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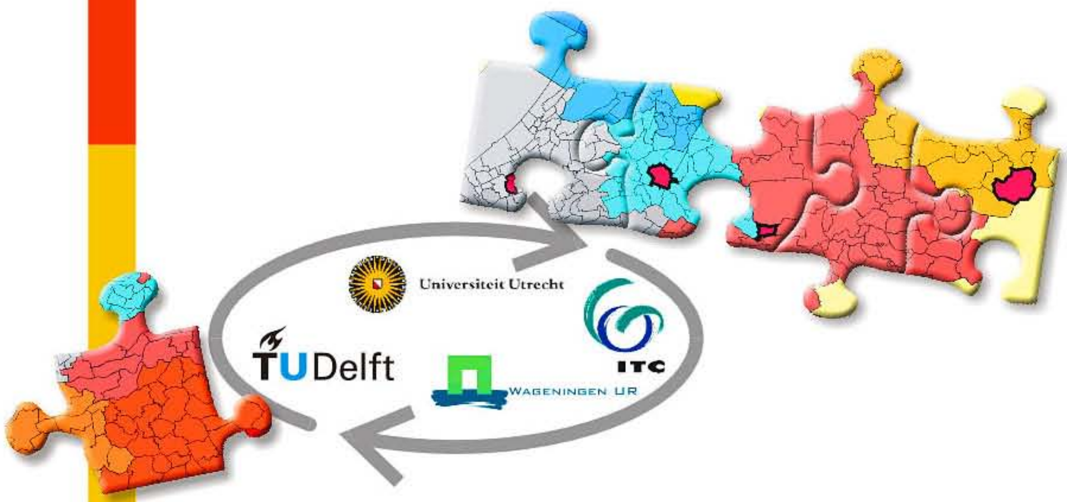
Geographical Information Management and Applications

# Assessment of a land changes dataset by volunteered geographic information

Ariën Sikken



# Assessment of a land changes dataset by volunteered geographic information

MSc Thesis report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**Author:** Ing. A. Sikken
**Professor:** Prof. Dr. Ir. A.K. Bregt
**Supervisors:** Dr. Ir. R.J.A. van Lammeren
R. Fuchs MSc.

# Abstract

With this thesis project it is explored whether Volunteered Geographic Information (VGI) could play a role in the assessment of a land changes dataset. The project is related to a European PhD research project that studies the relation between land changes and the greenhouse gases balance.

One of the datasets with land changes that is used for that project is the Corine Land Cover (CLC) land changes dataset (44 land classes), which covers most of Europe. As a consequence of this scale, its minimum mapping area for land changes is set to 5 hectares, while one of its other mapping rules is that linear objects (less than 100 meter width) are not mapped. It is thought that with these CLC mapping rules quite a number of small land changes is missed. Since it also deviates from other datasets with land change numbers, there have been raising questions about the quality of this dataset. The quality is determined by the correctness and completeness of its spatial, temporal and thematic properties.

In this thesis project, it has been analyzed how well this land changes dataset suits the European study, by which a distinguish is made on the three mentioned properties. First, the European study required a reclassification towards 5 land classes that were established by the Intergovernmental Panel on Climate Change (IPCC). Subsequently, the analysis that was performed on the dataset showed significant room for improvement on all three distinguished properties for their correctness. Completeness of the land changes dataset could also be improved, by adding missing locations, removing falsely mapped locations and updating information on new added attributes for the existing, as well as for the new land change locations. The assessment, by which should be concentrated on the above indicated items, is tested with a case study.

Within this case study in Drenthe (a Dutch province), there is chosen for an assessment approach by which everyone is able to participate and contribute. A concept that is called Volunteered Geographic Information. The idea behind it is that citizens have the most complete and specific knowledge on changed land in their own environment. Further, this approach is expected to be a low cost solution for collecting lots of information by which the dataset gets improved.

Before the pilot is launched, it is first studied what exactly is required and needed from the perspective of a participator. The outcomes of this study, together with the technical design conditions and the assessment requirements, form the basis for the design.

A selection of four solutions that could facilitate the VGI assessment, being Google Maps, Google Earth, ArcGIS API and OpenLayers, is compared on various items that fall under one of the categories functionality, user convenience and technology. It appeared that the OpenLayers solution best met the requirements.

Based on all the so far found requirements and made choices, the design is created for an assessment website that includes the OpenLayers solution. It is then launched by the website www.landchanges.eu to facilitate the case study in Drenthe.

A selection of 61 persons was approached by an e-mail message, in which they were introduced to the project and then asked to visit the website and assess the land changes dataset. During two weeks, 77 visits were registered. A large number of persons provided useful feedback on the design and concept. Further, in these two weeks there were 23 locations updated. Geometric adjustments were made to 16 locations, attribute adjustments to 12 locations (27 updates). There are land changes added and deleted, but most geometrical adjustments concerned

reshaping land changes from the original dataset. Attribute information was updated for existing land changes and provided with new ones. On thematic and temporal properties, but there was also provided supportive and background information.

This case study shows that the chosen approach could work, that the quality of land changes dataset indeed can be improved by VGI assessment.

The conclusions, discussion and recommendations indicate on which points the feedback and assessment contributions provide useful information to improve the initial design and approach. Application to a European extent seems to be possible, but therewith some new requirements arise. Some of these, but not all, can directly be influenced or solved.

Further research is needed to get better insight in the impact of the updates on thematic properties (shifts in the subdivision by land class) to the greenhouse gases balance. Also the impact of applying a 1 x 1 km resolution to the size of changes and its subdivision by land class needs further study.

# Acknowledgements

I would like to thank my two supervisors Ron van Lammeren and Richard Fuchs (both WUR) for their shown enthusiasm about this project and the chosen approach, which really stimulated me ongoing this MSc thesis project. Because of being so well informed on this topic and the wider context of the project, Richard was able to point me at lots of useful information and provided me with strict feedback, especially to the first chapters. By sharing his thoughts and advices, Ron helped me a lot to get this project and report well organized.

To three persons I am grateful for their assistance by taking some of the technical hurdles. Barend Köbben (ITC) provided really useful explanations on the WFS-T concept and its most important technical components in combination with OpenLayers. Aldo Bergsma (WUR) greatly helped me by installing GeoServer on the WUR server, and (again and again) replacing the data and configuration during the design and development phase. Further, it was really valuable to have my cousin Sander Elders willing to “re-introduce” me in the world that is called World Wide Web. He advised me on the current basics and standards for successful web-design, helped me testing the website on compatibility and functionality, and pointed me at some good working solutions for hosting and monitoring the assessment website.

Of course, I am also grateful to all the anonymous and known persons who participated during the case study. By visiting the website and updating the dataset, but also by providing really useful feedback from which future initiatives could hopefully benefit.

Thanks to all of you for the invested time and efforts!

Oosterhesselen, October 2011

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# List of abbreviations

| | |
|---|---|
| AI | Aerial image |
| API | Application Programming Interface |
| CBS | Centraal Bureau voor de Statistiek |
| CLC | CORINE Land Cover |
| CSS | Cascading Style Sheets |
| EEA | European Environment Agency |
| GDAL | Geospatial Data Abstraction Library |
| GIMA | Geographical Information Management and Applications |
| GIS | Geographic Information System |
| GML | Geography Markup Language |
| HTML | Hypertext Markup Language |
| IE | Internet Explorer |
| IT | Information Technology |
| IPCC | Intergovernmental Panel on Climate Change |
| KML | Keyhole Markup Language |
| LCCS | Land Cover Classification System |
| OGC | Open Geospatial Consortium |
| OSM | OpenStreetMap |
| OWS | OGC Web Services |
| PhD | Doctor of Philosophy |
| URL | Uniform Resource Locator |
| VGI | Volunteered Geographic Information |
| WFS(-T) | Web Feature Service (-Transactions) |
| WUR | Wageningen UR (University & Research centre) |

# 1 Introduction

This first chapter starts with an introduction on the research topic, which studies land changes as a factor to understand the impact of greenhouse gases. It is followed up by the problem identification, which concerns questions about the quality of a large dataset with land changes that is foreseen to play a key role in research on a European scale. The objective and research questions set out what exactly is foreseen to be reached by this project. Next, the scope delineates what is, and what is not part of this project.

