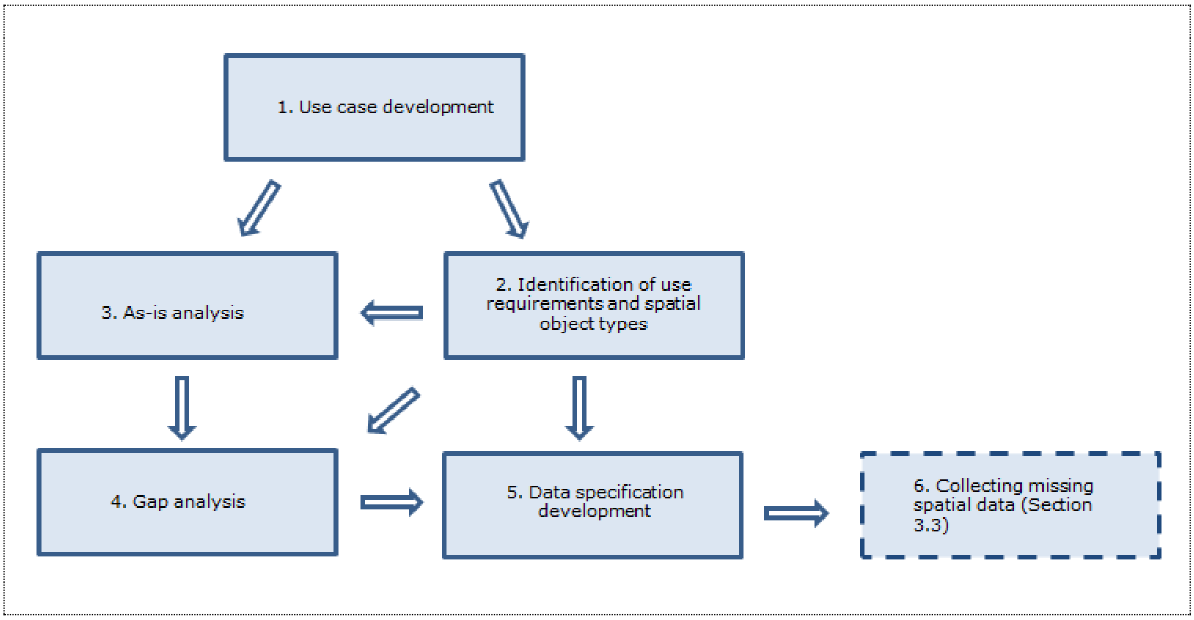


Figure 3.2: Data Specification Development Method (adapted from (Tóth, et al., 2013)

3.2.1 Use case

As mentioned, a use-case describes the processes that actors perform on a system to reach a specific goal. These processes, or steps in an use-case, generate or need data before the next step can be effectuated. By specifying and describing these steps the requirements of the system become apparent, which is the main intention to conduct use-cases.

The system of interest for this thesis is indicated by the first research question and can be stated as: *monitoring of EFA requirements for farmers*. The information needed for this use-case is gathered via an expert meeting where specialists of RVO.nl participate. Participants of the expert meeting are regulation specialists and geospatial specialists. Aim of this meeting is to define the exact use-case and specify the requirements. This serves as input for further stages.

3.2.2 Data collection and consolidation

Appendix A provides a checklist to support a structured and controlled way of information collection. This appendix documents summary information to keep track of the process and identifies questions that are important in each stage.

A useful tool is provided by table 3.1 which gives an overview of the input, the deliverables (output) and the tools that can be used in each stage of the method. The results of each stage are evaluated by an expert meeting to ensure an outcome that is desired by the stakeholders. This iterative approach is also characteristic of the method.

It is necessary to consult other parties. For instance, data providers need to be contacted to fill in the red spots in table 2.9, in order to conclude the development method.

A data specification is obviously the ultimate result of the method, as indicated in Table 3.1. As explained, section 2.3.3 gives rules how to model and communicate spatial information. UML schemes and an object feature catalogue are the normal parts of a data specification. The latter, object feature catalogue, is no part of this thesis.

The software product Enterprise Architect Version 11.1 is used for the creation of an UML- model of the data specification.

Table 3.1: Input, output, tools of the Data Specification Method (INSPIRE, 2008; Tòth et al., 2012)

Stage	Input	Output	Supporting tools[1]

1. Use case description		• Use case description:
		  ○ UML scheme
		  ○ Structured description (table)
		  ○ Narrative explanation
			- CAP, section 2.2
			- IMs, section 2.3
			- UML
			- Use case template (appendix B)
			- Expert meeting (section 3.3.1)

2. Identification of user requirements	▪ Use case descriptions stage 1 ▪ Checklist	• 'First cut' data specification • List of requirements • Amended use case (if necessary)	- UML - Feature Concept Dictionary[2] - Appendix A (checklist) - Consultation data providers
3. As-is analysis	▪ (Amended) use case stage 1 (or 2) ▪ List of requirements ▪ Checklist ▪ Data providers (BGT/IMWa)	• Description of the current situation	- IMs, theoretical framework section 2.3 - Appendix A (checklist)
4. Gap analysis	▪ (Amended) use case stage 1 (or 2) ▪ List of requirements ▪ Checklist ▪ As-is analysis	• Identification of gaps	- Appendix A (checklist)
5. Data specification	▪ (Amended) use case ▪ 'First cut' data specification ▪ List of requirements ▪ As-is analysis ▪ Gap analysis	• Data specification	- Feature Concept Dictionary[2] - Appendix A (checklist)

[1] Supporting tools include techniques and additional information used to complete a stage
[2] Feature concept dictionary is a semantic register of feature-related concepts (name, definition, description) that describe geographic data. Available at: http://www.geomultimedia.nl/beta/ef66716a-c19a-4fca-b3c0-fd45b2366af2/geoconceptregister/db/20130902/geoconceptregister/

3.3 Remote sensing method: OBIA

This part is the last stage of the Data Specification Cycle and uses the input of the previous stages. This input not only determines the objects of interest, but also describes them and serves as a semantical framework. The RS part uses two existing datasets: an inventory of trees in the Netherlands, called Tree Register ("Boomregister") and a corrected version of this Tree Register. The use of these datasets is compared with tree cover derived through an OBIA workflow.

This section first describes the used data and software and continues by describing the segmentation and classification. The accuracy is assessed to determine the usability of these three data sources.

3.3.1 Data and software

The data sets applied for the OBIA part consist of a true-orthorectified aerial image containing four bands: blue, green, red and near-infrared (NIR). This layer is also the basis for an NDVI and object height. Object height is determined using stereoscopy to derive a Digital Surface Model (DSM). Subtracting the DSM from a Digital Terrain Model (DTM) results in a normalized Digital Surface Model (nDSM) that gives object height. Images where corrected for radiometric and geometric disturbance by the image provider. The image provides also provided the height datasets. Resolution and acquisition date for the datasets are:

True Orthorectified	25 cm resolution	June 8, 2013
NDVI	25 cm resolution	June 8, 2013
nDSM	75 cm resolution	June 8, 2013
Tree Register	n.a.	2011

The Tree Register, explained in section 2.4.3, is corrected and validated using a process developed by NEO[16]. The process compares object height (OHM) and NDVI against the Tree Register. OHM and NDVI are the same datasets as aforementioned. Using these datasets the tree perimeter from the existing tree register is classified as tree, shrub, fuzzy tree or no tree, using following classification:

Tree:	(Mean NDVI≥0.1 AND Max OHM≥1.5) OR (Mean NDVI<0.1 AND Max OHM >1.5)
Shrub:	Mean NDVI≥0.1 AND (Max OHM≥0.5 AND Max OHM≤1)
No Tree:	(Mean NDVI<0.1 AND Max OHM<1.5) OR (Max OHM <0.5)
Fuzzy Tree:	Remaining objects

All objects classified as fuzzy tree are checked using aerial images and Google Streetview and reclassified into tree, no-tree or shrub if needed. Both, the corrected and uncorrected Tree Register, are used as alternative data sources.

[16] Netherlands Geomatics and Earth Observation BV, one of the companies that took the initiative for creating the Tree Register

Several software products are used in to complete the OBIA process, including the Segmentation Goodness Evaluation. eCognition 9 for segmentation, Quantum GIS Brighton 2.6.1 and ArcGIS 9.3 for Segmentation Goodness Evaluation, classification and accuracy assessment. The Segmentation Goodness Evaluation and accuracy assessment are analyzed using Microsoft Access 2010 and Microsoft Excel 2010.

3.3.2 Study area and subarea

The area of interest is part of a region called 'Land van Heusden en Altena' , located in the North-West part of province Noord-Brabant and roughly situated between the cities of Rotterdam and 's-Hertogenbosch. The area, just South of the city Gorinchem, is demarcated by two rivers, Waal/Merwede in the North and Bergsche Maas in the South and bordered by National Park 'Biesbosch' in the West. The area is an agricultural landscape with primarily arable land and fits the specific demands of the new CAP.

There are also green landscape elements present that primarily consist of trees (single, line and groups) and coppice. The study area has a surface of 1,430 hectares. A smaller subarea of almost 30 hectare is selected within this study area to decrease processing time and allow a quick evaluation of segmentation parameters. This subarea is a representative area with a limited surface that allows a quick segmentation. A reference layer is created within the sub-area. This reference layer consists of four trees with a height between 4 and 6 meter and a minimum crown diameter of 4 meter. Furthermore, one detached tree line, a tree line in approximation of a building and a tree line surrounded by other trees and hedges are selected. Study area, the smaller subarea and the reference objects are shown in Figure 3.3.

Figure 3.3: Study area, sub area and reference objects

The reference objects are manually digitized using true-ortho imagery as a reference. In case of ambivalence regarding the exact boundary of an object, additional imagery (i.e. NDVI and object-height) is used as orientation to allow for a good delineation. Section 3.3.3 explains this evaluation into more depth. Figure 3.4 shows the reference objects (Note that some objects are rotated for better picturing, Figure 3.3 shows the correct alignment).

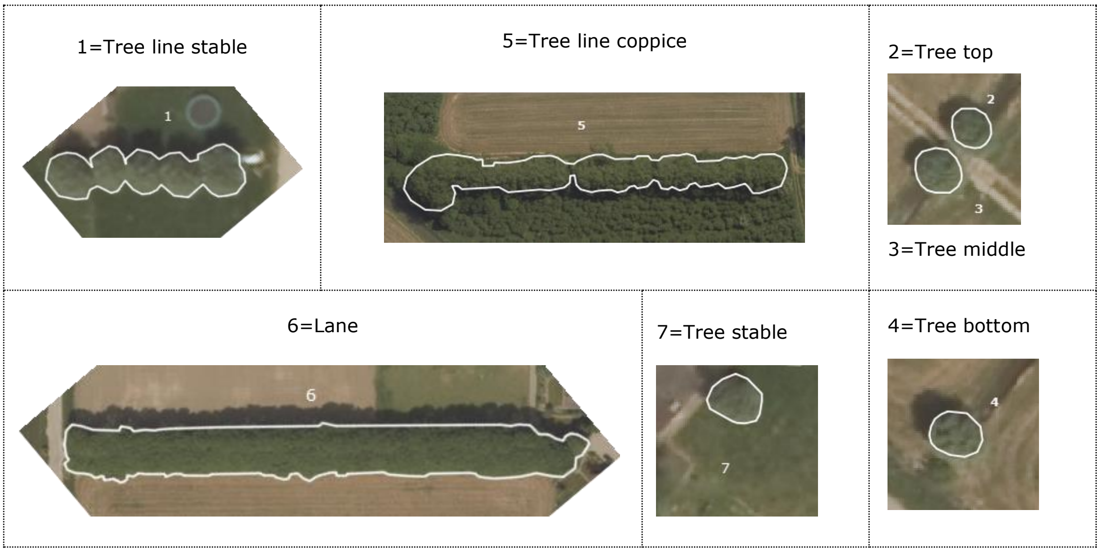


Figure 3.4: Reference objects, tree lines and single trees

3.3.3 Multi Resolution Segmentation

As mentioned in section 2.4.2, segmentation is the process of subdividing an image into segments that represent image objects. Segmentation is considered a central stage, because in a successful segmentation image objects are unambiguously linked with ground objects (Lizarazo & Elsner, 2011). MRS, standard in eCognition, is a bottom-up region growing algorithm that merges objects (pixels or image-objects) to create areas consisting of similar pixels (Trimble, 2014). This segmentation process minimizes the average heterogeneity of created areas and consists of two components: spectral heterogeneity and shape heterogeneity (Happ, et al., 2010). Figure 3.5 shows the relation between both components.

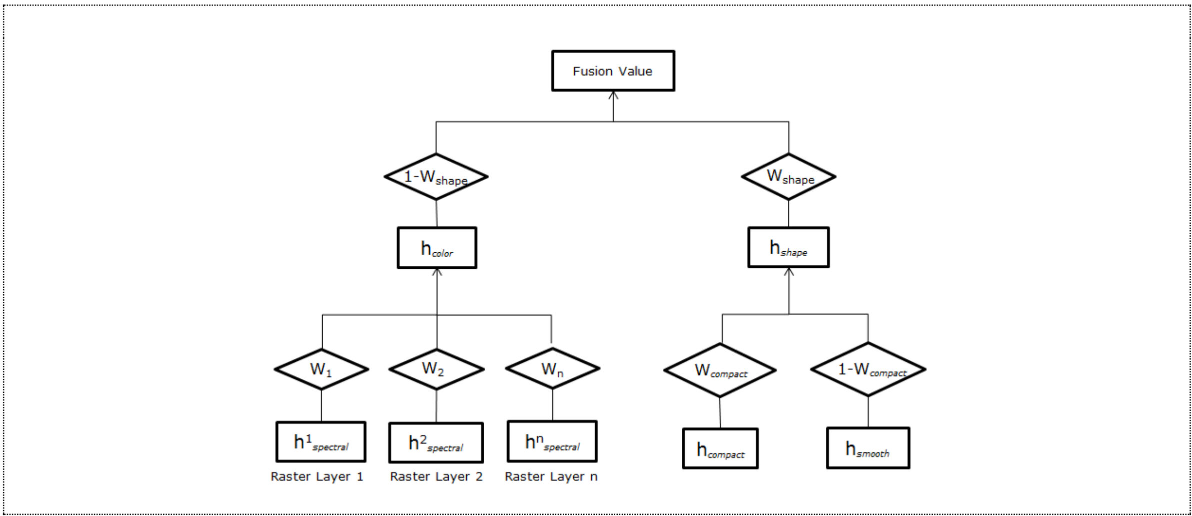


Figure 3.5: eCognition user parameters for MRS (Happ, et al., 2010) (Zhang, et al., 2010)

(Happ, et al., 2010) explain that the fusion value is an expression for the increase in heterogeneity and is calculated for each neighbor of a selected segment. The segment with the smallest fusion factor is chosen for a merge. This merge is executed if a user defined threshold, i.e. scale parameter, is not exceeded. The fusion value combines spectral heterogeneity and shape heterogeneity. Spectral heterogeneity ($h_{spectral}$) is the weighted average standard deviation for each band and is determined by the raster layers that are included into the segmentation process. A user can give a different weighting to raster layers, W_1 to W_n ranging from 0 to 1, depending on their importance in the segmentation process.

Shape heterogeneity (h_{shape}) depends on the components smoothness heterogeneity (h_{smooth}) and compactness heterogeneity ($h_{compact}$). Compactness is defined as the ratio between the perimeter of the segment and the square root of its area and smoothness is the ratio between the perimeter of the object and the perimeter of the minimum bounding rectangle (Happ, et al., 2010). Figure 3.6 shows some examples of different objects and their smoothness and compactness.

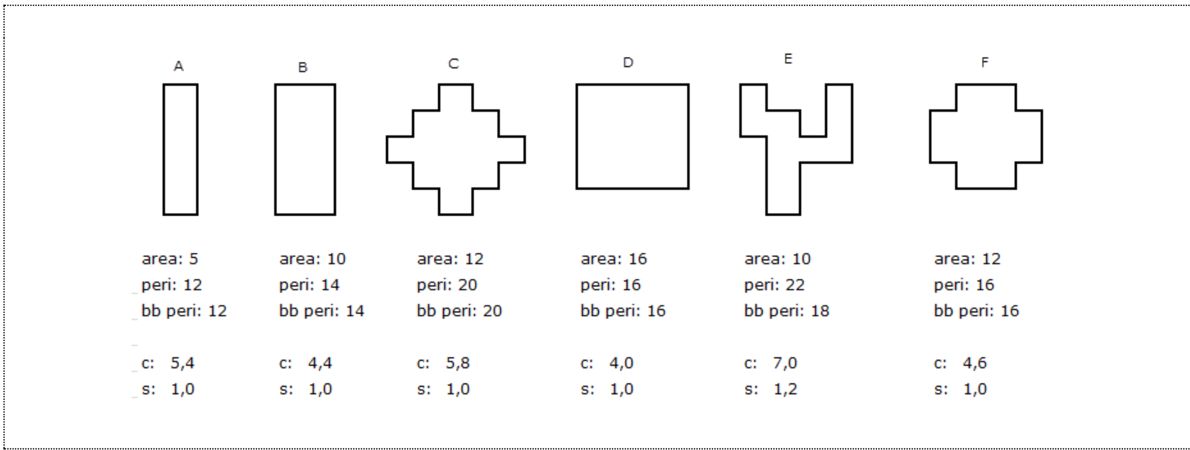


Figure 3.6: Smoothness (s) and Compactness (c) of different objects

As shown in Figure 3.6 an irregular object with a large boundary in relation to its area results in a large compactness. Smoothness shows small variance between the depicted objects.

The user defines three parameters; the already mentioned scale, shape (W_{shape}) and compactness ($W_{compact}$). Modifying the scale parameter results in different object sizes. Also note from Figure 3.5 that a large shape parameter reduces the influence of color in the segmentation process (Trimble, 2014).

Segmentation parameters are often selected using a trial-and-error approach, where visual inspection of the result determines the selected parameters. This thesis uses a more rigorous approach and evaluates the goodness of segmentation as explained in the next section. The final segmentation result is exported as shapefile with a selection of several attributes that could support classification. Attributes are the mean, median, minimum and maximum values of: NDVI, object height, the four spectral bands (red, green, blue and NIR).

3.3.4 Explaining Segmentation Goodness Evaluation

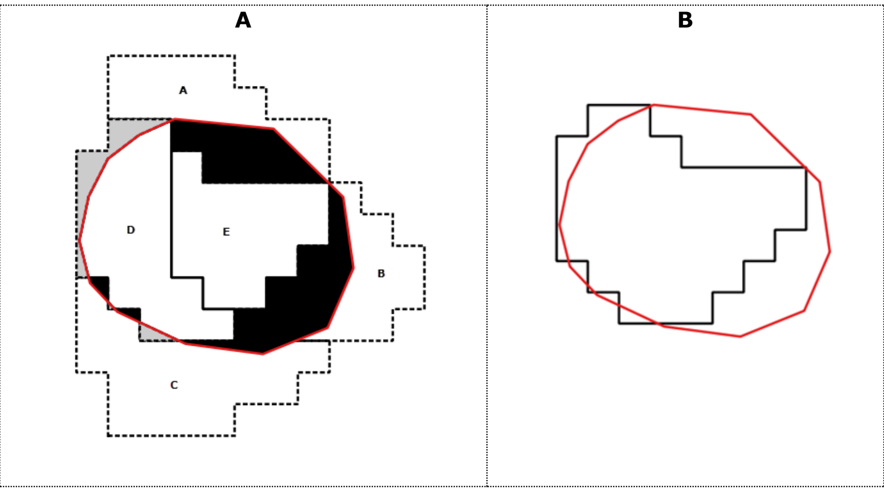
The combination of user defined parameters in a MRS process offers an almost unlimited number of possibilities. Comparable studies for the detection of tree cover are performed by (Meneguzzo, et al., 2013) and (Hellesen & Matikainen, 2013). They used scales of 10, 15 and 20 and developed a successful OBIA method. Although some studies also use larger scales, it is generally accepted that small scales are needed for detecting objects with a small area. Therefore the scales of 8, 10, 12 and 15 are used in this thesis. To limit the number of options, only compactness and shape parameters of 0.1, 0.3, 0.5, 0.7 and 0.9 are used. This results in a total of 25 different parameter combinations for each scale as shown in Table 3.2.

Table 3.2: the 25 compactness and shape combinations per scale

		Compactness				
		0.1	**0.3**	**0.5**	**0.7**	**0.9**
Shape	**0.1**	*1*	*2*	*3*	*4*	*5*
	0.3	*6*	*7*	*8*	*9*	*10*
	0.5	*11*	*12*	*13*	*14*	*15*
	0.7	*16*	*17*	*18*	*18*	*20*
	0.9	*21*	*22*	*23*	*24*	*25*

The segmentation is based on height or height combined with NDVI, which showed good results as indicated in section 2.4. The result of each segmentation is exported as a shapefile and processed in QGIS to derive the input for a Segmentation Goodness Evaluation. The aforementioned combinations result in a total of 200 different shapefiles: 25 shape and compactness combinations for each of the four scales and applied to two different input datasets.

Segmentation creates image segments that ideally coincide with real world object of interest. However, an optimal segmentation is not always the case and anomalies of over-segmentation or under-segmentation occur. If a real-world object is split into smaller sub-objects then over-segmentation occurred. The opposite is under-segmentation where a created segment is part of other objects. Marpu et al. (2010) developed a Segmentation Goodness Evaluation that uses these anomalies. Figure 3.6 shows a possible scenario, representing a tree boundary and created segments.



Light grey areas indicate extra pixels, whereas missing pixels are indicated in black. Reference object is indicated in red. The sub-objects D and E are for 60 percent or more within the reference object. This is not the case for sub-objects A to C

Figure 3.7: A schematic overview of segmentation evaluation (A) and recreated object (B)

The scenario of Figure 3.7 shows a reference object, representing a tree boundary, in red. The tree is segmented into five sub-objects, A to E. Sub-object E is completely within the reference object. Sub-object D is mostly within the reference area. The other objects only touch the boundary. This is the case for sub-objects A to C. As indicated by (Marpu, et al., 2010) only the sub-objects that are completely or to a large extent within the reference object are useful to reconstruct the reference object. Sub-objects that only touch the reference object are ignored, because they are not useful in reconstructing the shape of the reference object. This Segmentation Goodness Evaluation regards sub-objects useful if they are for 60 percent or more within a reference object. All other sub-objects are dismissed.

Also indicated in Figure 3.7 is the existence of missing and extra pixels. Missing pixels are pixels that are part of a dismissed sub-object, whereas extra pixels occur when the sub-object exceeds the boundary of a reference object. The following five metrics are used to evaluate the goodness of segmentation (Marpu, et al., 2010):

1. percentage of the area of lost pixels,
2. percentage of the area of extra pixels,
3. percentage of the area of the biggest sub-object within a reference object,
4. the number of reference objects which lost more than 25 percent of the pixels, and,
5. the number of reference objects which gained more than 25 percent of the pixels.

The first two metrics indicate under-segmentation and the third metric indicates over-segmentation. (Marpu, et al., 2010) argue that the effective shape of a reference object is lost if the area of missing or extra pixels exceeds 25 percent of the area of the reference object. This situation is undesirable and therefore a maximum threshold of 25 percent for extra pixels or missing pixels is set.

A GIS workflow transforms the segmentation result into the desired format and calculates the previously mentioned criteria. Figure 3.8 shows a workflow consisting of two parts, A and B. Part A prepares the segments and calculates the measure defined at criterion 3. Part B uses this output for the calculation of criterion 1 and 2.

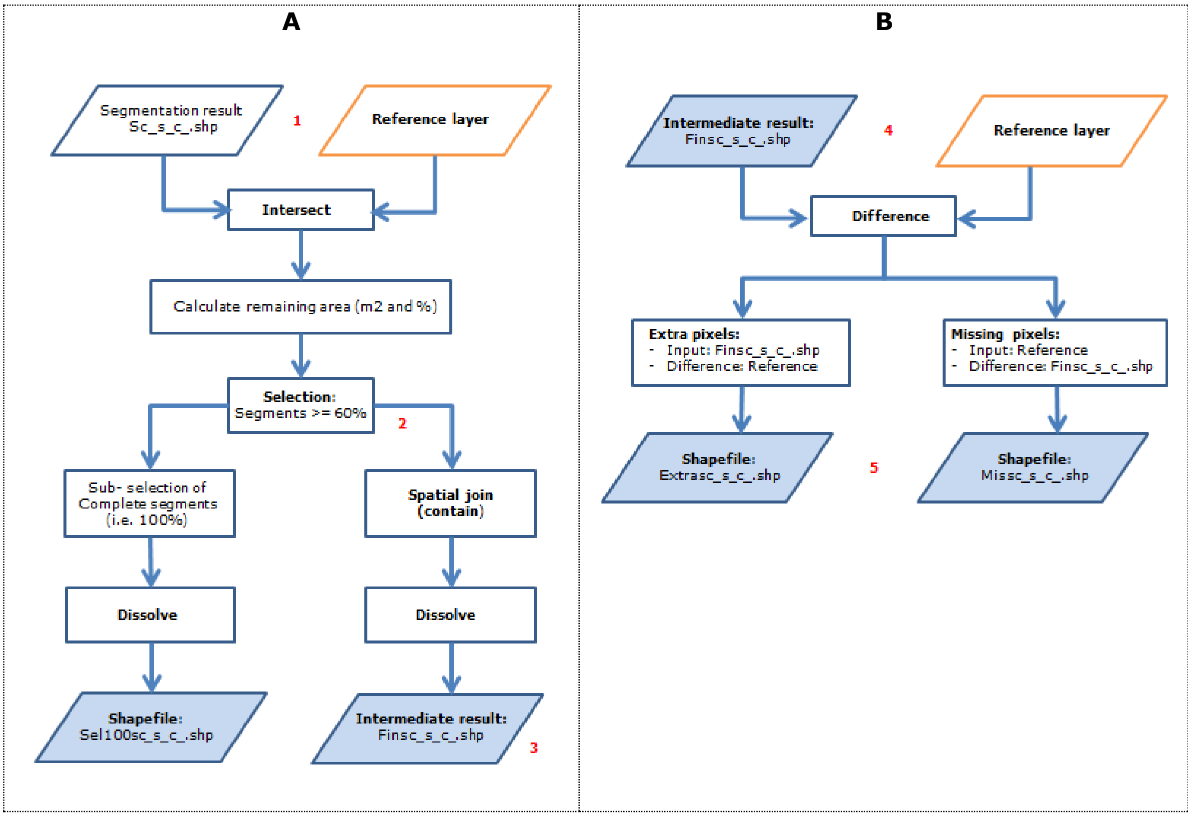


Figure 3.8: GIS Workflow Segmentation Goodness Evaluation

Part A of the GIS workflow starts with an intersect of the segmentation result and the reference objects, as indicated by [1]. The area (m^2) of the intersected segments is calculated and also the percentage of the remaining segment. Objects that are for 60 percent or more within the reference object are selected, as indicated by [2]. This selection is used for two separate processes. Firstly, a spatial join for the selection of the complete segments from the original segmentation result. This result is processed further in part B. Secondly, a sub-selection of segments that remain for 100 percent within the reference object. This set is used to calculate the area of the largest sub-objects within the reference object, according criterion 3. Results are saved as separate files after a dissolve operation.

The intermediate result, indicated by [3], is used for an additional evaluation before continuing with the second part. This evaluation assesses whether the segments from the intermediate result appear in each reference object. Segmentation parameters that result in missing reference objects are excluded for further processing in part B. Part B uses the reference layer and the intermediate result, indicated by [3], in a difference operation, indicated by [4]. Calculated are missing or extra pixels as indicated by [5]. This result is used to calculate criteria 1-2 and 4-5.

Statistics of missing- and extra pixels, the largest sub-objects and number of deformed objects due to gain or loss of pixels are calculated as means for a final assessment. Statistics consist of median value, first and third quartile, minimum and maximum values. The results for trees and tree lines are assessed in two separate groups.

3.3.5 Classification

The segmented objects are the building blocks to meaningful objects. An object based classification is performed by labelling the appropriate segments as tree canopy, whether it is a single tree or continuous canopy demarcating a tree line or tree group.

A classification strategy is conceived that enables a comparison between the three datasets considered in this thesis: the previously described OBIA method and the two already existing datasets, i.e. Tree Register and corrected Tree Register. Figure 3.9 shows the classification process.

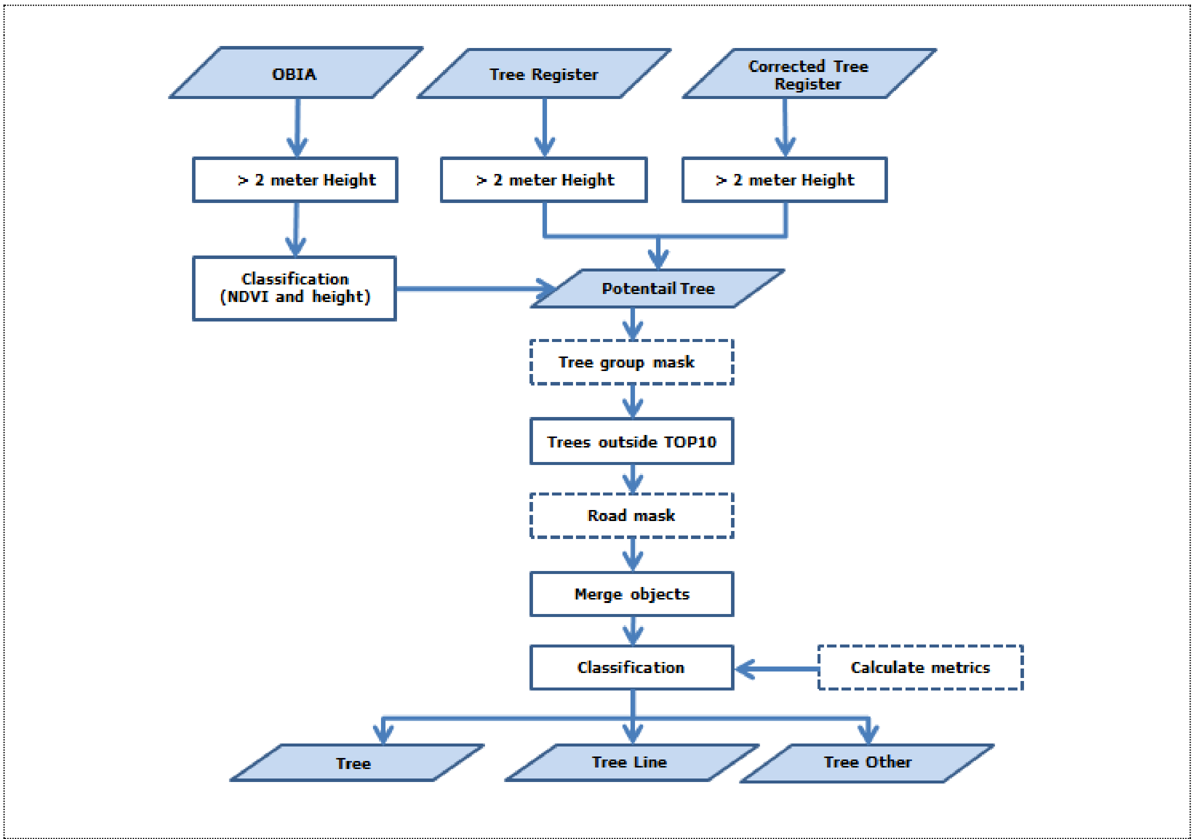


Figure 3.9: Classification workflow

The process starts by filtering out all segments with a height below 2 m. This threshold is used to avoid noise caused by tall herbaceous vegetation, hedges or shrubs and other non-vegetation objects. An additional classification based on NDVI and height is needed for the OBIA dataset to make a distinction between ascending green vegetation and other objects. Finally, this results in three comparable datasets representing tree canopy. These datasets are processed to classify tree canopy as single tree, tree line or other.

Two masks are applied in this classification workflow, as indicated in above figure. A first mask, "Tree Group Mask", consists of areas with a minimum size of 0.5 ha. These areas consist of TOP10 object of the type 'vegetation area' and domain forest (deciduous, coniferous, mixed) or poplar. Only potential trees outside these areas are used for further classification. A second mask, "Road Part Mask", uses TOP10 objects of the type 'road part' to prevent an erroneous classification of distinct objects that are connected through their crown area.

For instance, a row of trees along a road connected to another group of trees. It is important to note that, as indicated in chapter 2, BGT is preferred for this task but not yet available for the study area.

Metrics, e.g. length, width, area, perimeter, are calculated in ArcGIS for each merged tree canopy area to make a distinction in different types of tree canopy possible. Shape index enables a distinction between tree lines and other objects. The exact classification dependents on the outcome of the Data Specification Cycle (section 3.2).

3.3.6 Accuracy assessment

Most methods focus on a complete partitioning of the whole scene. Accuracy is determined in these cases by how well the map matches the situation in reality, using an error matrix often in combination with a kappa index to determine the validity of the error matrix (Congalton & Green, 2009). This thesis is only interested in specific objects (i.e. tree or crown area) and, furthermore, objects are the appropriate sampling unit in an object-based accuracy assessment instead of pixels (Congalton & Green, 2009). Therefor an object-based accuracy assessment is done, based on the work of (Ardilla, et al., 2012). They extracted tree crown objects in an urban environment. To encompass the need for object-based accuracy metrics, (Ardilla, et al., 2012) calculated the area of under- and over-identification to assess the boundary quality of detected objects. This idea is shown in Figure 3.10.

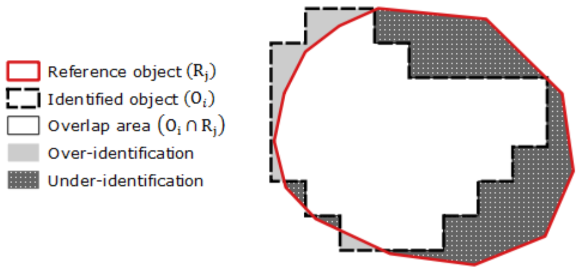


Figure 3.10: Over and under-identification of validation- and identified objects (Ardilla, et al., 2012)

These parameters are comparable to the Segmentation Goodness Evaluation metrics explained in section 3.3.4 but instead of calculating extra- and missing pixels, the match between a validation object (R_j) and an identified object (O_i) is calculated as follows:

$$\mathbf{OverID}(\mathbf{O_i}) = 1 - \frac{\mathrm{Area}\,(O_i \cap R_j)}{\mathrm{Area}(O_i)} \quad \mathbf{(1)}$$

$$\mathbf{UnderID}(\mathbf{O_i}) = 1 - \frac{\mathrm{Area}\,(O_i \cap R_j)}{\mathrm{Area}(R_j)} \quad \mathbf{(2)}$$

A good match between validation and identified object results in values of $\mathrm{OverID}(\mathrm{O_i})$ and $\mathrm{UnderID}(\mathrm{O_i})$ close to zero. Values close to 1 represent the opposite case and indicate a large difference between both objects. The total delineation error is calculated as (Ardilla, et al., 2012):

$$\textbf{Total error}\ (\mathbf{O_i}) = \sqrt{\frac{\mathrm{OverID}(\mathrm{O_i})^2 + \mathrm{UnderID}(\mathrm{O_i})^2}{2}} \qquad \textbf{(3)}$$

Calculations are grouped separately for single trees and other tree crown areas. Using above parameters also permits a rigorous scenario for Segmentation Goodness Evaluation parameters.

Next to identifying the above three parameters, the following object accuracy indicators are also calculated (Ardilla, et al., 2012):

- Correctly identified objects (true positive);
- Type I errors (false positives) or trees identified, but not present in reality;
- Type II errors (false negatives) or trees present in reality but not identified.

The six metrics are used for all three datasets to assess their suitability for tree detection. A validation layer is created consisting of tree crown boundaries to enable this accuracy assessment. A stratified sampling is used to create the validation layer. A grid consisting of 250x250 meter cells is used to divide the study area. Cells that coincide with tree cover are selected. Fifteen random points are placed within this selection and a buffer of 60 meter was applied. Tree crown areas within these buffers are manually digitized, based on a visual interpretation of the true-orthorectified aerial images, and saved as polygons. Ancillary data consisting of CIR images, object height and NDVI are used to facilitate a good manual digitization. A ground survey is used as a final moment to assure that the digitized objects are indeed trees, to make sure that no trees are missed and check the classification result.

4 Results and discussion

4.1 Introduction

This chapter is divided into two main parts and presents and discusses the results that are collected using the methods as described in the previous chapter 3.

The first part looks at the results for the Data Specification Cycle. It describes the data collection, followed by a short overview of the results from each of the five stages. The final outcome provides a data specification and UML-model that serves as an addition to the existing BGT/IMGeo model to encompass the desired EFA-layer. The results summarized in a separate section, before the first part concludes with a discussion of the findings.

The second part concentrates on the collection and validation of EFAs that are not provided through IMs. The use and accuracy of OBIA is compared with that of two alternative datasets, the Tree Register and a corrected version of the Tree Register. This part starts by showing the results for segmentation and Segmentation Goodness Evaluation and continues with an object based classification before closing with an accuracy assessment of the method. Before ending the second part by discussing its findings, an overview of the OBIA results is provided.

4.2 Results Data Specification Cycle

Information needed for the Data Specification Cycle is collected during two meetings, 1 September and 17 November 2014, at RVO.nl located in Assen. The primary goal of the first meeting was to define a consistent use-case and gather initial information to start this process. This meeting was attended by two EU-regulation experts and two GIS experts. A second, conclusive, meeting was held almost two months later. During this meeting the progress was discussed and blank spots were filled in. The composition of this meeting was slightly different, because only one person from each expert group remained and an IM expert was added.

Between these meetings regular contact was maintained by telephone or email. This regular contact was necessary to create an iterative approach and keep the use-case focused. Also additional information regarding the content of two IMs (i.e. IMWa and BGT/IMGeo) was collected to fill in the ambiguities that were indicated in Table 2.8 (section 2.3.9). Information regarding BGT/IMGeo was collected during two meetings with a BGT/IMGeo specialist from Geonovum. Two emails were sent to the info desk of Informatiehuis Water to collect the missing information regarding IMWa. This information, combined with the IMs that are explored in chapter 2 and details provided by EU regulations provided all the input needed to complete this data specification cycle.

The results presented in the next sections are a summary of the data development cycle. The detailed information is provided in Appendix C.

4.2.1 Use-case description

Section 3.2.1 already mentioned the important role of a use-case as a central part of a data development method. Defining a good use-case is therefore fundamental. The use-case explored in this thesis is:

"Monitoring of EFA requirements for farmers"

EFAs are only relevant to farmers who apply for income support regulated in the CAP. This application is only available for farms that meet specific conditions regarding farm size and registration[17].

A farmer who is entitled to income support provides the necessary data to the paying agency, RVO.nl. Information regarding agricultural parcels is provided through an internet GIS application or on paper. The farmer provides data regarding the location, area, crop type and ownership of the agricultural parcels.

RVO.nl checks the declared area of land on consistency, using the LPIS. A farmer should establish 5 percent of the area arable land as EFA if the total area of arable land exceeds 15 hectare. The exact requirements are provided in section 2.2.2. The farmer is responsible to assess whether there are special obligations regarding greening and EFA requirements. The farmer also choses how to meet these specific EFA requirements. The farmer provides this information to the paying agency, including the type of EFAs that are established, their area and the exact location of the EFA. The farmer includes this information in the application. The paying agency creates an EFA-layer as part of the LPIS. RVO.nl uses the LPIS to assess the farmer's application regarding the type and location of a specific EFAs. The EFAs in this thesis are on the EU gross list (this in contrast to normal EU regulations, where only the EFAs selected by an European Member state are part of the EFA-layer) and are stable over a period of three years. The additional requirement whether an EFA is on or adjacent to arable land is not part of this thesis.

An on-the-spot check is possible to assess the application of the farmer, regarding the provided declaration, the existence and total area of EFAs. On-the-spot checks are achieved in two ways: using RS or an actual inspection by the NVWA. Summarizing, this use-case consists of the following processes:

1) Farmer provides location of parcels and gives information about crop,
2) Farmer calculates the greening requirements,
3) Farmer mentions EFA requirements on application,
4) RVO.nl checks consistency of the parcels using a LPIS,
5) RVO.nl checks the attributed EFAs using an EFA-reference layer,
6) On-the-spot checks validate the provided parcel information.

[17] Important conditions are: chamber of commerce registration, minimum 0.3 hectare agricultural parcels, minimum subsidy of € 500

Figure 4.1 shows a UML-model of the described use-case.

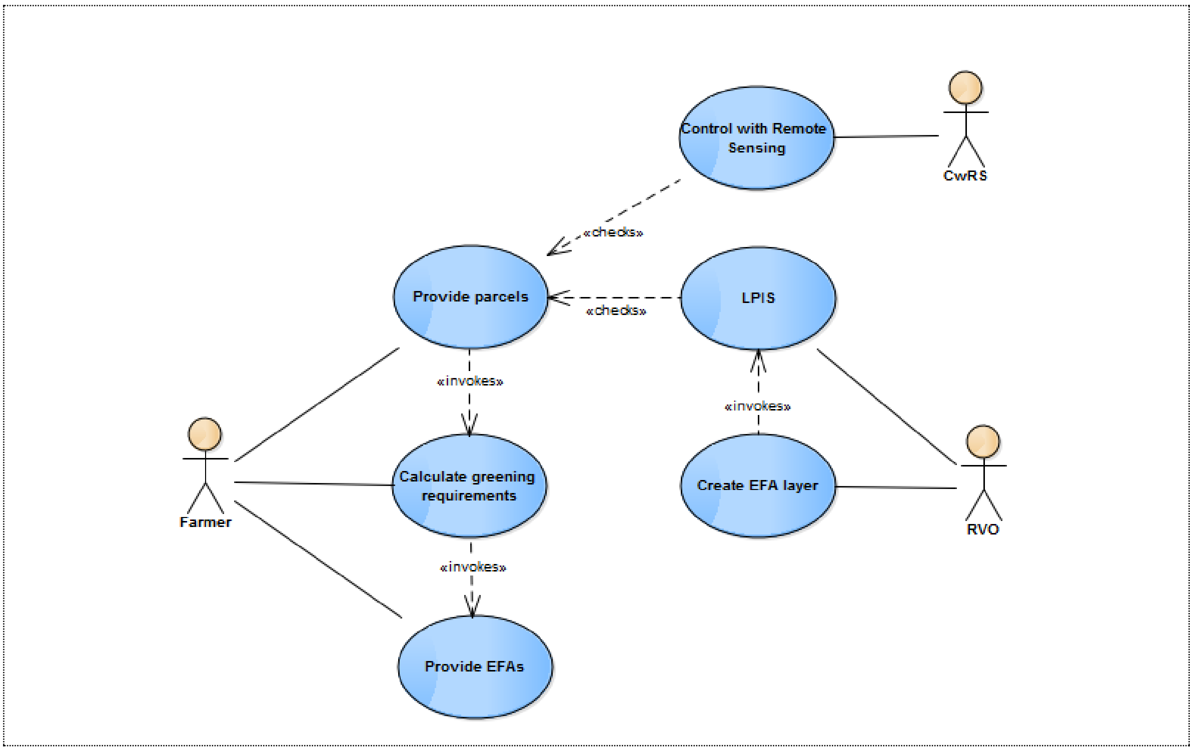


Figure 4.1: Diagram Use-case "Monitoring of EFA requirements for farmers"

It is important to note that this thesis does not explore all the separate processes of the use-case shown in Figure 4.1, but focusses on the creation of the EFA-layer, which is an essential part of the described use-case. It also goes beyond the explicit EU requirements by exploring all the EFA objects provided through the EU gross list and doesn't take land type (i.e. arable land) into account.

4.2.2 Requirements and spatial objects

The use-case delivers user requirements, defines spatial objects and their attributes and relationships. Three important requirements regarding the EFA-layer in this thesis are:

1. Objects of the EFA-layer are on the EU gross list,
2. Objects of the EFA-layer are stable over a period of three years,
3. Objects of the EFA-layer have specific dimensions and spatial representations.

The elements that populate the EFA-layer as well as their measurements are shown in Appendix C, table C.2 and C.3 respectively. These tables show that a potential EFA is a collection of blue and green landscape elements. Based on the properties of these elements a different grouping is possible in: green landscape elements, blue landscape elements and SNL elements. The latter is important as a distinct class, because SNL elements are mentioned explicitly as equivalent practices and are allowed as EFA to meet the greening requirements of the new CAP.

The grouping is also influenced by geographic representation and the attributes that are collected for each element. A draft model displaying Potential EFAs, attributes and relationships is shown in Figure 4.2.

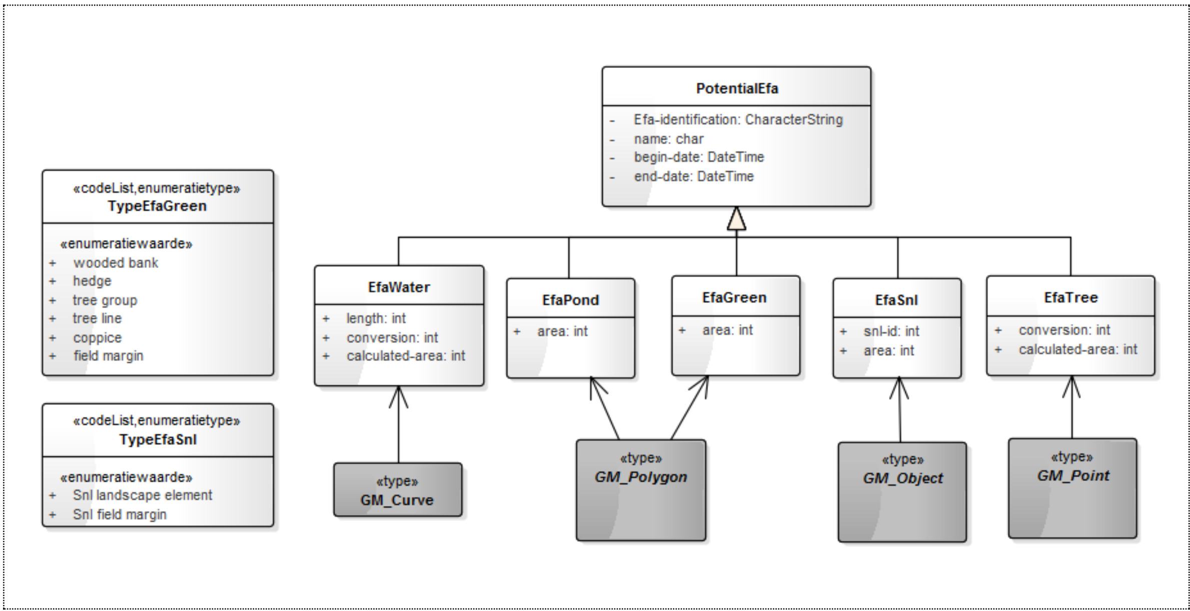


Figure 4.2: EFA-objects of the EFA layer

Although the attributes and geographic representation for ponds and green landscape elements are equal, they are visualized as separate classes to indicate the difference between green and blue landscape elements. The preliminary data model shown in Figure 4.2 and the data specification provided in Appendix C (table C.4), is based on the requirement analysis and allows a structured comparing of the existing IMs for the as-is and gap-analysis in the next section.

4.2.3 As-is and Gap analysis

The EFA-objects of the previous stage are compared to existing IMs. Of these IMs BRT/TOP10 and IMLB are to coarse and not used for further analysis. The remaining IMs provide relevant information regarding landscape elements: IMNa, IMWa, BGT/IMGeo and are already introduced in chapter 2. Appendix A provides a template that enables a structured collection of information regarding data structure and content. This template is used to compare the requirements with the existing situation to perform an as–is analysis and subsequent gap analysis. The completed template showed that four of the nine items are not needed in this use-case or need to be determined later: topology, coverage, object referencing model and portrayal.

From the remaining five items no gaps where indicated in two of them. The first, identifier management, regulates identifiers and the role they play for entities. PotentialEfa objects have their own unique identity. The second, registries, define the used reference system, which is 'Amersfoort/RD new' in all IMs.

Table 4.1 shows the gaps that are indicated for the remaining three items.

Table 4.1: Gap analysis

Object	IMNa	IMWa	BGT/IMGeo
EfaSNL	- Geometric representation tree (polygon instead point) - Accuracy (1:10,000) - Temporal profile: formal history is omitted	n.a.	n.a.
EfaPond	n.a.	- Accuracy (1:10,000)	- Update frequency (18 months instead 12 months)
EfaWater	n.a.	- Accuracy (1:10,000) - Watercourse width calculation	- Update frequency (18 months instead 12 months) - Geometric representation watercourse: polygon instead line.
EfaGreen	n.a.	n.a.	- Update frequency (18 months instead 12 months) - Thematic difference regarding coppice (missing specialization) - Geometric representation of: - tree line as point (separate single tree) or as area - hedge (<30 cm width) as line
EfaTree	n.a.	n.a.	- information not collected in rural area. No further gaps

In addition to these gaps it is already mentioned in section 2.3.1 that IMs are a semantic representation of geographic data and represent a view of the real world captured in an IM. An IM does not give an indication whether the described objects are actually collected. This distinction is shown Table 4.2, which is an updated version of Table 2.8, and indicates if information for a modelled object is collected (green cells), probably not collected (orange cells) or not modeled and not collected (red cells). Table 4.2 indicates that IMNa is the only source for EfaSnl (i.e. SNL objects). The use of IMWa is limited due to the width calculation of watercourses. This leaves BGT/IMGeo as a source for an EFA-layer, although the collection of some objects is questionable as indicated by the orange cells.

Table 4.2: Potential EFAs, objects and Information Models for EFAs

Object	Element	BGT/IMGeo	IMWa	IMNa
EfaWater	Watercourse	Water part	Water part	Only SNL objects
EfaPond	Pond	Water part	Water part	Only SNL objects
EfaGreen	Field margin	Vegetation area	n.a.	SNL Flower strip
	Hedges	Vegetation object ('plus' topography)	n.a.	Only SNL objects
	Coppice	Deciduous forest ('plus´ topography)	n.a.	Only SNL objects
	Wooded bank	Vegetation area	n.a.	Only SNL objects
	Tree in line	Vegetation area or object (collection of single tree)	n.a.	Only SNL objects
	Tree group	Vegetation area	n.a.	Only SNL objects
EfaTree	Tree single	Vegetation object ('plus' topography)	n.a.	Only SNL objects
EfaSnl	Equivalent practice	n.a.	n.a.	Only SNL objects

4.2.4 Data Specification Cycle results

BGT/IMGeo describes all landscape elements that apply as EFA, although some issues are identified in the previous section. A specialization to BGT/IMGeo, further referred to as IMEfa, is promising for several reasons: BGT/IMGeo provides all objects, existing IMs, like IMWa and IMNa, are looking for a connection to BGT/IMGeo by using semantics from this model. This turns BGT/IMGeo into a de-facto standard. It is also a better alternative source for blue landscape elements, since IMWa uses deviating definitions for watercourse width. For this reason a specialization is created for BGT/IMGeo that aims in modelling needed EFA-objects.

Table 4.2 indicates that two BGT/IMGeo objects are important in this regard: water part and vegetation area ('Begroeid terreindeel') and 'plus' topography of these classes. Figure 4.3 show the extension to the BGT/IMGeo model and the objects and attributes that are part of this extension. (A) shows in green the additional EFAobjects for the BGT/IMGEo object 'waterpart'. This specialization adds two objects: EFA watercourse (EfaWaterdeel) is added to the GML object Waterbody to change the geometry and add the desired attributes that are not provided by the original BGT/IMGeo model. EFA pool (EfaPoel) includes an additional attribute. (B) shows the attributes for both objects. (C) shows that class 'Vegetation' is specialized by adding three objects. EFAGroen is a specialization of PlantCover. EFAHakhout is a specialization of the IMGeo object PlantCover, which offers the possibility to register willow coppice. (D) shows the additional attributes and an enumeration list. A feature catalogue or object catalogue that provides definitions and descriptions of objects is a normal part of an IM. This is not included in this thesis.

Appendix C, Table C.6, suggests a mapping of IMNa onto IMEfa. Note that further research is needed regarding harmonization of this data.

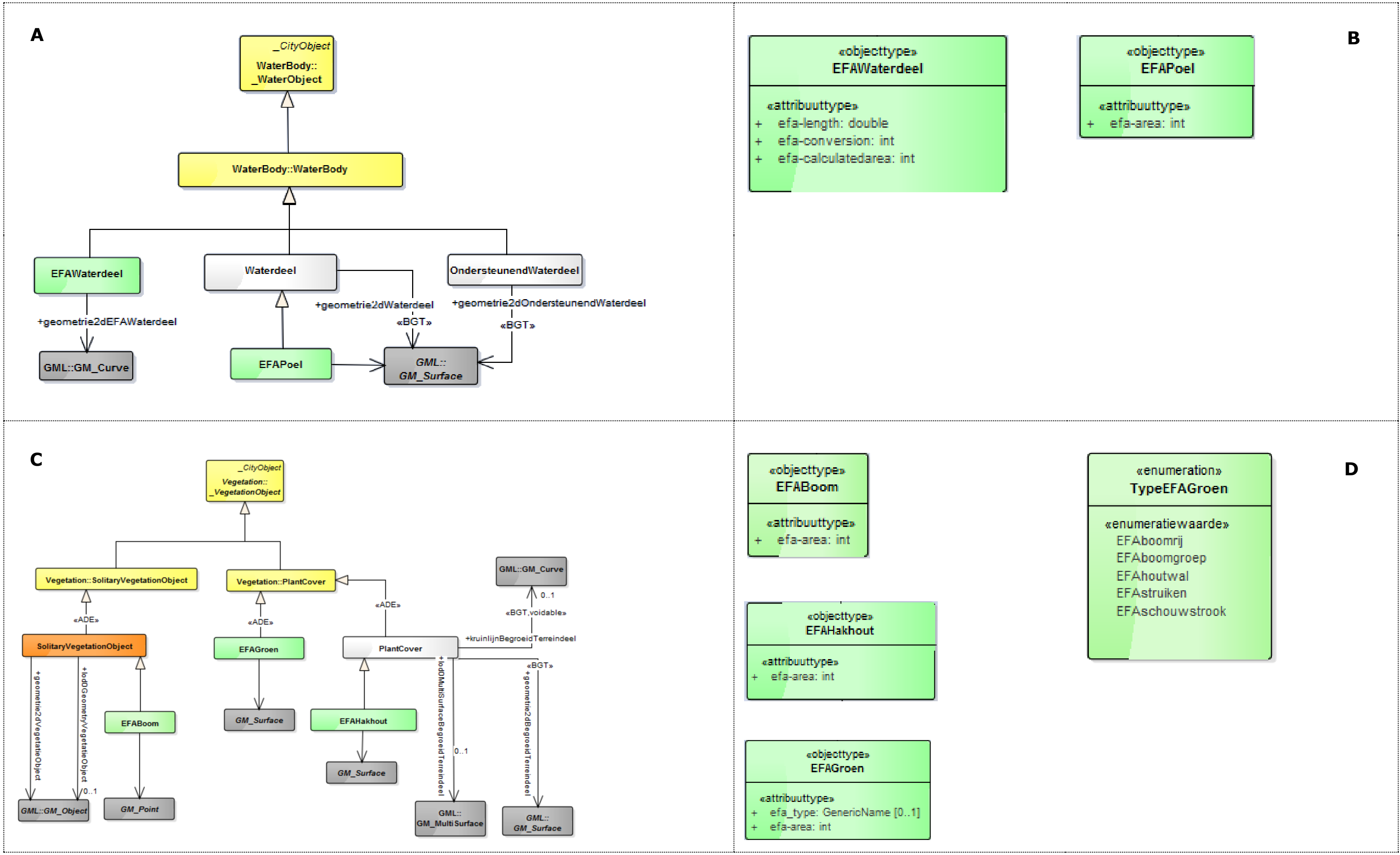


Figure 4.3: EFA extensions to BGT/IMGeo

4.2.5 Summary Data Specification Cycle results

Previous sections show that the use of a Data Specification Cycle resulted in a use-case (Monitoring of EFA requirements for farmers) from which one specific process (create an EFA-layer) is used for further analysis. This process provides all the objects that are needed to define and model EFA-objects and their constraints. The need for this information is also observed in the policy gap mentioned in section 2.2.4.

The subsequent definition of requirements and objects served as input for an as-is and gap analysis. For the as-is and gap analysis only BGT/IMGeo, IMWa and IMNa are used, showing that these IMs provided all the needed objects. However, some IMs lacked technical requirements, i.e. scale, geometric representation, update frequency and thematic difference in the case of coppice.

IMNa and IMWa provide only information for a subset of the EFA objects, namely landscape elements that are part of SNL or objects relating to water, respectively. IMLB is a specific model for the exchange of geospatial data needed for an effective monitoring of (EU) regulations. In this sense IMWa, IMNa, and IMLB are created for a specific domain and of less importance for general use. BRT/TOP10 is dismissed because of using a minimum threshold, making the model to coarse for further use.

BGT/IMGeo is becoming a 'default' IM, to which the other contrasted models adhere. It is also a better alternative source for blue landscape elements, since IMWa uses deviating definitions for watercourse width. For this reason a specialization is created for BGT/IMGeo that aims in modelling needed EFA-objects.

The specification cycle also showed that there is a difference between modelled objects and actually collected information. These are two different things and not formerly indicated when describing the IM gaps (section 2.3.9). This mismatch between modelled and collected information is identified for single trees and tree lines. The latter can be collected as a collection of single trees, but also as the required vegetation area. Collection of trees (single and line) is not structural in the rural area.