## 1.1 Background

Over the past hundred years, information on land cover and its use has been registered in European countries[1] for administrative areas, such as provinces, on an annual basis. Further, on a more irregular frequency, most countries produced several maps on land cover. Research on these datasets, in particular on land changes, could provide interesting insights in patterns and trends, which subsequently could be of high value to other research fields. One such field, discussed extensively in recent years by researchers and media, is greenhouse gases.

Almost all researchers nowadays acknowledge that the huge increase of atmospheric greenhouse gases over the past century is caused by human activities. As a result, mankind will be faced with serious environmental effects during the coming century. Probably the most illustrated examples are global warming and the rise of sea level, leading to unpleasant situations for people living near to oceans. Species that are not able to adapt at the same pace to such changes are in its worst scenario threatened by extinction. Also more extreme weather conditions are expected, expressed by droughts and floods. As a result from this, humanitarian catastrophes will occur more frequent and will be more intense. These are expected to hit the regions that will probably have the largest problems to deal with such extremes disproportionally hard.

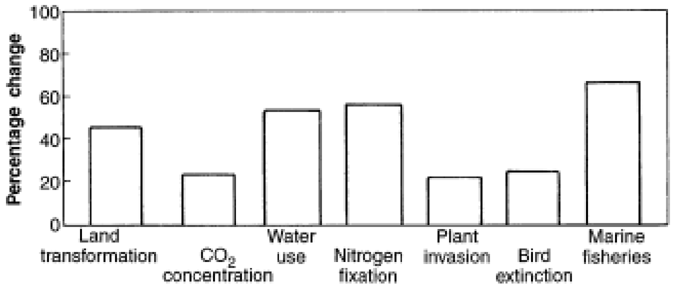


*Figure 1.1 Impact of human activities on the environment (Vitousek et al. 1997)*

Such examples emphasize and strengthen the importance of gaining more insight in the causes of the currently known problems. Research by House et al. (2002) and Brovkin et al. (2004) already reveals that significant parts of carbon emissions come with land change. It was estimated that between 10 and 30% of the total increase of atmospheric greenhouse gases comes from land changes by human activities. Besides carbon emissions, also the emission of methane and nitrogen have become important factors over the past 100 years.

In general can be concluded that the impact of human activities on the environment is enormous. Figure 1.1 illustrates that a total of between a third and a half of the Earth's land surface is directly changed due to human activities.

[1] All EU member states, Switzerland and Norway

Fuchs (2010), who is doing his PhD Research on the relation between greenhouse gases and land changes over the past century in Europe, explains the importance of getting more and better insights in historical developments in land changes. One of his main objectives is to create a spatial and temporal land change model with consistent time steps, spatial resolution and class definitions.

The annually collected data on land cover and its use could form a basis for this model, but one problem is that this data is partly summarized for administrative areas, which means it is not spatially explicit enough. Historical maps could additionally be used, since such maps provide often also information on land cover and its use. For example, from a (visual) comparison, land changes become clear over the time span of two maps that cover the same area. However, in particular during the first half of the past century, there have not been produced many of such maps. This is likely to be explained by the fact that its production was quite labour intensive during that time. People had to physically visit locations to map a situation. As a result of this, there is often quite a long period between maps wherefrom land changes could be derived. The introduction of Remote Sensing techniques during the 1960's and continuously improvements being made in computer technology, made it better possible to capture high detailed land cover data on a more frequent basis during the most recent decades.

One dataset that is produced by recent technology and derived from satellite images, is the CORINE Land Cover (CLC) dataset. This dataset contains land data for 1990[2] (CLC90), 2000 (CLC2000) and 2006 (CLC2006), and is produced by the European Environment Agency (EEA). For research on land changes on a European level over the past 20 years, the free available CLC dataset is currently considered to be the most suitable dataset. To indicate the value of future outcomes, which is derived from research on this dataset, insight in its quality is given. One quality aspect is the thematic accuracy, on which information is provided by the EEA (2002) for CLC2000. There was found an overall reliability of 87% +/- 0.8%. This fulfils the requirement of 85%, which was determined by the CLC2000 technical guidelines (EEA 2002).

Despite such promising accuracy scores, quite large differences in land classification data were still found by comparing remotely sensed data (from which the CLC dataset is derived) with the summarized data on administrative areas, which is more statistical. These differences are mainly to be explained by differences in techniques that were used for collecting data, and by differences in classification rules and class definitions. Apart from this, there is in general a growing concern about the accuracy of land cover data that is extracted from satellite images (Van Oort 2006).

Therefore, it is questionable whether the CLC dataset provides specific and reliable enough data for deriving information about the locations where land changes took place.

## 1.2 Problem identification

Since this CLC dataset is seen as the most suitable in its category that is currently available for research on land changes on a European scale, it will form the basis for further research during the in section 1.1 mentioned PhD project. In the guidelines and rules for mapping CLC2000/2006-Changes (EEA 2007) it is explained how land changes were identified and

[2] Data from 1988 and 1989 was also used for deriving parts of the CLC dataset.

mapped in the CLC datasets. Land changes in the CLC-Changes dataset are being mapped starting by a minimum area size of 5 hectares, but are only identified if:

1. the new parcel consists of one contiguous area of at least 5 hectares, and
2. its land use belongs to only one of the 44 classes from the CLC nomenclature.

Despite the fact that the CLC dataset has a relatively high spatial resolution for its European extent and purpose of use, it is assumed that numerous land changes are too small to meet these CLC mapping criteria. If this assumption is right and indeed a significant number of smaller land changes is missing, this could be of high influence to further research outcomes. Another issue of concern is that new linear infrastructural constructions, like railroads and highways, are not being mapped in CLC.

## 1.3 Research objective

The problem identification (section 1.2) stresses the urge for additional assessment on the completeness and correctness of this land changes dataset. Therefore, the general research objective could be described best as *Assessment of a land changes dataset by volunteered geographic information*. Experiences with other Web 2.0 solutions like OpenStreetMap[3] (OSM) and Wikimapia[4], and studies by Nuojua and Kuutti (2008) and Goodchild (2007), indicate that assessment of a land changes dataset by collecting information from citizens is a low-cost solution and provides good opportunities to benefit from local knowledge. A better understanding of the objective follows from the elucidation on its three main elements in the next subsections.

### 1.3.1 Land changes

According to Fuchs (2010) it is determined here, that land changes encompass all changes from one to another IPCC[5] land class that cannot (easily) be reversed. Based on this definition, it is outlined by some examples what exactly should be considered to be a land change, and what not. On a conversion of forest into cropland, or grassland into settlement, there could hardly be any discussion. Somewhat fuzzier it gets when dealing with temporal forests (e.g. spruce or poplar), planted on cropland and obliged to be clear felled after a period of 15-20 years. This should also be considered as land change, since it is not easily reversed. On the other hand, temporal interchanges between cropland and grazing land, being part of an agricultural crop rotation, should not be considered as land change. Periodical flooding of grasslands near to a river, often during winter season, is neither considered as a land change. Bu these definitions, the CLC-Changes dataset is reclassified into a land changes dataset that fits the IPCC land classes. This topic is further in detail discussed in chapter 2.

### 1.3.2 Volunteered Geographic Information

Instead of relying only on interpretations from (technical) experts, the innovative aspect of this land change assessment is the idea to benefit from local knowledge that is available by citizens.