4.3 Discussion data specification cycle

The Data Specification Cycle is used in two ways: on one hand it served as a framework to assess the 'fitness for use' for specific IMs and the creation of a new model, IMEfa. This model is an extension to BGT/IMGeo and includes potential EFAs. On the other hand the cycle identified unavailable objects (i.e. single trees and tree lines), for which RS could be an answer in their collection.

A complete IM not only defines the objects, but also shows the relation between objects. This is indicated in section 2.3. Defining an object in modelling is not only about literally describing what an object is. It also shows other characteristics of an object, such as its geometry, temporal aspects, data quality and data capturing. As described by (Devillers & Jeansoulin, 2006), these aspects relate to the internal data quality, i.e. the level of similarity between the produced data set and the perfect dataset, i.e. data produced without errors. This is in contrast to the external quality which looks for the fitness for use, i.e. how the dataset fits the user needs. The Data Specification Cycle uses both aspects of geospatial data and quality.

The Data Specification Cycle enables a structured way of comparing both internal and external data quality of different datasets. The use of a template was helpful to collect this information in a structured manner.

The complete cycle consisted of only two meetings; one for the selection of a use-case and a second to determine the progress. Remaining information was acquired by exchanging emails and phone calls. Only two meetings is a minimum to gather the needed information and the use of email and phone did not completely meet the iterative character of model building.

The cycle starts with a use-case and, although commonly used in the creation of IMs, INSPIRE does not give any advice on its implementation. The selection of a good use-case is essential, since its intention is to define and structure the spatial objects of interest. Only a single process ("create EFA-layer") of a complete use-case ("how to monitor EFA requirements") is scrutinized in this thesis, which raises the question whether a single process provides enough information to gather all the objects of interest. The main task in this thesis is to explore the objects that populate an EFA-layer, which is served by the selected process. However, by only pursuing a single process the complete relation to other objects is missing. And although this is not directly needed for an exact definition of the desired objects, it does gives insight in how other objects relate to EFA objects. This information could also be of use for RS. For example, the relation between an EFA and arable land is omitted in this thesis. For the actual collection of EFAs this relation is interesting and modeling it makes this relation visible. RS could benefit from this knowledge, because it shows the objects of interest and thereby rules out other areas, e.g. grassland.

Assessing the fitness for use starts with a solid definition of objects identified in the use-case. Finding a definition for objects was difficult for several reasons. The use of a hypothetical situation, as was the case by using a gross list inhibited a good definition, because there was no body of knowledge available regarding EFAs that were not implemented by The Netherlands (i.e. are not on the Dutch net list). Also EU regulation did not always provide a solid definition, which is left to working groups and member states. EU only gives guidelines regarding minimum measurements of objects and leaves out other important indicators. This shortage is also connected to the aforementioned lack of a body of knowledge, but also to the political discourse. A political discourse which is exemplified by the intention to change biodiversity and to take measures to alleviate climate change, but also wants to reduce administrative burden and concerns normal farming management. Policy makers claim to keep implementation simple, but by incorporating different views they make it very difficult to implement it. This conflicts with the view of modelers who are interested in a solid definition of geospatial data, such as geographic representations and data quality to name some geospatial denominators.

As a result of this discourse policy and implementation changes, even to date. In May 2015 the EU announces a simplification of the CAP and offers member states the freedom to create an EFA-layer that only shows the declared EFAs as one of the proposed six changes (EU, 2015). Nonetheless, this is not exceptional in the conception of IMs. The volatile reality is their playing field, which also explains the regular update of most of the IMs used in this thesis.

Next to assessing the requirements, also the definition of some of the IMs that are used as a reference were ambiguous. The information is important in the next stages, where desired objects are contrasted to existing objects. BGT/IMGeo leaves room for interpretation of objects to allow reuse of already collected geospatial data that is already available by stakeholders. Definitions are partial or omitted. For instance, the minimum dimension of objects is clearly specified in TOP10, but omitted in BGT/IMGeo. A risk of this freedom is that geospatial data is not collected in a consistent manner throughout The Netherlands.

4.4 Delineation trees, OBIA and Tree Register

Trees (single and line) are identified as missing objects in the Data Specification Cycle. The delineation of these objects is described in this section, using OBIA and two existing datasets: a Tree Register in an original and corrected version. The following sections give a short description of the objects of interest. Next the results of segmentation and Segmentation Goodness Evaluation are shown. After classifying the datasets and an assessment of their accuracy, this section wraps up by summarizing the results.

4.4.1 Typology

Table 4.3 defines the elements of interest. The definition is derived from the Data Specification Cycle (section 4.2).

Object	Dimension	Geometry	Scale
Tree (single)	≥ 4 m crown diameter	Point	1:5,000
Tree (line)	≥ 4 m crown diameter, space between crowns ≤ 5m	Polygon (crown area)	1:5,000

Table 4.3: Typology of elements

The elements mentioned in Table 4.3 are delineated using OBIA or Tree Register as source.

4.4.2 Segmentation

Before evaluating the exact results of the Segmentation Goodness Evaluation it is appropriate to show the result of the selected segmentation parameters in Figure 4.4. Only a small section of the complete study area is shown. The used parameters are: scale 10, shape 0.5 and compactness 0.1.

4.4.3 Segmentation Goodness Evaluation

Section 3.3.4 describes the proposed evaluation method that is used to compare the different segmentation parameters for MRS. Section 3.3.2 describes the area and reference layer that provides the objects used in this evaluation. This section presents the results of the Segmentation Goodness Evaluation, which ultimately derive the segmentation parameters that are needed for a complete segmentation of the study area.

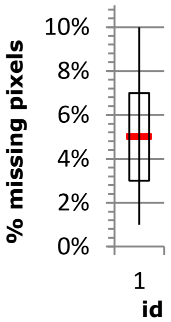
After executing the 200 different parameters in eCognition and a subsequent export of the results, the GIS workflow as described in figure 3.5 was applied for each parameter. A first evaluation, described in section 3.3.4, of the results between part A and part B in Figure 3.8 was performed.

Figure 4.4: Study area and segmentation result at scale 10, shape 0.5, compactness 0.1

After this first evaluation 117 segmentation results are dismissed for further evaluation: 65 combining height and NDVI and 52 using height as a segmentation basis. Dismissed parameters consisted mostly of large scales (i.e. 12 and 15) or parameters that use a combination of height and NDVI for segmentation. The final Segmentation Goodness Evaluation continues with 83 different segmentation parameters: 35 combining NDVI and height and 48 using height as segmentation basis.

The complete results of the Segmentation Goodness Evaluation are shown in Appendix D regarding segmentation on object height and Appendix E regarding segmentation on object height and NDVI. This section presents the main findings. Figure 4.6 shows the median of missing and extra pixels for tree reference objects, Figure 4.7 shows these results for tree lines. Each single segmentation parameter is labeled with an identification number. A full listing of parameter settings and identification numbers is available in Appendix D and E. Also shown is a 25 percent threshold demarcating the threshold above which objects are difficult to reconstruct, as mentioned in section 3.3.4. Also indicated is the number of deformed objects due to extra or missing pixels. A deformed object exists if a threshold of 25 percent missing or extra pixels is exceeded.

As indicated in section 3.3.2 a collection of four single trees and three tree lines are used in this Segmentation Goodness Evaluation. The median, first and third quartile and outliers for the missing pixels and extra pixels for trees are evaluated using the boxplots shown in Figure 4.8. The same is done for tree lines in Figure 4.9. Figure 4.5 explains the construction and use of boxplots in this thesis.



The boxplot shows how the data is distributed by indicating several parameters. In this example a single parameter with identification 1 has a median value of 5 percent missing pixels, indicated by the red line. The bottom and top boundary of the box show the first and third quartile respectively. In this figure 25 percent of all objects have a value of 3 percent missing pixels and 75 percent of all objects have 7 percent missing values. Maximum and minimum values is indicated by the thin lines on top or on the bottom of the box.

Figure 4.5: Boxplot explained

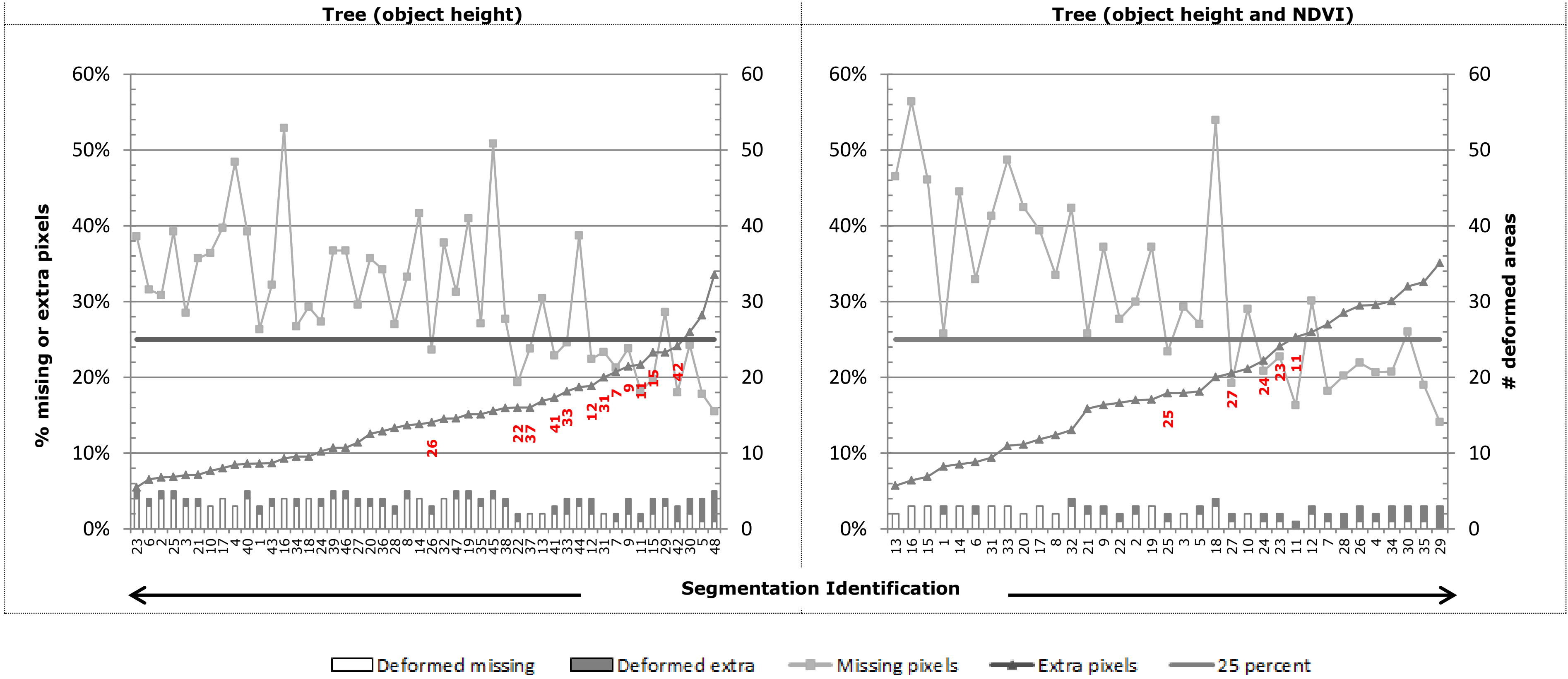


Figure 4.6: Median percentage showing missing and extra pixels for trees. Segmentation based on object height (left) or object height and NDVI (right)

Figure 4.6 shows that the percentage of missing pixels is almost the inverse of the percentage extra pixels. The range of extra and missing pixels is comparable for segmentation based on height or based on the combination of height and NDVI. More parameters based on height segmentation stay below the 25 percent threshold for missing or extra pixels. These parameters are selected for further evaluation, as indicated by the red identification numbers. Although the number of deformed objects (objects that miss or gain 25 percent or more of their pixels) is lower for the combined height and NDVI segmentation the number of selected parameters is lower compared to the height segmentation. 12 parameters are selected in case of height segmentation and 5 parameters for the height and NDVI segmentation.

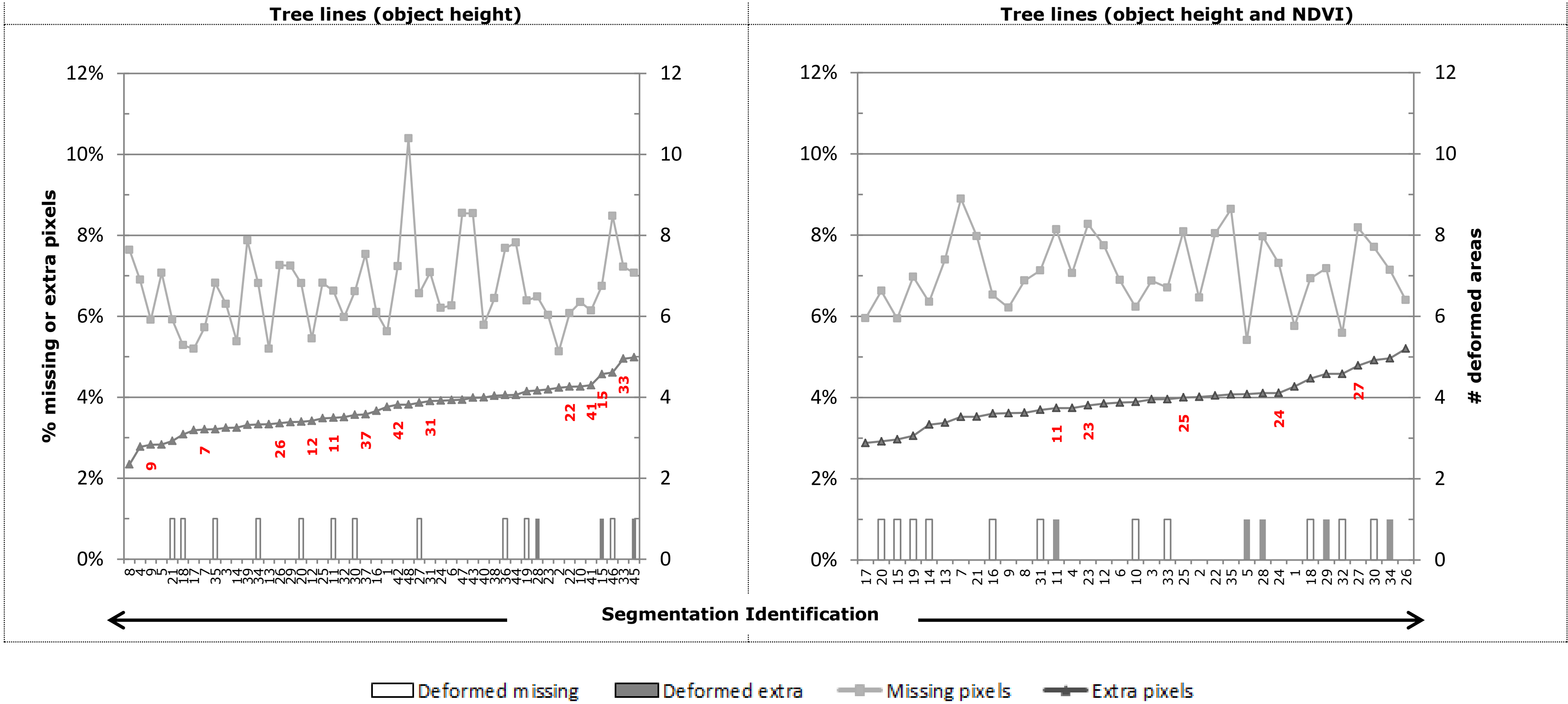


Figure 4.7: Median percentage showing missing and extra pixels for tree lines. Segmentation on object height (left) or object height and NDVI (right)

Figure 4.7 illustrates that the results for tree lines is less critical than for single trees, because all parameters stay well below the 25 percent threshold. The parameters selected in Figure 4.6 are also indicated in this figure. The ranges for the percentage of extra pixels and missing pixels are comparable for both segmentation options (height versus height and NDVI). The selected parameters 11 and 15 have deformed areas due to missing pixels in the case that the segmentation is based on height. For the combination of NDVI and height, parameter 11 shows a deformed area due to extra pixels. All deformed areas are on the account for one object, the tree row stable. The selected parameters are examined more closely using the boxplots of Figure 4.8 and Figure 4.9 on the next pages.

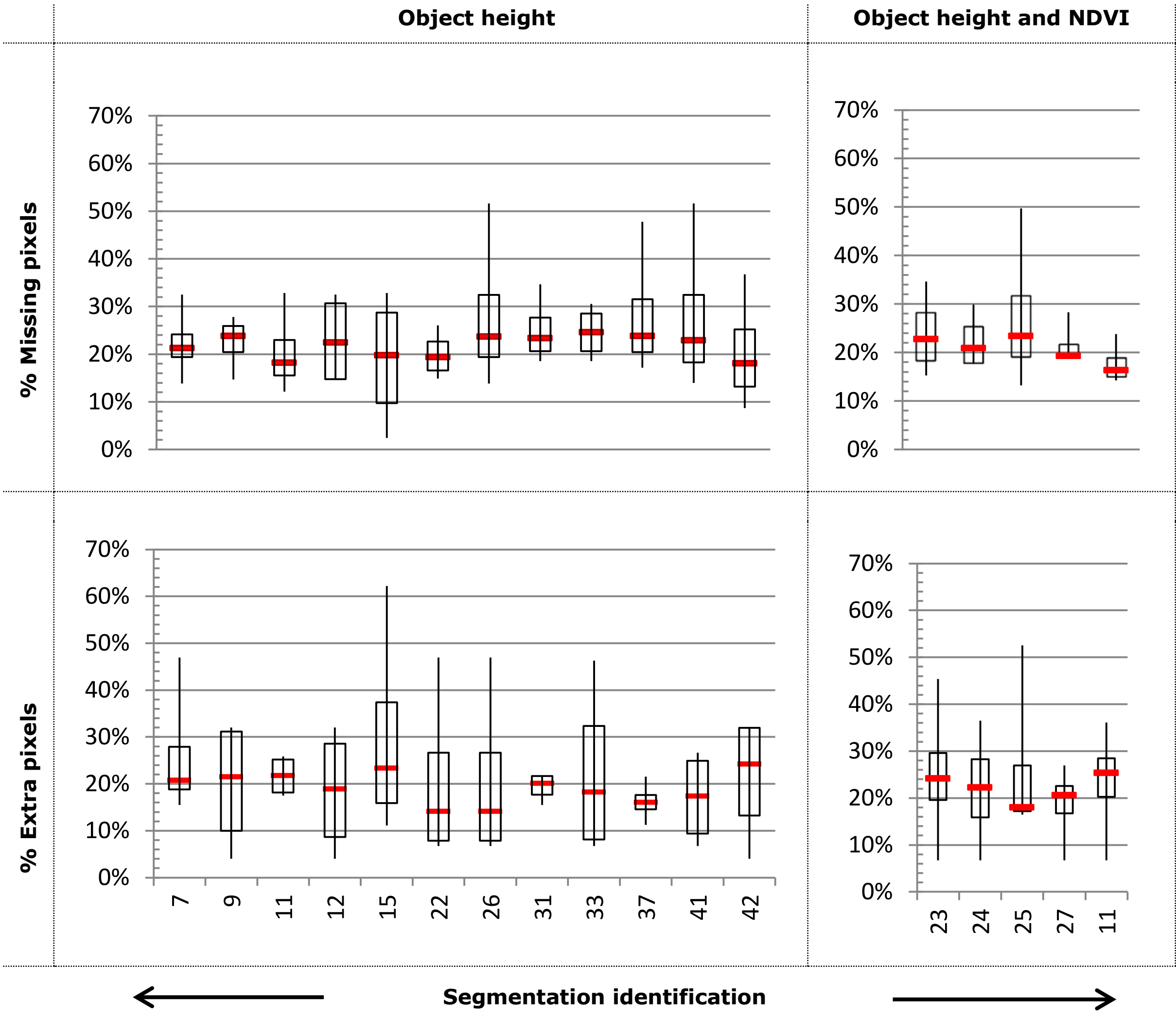


Figure 4.8: Boxplot showing missing and extra pixels for trees. Segmentation on object height (left) and object height and NDVI (right)

The boxplots in Figure 4.8 indicate that no parameter stays within the 25 percent missing or extra pixels threshold. There is a wide variety in ranges. However some parameters stand out if the aim is to select parameters with a low median, a narrow box and no extreme outliers. This good performance is available for parameters 11, 31 and 42 based on height segmentation or parameter 27 for segmentation based on NDVI and height. Of these parameters 31 (height segmentation) and 27 (height and NDVI) show good overall results.

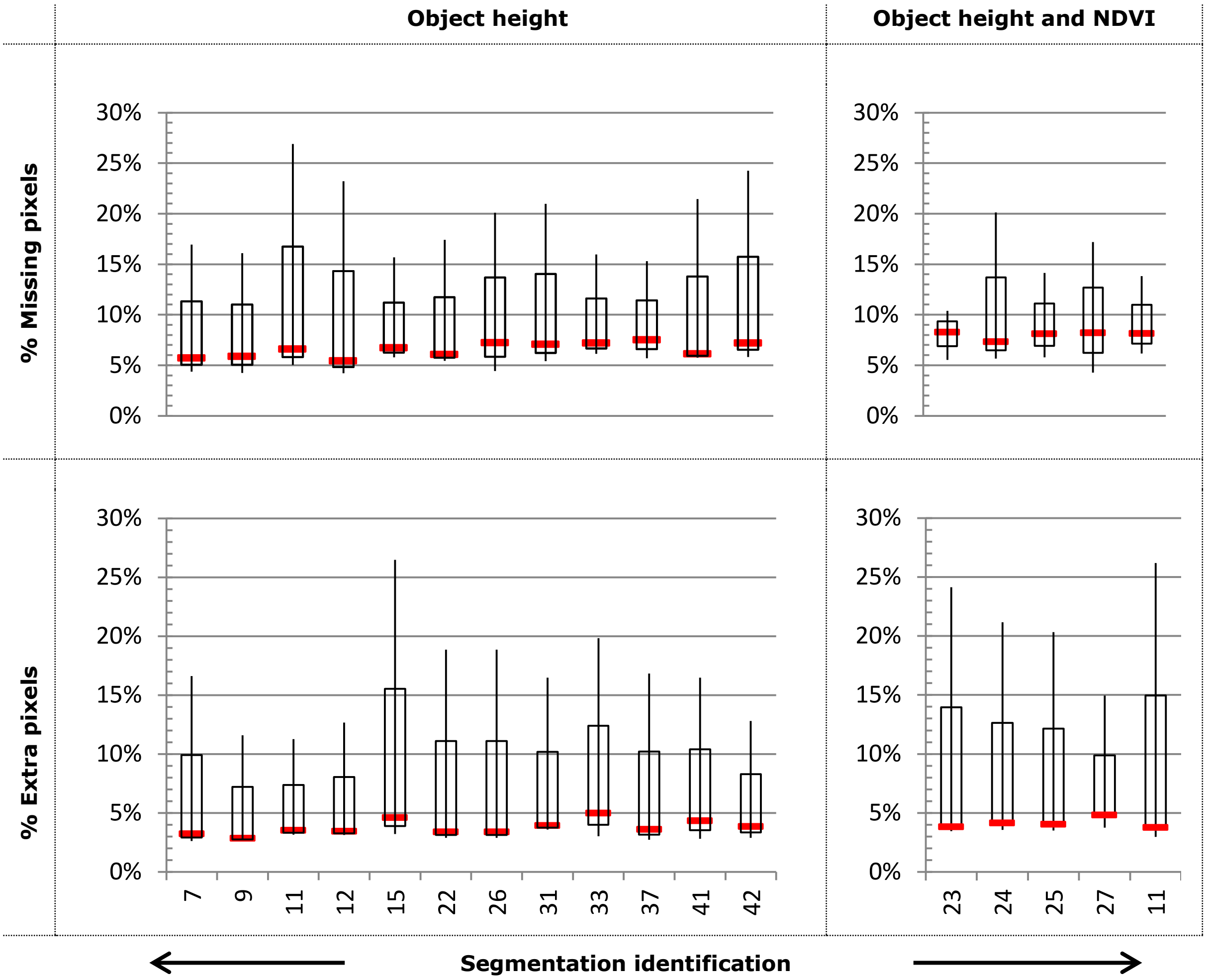


Figure 4.9: Boxplot showing missing and extra pixels for tree lines. Segmentation on object height (left) and object height and NDVI (right)

Figure 4.9 indicates an asymmetrical distribution for the tree line results. All parameters are skewed right, indicating fewer observations of the lower values. This is mainly caused by one single object; a tree line stable shown as object 1 in Figure 3.3. This reference object is difficult to detect in all parameters resulting in a large percentage of missing and extra pixels. The combined results for tree segmentation, Figure 4.8, and tree line segmentation show that parameter 31 (height segmentation) shows the best overall result in tree line delineation. This identification number refers to the segmentation parameter: scale 10, shape 5, compactness 1.

Criterion 3 of the evaluation parameters (section 3.3.4) referred to the area of the biggest sub-object within a reference object. This is translated as a segment that fits completely (i.e. for 100 percent) within the reference object. Results indicate that the number of segments that fit this description is very limited for the reference objects.

Figure 4.10 shows the segmentation results for reference object 1 (tree line stable in Figure 3.3) for a better understanding of the difference between segmentation based on height or height and NDVI. The figure shows four different segmentation parameters superimposed on the datasets for object height (column 1 and 3), NDVI (column 2 and 4) and the true-orthorectified aerial image.

Shown are the selected parameter scale 10, shape 0.5 and compactness 0.1 and three other parameters using scale 10 and shape 0.1 combined with a compactness of 0.1, 0.5 or 0.9.

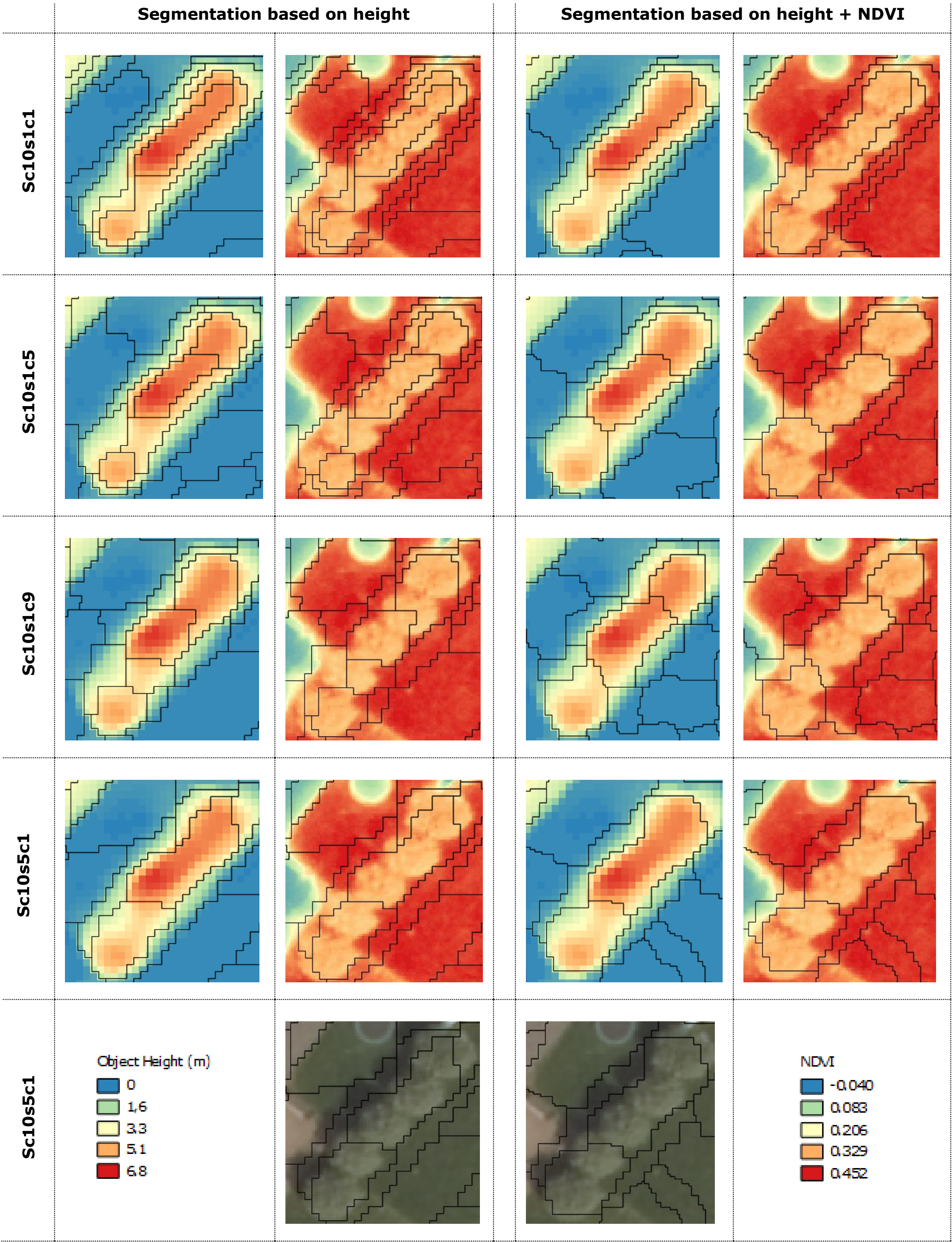


Figure 4.10: Segmentation based on height or height and NDVI

Figure 4.10 shows that larger compactness parameter creates more “square” segments, while a larger shape parameter reduces the importance of color variation in favor of segment shape. An inverse relation that is already explained in section 2.4.2 and Figure 3.5.
The color in the height datasets shows more variation, which leads to more and smaller segments in the segmentation based on height, compared to segmentation based on Height and NDVI. This effect is reduced slightly by using a larger shape parameter (i.e. sc10s5c1). Adding the NDVI dataset creates more “fuzziness” along the edges of the tree line. An explanation is that the height dataset shows a large variance around the edges, but this variance is more uniform compared to the NDVI where the distinction between tree and background is more difficult to make and with less variance. This effect is possibly increased by a difference in resolution between the height (75 cm) and NDVI (25 cm) datasets.

To conclude this section; the results indicate that no parameter is without deformed objects. The number of deformed objects due to missing pixels is larger. Of the 48 tested parameters based on object height only 12 stay within the 25 percent threshold for extra or missing pixels. For segmentation based on object height and NDVI this is only the case for 5 different parameters.
In general, the results indicate an under-segmentation for most parameters in the detection of trees. The results confirm, as indicated earlier, that the segmentation of trees is more critical than that of tree lines.

4.4.4 Classification results

This section describes the classification of the three used datasets: OBIA, tree register, and corrected tree register. As indicated in Figure 3.9 a comparable workflow is used for the classification of objects in all three datasets. However, an additional step in the OBIA classification is needed for the classification of potential trees crown. The exact parameters are tested by selecting several segments coinciding with tree canopy according the true-orthorectified image. By exploring the table attributes the following values are selected to make a good distinction between tree canopy and other objects possible: median NDVI>0.19 and minimum object height > 0.75 m.

The use of the “Tree Group Mask” and “Road Part Mask” was helpful in separating distinct elements. Figure 4.11 shows how the segments are colored according the area they coincide with. This prevented an erroneous classification of distinct objects but with touching canopy. However, to improve the classification result some manual selecting and deselecting of segments was necessary. Only objects outside the “Tree Group Mask” are processed further. This is also in line with the outcome of the Data Specification Cycle, which states that BGT (however not available) enables the distinction in tree groups and the interest is in detecting single trees and tree lines.

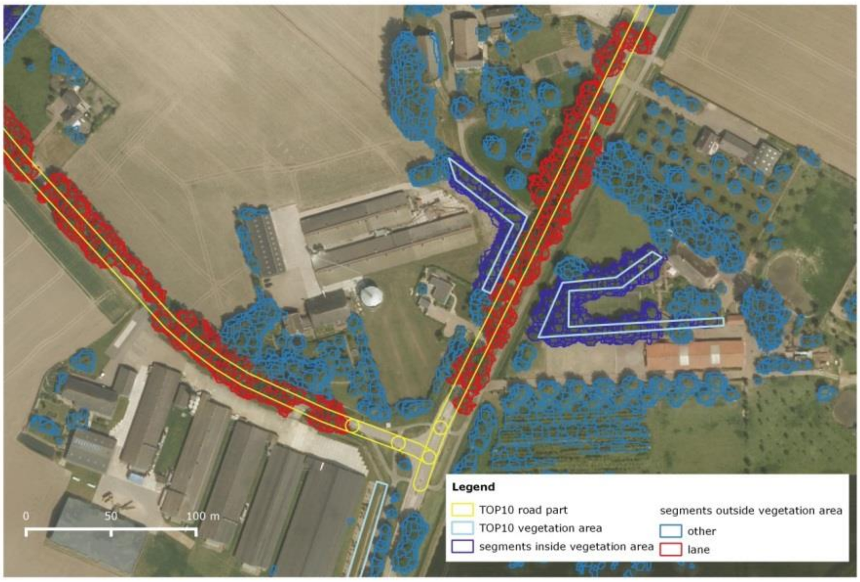


Figure 4.11: Use of TOP10 to prevent over merging of objects

(Wiseman, et al., 2009) performed a classification by querying the attributes of a shape file for the selection of segments that met specific conditions. A similar approach is used in this thesis by classifying the remaining objects through querying the shape files' attributes using Standard Query Language (SQL). This is done using the classes and requirements as mentioned in Table 4.4.

Table 4.4: SQL-based classification of trees

Classification	Requirement
Tree	Area ≤ 12.5 m^2
Tree (CAP)	Area > 12.5 m^2 AND (Shape index ≤ 1.7 AND Compactness ≤ 5.5 AND Area < 315 m^2)
Tree Line	Shape index > 2.5 AND Area > 12.5 m^2
Other	Remaining objects

Table 4.4 shows a distinction in "tree" and "tree (CAP)". This difference is based on the minimum diameter of 4 meter for a tree that is allowed for the new CAP (see Appendix C). A diameter of 20 meter, resulting in an area of 314 m^2, is regarded as a maximum tree canopy. The compactness, explained in figure 3.5 proved to be a good parameter to separate regular shapes from irregular shapes and helped in detecting a normal tree canopy. Table 4.5 gives an overview of total area (m^2), the number (#), and mean area size ($\bar{x}$ in m^2 per object) of object types that are created in the three data sets. These figures are calculated after intersection of the classification result with the area of interest.

Table 4.5: Tree canopy detected in the three datasets

	OBIA dataset			Tree register			Tree register corrected		
	m^2	#	$\bar{x}$	m^2	#	$\bar{x}$	m^2	#	$\bar{x}$
Tree	4,773	1,013	5	8,038	1,408	6	2,537	393	6
Tree (CAP)	26,664	620	43	34,812	843	41	32,528	720	45
Tree line	109,508	223	491	111,879	281	398	96,686	186	520
Other	162,602	498	327	154,208	714	216	142,997	576	248
Inside TOP10	384,845	426	903	461,340	4,016	115	356,409	1,918	185
Total	**688,392**	**2,780**	**-**	**770,277**	**7,262**	**-**	**631,157**	**3,793**	**-**

Table 4.5 shows some striking differences between the three datasets. For instance, the number of small trees (not CAP) is the lowest in the corrected Tree Register whereas the total number of objects is lowest in the OBIA dataset, although the total area tree cover is comparable to the corrected Tree Register. The mean object size indicates a small tree size in the OBIA dataset. Precise results indicate a total of 200 “trees” with an area size below 2 m^2 in the OBIA dataset. The Tree Register and corrected Tree Register score respectively 69 and 19 “trees” with an area below 2 m^2. This indicates a production of slivers during the classification. However, the accuracy assessment provided in the next section is needed to appreciate the real meaning of these results.

Figure 4.12 shows the classification result of the three datasets.

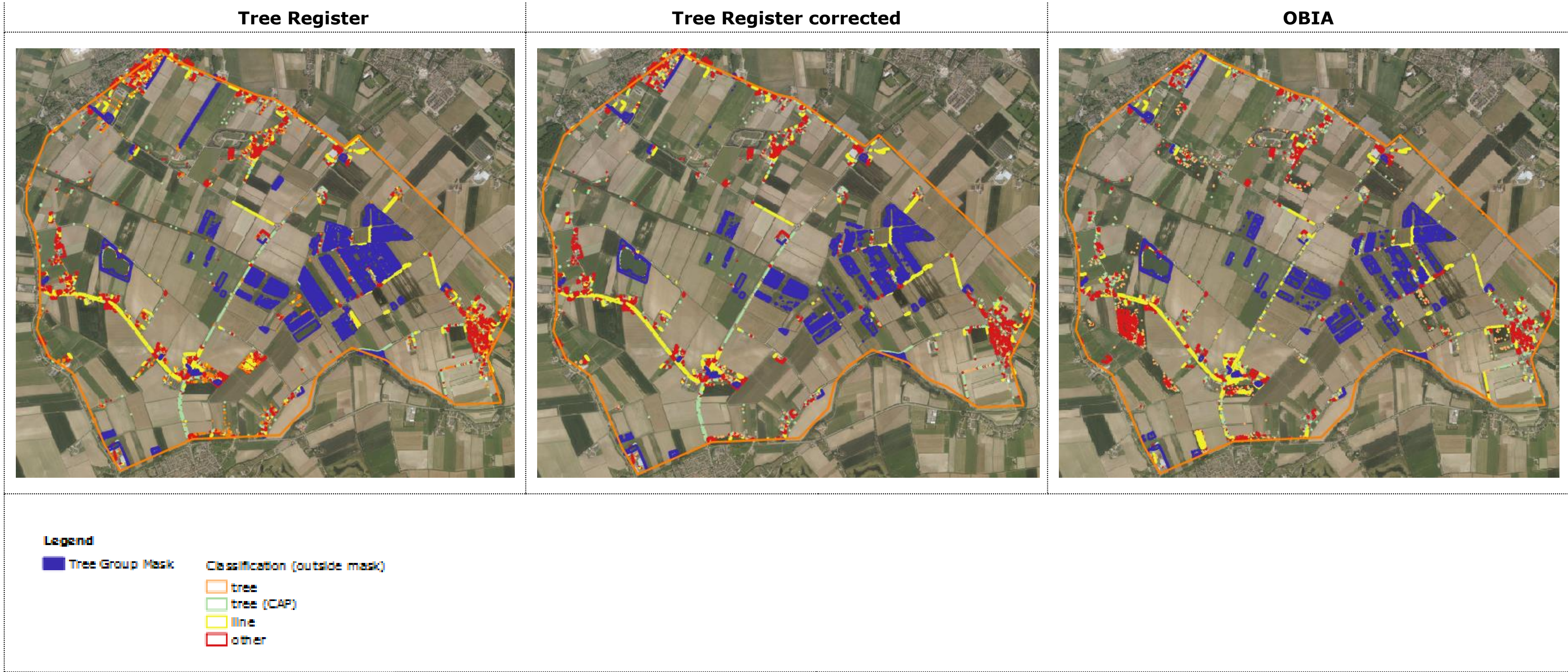


Figure 4.12: Classification results of the three datasets

Although the maps are small, some differences between the tree datasets can be observed. The ´Tree Register´ show more tree cover inside the TOP10 mask. Most of these vegetated areas consist of coppice, which is pruned and cut periodically. A correction of the ´Tree Register´ based on new images clears these periodic changes, as is the case in the TOP10 areas in the middle of the area. The long linear TOP10 area in the top left of the ´Tree Register´ consists of small trees (crown < 4 meter). These trees are deleted in the corrected Tree Register, because they are not visible in the used images. Therefore this area is also omitted in the OBIA dataset. An area in the bottom left of the 'OBIA' attracts attention, because it is not visible in the other datasets. This is caused by reflection leading to erroneous height in the stereoscopic processing. Figure 4.13 shows an example of these errors in detail.

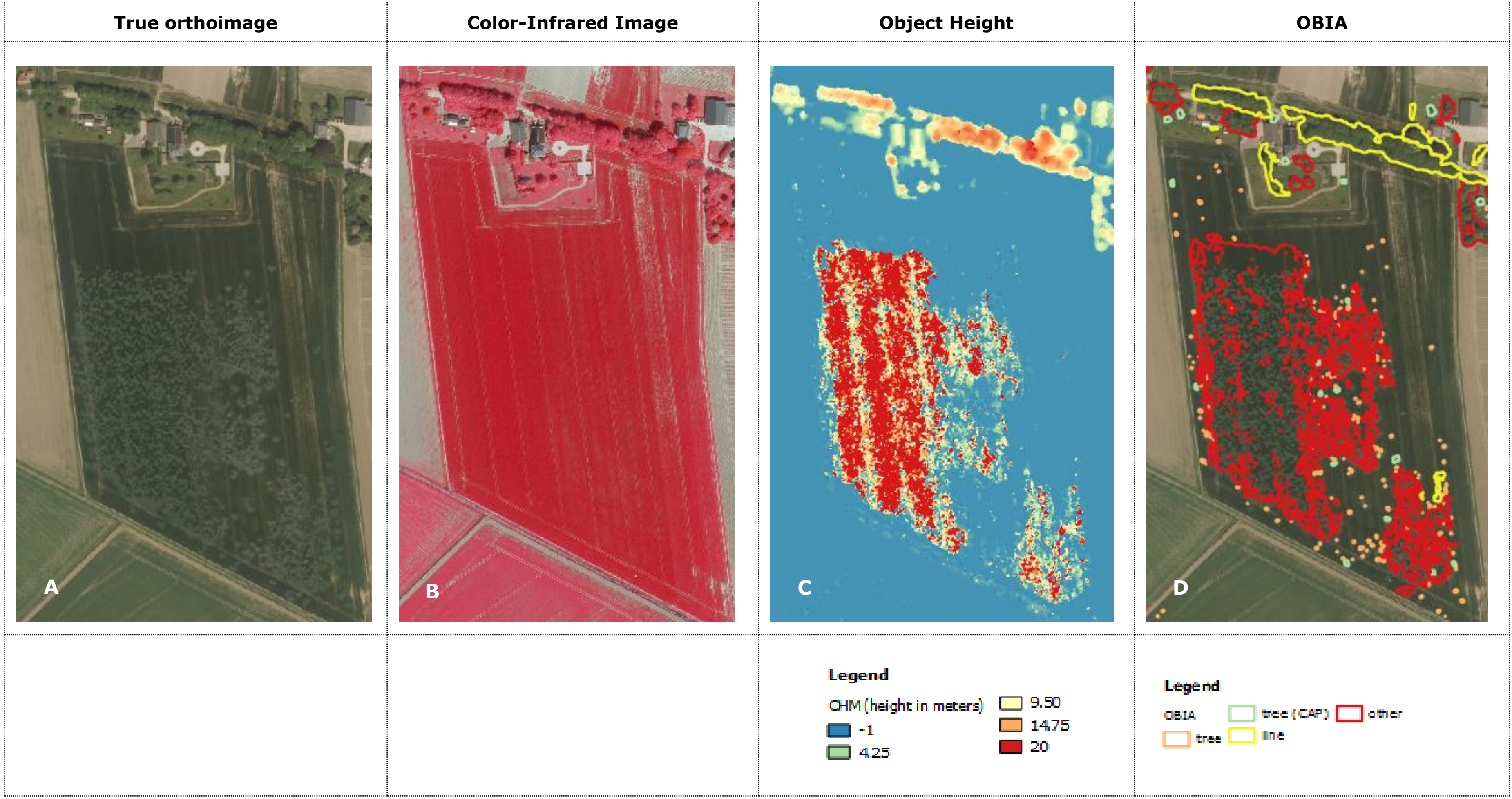


Figure 4.13: Height error and tree detection

Figure 4.13 shows a detail of the area that is also spotted in the low bottom left area of Figure 4.12. The true orthoimage (A) shows objects that look like reflection. These objects don’t occur in the CIR-image (B). The objects are interpreted as elevated objects in the DSM (C). Due to segmentation based on object height, these objects are subsequently identified as tree cover in the OBIA method (D). There are more areas where these anomalies occur, for instance over water covered areas. This is probably caused due to reflection.

4.4.5 Accuracy assessment

A sampling of 15 points is the basis for the accuracy assessment, as mentioned in section 3.3.6. Figure 4.14 shows how the samples are distributed across the study area, and also shows details for sample point 17 and sample point 20 as an example.

Figure 4.14: Sample points for accuracy assessment

A 60 meter buffer is applied to each point and all trees and tree lines intersecting this buffer are digitized. This also results in digitizing beyond the boundary of a buffer in case a tree or tree line exceeds this boundary.

A total of 131 validation objects are digitized, divided over three groups: 35 tree, 79 tree (CAP) and 17 tree lines. The category “tree line” consists of tree lines with a minimum of 2 trees. The validation objects are used to assess the object accuracy indicators (correctly assessed, false positive, false negative). Figure 4.15 shows the result of this assessment.

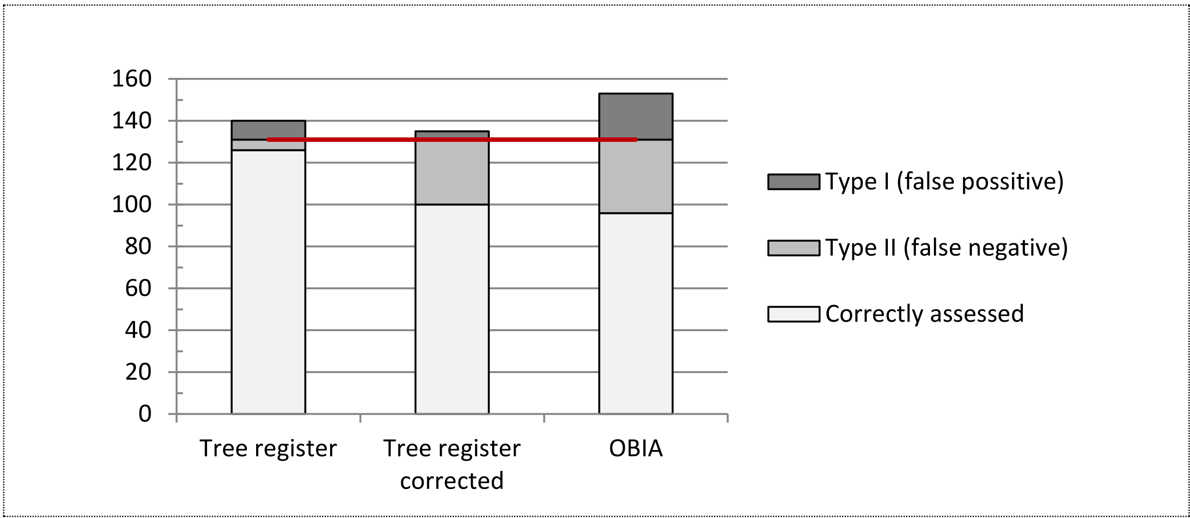


Figure 4.15: Thematic accuracy indicators for the three datasets

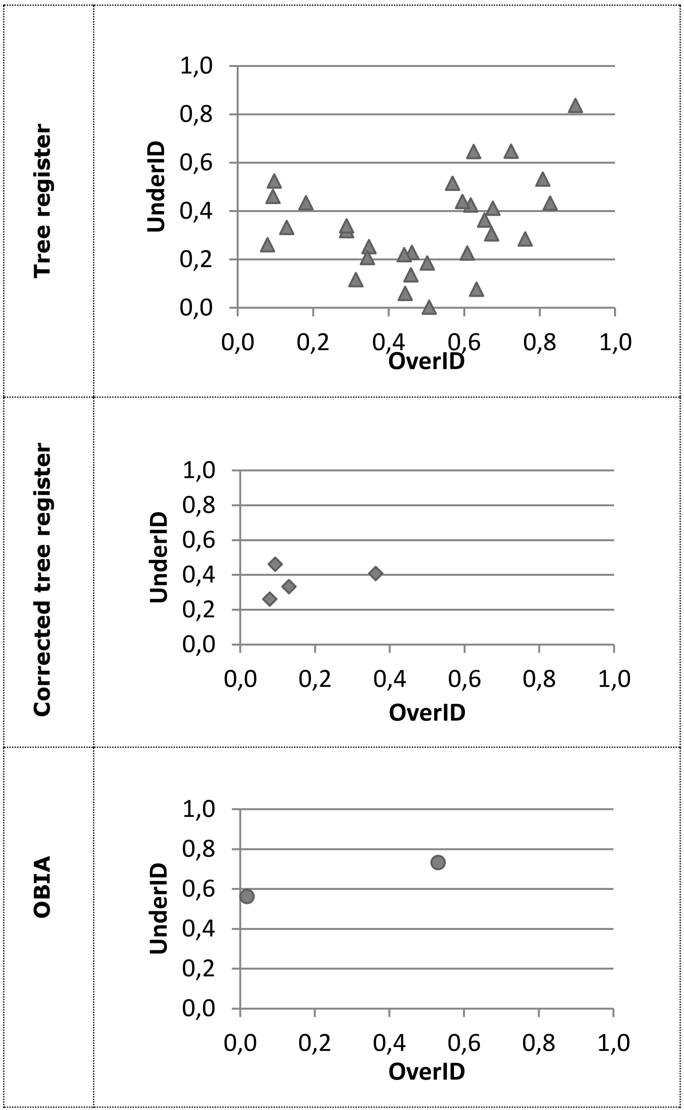
Figure 4.15 shows the 131 validation objects and the objects that are detected as Type I error. These results are also presented in Table 4.6. Results indicate that the original Tree Register identifies 126 out of 131 validation objects (96%) correct. The corrected Tree Register and the OBIA dataset perform below this score with 76% and 73% respectively. The difference between the corrected and uncorrected Tree Register is caused by false negatives (Type II errors) in detecting small trees (i.e. trees that do not meet the CAP requirements). These smaller trees are also missed in the OBIA dataset, which explains the large Type II error. Results indicate the best score with regard to false positives (Type I errors) for the corrected Tree Register. Overall, the OBIA method underperforms with regard to the object accuracy indicators.

	Tree Register	**Tree Register corrected**	**OBIA**
Correct	126 (96%)	100 (76%)	96 (73%)
Type I error[18]	9 (7%)	4 (4%)	22 (19%)
Type II error	5 (4%)	31 (24%)	35 (27%)

Table 4.6: Detection rate, Type I and Type II errors for tree objects

The object boundary assessment for small trees (diameter < 4 meter) is evaluated in Figure 4.16.

[18] Percentage Type I error is calculated as: (Type I error/(Correct + Type I error))*100



Three scatterplots illustrate over- and underID for the three datasets. The scatterplots also show that most small trees are detected in the Tree Register, while OBIA was successful in detecting two small trees.

Also shown is that the accuracy parameters for trees in the Tree Register show a large variance. The trees that show the largest over- and underID are removed from the corrected Tree Register, leaving only four small trees.

Figure 4.16: Scatterplot of over- and under-segmentation for small trees

The object boundary assessment for large trees (diameter ≥ 4 meter) and tree lines is shown in Figure 4.17.

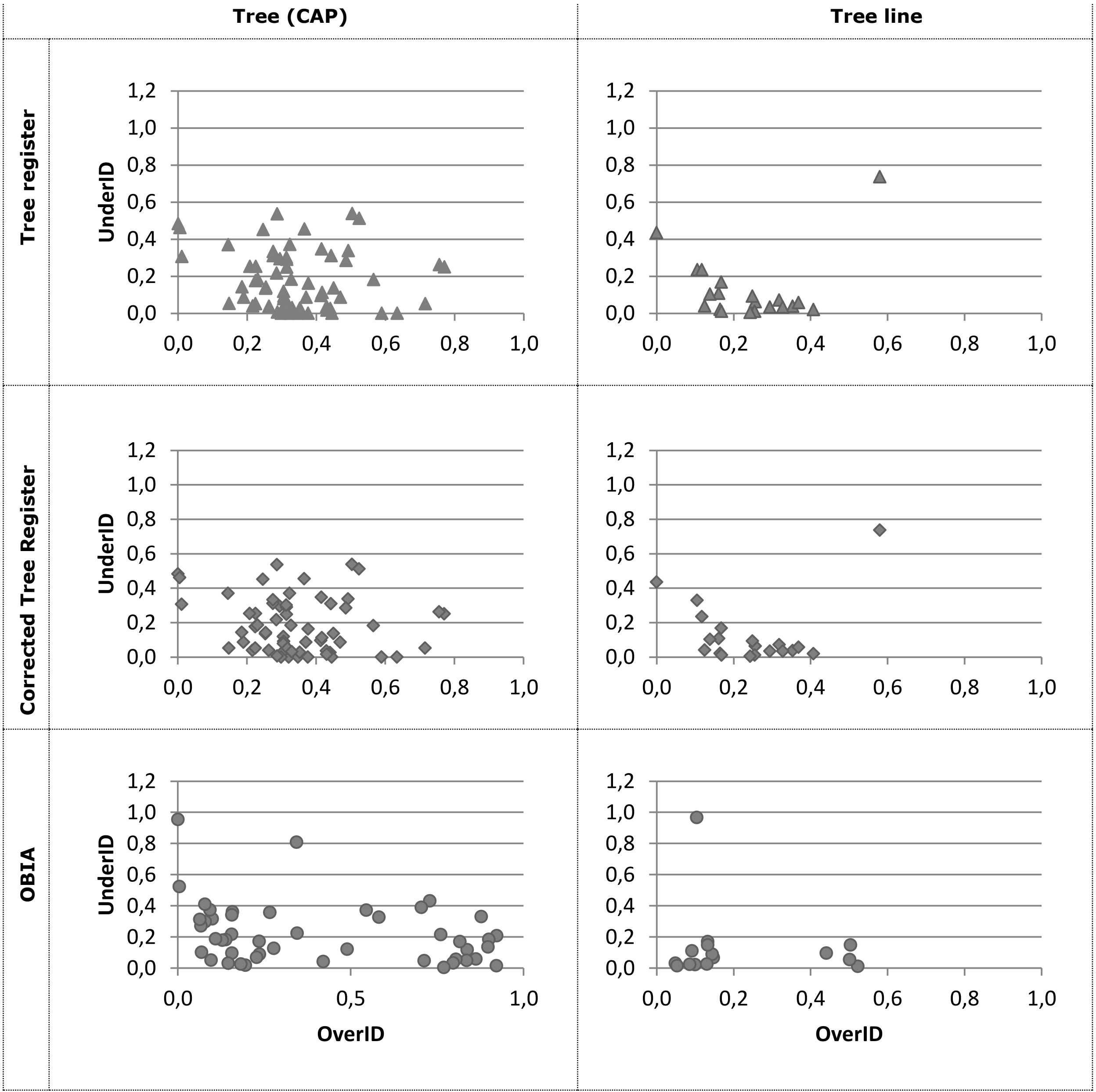


Figure 4.17: Scatterplot of over- and under-segmentation for tree (CAP) and tree line

Figure 4.17 shows only some small differences between the boundary accuracy of the corrected and original Tree Register. The boundary accuracy for the OBIA dataset shows the most variance. The results show a bipolar distribution in trees as well as tree lines, especially in the OBIA dataset. A closer examination of the results shows that although the validation objects are recognized and delineated as single objects (i.e. trees), this situation is not recognized in the OBIA method. The segmentation of trees in close proximity is difficult in an OBIA workflow. These trees are not delineated as single trees, but as a single object consisting tree crown that belongs to more than one tree. As a result the relation between segmented object and validation object no longer shows a one-to-one relation, but a one-to-many. In these cases the mean accuracy is calculated based on the validation object, resulting in a large over- and low underID.

Also bushes and hedges beneath trees make the distinction between single trees difficult in an OBIA segmentation. Figure 4.18 shows an example of this understory comparing the reference point with an image of the situation from April 10th.

Figure 4.18: Sample point 20 and understory (right image 10 April 2015)

Figure 4.18 illustrates that the reason for detecting a tree as line is caused by the hedges that create a layer underneath the trees. This understory is detected as a tree line. Connecting crowns and understory resulted in over-segmentation for the OBIA method, a problem that is probably increased by the larger resolution of the height dataset. Both Tree Registers show better results in this perspective. All datasets are comparable for problems related to underID. The corrected and uncorrected Tree Registers do not show much differences in UnderID and OverID.

Figure 4.19 shows boxplots of the three datasets illustrating the total delineation error grouped by tree, tree (CAP) and tree line. Total error is calculated using equation 4 (section 3.3.6). The OBIA dataset doesn’t show a boxplot for trees, because this group consisted only of two successfully detected objects.

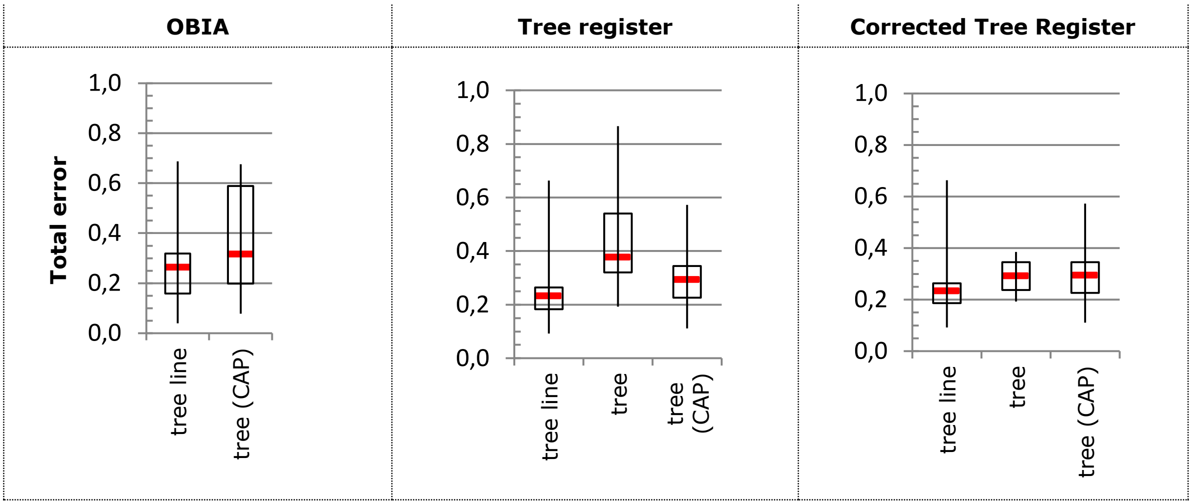


Figure 4.19: Boxplot total error

Figure 4.19 show a wide range between minimum and maximum values of trees, especially for the OBIA dataset. This is a result of the previously described many-to-one relation. Also indicated is a comparable result for tree lines and trees (CAP) in both Tree Registers. Because these groups consist of larger objects no correction occurred in the corrected Tree Register. Delineation error is largest for the OBIA dataset, indicated by the stretched box. This is especially true for tree (CAP).