[3] http://www.openstreetmap.org

[4] http://www.wikimapia.org

[5] Intergovernmental Panel on Climate Change

An online mapping application will be developed and launched to serve the contributing community, based on the Web 2.0 concept and technology, which foresees in user participation and user generated content (Goodchild 2007; Flanagin and Metzger 2008; Haklay 2010; Hall et al. 2010). Since this crowd sourcing project aims at collecting spatial data, it is better called Volunteered Geographic Information. This term was introduced by Goodchild (2007) and further discussed on its various aspects by many others (Elwood 2008; Flanagin and Metzger 2008; Goodchild 2008; Haklay 2010; Hall et al. 2010).

It becomes evident that, with VGI, we enter an area that offers us a promising potential (Goodchild 2007; Hall et al. 2010). Some projects that already have proven this, are the OpenStreetMap and Wikimapia projects. On the other hand, with this new form of data collection there also arise concerns about the quality and reliability of such spatial data (Flanagin and Metzger 2008). Where professional geographers are bounded by standards and procedures to assure a certain level of quality (Goodchild 2007; Flanagin and Metzger 2008; Haklay 2010), there is in case of VGI a wide variety of individuals who all have their own manner of working (Haklay 2010), often not even aware of existing standards and procedures.
From the established perception on quality, it indeed is for VGI collected data often difficult to determine the quality of a dataset for many of its aspects as found by Van Oort (2006), e.g. completeness, positional accuracy, variation in quality or lineage. The fact that it is difficult to control those aspects, does of course not necessarily mean that VGI collected data is of lower quality. At least, it enforces a reconsideration, and perhaps even redefinition, of the general accepted perception on the quality and reliability of spatial data.
Haklay (2010) found in his evaluation of the OSM map in comparison to the Ordnance Survey map fairly good results for VGI collected data. However, positional accuracy of digitized roads seemed to depend on the attitude and ability of an individual contributor, with inconsistent outcomes. He also found better coverage in cities and densely populated areas, than in rural and poor regions.
Flanagin and Metzger (2008) conclude that the credibility of VGI data could get more uncertain due to issues like the question who is responsible for the presented data, missing sources and unclear motives of individuals who participated.
Despite these concerns, with a large and cooperating community, there always seems to evolve a form of self-regulation and continuing improvement of the dataset (Flanagin and Metzger 2008; Hall et al. 2010; Haklay 2010). This idea is also confirmed by the significant improvements that can be noticed by comparing the OSM map that was being used by Haklay (2010), dated March 2008, with the OSM map for the same area, dated December 2010.

### 1.3.3 Assessment

Citizens participate in this project by assessing the land changes dataset via an online platform. There, each person can confirm a mapped land change to be correct. If the shape of a land change is considered incorrect, and/or its attribute values contain errors, this can be rectified with an easy-to-use digitize and attribute update tool. The precise definition of assessment that is needed for this project follows in chapter 2 after the land changes dataset has been analyzed.

## 1.4 Research questions

Three main research questions have been derived from the objective that was formulated in section 1.3. These are supposed to be answered by conducting this research.

1. On which properties from the land changes dataset is assessment required?
2. How is assessment of this land changes dataset by volunteered geographic information optimally facilitated?
3. What are the conclusions that can be drawn from a case study that includes the findings from research on the first two questions?

The first research question is treated in chapter 3, with an analysis on the dataset, from which becomes evident what kind of assessment exactly is needed. In chapter 4, the second question is subject to discussion, by outlining the design and development of the application for assessing land changes by volunteered geographic information. The third research question is answered by presenting and discussing the case study (chapter 5). Insight in the results of the assessment on the land changes dataset is given in chapter 6, followed by chapter 7 in which it is discussed and concluded what can be learned from this project and case study. A more detailed overview of the research phasing can be found in the next chapter.

## 1.5 Scope

Some restrictions have been formulated to define what is part of the research and case study, and what is not.

- The dataset to be assessed is the land changes dataset, derived from CLC.
- Only land changes between 1990 (+/- 1 year) and 2006 (+/- 1 year) are relevant.
- Only contributions to the land changes dataset that have been submitted before October 2011 are considered for the evaluation and interpretation of outcomes for this research, independent from an eventual decision to continue the VGI project.
- The research area is limited to the extent of Drenthe, a province in the North of the Netherlands.

Although it is out of scope for this research, it could appear that this application is successful and more improvements can still be expected after the end of this research. If so, it can be decided to continue the application to be operational, so that the participating community grows further and works on a complete and constantly up to date land change dataset that is free available.

# 2 Methodology

This chapter elaborates on the different phases that will be passed during this MSc thesis project. Figure 2.1 illustrates a schematic overview of those phases. In this figure it is also indicated where answers to the research questions from section 1.4 can be found.

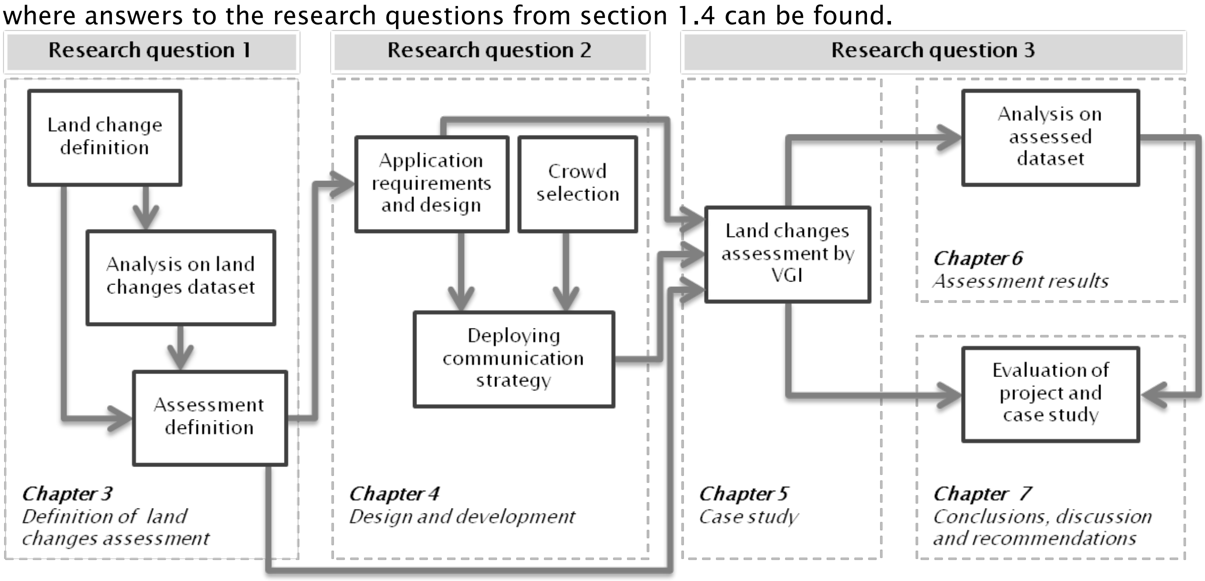


*Figure 2.1 Research methodology scheme*

## 2.1 Research phasing

The research project consists of five phases, as becomes clear from Figure 2.1. The following chapters each treat one of them. Each phase consists of one or more core elements (the boxes) on which the next sections briefly elaborate as an introduction to the following chapters.

### 2.1.1 Phase 1: Definition of land changes assessment (chapter 3)

*Land change definition*

For research on land changes and its relation to greenhouse gases, the nomenclature that is described by the IPCC (2003), consisting of six land classes, is best fitting. One of these (wetlands) is in this research combined with the category grassland. This means that the five remaining IPCC land classes are: *forest, cropland, grassland, settlement* and *other land*. This is much more compact than the so far applied CLC nomenclature with its 44 land classes. Obviously, this decrease in number of land classes implies that "CLC changes" do not always concern also "IPCC changes", which is illustrated by an example in Figure 2.2. This topic is further elaborated on in section 3.1.