The accuracy assessment and the Segmentation Goodness Evaluation, indicate that grouping objects with similar area is a useful approach when using a collection of reference or validation objects with a large difference in area.

4.4.6 Post-classification

The Data Specification Cycle resulted in special constraints regarding the geometry of objects. This is also mentioned as a reminder in section 4.4.1. Points are identified as the desired geometry for trees whereas polygons are the objective of tree lines. The classification of section 4.4.4 is not complete, because it didn't deliver the desired objects. A post-classification should alleviate this gap. However, this is not further explored in this thesis due to time constraints.

4.4.7 Summary results Remote Sensing

A Segmentation Goodness Evaluation is used for the selection of the best segmentation parameters. This evaluation demonstrated that a majority of parameters, 117 out of 200, where not useful for further evaluation mainly because a successfully delineation of one or more reference objects failed due to using a large segmentation scale parameter. The segmentation of the combined height and NDVI datasets underperforms when compared to the use of height solely. An explanation for this is that the segmentation based on height leads to smaller segments compared to the combination of height and NDVI. This is caused by fuzziness around the edges of segments, due to difficulties in separating the segment from background in the NDVI dataset and the differences between resolution of the used datasets.

The evaluation showed that all parameters have problems regarding under- or over segmentation. Ultimately, scale 10 shape 5 and compactness 1 is selected for final segmentation.

An object based classification is used to demarcate trees and tree lines in all three datasets by using SQL statements. Ultimately, four classes (tree, tree CAP, tree line and other) are created using ancillary data, i.e. TOP10. A distinction is made between trees inside or outside TOP10, based on a Tree Group Mask that selects forested areas of 5,000 m^2 or larger. This mask is used in combination with a Road Part Mask to enhance the distinction between separate elements with touching tree crown. Only the trees outside TOP10 are used for further evaluation.

The three classified datasets showed some remarkable differences in thematic accuracy (true positive, true negative and false negative scores). The differences are due to errors in the stereoscopic imagery and subsequent calculated object height, but are also caused by difficulties in detecting small trees in the OBIA and Corrected Tree Register datasets. The corrected Tree Register performed best by taking the boundary and object assessment into account. OBIA was not very good in detecting single trees. This is mainly inherent to the used segmentation method (MRS) that is not specifically designed for single tree detection but rather segments similar objects like tree crown area.

The applied accuracy assessment is also used as an alternative for the Segmentation Goodness Evaluation. The accuracy assessment needed less calculation and was therefore slightly easier to use compared to the Segmentation Goodness Evaluation. However, both methods highly depend on the manual creation of a reference or validation layer.

4.5 Discussion delineation of trees

The OBIA workflow in this thesis used a MRS for the delineation of trees in a typical agricultural area with arable land in a relatively small area of approximately 14 km^2 in South-West Netherlands. This is compared with the use of an open dataset representing trees, Tree Register, in an original and a corrected version.

A Data Specification (IMEfa) served as pivotal element in this thesis and not only identified the objects of interest (i.e. trees and tree lines), but also provided a definition of those objects. However, not all identified unavailable objects are delineated in this thesis. The detected gap regarding the specific coppice type, i.e. genus Salix, was not pursued in the thesis. This gap needed a different RS approach and would not be feasible within the time constraint of this thesis.

The technical capabilities of RS in the delineation of trees are another difficulty that needs to be solved. Abstracting objects from images is yet another dimension in modeling and asks for other capabilities. Section 4.3 described aspects that relate to the internal data quality of a dataset and how an IM defines this. This section identified some problems regarding thematic accuracy, i.e. object definition. Vagueness in object definition inhibited the use of the data specification, because the trees and tree lines are only described in terms of area as directed by EU regulations. A distinct quality of a tree, namely height, was not provided. Height was an essential parameter for a good delineation of trees.

This thesis used a minimum of two meter as an arbitrary threshold with the intent to exclude hedges or shrubs as potential trees.

Scale and positional accuracy are other important aspects of internal quality, which are difficult to assess or not defined. Scale is used as a parameter in MRS and defines the size of objects. This factor relates to different levels of detail that are present in an aerial image and the hierarchy that exists between these levels. For instance, wooded areas are identified at parcel level, whereas individual trees are identified at a lower hierarchical level. This study was interested in delineation of trees and used a method for this. However, the relation between the scale identified in the Data Specification (1:5,000) and the scale used in the MRS is difficult to assess. Positional accuracy, another aspect of internal data quality, is not defined in the Data Specification. This makes it difficult to relate the developed datasets to the desired Data Specification.

The used OBIA workflow consisted of several stages: segmentation, classification and accuracy assessment. To enable a comparison between the OBIA workflow and the two versions of the Tree Register, the last two stages are the same for all datasets. A segmentation was needed as an additional step to derive image objects from true orthorectified images and NDVI.

A method to assess segmentation parameters, other than by trial-and-error, was one of the other indicated gaps. To alleviate this gap a Segmentation Goodness Evaluation suggested by (Marpu, et al., 2010) was conducted. This method compared the segments derived from 200 different parameters with reference objects. For each reference object the area of extra- and missing pixels was calculated per segmentation parameter. The calculation of statistics enabled the selection of MRS parameters based on an informed decision.

Important in this evaluation is the choice of reference objects. Several decisions are important in this regard, beginning with the number and type of objects. This thesis selected four trees and three tree lines as reference objects. The selected trees fit the CAP description, but selecting trees with different crown sizes would have been preferable. The unilateral selection of small trees inhibited the use of the Segmentation Goodness Evaluation. This was indicated by the large number of parameters that were dismissed in the first round. All of the parameters that made it to the second round produced deformed objects. This was especially the case for the single trees. Therefore, dividing the Segmentation Goodness Evaluation in two groups (trees and tree lines) was a useful approach. The area of the biggest sub-object, in this thesis translated as the 100 percent area indicate large under-segmentation for tree objects. This could also indicate that the reference objects were not well chosen.

The selection of reference objects was hindered by practical implications, because segmentation of a large area is heavy on computing time and it would take days to scrutinize 200 different parameters settings. Therefore, a sub-area was selected for this Segmentation Goodness Evaluation.

Classification consisted of two stages plus an additional stage to classify OBIA segments as potential trees.

In contrast to the time spent on selecting the right segmentation parameters, the classification process was straight forward and was based on trial-and-error using a minimum object height and median NDVI as distinctive parameters. Comparing the results of the OBIA with the corrected and original Tree Register shows that the classification was reasonable. A final classification is used for the creation of four classes from the potential tree segments: single tree (CAP and no CAP), tree line, and other. A combination of area and shape parameters, i.e. shape index and compactness, enabled this classification. Linking this classification to the objects defined in the Data Specification was problematic due to inadequacies in finding a better classification and to the segmentation of tree crown area rather than single trees.

There is no standard method in OBIA for accuracy assessment. Since this thesis implements an object based analysis, an object oriented assessment is used for measuring the quality of the object boundary and the correct detection of objects. A validation layer consisting of 131 objects is created. The creation of a validation layer is influenced by subjective factors. This is also the case for the reference layer, created for the Segmentation Goodness Evaluation. OBIA always includes a visual interpretation needed to evaluate the segmentation and classification results. Meaning, as indicated by (Marpu, et al., 2010), there is always a subjective element in an evaluation.

A stratified sampling method is used to create the validation objects. (Congalton & Green, 2009) suggested that as a rule of thumb 50 samples should be selected for a small area as this thesis. However, this suggestion is meant for a classification of the whole scene. This thesis aimed at very specific objects. The selection of sample points was restricted to public areas to make a ground survey possible without trespassing private property. The selection of objects was typical for the single trees and tree lines in the area. Therefore, selecting more objects would not have a different outcome. Also the sample points were spread over the whole area to allow different circumstances. The accuracy measurement was aimed at trees and tree lines only, so no statement can be made for other objects.

An accuracy assessment for object boundary was not without problems, mainly because of the difference between objects in the validation layer and the actual segmentation outcome. These objects did sometimes have a one-to-many relation instead of a one-to-one relation. In this thesis, a solution is found in calculating mean values as done by (Ardilla, et al., 2012). However, this was not always simple because in several occasions one segmented object referred to several validation objects. Other boundary accuracy assessments would have faced the same problem, because they all need some kind of digitization, unless real ground data is used.

This brings other problems as well: data does not coincide with delineated objects. Because of these problems some researches (Aksoy, et al., 2010), (Krause, et al., 2010) use abstractions of the derived objects, which is an useful approach. Also reference objects and validation objects in this thesis are created at a very precise scale, a scale that does not coincide with the detection (OBIA) scale.

Comparing the accuracy results of this thesis with comparable studies is difficult, because the used method is different. For instance, (Aksoy, et al., 2010) and (Krause, et al., 2010) used an abstraction of the detected object. Although (Ardilla, et al., 2012) used a different segmentation method which accounts for their better boundary accuracy. They found comparable figures regarding the detection rate of single trees.

The OBIA method is comparable to the corrected Tree Register regarding the correctly assessed and false positive (type II) objects. The false negatives in the OBIA dataset are mainly the result of data errors in the height dataset. The used accuracy assessment did not give full detail about these errors, because this depended on the sampling. Figure 4.13 demonstrated this by showing an erroneous classified tree area (including tree single, -group and -line). However, a visual assessment reveals these otherwise “hidden” errors. These hidden errors are also indicated in Table 4.5 indicating differences in number of objects and mean objects size between the three datasets. For full appreciation of the classification results, these errors should also be quantifiable.

The accuracy assessment showed that the Tree register gave better results regarding false negatives, although this dataset is outdated since the information is collected between 2008 and 2012 (Van der Zon, 2013). The corrected version is an improvement but also excludes small trees (i.e. trees that do not comply to CAP).

Finally, the classification of the three datasets resulted in the creation of three maps showing trees and tree lines. To find a connection to the created IMEfa a further post-classification step is needed. This step creates polygons to represent tree lines and points to represent single trees. Due to time constraints this last step is not performed.

5 Closing the Gap?

5.1 Conclusion

This thesis was set out to explore an indicated gap between the geospatial data demand for EU member states regarding the new CAP and its availability. This geospatial data is needed to construct an EFA-layer for its effective monitoring and verification of farmers' applications. Section 2.2 describes this in detail as well as the different elements of an EFA-layer, focusing on landscape elements, policy and ecology.

Re-use of existing data could provide objects that populate an EFA-layer. Existing data is described in IMs, providing a structured description of geospatial data with the aim to improve interoperability. Section 2.3 describes in detail the IMs that are relevant to the rural area and are available nationwide. This relates to the first of two research questions that this study sought to answer:

1. ***Do existing information models provide the necessary information related to ecological focus areas (EFAs) mentioned in the new CAP?***
   a) How are EFAs currently modelled in information models relevant to the rural area, i.e. IMNa, IMLB, IMWa, BRT, BGT/IMGeo?
   b) What are the differences between EFAs mentioned in the new CAP and information models relevant to the rural area, i.e. IMNa, IMLB, IMWa, BRT, BGT/IMGeo?

If IMs provide no solution regarding green landscape elements then collecting own data is an alternative. Several studies regarding the detection of landscape elements use OBIA as a RS solution. Section 2.4 explored this together with a dataset that originates from active RS, the Tree Register. An IM also provides a thorough definition of objects and in this sense supports the use of RS in providing a definition of objects of interest. This brings us to the second research question explored in this thesis:

2. ***Is it possible to use Remote Sensing to delineate green landscape elements that are not provided through information models?***
   a) Is a pixel-based Remote Sensing method favorable over OBIA?
   b) What segmentation could be used in an OBIA workflow?
   c) How to delineate green landscape elements and measure accuracy?
   d) Is the delineation of green landscape elements mentioned in the new CAP but not available from information models more accurate using OBIA compared to the use of the Tree Register?

This chapter is structured as follows. The next section states the conclusions regarding IMs as posed in the first research question. The conclusions to the second research question are provided in section 5.1.2. The chapter ends with summing up some limitations to the conducted study and provides recommendations for policy makers, modelling specialists and further research.

5.1.1 Information models

An answer to the two sub questions helps in answering the first main question.

(Sub question 1a) An answer to the question how EFAs are currently modelled in IMs relevant to the rural area is provided in section 4.2. The process starts with identifying the objects in a use-case. One conclusion is that a more rigorous use-case provides a better informed model with respect to the needed objects and their relations. Nevertheless, the goal of the data specification should define the level of detail. If the purpose is only to determine how objects are currently modeled in IMs, a less detailed use-case constricted to a selection of processes is possible. A more rigorous use-case provides more information about other relations and is interesting if this information is needed for the purpose at hand.

(Sub question 1b) The differences between the EFAs and the IMs are described in section 4.2. The results indicate that not all used IMs where relevant in this process concerning modeling of EFAs. The usability of an IM for identifying EFAs depends on the users view that is incorporated in an IM, meaning that objects are described for a specific task. Domain specific models, such as IMNa, IMLB and IMWa, describe objects for a very specific task. It depends on the object whether its description fits the need. This is the case for IMNa, because it is the only source for the very specific landscape elements mentioned in SNL. IMWa and IMLB are supported by a small user base and therefor have a limited use. IMWa is used by a selection of Waterboards and the IMLB is mainly used to convey (geo)data concerning subsidy as monitored by RVO. Models that describe topographic maps provide a complete overview of the rural area and find good connection to the needed objects, although results indicated that the same objects are described differently in IMs.

(Main question 1) The results presented in this study indicate that existing IMs provide the necessary information related to EFAs. This is indicated by a successful use of the Data Specification Cycle in determining the geospatial information need by identifying objects that populate an EFA-layer. This information is used to assess how EFAs are currently modeled in a selection of IMs to assess their fitness for use and identify agreements and gaps. This study indicates that a successful use of the Data Specification Cycle depends on several factors: the ability to define needed objects, the usability of an IM as defined by the content (i.e. general or specific) and the existence of a body of knowledge. A body of knowledge assists in the translation of the content of regulations regarding geospatial demand into definitions of internal quality and also knows how available datasets (e.g. IMs) are constructed and the information they contain. The research indicated that modelled objects are not always collected and are therefore not available when exchanging the data.

The study eventually led to the creation of a new IM, IMEfa, to alleviate the need for the creation of an EFA-layer. IMEfa is a specialization of the existing BGT/IMGeo, which demonstrates that BGT/IMGeo shows best agreement between EFA need and EFA provision and is an accurate and flexible model to which other models can connect. By doing so, definition differences between models are decreasing.

5.1.2 Remote Sensing and Tree Register

Before concluding with an answer to the second main research question, first an answer to the four sub questions is provided.

(Sub question 2a) the literature study provided in section 2.4.1 answers this question by pointing out that OBIA is favorable over a pixel-based RS method regarding the delineation of landscape elements. Especially when using VHR aerial images. Although this study did not used the full capabilities of OBIA, for instance the use of contextual information, the results presented point out that the created objects through OBIA are easily adaptable in size and are directly recognizable if they coincide with image objects. This information is usable in finding the best segment parameters as is done in the Segmentation Goodness Evaluation. Not all the advantages provided in section 2.4.1 are confirmed, as the OBIA dataset contained a large number of very small "trees" (crown size below 2m^2) as indicated in section 4.4.4, this is comparable to a pepper-and-salt effect in a pixel based approach.

(Sub question 2b) section 2.4.2 provides an answer to the question what segmentation to use in an OBIA workflow. The literature contrasted in this section indicates that MRS is a frequently used algorithm and is also used successfully for the segmentation of trees. Furthermore, MRS is available as a standard method in the used software, i.e. eCognition. Results presented in this study indicate that MRS needs a considerable preparation time if a rigorous assessment of the needed parameters is done. However, it is unclear to what degree the time spent on the Segmentation Goodness Evaluation contributed to the overall segmentation result. The idea that a well-informed decision is better than a subjective trial-and-error selection of parameters is more appealing. Results indicate that the outcome of this evaluation greatly depends on a careful selection and delineation of reference objects that represent the aim of the study. It is important that this selection represents a collection of reference objects with varying sizes and under different conditions with a different background (i.e. spectral variation).

The needed computation time and high demands regarding computer hardware specifications are a point of consideration when selecting MRS. A frequently mentioned advantage of MRS, which is its ability to include different datasets, is not confirmed in the current study regarding combined segmentation of NDVI and object height.

(Sub question 2c) Landscape elements are delineated using a classification in two steps. A first additional classification for the OBIA dataset consisted of a subjective visual inspection of segments that coincide with trees that are visible in the aerial image. Some attributes are selected to deviate between segments and potential trees. A second classification is used for all three datasets and consists of a simple SQL instruction for a delineation of tree cover.

The use of ancillary data (TOP10) improved the method in separating connected landscape elements. Accuracy is measured using an object based approach, meaning that not only the thematic quality but also the boundary of an object is assessed.

This study indicates that the match between validation objects and delineated objects is very important and should be considered before using an object based accuracy assessment. The accuracy assessment is influenced to a great extent by the applied sampling strategy.

A visual assessment of the segmentation and classification results provides insight in the quality of derived segments and quality of classification. This could lead to identification of issues regarding data quality and improve a classification.

Results also indicate that the method that is used for accuracy assessment is also usable as Segmentation Goodness Evaluation and that the calculation of parameters in the former method is easier.

(sub question 2d) The final accuracy measurement indicated that the Tree Register identified 96 percent of the validation objects correctly. The OBIA method and the corrected Tree Register identified respectively 73 and 76 percent of the objects correctly. The better boundary accuracy of the corrected Tree Register and the lowest percentage Type I error (false negatives) favored this dataset over the OBIA and the uncorrected Tree Register.

(Main question 2) The results presented in this study indicate that it is possible to use RS for the delineation of green landscape elements that are not provided through IMs. However, its success depends on how well the applied RS method (in this study OBIA and the original and corrected Tree Register) succeeds in approximating the objects as defined in the IM. This success depends on the usability of an IM by providing a succinct description of the objects of interest and the subsequent capability of the used RS method to delineate these objects from the available datasets. A description of objects not only refers to thematic quality, such as dimension, area and height, but also includes other aspects of data quality. In other words, it covers the internal data quality which refers to the desired quality of a dataset and defines aspects like the already mentioned thematic quality, spatial accuracy, temporal accuracy. An IM provides the possibility to include details about internal data quality. However, aspects as the desired scale and (spatial) accuracy are important aspects in the use of RS and should be provided in an IM and transferable to use in RS. The technical capabilities of the used RS method depend on the used segmentation and classification techniques.

An OBIA workflow consists of several consecutive stages, where the previous stage builds on the next one. A visual assessment at the end of each stage is essential to evaluate the quality of the outcome and assess the usability for the next stage.

The corrected Tree Register was most accurate in the delineation of trees and tree lines. However, the applied segmentation and classification influence the accuracy greatly and therefore also a successful delineation of the desired objects according the specifications mentioned in an IM.

5.2 Limitations and recommendations

This final section provides limitations to this research and closes by summing up recommendations for policy makers, IM specialists and further research.

Limitations

As a result of the first part of this thesis an IM is constructed. Section 4.2 already noted that some specific constraints regarding EFAs (i.e. adjacent on arable land, on the Dutch list) are not used as part of the requirements. This is a limitation to the IMEfa model and further research regarding a complete use-case is therefore necessary, before implementation of this model is possible.

The extension to BGT/IMGeo, IMEfa, is specially derived to ease the need for the new CAP. Sections 1.3 and 2.2.1 identified that studies regarding ecology need detailed information regarding the spatial distribution of landscape elements. Further study is necessary to find out whether this information is provided by the suggested IMEfa.

The second part, regarding RS, used a relatively small area of 1,430 ha in this study. For a more consistent application a larger area is needed. Using object height and a vegetation index (NDVI) could make this possible for large areas, however additional research is needed to verify the results.

Also the applied classification to derive potential tree canopy for the OBIA dataset is rather limited. This was also indicated in section 4.4.6 which mentions that a more rigorous post-classification is needed to comply to the objects as specified in the Data Specification. A more rigorous classification using the full capabilities of eCognition (e.g. contextual information) could result in a better delineation of tree(line)s and therefore provide a better overall result. This indicates that the derived OBIA dataset is of rather limited use. However, the purpose of this study was to explore the use of IMs for the specification of an EFA-layer and use this result for the delineation of objects using RS.

Recommendations

For policy makers:

If the need for geospatial reference is part of a regulation it is better not to use a very precise and compulsory description of objects, but a more generalized one. The use of point, line or polygon representing areas is useable in this regard. It is also feasible to consult (geospatial) specialists for advice prior to publishing a regulation.

For information model specialists:

A searchable repository including all the objects that are used in IMs, including their definitions and relations to other IMs helps in finding the right object and connecting information. It is also difficult to find the right, newest, version of an IM. This could be implemented by making the semantic model of NEN-3610 searchable, including all underlying objects.

Another way is focusing on one or more 'default' models to which other IMs comply. BGT/IMgeo might become such a model, although further research is needed how this might work. Using this approach might reduce the number of very specific domain models and gives a better overview of the concept models that are in circulation and how (if so) they are used.

There is no standard for describing a standard. This makes it difficult to explore and compare IMs and assess their exact meaning.

For further RS research:

An object height dataset derived from stereoscopy could be improved by including other data to rule out areas that are homogenous in height, for instance water area. Objects from BGT or other (topographic) registries are also usable for this purpose.

The relation between Segmentation Goodness Evaluation or accuracy assessment and selection of reference objects needs further study. Also a good sampling for an object based image analysis is a topic that needs further consideration.

Further research regarding the implementation of IMEfa and harmonization of data is necessary, before it could result in actual exchange of data.

Bibliography

Aksoy, S., Gökhan Akçay, H. & Wassenaar, T., 2010. Automatic Mapping of Linear Woody Vegetation Features in Agricultural Landscapes Using Very High Resolution Imagery. *IEEE Transactions on Geoscience and Remote Sensing,* 48(1), pp. 511-522.

Albrecht, F., 2008. Assessing the spatial accuracy of object-based image classification. In: A. Car, G. Griesebner & J. Strobl, red. *Geospatial Crossroads @ GI_Forum 2008.* Heidelberg: Wichmann Verlag, pp. 11-20.

Anon., 2014. *FarmersGuardian.* [Online]
Available at: http://www.farmersguardian.com/home/hot-topics/cap-reform/hedges-among-options-for-greening-under-new-cap/65159.article
[Accessed 2 7 2014].

Antrop, M., 2006. From holistic landscape synthesis to transdisciplinary landscape management. In: B. Tress, G. Tress, G. Fry & P. Opdam, eds. *From Landscape Research to Landscape Planning: Aspects of Integration, Education and Application.* Wageningen UR Frontis series No. 12 ed. Wageningen: Springer, pp. 27-50.

Apeldoorn Van , D., Kempen, B., Sonneveld, M. & Kok, K., 2013. Co-evolution of landscape patterns and agricultural intensification: An example of dairy farming in a traditional Dutch landscape. *Agriculture, Ecosystems and Environment,* 2013(172), pp. 16-23.

Ardilla, J., Bijker, W., Tolpekin, V. & Stein, A., 2012. Context-sensitive extraction of tree crown objects in urban areas using VHR satellite images. *International Journal for Applied Earth Observation and Geoinformation,* Volume 15, pp. 57-69.

Baatz, M. & Schäpe, M., 2000. Multiresolution segmentation: an optimization approach for high quality multiscale image segmentation. In: J. Strobl, T. Blaschke & G. Griesebner, red. *Angewandte Geographische Informationsverarbeitung XII.* Karlsruhe: Wichmann.

Bakker, T., 2014. *pre IMWA 2014, Watersystemen.* [Online]
Available at: http://www.aquo.nl/documents/2014/02/rapport-preimwa-2014-watersystemen-publicatie01.pdf
[Accessed 17 7 2014].

Baudry, J., Bunce, R. & Burel, F., 2000. Hedgerows: An international perspective on their origin, function and management. *Journal of Environmental Management,* Volume 60, pp. 7-22.

Benthem, R., 2013. *Open tree data as a basis for web-services, Validation of a tree extraction algorithm,* Amersfoort: NEO Intern rapport.

BGT, 2014b. *Wet Basisregistratie Grootschalige Topografie.* [Online]
Available at: http://wetten.overheid.nl/BWBR0034026/geldigheidsdatum_22-02-2014
[Accessed 22 2 2014].

Blaschke, T., Hay, J.G., Kelly, M., Lang, S., Hofmann, P., Addink, E., Feitosa, R.Q., Meer Van der, F., Werff Van der, H., Coillie Van, F. & Tiede, D., 2014. Geographic Object-Based Image Analysis – Towards a new paradigm. *ISPRS Journal of Photogrammetry and Remote Sensing,* Volume 87, pp. 180-191.

Blaschke, T. & Strobl, J., 2001. What's wrong with pixels? Some recent developments interfacing remote sensing and GIS. *GIS–Zeitschrift für Geoinformationssysteme,* Volume 14, p. 12–17.

Campbell, J., 2007. *Introduction to Remote Sensing.* 4th red. London: Taylor and Francis.

CBS, PBL & Wageningen UR, 2013. *Land- en tuinbouw: ruimtelijke spreiding, grondgebruik en aantal bedrijven, 1980-2012.* [Online]
Available at: www.compendiumvoordeleefomgeving.nl
[Accessed 22 9 2014].

Coeur Le, D., Baudry, J., Burel, F. & Thenail, C., 2002. Why and how we should study field boundary biodiversity in an agrarian landscape context. *Agriculture, Ecosystems and Environment,* 2002(89), pp. 23-40.

Congalton, G. & Green, K., 2009. *Assessing the Accuracy of Remotely Sensed Data. Principles and Practices.* 2nd red. Boca Raton: CRC Press/Taylor&Francis.

Czerepowicz, L., Case, B. & Doscher, C., 2012. Using satellite image data to estimate aboveground shelterbelt carbon stocks across an agricultural landscape. *Agriculture, Ecosystems and Environment,* Volume 156, pp. 142-150.

Devillers, R. & Jeansoulin, R., 2006. Chapter 2, spatial data quality: concepts. In: R. Devillers & R. Jeansoulin, red. *Fundamentals of Spatial Data Quality.* London: ISTE ltd.

Dey, V., Zhang, Y., Zhong, M. & Salehi, B., 2013. Image Segmentation Techniques for Urban Land Cover Segmentation of VHR Imagery: Recent Developments and Future Prospects. *International Journal of Geoinformatics,* 9(4), pp. 15-35.

e-overheid, 2014. *Stelsel van Basisregistraties.* [Online]
Available at: http://www.e-overheid.nl/onderwerpen/stelselinformatiepunt/stelsel-van-basisregistraties/basisregistraties
[Accessed 22 9 2014].

EU, 2013a. *Regulation EU/1306/2013 Of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy.* [Online]
Available at: http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2013:347:SOM:EN:HTML
[Accessed 20 12 2013].

EU, 2013b. *Regulation EU/1307/2013 Establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy.* [Online]
Available at: http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2013:347:SOM:EN:HTML
[Accessed 20 12 2013].

EU, 2013c. *Working document delegated act for direct payments DS/EGDP/2013/10. Legal draft of the Articles related to the payment of agricultural practices beneficial for the climate and the environment (Equivalence –ecological focus areas).* sl:sn

EU, 2013d. *Green Infrastructure (GI) - Enhancing Europe's Natural Capital.* [Online]
Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013SC0155
[Accessed 13 9 2014].

EU, 2014a. *Draft Guidance document on the implementation of the EFA-layer referred to in article 70(2) of regulation (EU)1306/2013,* Bruxelles: European Commission.

EU, 2014b. *Commission delegated regulation (EU) No 639/2014.* [Online]
Available at: http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32014R0639
[Accessed 14 9 2014].

EU, 2014c. *Agiculture and rural development, the history of the CAP.* [Online]
Available at: http://ec.europa.eu/agriculture/cap-history/index_en.htm
[Accessed 9 22 2014].

EU, 2014d. *Agriculture and rural development, Agri-environment measures.* [Online]
Available at: http://ec.europa.eu/agriculture/envir/measures/index_en.htm
[Accessed 22 9 2014].