*Analysis on land changes dataset*

Before any analysis on the land changes dataset can be performed, it is first required to reclassify the 44 CLC land classes towards the 5 that were defined by the IPCC. Fuchs (2010) outlined in his PhD project proposal the process to be followed to do this. First, the CLC dataset will be harmonized according to the Land Cover Classification System (LCCS) that was established by Di Gregorio and Jansen (1998). This classification system breaks down each class to its semantic meanings, after which it is resorted by its components into new classes. Next, this harmonized dataset will be validated, after which it can be aggregated into the five IPCC land classes. This reclassification was during December 2010 executed by Fuchs. The resulting dataset is thoroughly analysed in chapter 3, to find out on which of its aspects VGI assessment is required.

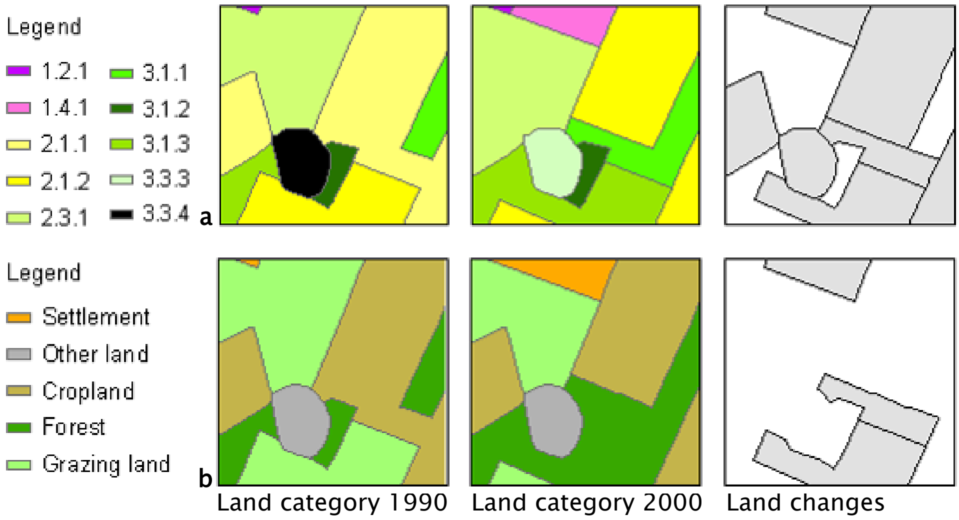


*Figure 2.2* *CLC land classes (a) and IPCC land classes (b) (own production)*

*Assessment definition*

The assessment cannot be seen apart from the 5 established land classes, since a comparison between these land classes over a time span determines whether a land change is correct or not. On each of the five land classes there will be formulated a brief and crisp description, that is understandable for any of the wide variety of people who is aimed at. These descriptions form the classification rules, on which all participants base their land classification decisions.

The assessment can be divided into three main components, being (1) geometric, (2) thematic and (3) temporal assessment. A short introduction to these three is given here.

1. If a land change shape is considered to be incorrect, this should be corrected by adjustment of its vertices. For missing land changes the available functionality must foresee in drawing its shape, while a land change must be deleted when it appears not to be a one. For correctly mapped land changes it is also highly valuable to have them assessed by validating its correctness: the more agreement on a change, the higher its reliability can be seen.
2. Thematic assessment consists of an evaluation on the former and new land class of a land change. Further it could be valuable to acquire supportive information.
3. The temporal assessment focuses on the time component. Did a land change took place in the time span that is indicated and could it possibly be even more detailed specified.

A more extensive analysis on the dataset to find out on which the assessment should focus follows in chapter 3.

### 2.1.2 Phase 2: Design and development (chapter 4)

*Application requirements and design*

Main purpose of the VGI application is to provide functionality to citizens to share geographic information (shapes and/or attribute information). An example of a VGI mapping application is given by Figure 2.3, which represents the Wikimapia project. On the left side there is shown functionality for drawing or adjusting shapes, where on the right side a form is shown, which must be filled in before a contribution is processed.

The design will likely have functionality similar to this example. Further, it preferably:

1. Is as much as possible based on open source solutions;
2. Follows the standards that have been defined by the Open Geospatial Consortium[6].

The application to be built for this project should facilitate assessment on the items that will be presented in section 3.4, with the datasets and functionality that are being defined in chapter 4.

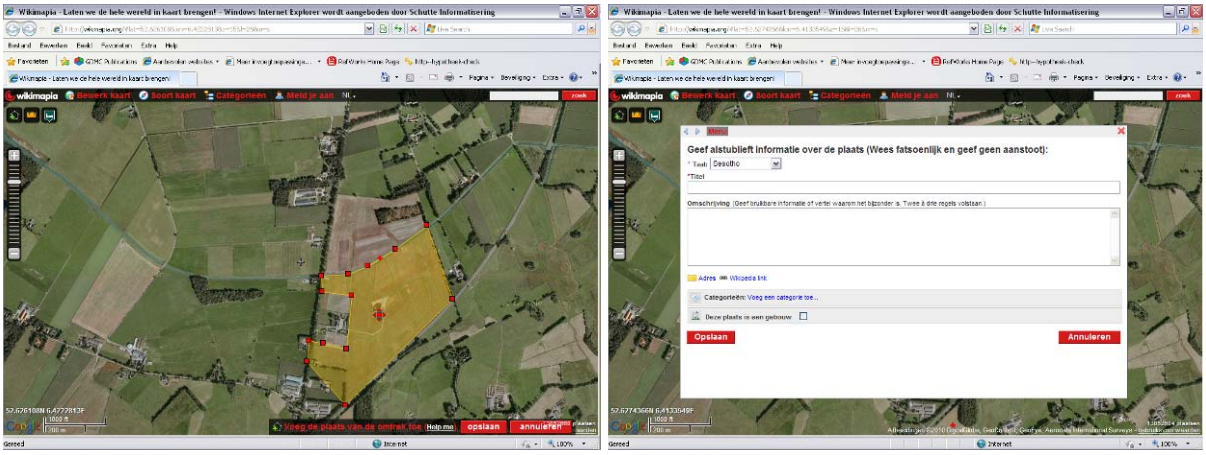


***Figure 2.3** Wikimapia VGI application*

The additions and adjustments to the land changes dataset are automatically processed, after which the updated dataset will be immediately shown in the application. This assures that each visitor always sees the most recent version of the land changes dataset.

However, since the extent of the case study is expected to be too limited to have a self-regulating community established (see also section 1.3.2), it is decided that all contributions still need expert validation.

*Crowd selection*

It is expected that land changes assessment by VGI does not require any specific expertise. In principal, it is aimed to have the participation community as large as possible. With the VGI assessment application design, anyone should be able to participate in this assessment, if having knowledge on how to use a personal computer and one must have access to internet.

*Deploying communication strategy*

The communication strategy is a highly important item to be developed and deployed. Crucial part of this research is the participation of people, from who it is expected to contribute information on land changes. Publicity to this project could for example be given to the general public via a wide range of (social) media, or by distributing information about the project via networks of land owners or professionals involved in this field.

Once the VGI application is launched and thoroughly tested, an effective publicity campaign can be started. If at a certain point the activity halts, it could be decided to put additional efforts in publicity around the project.

[6] http://www.opengeospatial.org

### 2.1.3 Phase 3: Case study (chapter 5)

*Land changes assessment by VGI*

The case study is executed in Drenthe, a province in the Netherlands. During one month, the content of the land changes dataset is foreseen to be assessed by VGI. It is monitored how the website activity (visits) and VGI assessment (contributions) evolves.

This chapter presents the activity that was registered during this pilot in terms of website visits and visitor characteristics. It is also elaborated in this chapter how these visitors observed the VGI concept and application design. All the difficulties that were encountered by participants are listed and it is described how issues, when necessary, were adequately being fixed.

### 2.1.4 Phase 4: Assessment results (chapter 6)

*Analysis on assessed dataset*

The contributions that were made by visitors are presented in chapter 6. The quality of the VGI updated locations is determined by comparing it to the original and the correct dataset. This is outlined by a separate analysis on the geometric, thematic and temporal correctness of all contributions.

Except for the determination of overall quality, it is also tried to estimate the impact of certain aspects by making a distinguish based on e.g. the land classes or the presence or absence of supportive datasets.

### 2.1.5 Phase 5: Conclusions, discussion and recommendations (chapter 7)

*Evaluation of project and case study*

In this final chapter, the most important findings from the previous chapters are written down. It starts with the conclusions for the land changes (dataset) and required assessment. These conclusions are the answers to the first research question.

Next, the conclusions on VGI requirements and the application design are outlined. These conclusions are the answers to the second research question.

The design is then applied in a case study, with a pilot on land changes assessment by VGI in Drenthe, of which conclusions are drawn on participation, feedback and assessment results. These conclusions are the answers to the third research question.

All these items are part of a discussion on the applicability on European scale, the concept and design, and finally on the quality of VGI assessed data. This discussion leads to several recommendations for further research, and recommendations to be applied on further initiatives.

# 3 Definition of land changes assessment

This chapter contains a more in depth study on the definitions that need to be established for land changes and for the assessment. Further it provides insight in the characteristics of the land change dataset (see Figure 3.1). In section 3.1, by discussing what should be considered to be a land change for this research and what should not. Next, section 3.2 elaborates on the reclassification of the CLC dataset towards the IPCC classification for which first crisp class descriptions are provided. The resulting dataset is then analysed by the characteristics of its content, such as the validity and appearance of the different land change classes. In section 3.3 a closer look is taken on the spatial, thematic and temporal completeness and correctness of the dataset as a whole, and also for individual land changes. Further, some research is done here on how these land change numbers relate to data from other sources. Finally, section 3.4 defines the assessment items.

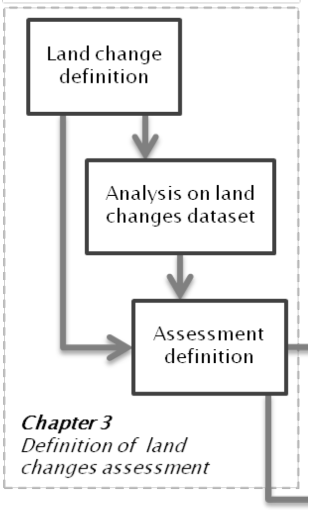


***Figure 3.1*** *Phase 1*

## 3.1 Definition of land changes

Should we speak of a land change when an agricultural field has cereals on it the one year and potatoes on it the next year? Or for example cropland that is afforested, production grassland that is converted to natural grassland, or an abandoned soccer field that changed into natural grassland or transformed to residential area. Like these, many other examples can be thought of. It is for all examples clear that something changed. But what is it that exactly changed: the *land cover,* the *land use*, or a combination of both? And should it actually be called a land change, or is it considered to be part of usual variation within one single land class, such as a crop rotation?

Jansen (2010) extensively discusses the characteristics of both land use and land cover, and points out on what aspects they differ from each other. A land cover class defines more a static condition of coverage that applies to an area, where a land use class describes more the activities that take place in an area, often with aspects that go beyond land cover, such as socio-economic, cultural and legal aspects.

Despite this distinguish, in practise, land (change) datasets are often based on a classification that is a mixture of land cover and land use. Although the name Corine Land Cover (CLC) suggests that it concerns a land cover dataset, such a mixture also applies to CLC.

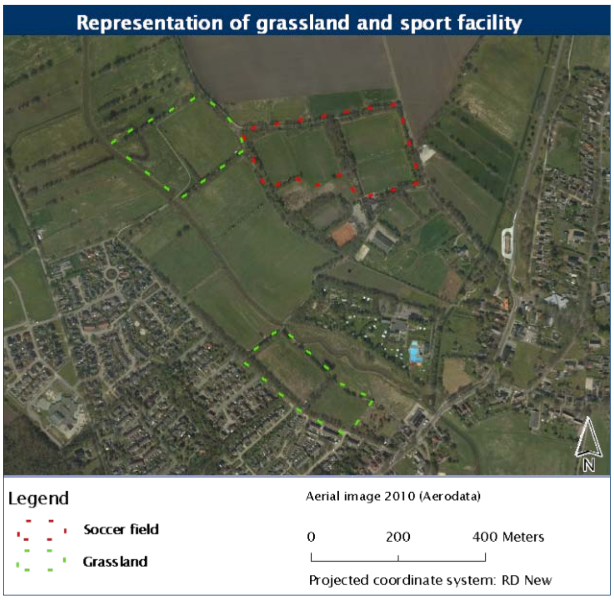


***Figure 3.2*** *Identical land cover for different land use*

Especially for changes in land use it is not always obvious to distinguish those different land classes with the current techniques that are based on interpretation of satellite (or aerial) images.

Figure 3.2 shows an example of quite identical patterns for (1) natural grasslands with hedgerows around and (2) an adjacent sport facility with soccer fields.
In this research, only "not easily reversible" changes are of interest. That not all observable land changes are relevant for this research, simply because they do not imply a permanent land change, becomes clear from the following examples of (1) an agricultural crop rotation system, (2) in the case of grassland that has been temporarily flooded for safety purposes or to function as an ice rink by winter day, or (3) a recently clear felled forest parcel as part of a forestry management plan. The applied 'remote' classification technique, in combination with this mixture of classifying land use and land cover, makes the CLC dataset sensitive for misclassifications on issues like the given examples.
The organization that has defined the digitizing instructions for CLC, the Commission of the European Communities (1995), advices for 1/3 of CLC land classes to consult additional information such as aerial photographs and topographic maps (or ultimately to visit an area). Whether this suggestion was actually followed or not is unknown, but a quick scan reveals that this has not reflected in improved spatial accuracy for these classes. Similar errors and a comparable level of accuracy were found as for the other land classes. Many of such mistakes (thematically and spatially) could have been easily prevented by consultation of the suggested ancillary data.
Another uncertainty factor comes with the composition of some of the CLC land classes in combination with the minimum mapping area. One example is Complex Cultivation Patterns, which exists of a combination of crop- and grassland, without one of both covering a continuous area of 25 ha. As a result, significant changes that occur within this range will likely not be notified.

## 3.2 Preparation of the land changes dataset

The earlier discussed CLC land changes dataset is in its original format with 44 land classes not useful for research on greenhouse gases in relation to land changes. A reclassification from the CLC nomenclature towards a suitable one must be applied now to both time spans 1990-2000 and 2000-2006. The IPCC defined a suitable nomenclature within the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003). The harmonization from CLC classification to IPCC classification was done by applying the LCCS method from Di Gregorio and Jansen (1998), of which the reclassification schedule can be found in Appendix I. The provided descriptions for IPCC, however, depend on national definitions and remain therefore fuzzy on some quite important aspects. To avoid inconsistencies during the assessment, crisp definitions for the five IPCC land classes that are important for climate research are defined as follows:

*Forest* All types of woody vegetation, such as forests, wooded parks and coppice fall under this land class. In general can be said that it concerns vegetation higher than 3 meter, or expected to be in future. This latter could be the case in situations of new planted forest, recently cut coppice or clear felled area in forest.

*Cropland* This land class includes all agricultural fields on which crops or bulbous plants are grown. Temporary fallow (3 years) land also falls in this class. Even so do tree and plant nurseries, vineyards and orchards.