EU, 2015. *CAP simplification: Commisioner Hogan announces first actions and further steps.* [Online]
Available at: http://ec.europa.eu/agriculture/newsroom/204_en.htm
[Accessed 14 5 2015].

EZ, 2014. *Kamerbrief Uitwerking directe betalingen Gemeenschappelijk Landbouwbeleid.* [Online]
Available at: http://www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2014/06/05/kamerbrief-uitwerking-directe-betalingen-gemeenschappelijk-landbouwbeleid.html
[Accessed 22 9 2014].

FAO, 2013. *Climate-smart agriculture, Sourcebook.* [Online]
Available at: http://www.fao.org/climatechange/climatesmart/en/
[Accessed 13 9 2014].

FarmersGuardian, 2014. *Hedges greening option will create 'significant issues'.* [Online]
Available at: http://www.farmersguardian.com/home/hot-topics/cap-reform/hedges-greening-option-will-create-significant-issues/65557.article
[Accessed 22 9 2014].

Fonseca, F., Davis, C. & Camara, G., 2003. Bridging Ontologies and Conceptual Schemas in Geographic Information Integration. *GeoInformatica,* 7(4), pp. 355-378.

Geonovum, 2013. *Raamwerk van geo-standaarden 2.2.* [Online]
Available at: http://www.geonovum.nl/onderwerpen/basismodel-geo-informatie-

nen3610/nieuws/raamwerk-geostandaarden-22-vastgesteld
[Accessed 27 10 2013].

Geonovum, 2014. *Objectenhandboek BGT | IMGeo.* [Online]
Available at: http://www.geonovum.nl/wegwijzer/standaarden/objectenhandboek-bgtimgeo-versie-11
[Accessed 11 2 2014].

Geonovum, 2014. *Raamwerk van Geostandaarden, versie 2.3.* [Online]
Available at: http://www.geonovum.nl/onderwerpen/geo-standaarden/documenten/raamwerk-van-geo-standaarden-versie-23
[Accessed 22 9 2014].

Grashof-Bokdam, C. & Van Langevelde, F., 2004. Green veining: landscape determinants of biodiversity in European agricultural landscapes. *Landscape Ecology,* Volume 20, pp. 417-439.

Happ, P.N., Ferreira, R.S., Bentes, C., Costa, G.A.O.P. & Feitosa, R.Q., 2010. *Multiresolution Segmentation: a parallel approach for High Resolution Image Segmentation in Multicolor Architectures.* Ghent, sn

Hellesen, T. & Matikainen, L., 2013. An Object-Based Approach for Mapping Shrub and Tree Cover on Grassland Habitats by Use of LiDAR and CIR Orthoimages. *Remote Sensing,* Volume 5, pp. 558-583.

Hendriks, P. & Ottens, H., 1997. Kennismaking met GIS. In: P. Hendriks & H. Ottens, eds. *Geografische Informatie Systemen in ruimtelijk onderzoek.* Assen: Van Gorcum, pp. 1-20.

Hengl, T., 2006. Finding the right pixel size. *Computer and Geosciences,* Volume 32, pp. 1283-1298.

IHW, 2013a. *InformatieModel Water (IMWA) 2013.* [Online]
Available at: http://www.aquo.nl/documents/2013/09/rapport-imwa.pdf
[Accessed 2014].

IHW, 2013b. *Uitwisselingsmodel Aquo (UM Aquo) Kaderrichtlijn Water, Metingen, Nomen, Waterwet.* [Online]
Available at: http://www.aquo.nl/documents/2013/09/rapport-um-aquo.pdf
[Accessed 2014].

IMLB, 2012. *IMLB Objectencatalogus,* s.l.: Intern rapport.

IMNa, 2012. *Informatiemodel Natuur (IMNa), ter ondersteuning van de Digitale Keten Natuur.* [Online]
Available at: http://www.portaalnatuurenlandschap.nl/assets/GBO-P-Informatiemodel_Natuur_v2.0_beta.pdf
[Accessed 10 1 2014].

INSPIRE, 2008. *Drafting team "Data Specifications" Methodology for the development of data specifications.* [Online]
Available at: http://inspire.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.6_v3.0.pdf
[Accessed 14 4 2014].

Kadaster, 2013. *Basisregistratie Topografie, Catalogus en Productspecificatie Versie 2.1.* [Online]
Available at: http://www.kadaster.nl/BRT
[Accessed 22 9 2014].

Kaper, M., 2012. *Informatiemodel Landbouw (IMLB), versie 0.9. Concept,* Assen: Dienst Regelingen.

Krause, A., Danes, M., Janssen, H., Kramer, H. & Rip, F., 2010. *Recording small landscape features with object recognition; Possibilities and limitations of automated procedures to support monitoring in the frame of GeoCAP.* [Online]
Available at: http://edepot.wur.nl/164770
[Accessed 20 12 2013].

Kuhn, W., 2005. Geospatial Semantics: Why, of What, and How?. *Journal on Data Semantics ,* Volume 3, pp. 1-24.

Lillesand, T., Kiefer, R. & Chipman, J., 2008. *Remote Sensing and Image Interpretation.* 6th ed. New York: Wiley.

Lizarazo, I. & Elsner, P., 2011. *Chapter 13, Segmentation of Remotely Sensed Imagery: Moving from sharp objects to Fuzzy Regions.* [Online]
Available at: http://www.intechopen.com/books/image-segmentation
[Accessed 26 3 2015].

Longley, P., Goodchild, M., Maguire, D. & Rhind, D., 2011. *Geographic Information Systems & Science.* 3rd ed. Hoboken: John Wiley & Sons, Inc.

Lu, D. & Weng, Q., 2007. A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing,* 28(5), pp. 823-870.

Marpu, P., Neubert, M., Herold, H. & Niemeyer, I., 2010. Enhanced evaluation of image segmentation results. *Journal of Spatial Science,* 55(1), pp. 55-68.

Marshall, E. & Moonen, A., 2002. Field margins in northern Europe: their functions and interactions with agriculture. *Agriculture, Ecosystems and Environment,* Volume 89, pp. 5-21.

Meneguzzo, D., Liknes, C. & Nelson, M., 2013. Mapping trees outside forests using high-resolution aerial imagery: a comparison of pixel- and object-based classification approaches. *Environmental Monitoring and Assessment,* Volume 185, p. 6261–6275.

Nederlands Normalisatie Instituut, 2011. *Nederlandse Norm NEN 3610, Basismodel Geo-informatie, termen, definities, relaties en algemene regels voor de uitwisseling van informatie over aan de aarde gerelateerde ruimtelijke objecten,* Delft: NNI.

Oosterbaan, A. & Pels, M., 2007. Monitoring of Small Landscape Elements in The Netherlands. *Landscape Research,* 32(1), pp. 95-102.

Overmars, K.P., Schulp, C.J.E., Alkemade, R., Verburg, P.H., Temme, A.J.A.M., Omtzigt, N. & Schaminée, J.H.J., 2014. Developing a methodology for a species-based and spatially explicit indicator for biodiversity on agricultural land in the EU. *Ecological Indicators,* Volume 37, pp. 186-198.

Paine, D. & Kiser, J., 2003. *Aerial photography and image interpretation.* 1st red. Hoboken: Wiley.

Pe'er, G., Dicks, L.V., Visconti, P., Arlettaz, R., Báldi, A., Benton, T.G., Collins, S., Dieterich, M., Gregory, R.D., Hartig, F., Henle, K., Hobson, P.R., Kleijn, D., Neuman, R.K., Robijns, T., Schmidt, J., Schwartz, A., Sutherland, W.J., Turbé, A., Wulf, F. & Scott, A.V., 2014. EU agricultural reform fails on biodiversity, Extra steps by Member States are needed to protect farmed and grassland ecosystems. *Science,* 344(6188), pp. 1090-1092.

Räsänen, A., Rusanen, A., Kuitunen, M. & Lensi, A., 2013. What makes segmentation good? A case study in boreal forest habitat mapping. *International Journal of Remote Sensing,* 34(23), pp. 8603-8627.

Richards, J., 2013. *Remote Sensing Digital Image Analysis, an introduction.* Fifth ed. Berlin: Springer-Verlag.

Rip, F. & Bulens, J., 2013. *IM-Tree. Towards an information model for an integrated tree register.* Leuven, 16th AGILE Conference on Geographic Information Science.

Sheeren, D. et al., 2009. Discriminating small wooded elements in rural landscape from aerial photography: a hybrid pixel/object-based analysis approach. *International Journal of Remote Sensing,* 30(19), pp. 4979-4990.

SNL, 2009. *Subsidiestelsel Natuur- en Landschapsbeheer.* [Online] Available at: http://www.portaalnatuurenlandschap.nl/themas/subsidiestelsel-natuur-en-landschapsbeheer/over-het-subsidiestelsel-natuur-en-landschapsbeheer/ [Accessed 22 9 2014].

Stoate, C., Báldi, A., Beja, P., Boatman, N.D., Herzon, I., Doorn Van, A., Snoo De, R.G., Rakosy, L. & Ramwell, C., 2009. Ecological impacts of early 21st century agricultural change in Europe – A review. *Journal of Environmental Management,* Volume 91, pp. 22-46.

Tansey, K., Chambers, I., Anstee, A., Denniss, A. & Lamb, A., 2009. Object-oriented classification of very high resolution airborne imagery for the extraction of hedgerows and field margin cover in agricultural areas. *Applied Geography,* Volume 29, pp. 145-157.

Thornton, M., Atkinson, P. & Holland, D., 2007. A linearised pixel-swapping method for mapping rural linearland cover features from fine spatial resolution remotely sensed imagery. *Computers and Geosciences,* Volume 33, pp. 1261-1272.

Tóth, K., Portele, C., Illert, A., Lutz, M. & Nunes de Lima, V., 2013. *A conceptual Model for Developing Interoperability Specifications in Spatial Data Infrastructures. JRC Reference reports.* [Online]
Available at: http://inspire.jrc.ec.europa.eu/index.cfm/newsid/10721
[Accessed 8 12 2013].

Trimble, 2014. *Trimble eCognition Developer Reference Book,* Munich: Trimble Germany Gmbh.

Van den Brink, L., Krijtenburg, D., Van Eekelen, H. & Maessen, B., 2013a. *Basisregistratie Grootschalige Topografie, Gegevenscatalogus BGT 1.1.1.* [Online]
Available at: http://www.geonovum.nl/onderwerpen/bgt-imgeo-standaarden/verplicht-en-optioneel-bgtimgeo
[Accessed 23 9 2014].

Van den Brink, L., Stoter, J. & Zlatanova, S., 2013c. UML-Based approach to Developing a CityGML Application Domain Extension. *Transactions in GIS,* 2013(17(6)), pp. 920-942.

Van den Brink, L., Van Eekelen, H. & Reuvers, M., 2013b. *Basisregistratie Grootschalige Topografie, Gegevenscatalogus IMGeo 2.1.1.* [Online]
Available at: http://www.geonovum.nl/onderwerpen/bgt-imgeo-standaarden/verplicht-en-optioneel-bgtimgeo
[Accessed 9 23 2014].

Van der Zanden, E., Verburg, P. & Mücher, C., 2013. Modelling the spatial distribution of linear landscape elements in Europe. *Ecological Indicators,* Volume 27, pp. 125-136.

Van der Zon, N., 2013. *Kwaliteitsdocument AHN2. Versie 1.3.* [Online]
Available at: http://www.ahn.nl/binaries/content/assets/hwh---ahn/common/wat+is+het+ahn/kwaliteitsdocument_ahn_versie_1_3.pdf
[Accessed 29 11 2013].

Wiseman, G., Kort, J. & Walker, D., 2009. Quantification of shelterbelt characteristics using high-resolution imagery. *Agriculture, Ecosystems and Environment,* Volume 131, pp. 111-117.

Wu, J., 2013. Chapter 11. Landscape Ecology. In: R. Leemans, ed. *Ecological Systems.* Wageningen: Springer, pp. 179-200.

Zhang, Y., Maxwell, T., Tong, H. & Dey, V., 2010. *Developement of Supervised Software Tool for Automated Determination of Optimal Segmentation Parameters for Ecognition.* Vienna, Proceedings of ISPRS TC VII symposium-100 Years ISPRS.

Appendix A Checklist data development cycle

Component	Use-case requirements	as-is analysis	gap analysis
	Describe the use case requirements in particular for input data sources in view of a harmonized product as described in the use case.	Identify and describe the available data sources as well as possible for the use case.	Check the data interoperability components for differences and/or contradictions between the available data sources and the target specification (use case requirements).
1. Context	What are the main characteristics of the use case (general purpose, required level of detail, geographic extent, etc.	What are the existing data sets that have been identified for this use case.	If already identified, what are the main issue(s) in this use case?
2. Requirements	Identify the requirements regarding the feature classes (objects), attributes, relations, properties, operations, constraints.	Identify the existing IMs, especially the existing features and attributes.	Identify the missing data (features, attributes, etc.)
3. Vector geometry	Requirements of features regarding geometry: • Dimensionality (0D, 1D, 2D, 3D) • Interpolation types for curves and surface? • Sharing of geometry objects required?	Geometry used?	Does the data source differ from the use case requirements with respect to geometry?
4. Topology	Is topology required?	Is topology used?	Does the data source differ from the use case requirements with respect to topology?
5. Coverages	Are coverages required?	Are coverages used?	Does the data source differ from the use case requirements with respect to resolution, type of grid, etc.?
6. Temporal profile	Identify the requirements regarding temporal aspects: • Support features that move or change over time • Support multiple versions or versioning of properties.	Are temporal aspects modelled?	Does the data source differ from the use case requirements with respect to temporal aspects?

7. Object referencing model	Object referencing connects the same objects across different datasets. Are object referencing methods required?	Are object referencing methods applied? If yes, which methods: • By name? • By code (e.g. administrative unit code)? • By identifier? • By geometry? • Other, i.e. linear referencing, by address)?	If the use case requires object referencing methods, does the data source meet the requirements of the object referencing methods?
8. Portrayal	Which data do you need to display and how? I.e.: • Map service and/or feature service? • Which scales? • Which symbolization? • Portrayal rules? • Is a portrayal catalogue required?	• Is existing data supplied with symbolization? • If yes, how? I.e. by view services, within GIS formats, etc.) • For which scales? • Are there existing portrayal catalogues?	If the use case requires portrayal: does the data source provide the necessary input for portrayal?
9. Identifier Management	• Are identifiers required? • For which features? • Which roles do identifiers for entities play? • Which are the required characteristics of identifiers (i.e. unique, stable)? • Is there a management for such identifiers specified?	• Are there identifiers in the existing data sets? • What do you know about them? • Which roles do identifiers for entities play? • Is there a management for such identifiers specified? • Relevant for existing data?	Is identifier definition and management consistent?

10. Registers and registries	Which registers are required, if any? • Reference system • Units of measurement • Feature concept dictionary • Feature catalogue codelist • Thesauri • Portrayal catalogues • Etc. Do these registers require to be conform ISO standards or other standards?	Which registers are available, if any?	• Are registers to be created new? • Are existing registers adopted? • Do they need to be modified?
11. Data quality	Data quality requirements? If yes: • Positional accuracy? • Thematic acuracy? • Logical consistency? • Temporal accuracy? Data quality management: • Interaction with user on quality? • Requirements, e.g. published quality levels? • Quality evaluation? • Conformance testing?	Data quality requirements in existing data?	Does the data source meet the use case requirements with respect to data quality?
12. Data capturing	• What is the level of detail required? • Which selection criteria are required, i.e. all features, features with a specific area or length? • Where are they defined?	• What are the levels of detail available? • Which selection criteria are there in existing data? • Are they documented?	• For which features are there more data available than required? • And less?

Appendix B Use-case template

Use case <name of use case>
Description
<short description of use case>
Legal notes
<overview of appropriate legislation>
Actors
<persons and organizations involved in the use case>
Input
< Spatial data, information exchange, etcetera that is needed for this use case>
Output
< Spatial data, information exchange, etcetera provided by the use case>
Additional
<additional remarks necessary to the use case>

Appendix C Data Development Cycle

Stage 1 Use case: create an EFA-layer

The first stage describes the use case related to collection of landscape elements for the creation of an EFA-layer.

Narrative description:

The use-case explored is:

"Monitoring of EFA requirements for farmers"

EFAs are only relevant to farmers who apply for income support regulated in the CAP. This application is only available for farms that meet specific conditions regarding farm size and registration. Important conditions are that a farm needs to be registered at the chamber of commerce, has a minimum size of 0.3 hectares and applies for at least 500 euro subsidy.

A farmer that is entitled to income support provides the necessary data to the paying organization, RVO. Information regarding agricultural parcels is provided through an internet GIS application or on paper. The farmer provides data regarding the location, area, crop type and ownership of the agricultural parcels.

The declared area of land is checked by RVO on consistency, using the LPIS. A farmer should establish 5 percent of the area arable land as EFA if the total area of arable land exceeds 15 hectare. The farmer is responsible to assess whether there are special obligations regarding greening and EFA requirements. The farmer also choses how to meet the specific EFA requirements and provides this information to the paying agency. This information includes the type of established EFAs, their area and exact location. The farmer provides this information with the application for subsidy.

The paying agency creates an EFA-layer as part of the LPIS. RVO uses the LPIS to assess the farmer's application regarding agricultural parcels (size, location, crops type) and the type and location of specific EFAs. The EFAs in this thesis are on the EU gross list (this in contrast to normal EU regulations, where only the EFAs selected by an European Member state are part of the EFA-layer) and are stable over a period of three years. The requirement whether an EFA is on or adjacent to arable land is not assessed in this use-case.

An on-the-spot check is possible to assess the application of the farmer, regarding the provided declaration, the existence and the total area of EFAs. On-the-spot check are achieved in two ways: using RS or an actual visit by the NVWA. Summarizing, this use-case consists of the following processes:

1) A farmer provides location of parcels and gives information about crop
2) A farmer calculates the greening requirements
3) A farmer mentions EFA requirements on application
4) RVO checks consistency of the parcels
5) RVO checks the attributed EFAs
6) On-the-spot checks validate the provided parcel information

Figure C.1 shows a UML-model of the described use-case.

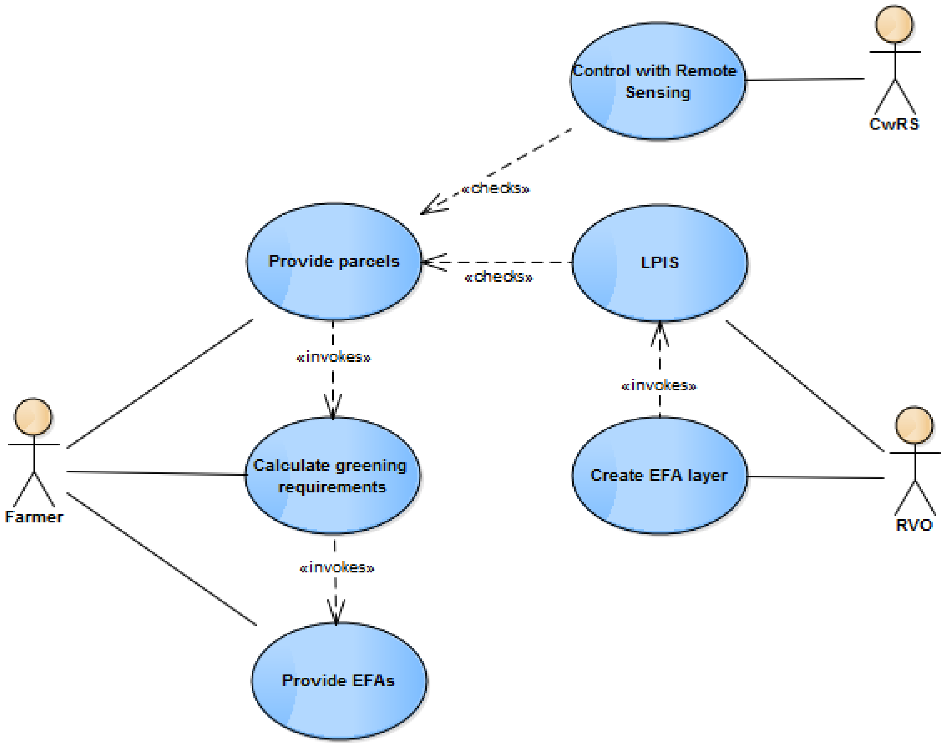


Figure C.1: Diagram Use-case "Monitoring of EFA requirements for farmers"

It is important to note that this thesis does not explore all the separate processes of the use-case shown in previous figure, but focusses on the creation of the EFA-layer, which is an essential part of the described use-case. It also goes beyond the explicit requirements of the use-case by exploring all the EFA objects provided through the EU gross list, regardless the type of parcel (arable land or grassland).

Legislative background:

There are several EU regulations that are important for EFAs and thus for this use case:

- EU 1307/2013 (source) establishes rules for direct payments and explains how greening conditions are met. The need to establish EFAs is regulated and preconditions regarding EFAs are given.
- EU 1306/2013 (source) establishes rules regarding financing and monitoring of the new CAP and mentions the need for an EFA reference layer.
- Guidance document DSCG/2014/31 (source) gives guidance to the establishment of the EFA-layer.
- Delegated regulation EU 639/2014 (source) gives further criteria that apply to EFAs. Those criteria comprise: minimum and maximum dimensions and weighting and conversion factors.
- Letters ministry Economic Affairs (source and source) give direction to the implementation of EFAs in the Netherlands.

Table C.1 summarizes the use-case.

Table C.1: Summary of use-case

USE CASE: Create an Ecological Focus Area (EFA) reference layer

Summary:

Member states need a reference layer to accommodate Ecological Focus Areas (EFAs). To meet the greening requirements of the new CAP an arable farmer needs to convert 5% of farm's arable land to EFAs, if specific conditions regarding farm size and crop type are met. EFAs in this use-case are landscape elements that are listed on the EU gross list or implemented by Dutch government.

The purpose of this use-case is to establish an EFA-layer by focusing on landscape elements that meet the description of EFA and that are already available in existing Dutch Information Models (IMs). Therefore the focus is not only on potential EFAs (i.e. EFAs situated on or adjacent to arable land), but EFAs in general and how they are modelled in IMs.

Flow of events:

1. Determine and define potential EFAs:
    a. Definition according EU regulations
    b. Minimum and maximum dimensions
    c. Temporal aspects (i.e. stable over a period of three years)
2. Explore current IMs for existence of EFAs: : how 'map' the description of EFAs on existing IMs
3. Collect remaining landscape elements using remote-sensing

Actors:

- RVO.nl (paying agency)

Input:

Information models:

BGT version 1.1.1, IMGeo version 2.1.1, IMWa version 5.0, IMNa version 2.0, IMLB version 0.9)

Output:

Data model for Reference layer Ecological Focus Area (EFA-layer)

Stage 2 Identification of user requirements and spatial object types

This stage intends to create a list of spatial objects, based on the former use case. Draft definitions and descriptions as well as attributes, object relations, temporal aspects, level of detail and data quality are important aspects in this stage.

Table C.2 provides a complete list of EFAs, their origin (i.e. implemented by The Netherlands or on the EU-gross list) and if a feature is part of the EFA- layer or not.

Table C.2: EFAs and potential EFAs for reference layer

EFA	Origin	EFA-layer
Catch crop	NL implementation	No*
Nitrogen fixing crop	NL implementation	No*
Field margin	NL implementation	Yes**
Watercourse	NL implementation	Yes***
Coppice ('Wilgenhakhout')	NL implementation	Yes
Landscape elements (only SNL)	NL implementation	Yes
Tree (single, group, line)	EU gross list	Yes
Wooded bank	EU gross list	Yes
Hedge	EU gross list	Yes
Pond	EU gross list	Yes

*: catch crop and Nitrogen fixing crop are not stable over a period of 3 years and therefore not included.
**: flower strips as field margins are not included in the EFA-layer, except those that are part of SNL. These managed field margins have a long term contract between farmer and province and are stable over a period of three years. The same applies to banks of watercourses (in Dutch 'schouwstrook'), that are also regarded as field margins.
***: watercourses are part of so called equivalent practice and are only allowed in combination with a SNL field margin (i.e. flower strip).

Table C.3 gives measurement criteria, definitions and additional requirements that apply to EFAs. This specification serves two goals: to find matching objects in existing IMs and as an aid for detection through remote sensing. Table C.3 shows a large collection of landscape elements. These element can be grouped in the following possible objects and definitions:

- PotentialEfa: delineated area to safeguard and improve biodiversity on farms as regulated in EU 1307/2014.
- EfaGreen: green landscape elements mentioned table C.3, except solitary tree, and adhering to the dimensions and additional requirements.
- EfaTree: solitary tree and adhering to minimum crown diameter.
- EfaWater: blue landscape element mentioned in table C.3 and adhering to the dimensions and additional requirements.
- EfaPond: Open (semi)natural area containing water of at least 0.1 ha or larger.
- EfaSnl: Elements under a special conservation regime (SNL). These elements are part of a 'Field Margin' package in the new CAP.

Above grouping is based on the attributes that are needed to describe the objects and the geometric representation of each object. For each PotentialEFA information regarding the existence of an element (i.e. begin date and end date) as well as an element's name is needed. Some elements are represented by polygons or points, while watercourses are represented by lines. A conversion factor is used to calculate a representative area in the latter case. EfaPond is comparable to EfaGreen regarding the attributes, but is added as a distinct object to indicate the difference between green and blue landscape elements.

Table C.3: EFA landscape elements definition and measurement

Element		Definition	Measure	Additional requirement
Field margin		Semi-natural habitat connected to a parcel, i.e. banks along watercourses. Crop edges and margin strips are part of the reference layer for parcels (AAN-layer) and are not regarded as field margin	Width ≥ 1 m and ≤ 20 m	Only field margins outside AAN, e.g. bank (schouwstrook)
Hedges		Linear landscape element consisting of bushes forming a hedge. A hedgerow need not contain trees, but any trees that are growing within it form part of the hedgerow (Tansey et al., 2009)	≤ 10 m width	
Wooded bank		Linear landscape element consisting of trees and/or bushes. A wooded bank may grow on an earth bank. A wooded bank is cut periodically	≤ 10 m width	
Trees	Isolated	Single tree, no additional specification regarding tree species	≥ 4 m crown diameter	
	Line	Linear elements consisting of trees, no additional specification regarding tree species	≥ 4 m crown diameter	Space between crowns ≤ 5m
	Group	Patch elements consisting of trees, no additional specification regarding tree species	≤ 0.3 ha	Connected by overlapping crown cover
Pond		Open (semi)-natural area containing water. No plastic or concrete reservoir	≤ 0.1 ha	Plastic or concrete reservoir not allowed
Watercourse		System of a specific width that contains surface water. Banks are part of the watercourse	Width ≥ 1 and ≤ 6 m	Channels with concrete walls not allowed
Coppice (wilgenhakhout)		An area of willows (genus Salix) for production of energy crop. Coppice is cut (harvested) periodically in a 2-4 year cycle	≤ 0.3 ha	
SNL		Landscape elements under SNL regime are part of equivalent practices	-	Measurements according SNL

Figure C.2 show how the different objects with their attributes relate. The figure also shows the needed geographic representation.

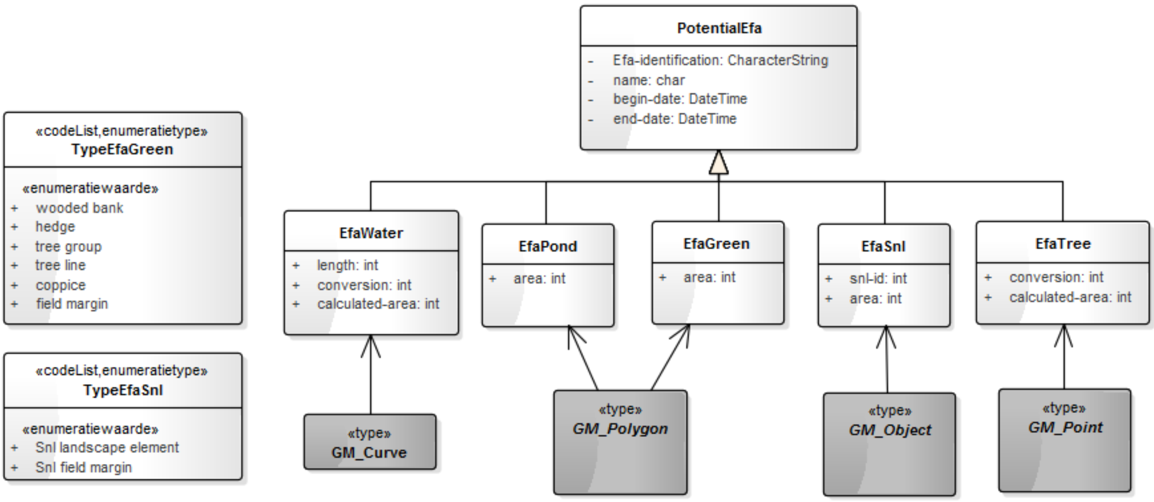


Figure C.2: PotentialEfa-objects

GM_Object is used to enable the representation of different elements that populate the EfaSnl class (e.g. wooded bank or field margin as polygon and single tree as point). GM_Object enables the use of constraints to specify the correct geometry, i.e. surface or point (NEN-3610).