*Grassland* Grassland encompassed agricultural –, as well as nature pastures. The first one includes meadows for waders, grazed land and grass pasture. Natural pastures are often (very) extensively, or even not, managed. Heath and moors, wetlands (e.g. bog or marsh), thickets with grass, herbs and shrubs are also considered as grasslands.

*Settlement* This land class encompasses all industrial and built up areas, including its public gardens, as well as large infrastructural objects, such as highways, railroads and airports. Also sports – and leisure parks/facilities fall under this class.

*Others* This land class includes the areas that are covered by water, such as rivers, lakes and artificial water bodies with a natural character, dunes and beaches. Water as a result of active sand mining should be classified as settlement. All other areas that cannot be classified within one of the other four classes, fit in this land class.

This new land changes dataset forms the basis for the VGI assessment on land changes. To get some better understanding on what exactly is within this land change dataset, some statistics are provided by Table 3.1 and Table 3.2.

| from ▼ to ► | cropland | forest | grassland | settlement | Others | *total ha* |
|---|---|---|---|---|---|---|
| cropland | 280 ha | 994 ha | 659 ha | 3028 ha | 115 ha | *4796 (66%)* |
| forest | 0 ha | 17 ha | 92 ha | 53 ha | 0 ha | *145 (2%)* |
| grassland | 572 ha | 8 ha | 120 ha | 1628 ha | 87 ha | *2295 (32%)* |
| settlement | 0 ha | 11 ha | 0 ha | 63 ha | 15 ha | *26 (0%)* |
| others | 0 ha | 0 ha | 0 ha | 0 ha | 0 ha | *0 (0%)* |
| *total ha* | *572 (8%)* | *1013 (14%)* | *751 (10%)* | *4709 (65%)* | *217 (3%)* | ***7262 (100%)*** |

***Table 3.1*** *IPCC land changes in Drenthe over 1990-2000*

| from ▼ to ► | cropland | forest | grassland | settlement | Others | *total ha* |
|---|---|---|---|---|---|---|
| cropland | 0 ha | 121 ha | 1001 ha | 1386 ha | 60 ha | *2568 (72%)* |
| forest | 0 ha | 651 ha | 32 ha | 64 ha | 21 ha | *117 (3%)* |
| grassland | 0 ha | 0 ha | 223 ha | 827 ha | 25 ha | *852 (24%)* |
| settlement | 0 ha | 0 ha | 0 ha | 412 ha | 15 ha | *15 (0%)* |
| others | 0 ha | 0 ha | 26 ha | 0 ha | 0 ha | *26 (1%)* |
| *total ha* | *0 (0%)* | *121 (3%)* | *1059 (30%)* | *2277 (64%)* | *121 (3%)* | ***3578 (100%)*** |

***Table 3.2*** *IPCC land changes in Drenthe over 2000-2006*

### 3.2.1 Discussable land changes

Not surprisingly, after reclassification, a certain area is marked with an equal old and new land class. For 1990-2000 this counts for only 6% of the total changed area, while for 2000-2006 this percentage is quite significant with 26%. In particular, the change *forest->forest* is remarkable. Further analysis on this category reveals that 80% of the area concerns a CLC change from Transitional Woodland Shrubs towards Forest (broad-leaved, coniferous or mixed). Since these areas all cover recently afforested areas this seems to be a correct classification. The CLC change for the remaining 20% is vice versa. Here it concerns clear felling of forest intended to become

heath. This implies that, according to the defined IPCC descriptions, the change should actually be *forest->grassland* instead of *forest->forest*.
Another significant change is *settlement->settlement*. For 98% this concerns a CLC change from Construction Site towards Discontinuous Urban Fabric or Industrial Commercial Unit, which are in theory both plausible changes. Based on a quick scan, for some of the changes the old CLC land class was clearly wrong defined, but still these would be *settlement->settlement* IPCC changes. One divergent area in the *settlement->settlement* category was changed towards Sports & Leisure Facilities. Though this neither has consequences for the IPCC classification, it must be said that this new class is not correct, as it should be Discontinuous Urban Fabric.
Overall, there seems to be quite some uncertainty in this category. It is therefore decided to keep these changes in dataset to let them be assessed.

### 3.2.2 Accepted land changes

In this section, the focus is on land changes for which the old and new land class varies. During 1990-2006 in total 10.840 ha land changed from one into another IPCC land class. This is an area as large as just over 4% of the provincial area of Drenthe, that is roughly 268.000 ha. If the invalid IPCC land changes are included, this is even slightly over 4,7%. If compared to national level, Drenthe changed with its 4% below national average, that is just over 5%.
Although, looking more in depth to these numbers and its geographic distribution, it appeared that in reality a smaller surface of the province Drenthe has been transformed. This is explained by some areas that changed in the 1990-2000 time span and then again in the 2000-2006 time span. Such overlap was found for 348 ha land at 5 locations (apart from slivers), of which one major location that covers 239 ha.

It is then interesting to see how these land changes are subdivided by land class. First, by looking to the land class before a change took place, shown in Table 3.1 and Table 3.2. For both time spans it appears that over 95% of the area is transformed from crop- or grassland into another land class. It must be said, that there were found quite some changes *cropland->grassland* (15% of changed area) and vice versa (5%). Many are highly questionable, which should hopefully also become clear later on from the VGI assessment. If changes between these two classes are disregarded, still 96% of 'new' settlement, forest or other land was crop- or grassland before. Which remains is 3% of forest that changed into grassland, settlement or other land. The percentage of land that changed from settlement or other land into another class is negligible. Those outcomes do not really surprise, as over 80% of the provincial area of Drenthe is covered by crop- and grassland. This means that this area has the largest potential for transformation to another land class. Further, (legislative) restrictions are relatively low compared to some of the other classes and involved development costs for such an area are relatively low. Sometimes, for example to afforest agricultural areas, it is even stimulated with governmental (national[7] and provincial[8]) financial programs. And finally, if for example a city has expansion plans and there is adjacent agricultural area, forest and water (other land) available, it is quite understandable for many reasons to concentrate on the agricultural area for realisation of such plans.

[7] http://www.pleinplus.nl/algemeen/toonbijlage.asp?id=9859
[8] http://www.regiebureau-pop.eu/files/file_1548_221_eerste_bebossing_van_landbouwgrond.pdf

If we now look into which classes land changed, it appears that in line with global trends, we can notify an urbanization trend. Over 1990-2000, 65% of the area transformed into settlement, and over the time span 2000-2006 it concerns 64% of all changed area. If the interchange between grassland and cropland is again disregarded, even 81% of changed land has turned into settlement, which is pretty much in line with percentages on national level. In reality, however, this percentage is lower, since a quick scan showed quite some locations where new nature development projects were mapped as new settlement. Of the remaining 19%, most land was afforested (13%), and some land that changed into other land (4%) or grassland (2%). This latter category is in reality slightly higher, as the in section 3.2.1 mentioned forest that changed into heath should also be counted here. It is further noteworthy that no land was transformed to cropland apart from the *grassland->cropland* category.

## 3.3 Quality of the land changes dataset

During this research project, the quality of the land changes dataset is determined by the correctness and completeness of its spatial, temporal and thematic properties. Section 3.4 lists the items on which correctness and completeness will be assessed, thus on which items the quality could be improved.
In this chapter, so far mainly the thematic aspects of land changes have been discussed. First more in general and after that for the land changes dataset specifically. With all land changes having assigned an old - and new IPCC land class, it can be concluded that the dataset is thematically complete. However, completeness can also be looked at from other points of view. Very important is the question whether the dataset is complete (no land changes are missing) or possibly over complete (mapped features that in reality are no land changes). Also, from a temporal view: is the temporal information about the land changes of sufficient detail for this or future research? These issues on completeness will be discussed in this section. Further, there will be paid attention to the correctness of this dataset. Again, there will be looked at it from different sides. The thematic correctness (is the right land class assigned) is one aspect, but there is also the temporal correctness (is the right time span assigned to a change) and last but not least of course the spatial correctness. This latter issue concerns the shape (and size) of a land change and whether a mapped land change is positioned at the right location.