Also shown are two codelists that indicate the elements that belong to a specific object. The specific requirements regarding data content and structure are specified in table C.4.

Table C.4: Data specification for PotentialEfa

Component	Description	Requirements
1. Vector geometry	Requirements of features regarding geometry: - Dimensionality (0D, 1D, 2D, 3D) - Interpolation types for curves and surface? - Sharing of geometry objects required?	EfaWater - 2-D, vector - Line, representing center of an element - Polygon, calculated area (using length and conversion factor) EfaPond: - 2-D, vector - Polygon, representing water covered area EfaGreen: - 2-D, vector - Polygon, representing o Canopy area (hedges/tree group) o Crown area (trees in line) EfaTree: - 2-D, vector - Point, representing solitary tree EfaSnl: - 2-D, vector - Object, representation depends on object type.
2. Topology	Is topology required?	Not needed
3. Coverages	Are coverages required? (Coverages express continuous data, e.g. temperature, elevation, sensor)	Not needed

4. Temporal profile	Identify the requirements regarding temporal aspects: - Support features that move or change over time - Support multiple versions or versioning of properties.	Material history (changes of object in real world) and Formal history (changes of object in registration) are needed for all objects
5. Object referencing model	Object referencing connects the same objects across different datasets. (location of an object is determined by referring to spatial location of another object) Are object referencing methods required?	Feasible if objects that originate from other IMs are incorporated into a new IM. In this case the original object ID is used.
6. Portrayal	Which data do you need to display and how? I.e.: - Map service and/or feature service? - Which scales? - Which symbolization? - Portrayal rules? - Is a portrayal catalogue required?	Not determined.
7. Identifier Management	- Are identifiers required? - For which features? - Which roles do identifiers for entities play? - Which are the required characteristics of identifiers (i.e. unique, stable)? - Is there a management for such identifiers specified?	A unique identification for an EFA-object is applied. E.g.country code (NL) code for IM (EFA), stakeholder code, unique ID: NL.EFA.xxx.123456
8. Registers and registries	Which registers are required, if any? - Reference system - Units of measurement - Feature concept dictionary - Feature catalogue codelist - Thesauri - Portrayal catalogues - Etc. Do these registers require to be conform ISO standards or other standards?	Model uses local reference system: Amersfoort/RS new, EPSG::28992
9. Data quality	Data quality requirements? (i.e. positional, thematic and temporal accuracy, logical consistency?)	- Accuracy: cartographic scale of 1:5,000. - Temporal accuracy: Annual update. - Thematic accuracy: specification according table C.3 and for watercourses as specified in figure C.3.
10. Data capturing	- What is the level of detail required? - Which selection criteria are required, i.e. all features, features with a specific area or length? - Where are they defined?	Data not available in existing information models are captured through remote sensing at a spatial resolution of 1:5,000. The minimum and maximum dimensions for EFAs (table C.3) also apply to objects derived through remote sensing.

Figure C.3 gives a schematic overview of a watercourse and adjacent objects and also shows a picture of a comparable situation.

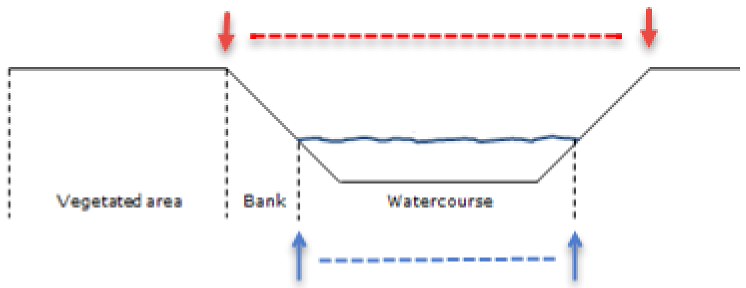
	
	A = Watercourse B, C = Vegetation area (Begroeid terreindeel, grasland overig) D, E= Bank (oever/slootkant)

Figure C.3: Schematic overview and picture of watercourse (picture from IMGeo objectenhandboek)

Banks (D and E in figure C.3) are part of a watercourse, regarding its definition in table C.3. A field margin (B and C in figure C.3) is a potential EFA. The watercourse itself (A in figure C.3) should be represented as a line and a conversion and weighting are used to calculate the area. The width of a watercourse is calculated as indicated by the red arrows.

Stage 3 As-is analysis

This stage compares the data requirements from the previous stages with the existing situation.

An initial exploration of IMs resulted in three potentially beneficiary IMs for elements of the EFA-layer:

1. IMNa. For equivalent practices, consisting of objects that are currently registered and managed under SNL conditions. This relates to elements that populate EfaSnl;
2. BGT/IMGeo. As potential source for all objects: EfaWater, EfaGreen and EfaPond;
3. IMWa. As potential source for EfaWater and EfaPond.

Table C.5 gives an overview of the as-is analysis.

Table C.5: As-is analysis

Component	As-is

1. Vector geometry	EfaSnl:
	- IMNa models SNL objects as polygon/2-d.
	
	EfaWater/EfaPond:
	• IMWa models water(parts), including ponds and watercourses:
	  o Watercourses: 2-d line and sometimes as polygon/2-d.
	  o Ponds: polygon/2-d.
	• BGT/IMGeo models watercourses and ponds. Both are represented as polygon/2-d objects.
	
	EfaGreen/EfaTree:
	- BGT/IMGeo: hedges are additional IMGeo objects and modelled as line (<30 cm) or polygon (> 30 cm)
	- BGT/IMGeo: trees are additional IMGeo objects and modelled as point.
	- BGT/IMGeo: tree lines are modelled as point (IMGeo) or polygon (or BGT vegetation area)
	- BGT/IMGeo: wooded bank, tree group and field margin along watercourse are modelled as BGT object and represented as polygon/2-d objects.

2. Topology	Not needed
3. Coverages	Not needed
4. Temporal profile	- IMNa: only material history - BGT/IMGeo: only formal history. - BGT/IMGeo: attribute "status" provides additional information (i.e. planned, existing, history) that could replace material history. - IMWa: material and formal history
5. Object referencing model	Determined later
6. Portrayal	Not needed
7. Identifier Management	All considered IMs use their own identifier management.
8. Registers and registries	All considered IMs use 'Amersfoort/RS new' as reference system.
9. Data quality	**Accuracy:** IMNa (objects EfaSnl): 1:10,000 IMWa (objects EfaWater/EfaPond): 1:10,000. Not all waterboards adhere to IMWa standards, which could mean differences in consistency of data between different parts of the Netherlands. IMWa is in transition to find connection to the BGT/IMGeo standards. BGT/IMGeo (All PotentialEfa objects, except EfaSnl): 1:5,000 .

	Thematic quality: • BGT/IMGeo uses no minimum dimensions in modelling geospatial data. **EfaGreen:** • BGT/IMGeo contains an object 'vegetation area' ('BegroeidTerreindeel') which models wooded bank, tree group, tree line and field margins along watercourses • BGT/IMGeo models hedges as part of the not compulsory IMGeo. See vegetation object under EfaTree. • BGT/IMGeo provides information regarding coppice as 'plus' topography (i.e. IMGeo) however there is no further distinction in species. Thus it is not possible to distinct in coppice consisting of genus Salix (Wilgenhakhout). **EfaTree:** • BGT/IMGeo models solitary trees (and hedges) as a 'SolitaryVegetationobject' ('VegetatieObject'). This is additional topography part of IMGeo, which is not compulsory. **EfaSnl:** • IMNa models all elements that are part of SNL. IMNa is the only source for these objects **EfaWater:** • BGT/IMGeo and IMWa both contain an object 'water part' which models watercourses and pools. • BGT/IMGeo and IMWa both consider 'bank' as part of the watercourse. • IMWa and BGT/IMGeo have a different definition of watercourse width. The blue arrows in figure 4 indicate the IMWa's calculation, while the red arrow indicate BGT/IMGeo's calculation. The red arrow is the required width for this use-case. **Temporal accuracy:** • BGT/IMGeo is updated every 18 months. • IMNa and IMWa are updated annually.
10. Data capturing	Use of Remote Sensing for collection of landscape elements is part of the research

Stage 4 Gap analysis

Identifies user requirements that cannot be met by the current available data. This stage reveals gaps that can be filled using Remote Sensing.

The previous stages defined the requirements and indicated whether these are met by the diverse elements. Stage 2 and 3 indicate that all needed objects are collected, but there are some differences in the modelling of objects:

Vector geometry representation:

- BGT/IMGeo represents not all EfaGreen elements as polygon:
    - Hedges < 30 cm as line.
    - Tree row as single point or polygon.

- BGT/IMGeo represents EfaWater as polygon and not as line.
- IMNa represents not all EfaSnl elements as required:
    - o Tree as polygon, instead of point.

Accuracy

- Cartographic scale of IMNa and IMWa is to coarse: 1:10,000 while EFA-layer requires 1:5,000.

Thematic quality:

- IMWa calculates the width of watercourses differently from the requirements of this use-case.
- BGT/IMGeo models coppice as 'plus' topography although there is no distinction in coppice type. For this use-case a distinction in coppice consisting of the genus Salix (Wilgenhakhout) is needed.

Temporal profile:

- Formal and material history is needed for a PotentialEfa. IMNa only provides material history

Temporal quality:

- Temporal quality of BGT/IMGeo is 18 months, while 12 months is desired.

Above gaps indicate semantic differences between models and objects needed for the EFA-layer. But there is an additional gap regarding collecting elements. Especially BGT/IMGeo offers organizations a great level of freedom in collecting the geospatial information regarding objects of their responsibility. This is done deliberately to simplify a connection to the already available geospatial information. However, this not only brings interpretation differences between an object that is collected by different organizations, it also leads to differences in whether objects (i.e. additional IMGeo objects) are actually collected. This indicates additional gaps in case of:

- o Solitary trees are modelled as 'plus' topography although its availability in the rural area is questionable.
- o Hedges are modelled as 'plus' topography although its availability in the rural area is questionable.
- o Trees in line exist as vegetation area (polygon) or as a collection of single trees. Also here, the availability in the rural area is questionable.

Stage 5 Data specification development

A data specification is created according to the results of the 'as-is' and gap analysis. Technical and financial feasibility should be considered in this stage as well.

Some gaps are identified in the previous stage. These gaps refer to the temporal quality (18 months instead 12 months update time) and geometric misfit for watercourses and seem of subsidiary level. BGT/IMGeo model and provides a data specification that adapts the existing information model to make a further specification.

BGT/IMGeo offers good possibilities to serve as a blue print for an EFA-layer, or IMEfa. Important in this regards is that BGT/IMgeo is a national source for information and also a source to which other standards connect by adhering to its modelling principles, i.e. semantics. This is the case for IMNa and IMWa. IMNa is the only source for EfaSnl, but it is possible to "map" EfaSnl onto the identified objects in IMEfa. Table C.6 provides a suggestion for the combination of objects.

Table C.6: Mapping SNL onto other objects

Object	SNL element
EfaGreen	L01.02 Houtwal en houtsingel L01.03 Elzensingel L01.04 Bossingel en bosje L01.05 Knip- of scheerheg L01.06 Struweelhaag L01.07 Laan L01.11 Hakhoutbosje L01.12 Griendje L01.13 Bomenrij en solitaire boom L01.14 Rietzoom en klein rietperceel L01.15 Natuurvriendelijke oever
EfaTree	L01.08 Knotboom L01.13 Bomenrij en solitaire boom
EfaWater	Not available
EfaPond	L01.01 Poel en klein historisch water

The name of the SNL object in table C.6 refers to the original name of the object in the Index Nature and Landscape (see section 2.2.3). Elements that that originate from this model have a unique identification, that should also be used in an IMEfa. Note that at this moment this is not possible yet, due to differences in geometry (i.e. tree) and accuracy between IMNa and BGT/IMGeo. Also note that the element "L01.13 Bomenrij en solitaire boom" is included twice. Therefore, the use of IMNa as a source for IMEfa needs further research regarding harmonization of data.

The specialization of BGT/IMGeo regarding EFAs, IMEfa, is restricted to two objects that describe EFAs: water part and vegetation area ('Begroeid terreindeel') and plus classification of these objects. Table C.7 gives an overview of EFA landscape elements and subsequent objects using the information derived in the previous stages. Also included is a classification according BGT/IMGeo using Dutch names.

Table C.7: Mapping of EFA on the model BGT/IMGeo

BGT Feature	BGT classification	Plus classification	EFA	Remark
Begroeid terreindeel (Vegetation area)	Tree single		Tree single	'plus' classification Rural partial available
	Houtwal		Wooded bank	BGT
	Loofbos	Griend/Hakhout	Coppice	'plus' classification
	Loofbos Gemengd bos Naaldbos	→	Trees group/ Tree line	BGT
	Struiken		Hedges	BGT
	Grasland overig		Field margin	BGT
Waterdeel (Water part)	Waterloop	Sloot	Water course	BGT Surface instead line
	Watervlakte	Meer, plas, ven, vijver	Pool	'plus' classification

Figures C.4 and C.5 show the extended BGT/IMGeo model with the added objects in green. Figure C.4 shows that EFAWaterdeel is a specialization of WaterBody and ads the extra attributes length, conversion factor and calculated area. Also the geometry is changes from surface into line. Figure C.5 shows the three additional EFA classes and their attributes.

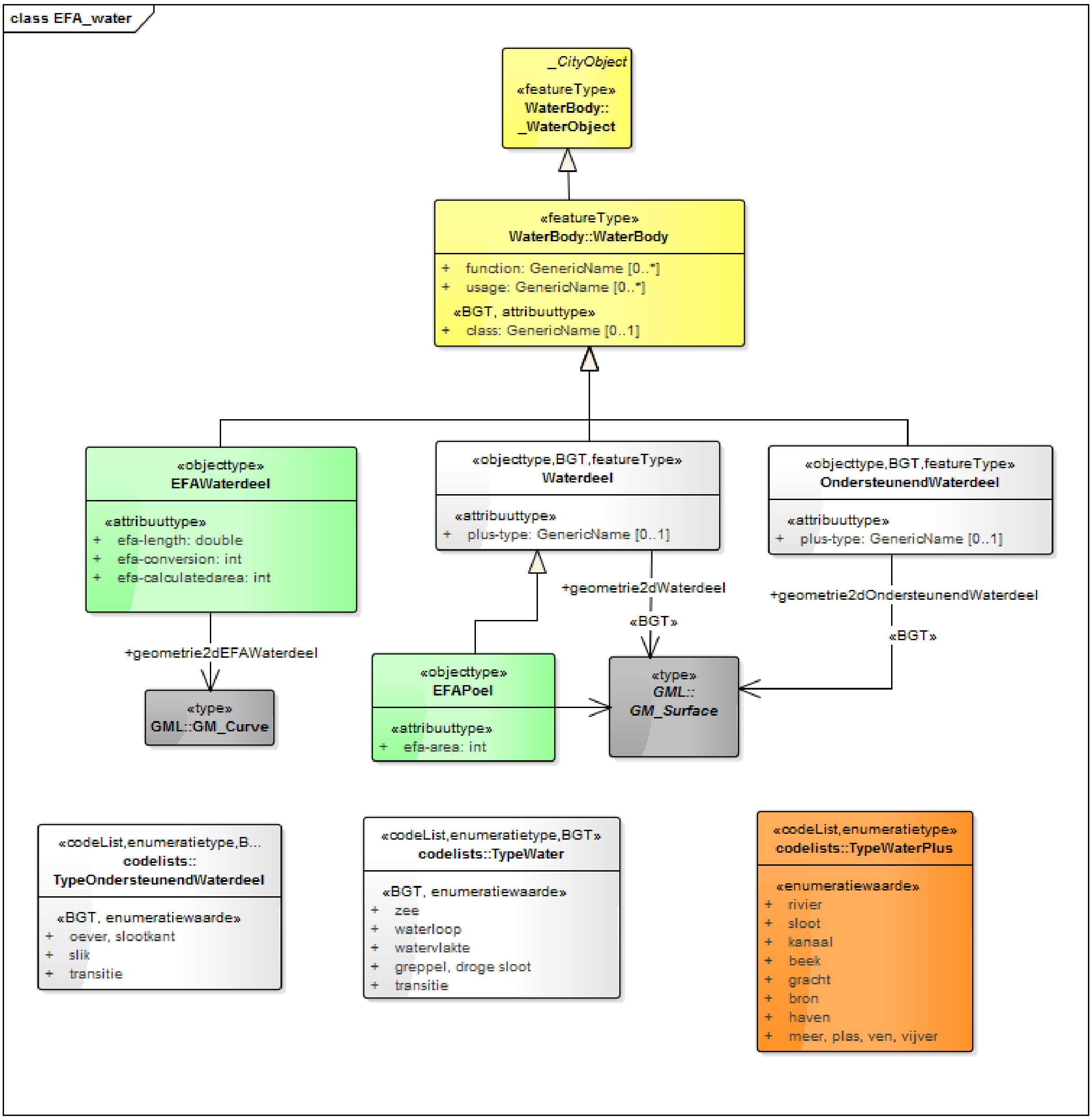


Figure C.4: Draft data model EFA water part

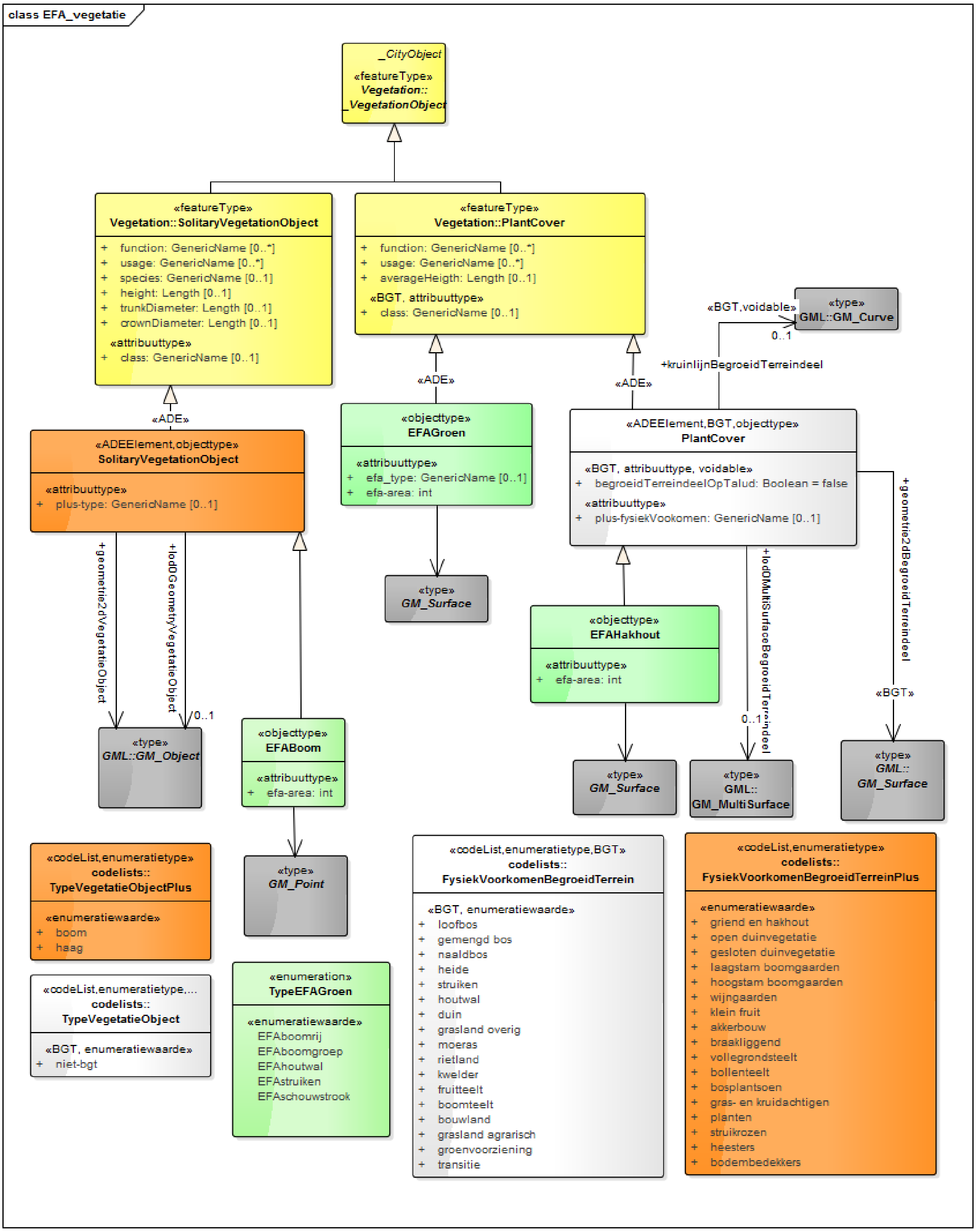


Figure C.5: Draft data model EFA Vegetation area

Appendix D Segmentation Goodness Evaluation Object height

PERCENTAGE EXTRA PIXELS													
		ROW						TREE					
parameter	ID	min	1st Q	median	3rd Q	max	def	min	1st Q	median	3rd Q	max	def
sc8s1c1	1	2,5%	3,1%	3,8%	10,4%	17,0%	0	4,0%	5,5%	8,6%	16,8%	33,7%	1
sc8s1c3	2	2,2%	3,2%	4,2%	11,7%	19,2%	0	4,0%	5,9%	6,8%	11,8%	25,7%	1
sc8s1c5	3	2,3%	2,8%	3,2%	9,5%	15,7%	0	6,5%	6,9%	7,1%	11,9%	25,7%	1
sc8s1c7	4	2,3%	2,5%	2,8%	6,6%	10,4%	0	0,0%	5,2%	8,5%	10,0%	10,2%	0
sc8s1c9	5	2,5%	2,7%	2,8%	8,1%	13,4%	0	6,8%	21,7%	28,2%	30,8%	33,7%	3
sc8s3c1	6	3,2%	3,6%	3,9%	11,9%	19,9%	0	4,0%	5,5%	6,5%	12,4%	28,4%	1
sc8s3c3	7	2,6%	2,9%	3,2%	9,9%	16,6%	0	15,5%	18,8%	20,7%	27,9%	47,0%	1
sc8s3c7	8	1,9%	2,1%	2,3%	7,9%	13,4%	0	0,0%	6,4%	13,7%	28,0%	55,4%	1
sc8s3c9	9	2,7%	2,8%	2,8%	7,2%	11,6%	0	4,0%	10,0%	21,5%	31,2%	32,0%	2
sc8s5c1	10	2,5%	3,4%	4,3%	9,0%	13,7%	0	4,0%	6,3%	7,7%	12,0%	23,3%	0
sc8s5c3	11	3,1%	3,3%	3,5%	7,4%	11,3%	0	17,5%	18,2%	21,7%	25,2%	25,9%	1
sc8s5c5	12	3,1%	3,3%	3,4%	8,0%	12,7%	0	4,0%	8,7%	18,8%	28,6%	32,0%	2
sc8s5c7	13	2,6%	3,0%	3,3%	5,0%	6,7%	0	3,0%	12,9%	16,9%	18,6%	21,7%	0
sc8s5c9	14	2,7%	3,0%	3,2%	5,0%	6,8%	0	8,6%	12,1%	13,8%	16,4%	22,6%	0
sc8s7c1	15	3,2%	3,9%	4,6%	15,5%	26,5%	1	11,1%	15,9%	23,3%	37,4%	62,2%	2
sc8s7c5	16	3,5%	3,6%	3,7%	9,8%	16,0%	0	0,8%	4,1%	9,3%	13,6%	14,3%	0
sc8s7c7	17	3,1%	3,2%	3,2%	8,7%	14,3%	0	0,8%	2,3%	8,0%	13,5%	14,3%	0
sc8s7c9	18	3,0%	3,0%	3,1%	7,3%	11,5%	0	3,7%	5,4%	9,5%	13,5%	14,3%	0
sc8s9c5	19	3,8%	4,0%	4,1%	8,4%	12,7%	0	5,2%	11,2%	15,1%	22,4%	38,4%	1
sc8s9c7	20	2,8%	3,1%	3,4%	8,0%	12,7%	0	5,2%	7,3%	12,5%	19,4%	26,5%	1
sc8s9c9	21	2,9%	2,9%	2,9%	5,6%	8,3%	0	5,2%	6,0%	7,1%	12,6%	26,5%	1
sc10s1c1	22	2,6%	3,4%	4,3%	10,0%	15,7%	0	11,2%	14,6%	16,0%	20,6%	33,7%	1
sc10s1c3	23	2,9%	3,5%	4,2%	11,7%	19,2%	0	0,0%	3,0%	5,5%	11,7%	25,7%	1
sc10s1c5	24	2,4%	3,2%	3,9%	8,1%	12,3%	0	6,5%	6,9%	10,2%	16,4%	25,7%	1
sc10s1c7	25	2,6%	3,1%	3,5%	8,6%	13,7%	0	0,0%	5,1%	6,9%	12,2%	27,8%	1
sc10s1c9	26	2,9%	3,1%	3,4%	11,1%	18,9%	0	6,8%	7,9%	14,1%	26,7%	47,0%	1
sc10s3c1	27	2,6%	3,2%	3,9%	7,5%	11,1%	0	5,9%	6,8%	11,4%	18,9%	28,4%	1
sc10s3c3	28	2,0%	3,1%	4,2%	15,8%	27,4%	1	0,0%	5,1%	13,3%	28,7%	55,1%	1
sc10s3c7	29	3,0%	3,2%	3,4%	12,7%	22,0%	0	6,8%	17,9%	23,3%	25,8%	28,0%	1
sc10s3c9	30	3,1%	3,3%	3,6%	7,8%	11,9%	0	6,4%	20,3%	26,0%	28,4%	32,6%	2
sc10s5c1	31	3,6%	3,8%	3,9%	10,2%	16,5%	0	15,5%	17,7%	20,0%	21,6%	21,7%	0
sc10s5c7	32	3,1%	3,3%	3,5%	5,5%	7,5%	0	3,1%	9,4%	14,5%	19,4%	24,9%	0
sc10s7c1	33	3,0%	4,0%	5,0%	12,4%	19,8%	0	6,8%	8,1%	18,2%	32,4%	46,3%	2
sc10s7c7	34	3,3%	3,3%	3,3%	6,9%	10,5%	0	0,0%	4,4%	9,5%	18,1%	32,9%	1
sc10s7c9	35	3,2%	3,2%	3,2%	6,6%	9,9%	0	5,9%	11,4%	15,1%	24,9%	48,2%	1
sc10s9c9	36	3,1%	3,6%	4,1%	7,1%	10,2%	0	5,2%	7,8%	12,9%	19,4%	26,5%	1
sc12s1c1	37	2,7%	3,2%	3,6%	10,2%	16,8%	0	11,2%	14,6%	16,0%	17,6%	21,5%	0
sc12s1c3	38	2,6%	3,3%	4,0%	11,6%	19,2%	0	4,0%	6,2%	16,0%	25,1%	25,7%	1
sc12s1c5	39	2,9%	3,1%	3,3%	13,4%	23,5%	0	4,0%	6,2%	10,7%	17,3%	25,7%	1
sc12s1c7	40	3,0%	3,5%	4,0%	8,8%	13,7%	0	6,8%	6,9%	8,6%	14,1%	25,7%	1
sc12s1c9	41	2,8%	3,5%	4,3%	10,4%	16,5%	0	6,8%	9,4%	17,3%	24,9%	26,6%	1
sc12s3c9	42	2,9%	3,4%	3,8%	8,3%	12,8%	0	4,0%	13,2%	24,1%	32,0%	32,0%	2
sc12s5c1	43	3,4%	3,7%	4,0%	10,2%	16,5%	0	6,8%	7,0%	8,7%	19,8%	48,3%	1
sc12s5c9	44	4,0%	4,0%	4,1%	8,3%	12,5%	0	0,8%	13,4%	18,7%	22,3%	29,6%	1
sc12s9c9	45	4,7%	4,8%	5,0%	15,4%	25,8%	1	0,0%	9,9%	15,6%	20,4%	27,5%	1
sc15s1c5	46	2,6%	3,6%	4,6%	9,6%	14,5%	0	4,0%	6,2%	10,7%	17,3%	25,7%	1
sc15s1c7	47	3,1%	3,5%	3,9%	10,0%	16,1%	0	6,8%	7,9%	14,6%	22,1%	25,7%	1
sc15s3c5	48	3,2%	3,5%	3,8%	12,2%	20,5%	0	26,4%	29,8%	33,6%	39,1%	47,7%	4

PERCENTAGE MISSING PIXELS													
		ROW						**TREE**					
parameter	**ID**	**min**	**1st Q**	**median**	**3rd Q**	**max**	**def**	**min**	**1st Q**	**median**	**3rd Q**	**max**	**def**
sc8s1c1	1	4,2%	4,9%	5,6%	9,4%	13,1%	0	14,9%	19,9%	26,3%	32,6%	36,8%	2
sc8s1c3	2	4,7%	4,9%	5,1%	7,9%	10,7%	0	25,4%	28,9%	30,8%	32,6%	35,3%	4
sc8s1c5	3	4,9%	5,6%	6,3%	9,1%	11,9%	0	17,6%	23,4%	28,5%	34,0%	41,2%	3
sc8s1c7	4	5,2%	6,1%	6,9%	12,0%	17,2%	0	18,1%	39,5%	48,4%	54,0%	65,6%	3
sc8s1c9	5	4,3%	5,7%	7,1%	15,5%	23,9%	0	14,0%	16,3%	17,8%	20,4%	26,1%	1
sc8s3c1	6	4,2%	5,2%	6,3%	8,8%	11,4%	0	17,8%	27,0%	31,6%	34,4%	38,3%	3
sc8s3c3	7	4,4%	5,0%	5,7%	11,3%	16,9%	0	13,8%	19,4%	21,3%	24,1%	32,5%	1
sc8s3c7	8	4,7%	6,2%	7,6%	11,4%	15,1%	0	28,3%	31,7%	33,3%	50,3%	100%	4
sc8s3c9	9	4,2%	5,1%	5,9%	11,0%	16,1%	0	14,7%	20,4%	23,8%	25,9%	27,8%	2
sc8s5c1	10	5,2%	5,8%	6,3%	14,3%	22,3%	0	25,0%	32,1%	36,4%	41,6%	51,6%	3
sc8s5c3	11	5,0%	5,8%	6,6%	16,8%	26,9%	1	12,1%	15,5%	18,2%	23,0%	32,8%	1
sc8s5c5	12	4,2%	4,8%	5,5%	14,3%	23,2%	0	14,7%	14,8%	22,4%	30,7%	32,5%	2
sc8s5c7	13	4,9%	5,0%	5,2%	14,5%	23,7%	0	6,4%	19,6%	30,4%	39,3%	47,0%	2
sc8s5c9	14	4,2%	4,8%	5,4%	14,2%	22,9%	0	29,2%	34,1%	41,6%	48,9%	53,0%	4
sc8s7c1	15	5,8%	6,3%	6,7%	11,2%	15,7%	0	2,4%	9,7%	19,8%	28,8%	32,8%	2
sc8s7c5	16	4,8%	5,5%	6,1%	10,5%	14,9%	0	29,2%	42,9%	52,9%	59,3%	62,3%	4
sc8s7c7	17	4,3%	4,7%	5,2%	11,3%	17,4%	0	26,5%	28,5%	39,7%	52,3%	58,3%	4
sc8s7c9	18	4,4%	4,8%	5,3%	15,7%	26,2%	1	29,0%	29,1%	29,3%	32,3%	40,9%	4
sc8s9c5	19	4,9%	5,7%	6,4%	16,9%	27,4%	1	33,9%	34,2%	41,0%	49,0%	53,4%	4
sc8s9c7	20	5,3%	6,1%	6,8%	17,1%	27,4%	1	24,8%	32,0%	35,7%	39,7%	47,6%	3
sc8s9c9	21	4,9%	5,4%	5,9%	15,8%	25,8%	1	24,8%	32,0%	35,7%	38,1%	41,2%	3
sc10s1c1	22	5,4%	5,8%	6,1%	11,7%	17,4%	0	14,9%	16,6%	19,3%	22,7%	26,1%	1
sc10s1c3	23	5,0%	5,5%	6,0%	8,4%	10,7%	0	25,4%	28,9%	38,6%	51,8%	65,6%	4
sc10s1c5	24	5,0%	5,6%	6,2%	14,3%	22,3%	0	12,5%	22,1%	27,4%	29,9%	31,6%	3
sc10s1c7	25	5,7%	6,3%	6,8%	13,4%	20,0%	0	25,4%	27,6%	39,2%	54,0%	65,6%	4
sc10s1c9	26	4,4%	5,9%	7,3%	13,7%	20,1%	0	13,8%	19,4%	23,6%	32,5%	51,6%	2
sc10s3c1	27	5,2%	5,9%	6,6%	19,4%	32,3%	1	17,8%	24,0%	29,6%	34,4%	38,3%	3
sc10s3c3	28	5,2%	5,8%	6,5%	11,5%	16,6%	0	13,8%	19,4%	27,0%	41,0%	65,6%	2
sc10s3c7	29	5,2%	6,2%	7,2%	12,4%	17,6%	0	19,9%	26,2%	28,6%	29,9%	32,8%	3
sc10s3c9	30	4,8%	5,7%	6,6%	15,9%	25,3%	1	19,0%	21,8%	24,3%	27,6%	32,8%	2
sc10s5c1	31	5,4%	6,2%	7,1%	14,0%	21,0%	0	18,5%	20,6%	23,4%	27,7%	34,7%	2
sc10s5c7	32	5,2%	5,6%	6,0%	15,2%	24,5%	0	35,8%	36,5%	37,8%	38,8%	38,9%	4
sc10s7c1	33	6,1%	6,7%	7,2%	11,6%	16,0%	0	18,5%	20,6%	24,6%	28,5%	30,5%	2
sc10s7c7	34	5,9%	6,3%	6,8%	16,2%	25,6%	1	12,7%	23,0%	26,7%	36,9%	66,4%	3
sc10s7c9	35	5,9%	6,4%	6,8%	17,8%	28,8%	1	7,6%	20,8%	27,1%	29,1%	29,4%	3
sc10s9c9	36	5,1%	6,4%	7,7%	17,7%	27,6%	1	24,8%	31,8%	34,3%	35,0%	37,0%	3
sc12s1c1	37	5,7%	6,6%	7,5%	11,4%	15,3%	0	17,2%	20,4%	23,8%	31,5%	47,8%	2
sc12s1c3	38	5,3%	5,9%	6,4%	8,6%	10,7%	0	15,7%	23,0%	27,7%	34,3%	47,2%	3
sc12s1c5	39	5,5%	6,7%	7,9%	8,9%	9,9%	0	25,4%	30,6%	36,7%	43,3%	49,7%	4
sc12s1c7	40	5,5%	5,7%	5,8%	12,9%	20,0%	0	25,4%	27,6%	39,2%	50,5%	51,6%	4
sc12s1c9	41	5,8%	6,0%	6,1%	13,8%	21,4%	0	14,0%	18,3%	22,9%	32,5%	51,6%	2
sc12s3c9	42	5,8%	6,5%	7,2%	15,7%	24,2%	0	8,7%	13,2%	18,0%	25,2%	36,8%	1
sc12s5c1	43	5,9%	7,2%	8,5%	14,8%	21,0%	0	21,3%	24,9%	32,2%	41,6%	51,6%	3
sc12s5c9	44	4,8%	6,3%	7,8%	12,9%	18,0%	0	22,7%	29,4%	38,7%	49,0%	58,3%	3
sc12s9c9	45	5,8%	6,4%	7,1%	15,2%	23,3%	0	30,4%	43,8%	50,9%	55,9%	63,6%	4
sc15s1c5	46	6,8%	7,7%	8,5%	16,8%	25,1%	1	25,4%	30,6%	36,7%	43,3%	49,7%	4
sc15s1c7	47	6,1%	7,3%	8,5%	13,9%	19,2%	0	25,4%	27,6%	31,3%	38,6%	51,6%	4
sc15s3c5	48	6,1%	8,3%	10,4%	14,9%	19,5%	0	5,5%	12,7%	15,5%	20,1%	32,4%	1

100% AREA											
		ROW					TREE				
parameter	ID	min	1st Q	median	3rd Q	max	min	1st Q	median	3rd Q	max
sc8s1c1	1	0,0%	35,8%	71,6%	73,2%	74,7%	0,0%	0,0%	15,7%	32,1%	34,4%
sc8s1c3	2	0,0%	35,3%	70,6%	72,6%	74,6%	0,0%	0,0%	10,1%	23,7%	34,4%
sc8s1c5	3	10,2%	41,5%	72,8%	74,9%	77,0%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s1c7	4	8,3%	41,8%	75,2%	76,1%	77,0%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s1c9	5	6,0%	40,0%	73,9%	75,0%	76,0%	0,0%	0,0%	4,5%	15,3%	34,4%
sc8s3c1	6	0,0%	34,6%	69,3%	70,3%	71,3%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s3c3	7	0,0%	36,5%	73,0%	73,4%	73,9%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s3c7	8	5,6%	41,1%	76,7%	77,2%	77,7%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s3c9	9	8,3%	42,5%	76,7%	77,1%	77,5%	0,0%	0,0%	0,0%	0,0%	0,0%
sc8s5c1	10	0,0%	35,5%	71,0%	71,1%	71,3%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s5c3	11	0,0%	36,1%	72,1%	72,9%	73,6%	0,0%	0,0%	0,0%	0,0%	0,0%
sc8s5c5	12	0,0%	36,2%	72,5%	72,8%	73,0%	0,0%	0,0%	0,0%	10,1%	40,3%
sc8s5c7	13	16,2%	45,5%	74,7%	75,5%	76,3%	0,0%	0,0%	0,0%	5,0%	20,2%
sc8s5c9	14	21,3%	49,7%	78,0%	78,1%	78,2%	0,0%	0,0%	14,6%	29,4%	30,3%
sc8s7c1	15	0,0%	32,8%	65,6%	66,6%	67,5%	0,0%	0,0%	0,0%	0,0%	0,0%
sc8s7c5	16	10,7%	41,6%	72,6%	73,1%	73,6%	0,0%	0,0%	10,1%	21,3%	24,6%
sc8s7c7	17	6,0%	41,5%	77,0%	77,1%	77,2%	18,4%	26,5%	29,7%	31,0%	32,9%
sc8s7c9	18	10,7%	43,9%	77,2%	77,3%	77,4%	12,3%	21,0%	26,5%	29,4%	30,3%
sc8s9c5	19	14,4%	43,4%	72,4%	73,1%	73,7%	0,0%	0,0%	0,0%	5,0%	20,2%
sc8s9c7	20	19,9%	47,6%	75,3%	76,3%	77,2%	0,0%	0,0%	0,0%	5,0%	20,2%
sc8s9c9	21	28,3%	53,4%	78,5%	78,8%	79,0%	0,0%	0,0%	7,2%	18,0%	29,1%
sc10s1c1	22	0,0%	33,3%	66,6%	67,6%	68,6%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s1c3	23	0,0%	33,7%	67,4%	68,2%	69,0%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s1c5	24	10,2%	38,9%	67,5%	69,4%	71,2%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s1c7	25	0,0%	34,4%	68,9%	71,7%	74,6%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s1c9	26	0,0%	34,9%	69,8%	69,9%	69,9%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s3c1	27	0,0%	32,9%	65,9%	66,4%	66,8%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s3c3	28	0,0%	33,5%	67,0%	68,5%	70,0%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s3c7	29	0,0%	35,0%	70,0%	70,2%	70,4%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s3c9	30	0,0%	35,8%	71,6%	72,0%	72,3%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s5c1	31	0,0%	33,6%	67,2%	67,3%	67,3%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s5c7	32	11,6%	40,3%	68,9%	69,3%	69,8%	0,0%	0,0%	0,0%	8,1%	32,4%
sc10s7c1	33	0,0%	28,1%	56,3%	56,9%	57,6%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s7c7	34	4,6%	37,7%	70,9%	71,5%	72,0%	0,0%	0,0%	0,0%	8,2%	32,9%
sc10s7c9	35	7,0%	39,8%	72,6%	72,7%	72,8%	0,0%	0,0%	4,5%	12,7%	23,9%
sc10s9c9	36	17,2%	45,4%	73,7%	74,0%	74,3%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s1c1	37	0,0%	29,8%	59,7%	61,9%	64,1%	0,0%	0,0%	0,0%	8,6%	34,4%
sc12s1c3	38	0,0%	30,6%	61,2%	64,7%	68,3%	0,0%	0,0%	0,0%	8,6%	34,4%
sc12s1c5	39	0,0%	31,2%	62,5%	63,5%	64,6%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s1c7	40	0,0%	32,1%	64,3%	67,6%	70,9%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s1c9	41	0,0%	32,1%	64,3%	64,8%	65,3%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s3c9	42	0,0%	33,5%	66,9%	67,3%	67,7%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s5c1	43	0,0%	30,5%	61,0%	61,6%	62,1%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s5c9	44	10,7%	39,3%	68,0%	68,0%	68,0%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s9c9	45	5,6%	37,1%	68,6%	68,7%	68,7%	0,0%	0,0%	0,0%	5,0%	20,2%
sc15s1c5	46	0,0%	26,7%	53,4%	55,9%	58,4%	0,0%	0,0%	0,0%	0,0%	0,0%
sc15s1c7	47	0,0%	29,4%	58,8%	62,4%	66,0%	0,0%	0,0%	0,0%	0,0%	0,0%
sc15s3c5	48	0,0%	29,3%	58,7%	58,7%	58,7%	0,0%	0,0%	0,0%	0,0%	0,0%

Appendix E Segmentation Goodness Evaluation Object height and NDVI

PERCENTAGE EXTRA PIXELS													
		ROW						TREE					
parameter	ID	min	1st Q	median	3rd Q	max	def	min	1st Q	median	3rd Q	max	def
sc8s1c1	1	3,2%	3,7%	4,3%	10,8%	17,3%	0	4,0%	4,9%	8,2%	14,9%	26,0%	1
sc8s1c3	2	2,5%	3,2%	4,0%	8,5%	13,0%	0	4,0%	9,3%	17,0%	24,3%	28,4%	1
sc8s1c5	3	3,4%	3,7%	4,0%	9,2%	14,3%	0	6,8%	14,8%	17,9%	19,8%	23,9%	0
sc8s1c7	4	3,5%	3,6%	3,7%	10,2%	16,7%	0	6,8%	15,9%	29,6%	40,9%	43,2%	1
sc8s1c9	5	3,1%	3,6%	4,1%	15,9%	27,7%	1	12,9%	16,6%	18,1%	20,2%	25,5%	1
sc8s3c1	6	3,0%	3,4%	3,9%	11,0%	18,0%	0	0,0%	3,0%	8,8%	22,5%	49,0%	1
sc8s3c3	7	3,5%	3,5%	3,5%	10,9%	18,3%	0	6,8%	15,8%	27,0%	39,7%	52,9%	1
sc8s3c5	8	3,5%	3,6%	3,6%	10,0%	16,5%	0	0,1%	6,0%	12,4%	17,8%	20,4%	0
sc8s3c7	9	3,6%	3,6%	3,6%	11,3%	19,0%	0	12,5%	12,6%	16,4%	25,4%	41,5%	1
sc8s3c9	10	3,3%	3,6%	3,9%	8,7%	13,5%	0	18,5%	20,3%	21,1%	21,8%	23,2%	0
sc8s5c1	11	3,0%	3,4%	3,7%	15,0%	26,2%	1	6,8%	20,2%	25,3%	28,5%	36,1%	1
sc8s5c3	12	3,3%	3,6%	3,9%	12,5%	21,1%	0	12,3%	21,3%	26,0%	31,8%	44,2%	1
sc8s5c5	13	3,0%	3,2%	3,4%	11,3%	19,1%	0	0,0%	1,6%	5,7%	11,5%	18,1%	0
sc8s5c7	14	3,3%	3,3%	3,3%	6,1%	8,9%	0	0,0%	0,4%	8,5%	16,9%	18,3%	0
sc8s5c9	15	2,9%	3,0%	3,0%	7,1%	11,1%	0	0,0%	2,2%	6,9%	12,4%	17,1%	0
sc8s7c5	16	3,6%	3,6%	3,6%	5,7%	7,8%	0	0,0%	2,2%	6,4%	10,1%	10,8%	0
sc8s7c9	17	2,5%	2,7%	2,9%	11,5%	20,0%	0	3,1%	6,1%	11,8%	20,5%	32,3%	0
sc8s9c5	18	3,3%	3,9%	4,5%	6,5%	8,5%	0	6,9%	10,3%	20,0%	30,4%	35,7%	1
sc8s9c7	19	3,0%	3,0%	3,1%	4,3%	5,6%	0	10,6%	12,5%	17,1%	21,3%	22,5%	0
sc8s9c9	20	2,4%	2,7%	2,9%	4,5%	6,0%	0	0,0%	7,9%	11,2%	14,1%	21,0%	0
sc10s1c1	21	3,2%	3,4%	3,5%	10,6%	17,7%	0	4,0%	9,4%	15,9%	28,6%	52,7%	1
sc10s1c3	22	1,9%	3,0%	4,0%	11,7%	19,4%	0	0,0%	8,3%	16,6%	29,4%	51,1%	1
sc10s1c5	23	3,5%	3,6%	3,8%	14,0%	24,1%	0	6,8%	19,6%	24,1%	29,6%	45,4%	1
sc10s1c7	24	3,6%	3,8%	4,1%	12,6%	21,2%	0	6,8%	15,9%	22,2%	28,3%	36,5%	1
sc10s1c9	25	3,5%	3,8%	4,0%	12,2%	20,3%	0	16,5%	17,2%	17,9%	26,9%	52,5%	1
sc10s3c1	26	3,7%	4,5%	5,2%	10,4%	15,6%	0	4,0%	11,2%	29,5%	46,2%	49,0%	2
sc10s3c3	27	3,8%	4,3%	4,8%	9,9%	15,0%	0	6,8%	16,7%	20,6%	22,6%	26,9%	1
sc10s3c5	28	3,6%	3,9%	4,1%	15,0%	26,0%	1	7,9%	14,6%	28,5%	43,1%	51,7%	2
sc10s5c1	29	4,1%	4,3%	4,6%	15,2%	25,7%	1	25,9%	29,2%	35,1%	41,4%	46,2%	3
sc10s5c3	30	4,6%	4,8%	4,9%	11,5%	18,0%	0	20,4%	25,6%	32,0%	38,6%	44,2%	2
sc10s5c7	31	3,6%	3,7%	3,7%	10,2%	16,8%	0	0,0%	0,4%	9,4%	18,3%	18,6%	0
sc10s7c9	32	3,7%	4,2%	4,6%	8,8%	12,9%	0	1,0%	5,7%	13,0%	22,3%	32,8%	1
sc10s9c9	33	3,4%	3,7%	4,0%	11,2%	18,5%	0	4,2%	7,0%	11,0%	16,4%	23,7%	0
sc12s1c7	34	4,2%	4,6%	5,0%	19,2%	33,5%	1	6,8%	21,2%	30,1%	34,2%	34,4%	2
sc12s3c3	35	4,1%	4,1%	4,1%	13,6%	23,1%	0	16,0%	24,2%	32,6%	39,3%	42,3%	2

PERCENTAGE MISSING PIXELS													
		ROW						**TREE**					
parameters	**ID**	**min**	**1st Q**	**median**	**3rd Q**	**max**	**def**	**min**	**1st Q**	**median**	**3rd Q**	**max**	**def**
sc8s1c1	1	5,4%	5,6%	5,8%	11,0%	16,2%	0	17,4%	20,5%	25,8%	33,2%	42,5%	2
sc8s1c3	2	5,5%	6,0%	6,5%	12,4%	18,4%	0	17,8%	26,9%	30,0%	31,6%	36,3%	2
sc8s1c5	3	4,7%	5,8%	6,9%	14,0%	21,2%	0	19,4%	24,4%	29,3%	33,1%	34,7%	2
sc8s1c7	4	4,6%	5,8%	7,1%	14,4%	21,8%	0	17,3%	17,5%	20,7%	25,3%	29,9%	1
sc8s1c9	5	5,1%	5,3%	5,4%	5,8%	6,3%	0	10,8%	22,0%	27,0%	36,4%	60,5%	2
sc8s3c1	6	5,6%	6,3%	6,9%	10,1%	13,3%	0	13,8%	26,0%	33,0%	43,3%	65,6%	2
sc8s3c3	7	5,1%	7,0%	8,9%	13,9%	18,9%	0	2,1%	13,5%	18,2%	21,4%	28,3%	1
sc8s3c5	8	5,3%	6,1%	6,9%	14,7%	22,5%	0	21,2%	23,3%	33,5%	43,3%	44,1%	2
sc8s3c7	9	4,4%	5,3%	6,2%	13,4%	20,5%	0	18,4%	30,8%	37,2%	42,9%	53,1%	2
sc8s3c9	10	4,8%	5,5%	6,2%	17,8%	29,4%	1	17,1%	23,7%	29,0%	36,0%	47,7%	2
sc8s5c1	11	6,2%	7,1%	8,1%	11,0%	13,8%	0	14,3%	15,0%	16,3%	18,9%	23,8%	0
sc8s5c3	12	5,2%	6,5%	7,7%	12,9%	18,1%	0	17,9%	26,9%	30,1%	36,1%	53,3%	2
sc8s5c5	13	6,4%	6,9%	7,4%	11,8%	16,1%	0	22,9%	39,5%	46,5%	48,3%	48,9%	2
sc8s5c7	14	4,6%	5,5%	6,4%	21,9%	37,5%	1	39,8%	42,1%	44,5%	53,2%	74,4%	3
sc8s5c9	15	4,7%	5,3%	5,9%	16,2%	26,5%	1	38,0%	41,3%	46,1%	53,8%	66,1%	3
sc8s7c5	16	4,9%	5,7%	6,5%	20,7%	35,0%	1	39,1%	47,0%	56,4%	68,1%	83,1%	3
sc8s7c9	17	4,7%	5,3%	5,9%	12,8%	19,6%	0	13,3%	32,2%	39,4%	45,6%	61,5%	3
sc8s9c5	18	6,2%	6,6%	6,9%	17,9%	28,9%	1	38,7%	45,1%	53,9%	62,6%	68,3%	3
sc8s9c7	19	5,0%	6,0%	7,0%	19,4%	31,9%	1	27,9%	33,3%	37,2%	41,5%	47,6%	3
sc8s9c9	20	5,0%	5,8%	6,6%	19,4%	32,2%	1	22,8%	26,6%	42,5%	61,8%	76,4%	2
sc10s1c1	21	6,2%	7,1%	8,0%	11,8%	15,7%	0	13,4%	19,5%	25,8%	35,0%	49,7%	2
sc10s1c3	22	7,3%	7,7%	8,0%	11,3%	14,6%	0	13,8%	17,8%	27,7%	43,6%	65,6%	1
sc10s1c5	23	5,5%	6,9%	8,3%	9,3%	10,4%	0	15,3%	18,4%	22,7%	28,2%	34,7%	1
sc10s1c7	24	5,7%	6,5%	7,3%	13,7%	20,1%	0	17,7%	17,8%	20,9%	25,3%	29,9%	1
sc10s1c9	25	5,8%	6,9%	8,1%	11,1%	14,1%	0	13,2%	19,1%	23,4%	31,7%	49,7%	1
sc10s3c1	26	4,9%	5,6%	6,4%	12,3%	18,2%	0	1,7%	10,8%	21,9%	31,5%	35,9%	1
sc10s3c3	27	4,3%	6,2%	8,2%	12,7%	17,2%	0	18,9%	19,0%	19,3%	21,7%	28,3%	1
sc10s3c5	28	6,0%	7,0%	8,0%	12,4%	16,9%	0	16,3%	18,5%	20,2%	21,9%	24,0%	0
sc10s5c1	29	5,6%	6,4%	7,2%	10,5%	13,8%	0	2,1%	8,4%	14,1%	19,2%	23,8%	0
sc10s5c3	30	4,7%	6,2%	7,7%	18,5%	29,3%	1	17,9%	21,1%	26,0%	32,0%	38,5%	1
sc10s5c7	31	4,9%	6,0%	7,1%	18,3%	29,4%	1	30,9%	37,6%	41,3%	50,7%	74,4%	3
sc10s7c9	32	5,4%	5,5%	5,6%	15,6%	25,6%	1	12,8%	32,7%	42,4%	47,7%	54,6%	3
sc10s9c9	33	5,3%	6,0%	6,7%	19,1%	31,4%	1	30,9%	41,0%	48,7%	55,0%	60,7%	3
sc12s1c7	34	5,2%	6,2%	7,1%	7,2%	7,2%	0	17,5%	17,7%	20,8%	30,2%	49,4%	1
sc12s3c3	35	5,2%	6,9%	8,6%	12,2%	15,8%	0	13,8%	17,6%	19,0%	21,4%	28,3%	1

100% AREA											
		ROW					**TREE**				
parameter	**ID**	**min**	**1st Q**	**median**	**3rd Q**	**max**	**min**	**1st Q**	**median**	**3rd Q**	**max**
sc8s1c1	1	0,0%	32,7%	65,4%	68,0%	70,6%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s1c3	2	0,0%	32,0%	64,1%	67,2%	70,3%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s1c5	3	0,0%	33,7%	67,3%	68,9%	70,5%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s1c7	4	0,0%	34,2%	68,4%	68,8%	69,2%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s1c9	5	0,0%	34,3%	68,7%	71,2%	73,7%	0,0%	0,0%	0,0%	0,0%	0,0%
sc8s3c1	6	0,0%	32,2%	64,4%	66,4%	68,4%	0,0%	0,0%	0,0%	8,6%	34,4%
sc8s3c3	7	0,0%	32,6%	65,1%	65,3%	65,5%	0,0%	0,0%	0,0%	0,0%	0,0%
sc8s3c5	8	2,5%	35,4%	68,3%	68,8%	69,4%	0,0%	0,0%	0,0%	10,1%	40,4%
sc8s3c7	9	0,0%	35,6%	71,2%	71,4%	71,7%	0,0%	0,0%	0,0%	0,0%	0,0%
sc8s3c9	10	3,7%	37,6%	71,5%	71,8%	72,1%	0,0%	0,0%	0,0%	8,5%	34,2%
sc8s5c1	11	0,0%	31,9%	63,7%	66,8%	69,8%	0,0%	0,0%	0,0%	0,0%	0,0%
sc8s5c3	12	0,0%	33,0%	66,0%	67,5%	69,0%	0,0%	0,0%	0,0%	7,9%	31,5%
sc8s5c5	13	0,0%	35,0%	70,1%	70,8%	71,5%	0,0%	0,0%	0,0%	13,0%	51,9%
sc8s5c7	14	11,1%	42,4%	73,7%	73,7%	73,8%	0,0%	0,0%	12,8%	29,9%	42,8%
sc8s5c9	15	18,8%	47,6%	76,5%	77,0%	77,6%	0,0%	11,9%	22,2%	35,8%	57,5%
sc8s7c5	16	11,1%	39,4%	67,6%	69,2%	70,8%	0,0%	0,0%	8,5%	19,8%	28,5%
sc8s7c9	17	17,0%	46,3%	75,5%	76,8%	78,1%	0,0%	0,0%	7,6%	17,5%	24,3%
sc8s9c5	18	7,7%	39,4%	71,2%	72,3%	73,3%	0,0%	0,0%	5,1%	13,7%	24,4%
sc8s9c7	19	14,9%	45,5%	76,2%	76,2%	76,2%	0,0%	14,5%	19,5%	20,8%	24,4%
sc8s9c9	20	15,6%	46,1%	76,7%	77,6%	78,4%	0,0%	10,3%	18,6%	26,2%	33,9%
sc10s1c1	21	0,0%	30,1%	60,2%	62,5%	64,7%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s1c3	22	0,0%	29,6%	59,1%	60,8%	62,4%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s1c5	23	0,0%	30,6%	61,1%	62,6%	64,0%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s1c7	24	0,0%	30,5%	61,0%	64,0%	67,0%	0,0%	0,0%	0,0%	8,6%	34,4%
sc10s1c9	25	0,0%	30,3%	60,6%	64,4%	68,2%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s3c1	26	0,0%	29,1%	58,2%	59,7%	61,3%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s3c3	27	0,0%	30,5%	60,9%	61,8%	62,7%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s3c5	28	0,0%	30,5%	60,9%	63,8%	66,6%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s5c1	29	0,0%	27,1%	54,3%	55,9%	57,5%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s5c3	30	0,0%	29,1%	58,2%	60,1%	62,0%	0,0%	0,0%	0,0%	0,0%	0,0%
sc10s5c7	31	0,0%	33,8%	67,5%	68,0%	68,4%	0,0%	0,0%	0,0%	6,4%	25,6%
sc10s7c9	32	11,1%	40,5%	69,9%	70,9%	71,8%	0,0%	5,6%	11,3%	20,7%	37,3%
sc10s9c9	33	9,6%	41,0%	72,3%	73,6%	74,8%	0,0%	0,0%	11,8%	25,3%	30,5%
sc12s1c7	34	0,0%	27,4%	54,8%	57,9%	61,0%	0,0%	0,0%	0,0%	0,0%	0,0%
sc12s3c3	35	0,0%	26,3%	52,7%	54,7%	56,7%	0,0%	0,0%	0,0%	0,0%	0,0%