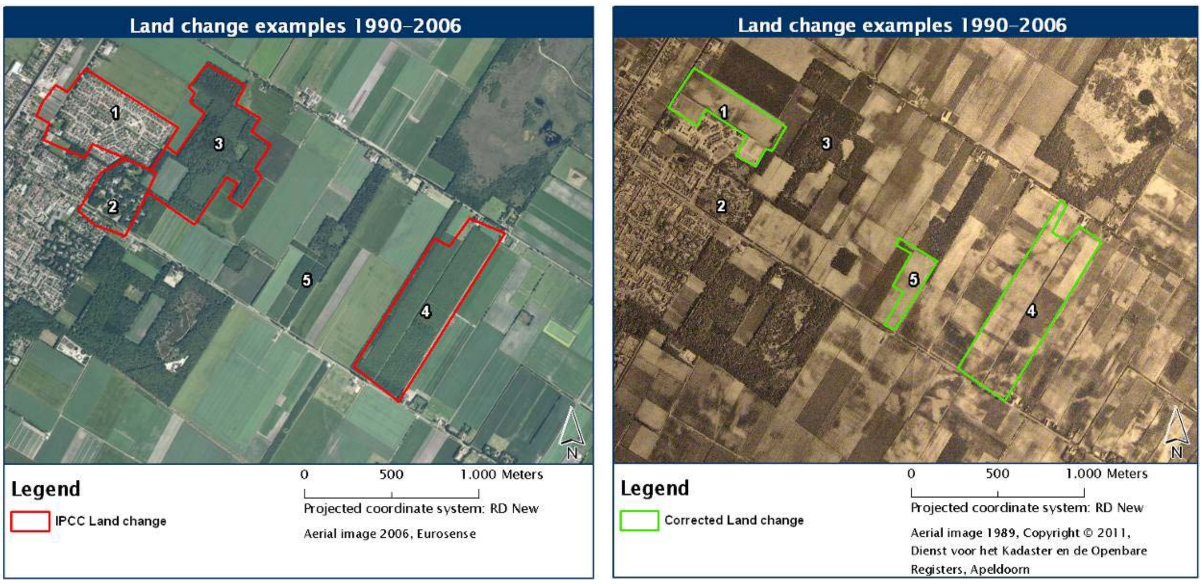


***Figure 3.3*** *Spatial correctness of land changes over 1990-2006*

### 3.3.1 Correctness and completeness of IPCC land changes

The discussion on the quality of this IPCC land changes dataset starts with one randomly chosen area with a series of nearby each other located land changes, shown on Figure 3.3. The original IPCC dataset (left) and a corrected one (right) are compared. One by one, the 5 important locations in this area are analyzed.

| Land change: 1 | original | correct |
|---|---|---|
| *Defined as land change* | yes | yes |
| *Old land class* | cropland | Cropland |
| *New land class* | settlement | settlement |
| *Area of changed land* | 25 ha | 14 ha |

Land change 1 is thematically correct. The northeast – and southeast oriented borders are well defined. The other borders are incorrect, which resulted in a land change area that is two times the real area.

| Land change: 2 | original | correct |
|---|---|---|
| *Defined as land change* | yes | no |
| *Old land class* | settlement | settlement |
| *New land class* | forest | settlement |
| *Area of changed land* | 11 ha | 0 ha |

According to the definitions for IPCC land categories, the area of land change 2 “covers” settlement in as well 1990 as 2000. Apart from thematic misclassification, also the borders of this “land change” are messy.

| Land change: 3 | original | correct |
|---|---|---|
| *Defined as land change* | yes | no |
| *Old land class* | cropland | forest |
| *New land class* | forest | forest |
| *Area of changed land* | 33 ha | 0 ha |

The mapped area was already forest in 1990, except for some small and fragmented areas that were more recently afforested. Further, except for an included agricultural parcel, the outline is positioned fairly good.

| Land change: 4 | original | correct |
|---|---|---|
| *Defined as land change* | yes | yes |
| *Old land class* | cropland | cropland |
| *New land class* | forest | forest |
| *Area of changed land* | 33 ha | 34 ha |

This land change from cropland to forest is quite well digitized, with over 90% of the border in its right position. This also results in a well mapped area. Only where the shape is a little more complex, the outline deviates.

| Land change: 5 | original | correct |
|---|---|---|
| *Defined as land change* | no | yes |
| *Old land class* | cropland | cropland |
| *New land class* | cropland | forest |
| *Area of changed land* | 0 ha | 6 ha |

This land change shows that the original land changes dataset is incomplete. On this location, an area of 6 ha cropland was afforested. In the dataset it misses, despite meeting all criteria to be mapped.


*Figure 3.4 Linear objects (< 100 m width) are ignored*

Apart from inexplicable missing land changes (e.g. location 5 in Figure 3.3), there is also a category of missing land changes for which there is an explanation available. Those are changes that do not meet one of the two main criteria to be mapped. The first one is that linear objects must have a width of at least 100 meter to be mapped (Figure 3.4). This implicates that new large infrastructural objects such as (rail)roads are ignored. The second one is that all changed areas must be larger than 5 ha to be included in the land changes dataset (Figure 3.5). It is realized that e.g. land changes that are missing because of being too small, will often also not be taken into account in the research project on greenhouse gases on a European level, due to the applied resolution of 1 x 1 km in that project. Nevertheless, to get better insight in the impact of such missing areas to the whole dataset (probability density function), which is at this point difficult to estimate, it is aimed to acquire information for as many as possible land changes with this VGI project.

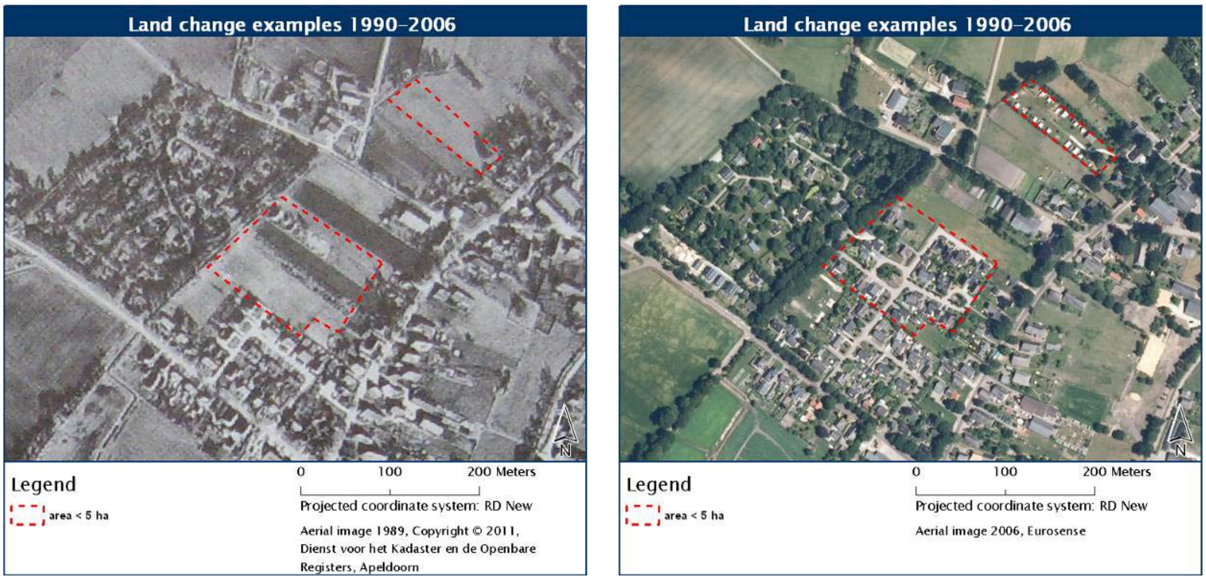


*Figure 3.5 Objects < 5 ha are ignored*

### 3.3.2 Method for determining the spatial correctness

The positional accuracy of (VGI assessed) data can be determined by measuring the deviation of an object against its correct delineation. For the accuracy of line segments, a simple way to do this is introduced by Goodchild and Hunter (1997). With this method, the percentage of a line that is within a certain distance of a high accurate (i.e. correct) line is measured. Haklay (2010), for example, applied this method to determine the accuracy of VGI data for OpenStreetMap.

Although this project deals with areas instead of lines, the introduced method can be applied to the delineation of land changes in order to determine its positional accuracy. Following this method, statistics are gathered for 12 land changes: 6 changes towards forest and 6 changes towards settlement. From both time spans 3 randomly chosen changes are taken for each class. The mean of the delineation accuracy for the 6 changes towards forest lies significant higher than for the 6 changes towards settlement, see also Figure 3.6. In general can be said that for the analyzed land changes, the spatial positioning of

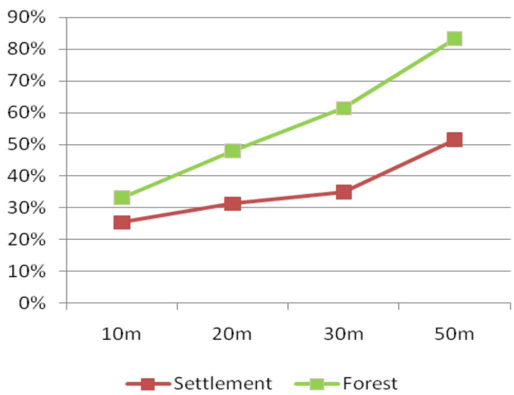


*Figure 3.6 Spatial accuracy scores*

changes towards forest is higher than for changes towards settlement. Not completely surprisingly, since borders of afforested areas are often not complex or fuzzy, and therefore good identifiable with automated processing.

It is important, on the other hand, to realize that the applicability of this method has its limitations if applied to areas. For example, it is difficult to determine how correct the shape and size of a mapped area is only from this positional accuracy.

On two of the land changes will be further elaborated (Figure 3.7) to explain this. A high positional accuracy automatically means that an area nearby the correct area is covered and that the outline of a land change is for a certain part close to its correct position. The correct position of land changes is in this research project determined by a detailed study on the aerial image 2006 and is often supported by field knowledge and/or ancillary datasets.

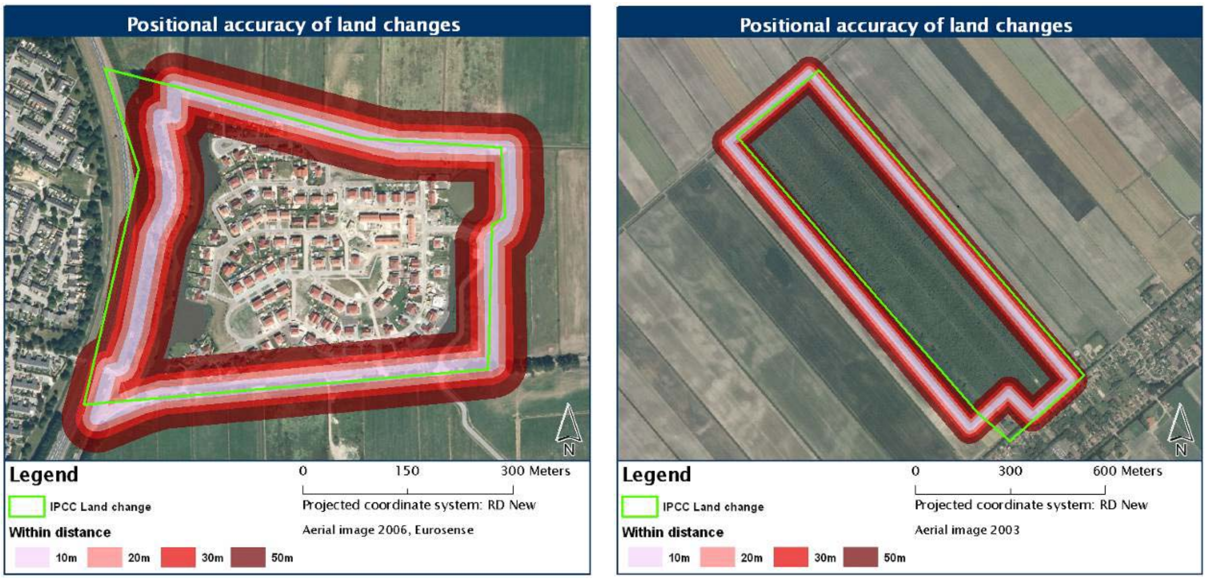


*Figure 3.7 Positional accuracy of new settlement (left) and forest (right)*

This can be explained by looking again to Figure 3.7 and relate this to the information that is provided in Table 3.3. The land change that is significant worse in positional accuracy, has an equal share of its area that overlaps with the correct land change. Also interesting is to notice that in this example the size of the worse positioned land change far more closely approaches the correct size than the better positioned land change. This means that higher accurate spatial positioning does not naturally mean that the size of a changed area lies closer to the real size.

| land change | 10m | 20m | 30m | 50m | correct / IPCC area (overlap) |
|---|---|---|---|---|---|
| Figure 3.7 settlement | 68% | 71% | 75% | 92% | 88% (87%) |
| Figure 3.7 Forest | 10% | 18% | 27% | 96% | 98% (86%) |

*Table 3.3 Positional accuracy (% distances)*

With the right tools being offered, it is expected that contributors are well enough equipped to achieve an assessment accuracy by which the mean deviation from the correct delineation of land changes is less than 10 meter. If this appears to be true, it means that the positional correctness of VGI acquired data is significantly improved compared to the original land change data.

### 3.3.3 IPCC data in relation to other land data

In section 3.2, some analysis was already done on the absolute numbers and percentages of the CLC and IPCC land changes. What could tell us more about the reliability, is the accumulated size of changed IPCC areas in comparison to other datasets. One of the datasets that will also be used by Fuchs (2010) comes from Eurostat. He found significant differences for data on national level. This could to some extent be explained by the fact that Eurostat concerns statistical information that is gathered in a completely different way, by field visits on measure points in a grid. Further, deviations can occur due to different land classification rules. Unfortunately, Eurostat does not provide suitable land information on NUTS II level, which is equal to provincial level.
Another database, with official national statistics from Statistics Netherlands (CBS), does provide data on land changes that could be compared with the IPCC data for Drenthe. Table 3.4 shows this comparison of data on land changes over the time spans 1990-2000 and 2000-2006.

| Land class | IPCC | CBS[9] | IPCC | CBS |
|---|---|---|---|---|
| Forest | 832 ha | 5300 ha | -4 ha | -400 ha |
| Cropland & Grassland | -5822 ha | -4900 ha | -2480 ha | -2000 ha |
| Settlement | 4764 ha | -1200 ha | 2393 ha | 1900 ha |
| Others | 226 ha | 1000 ha | 91 ha | 300 ha |

***Table 3.4*** *IPCC & CBS land changes in Drenthe over 1990-2000 (left) and 2000-2006 (right)*

The list of CBS land classes and the reclassification schedule towards IPCC is included as Appendix II. The comparison could not be made on the original IPCC classes, because CBS classes do not make any distinguish between cropland and grassland. In order to make a decent comparison, these two classes were also combined for the IPCC data. Some other aspects that are noteworthy:

- The CBS data was originally in $km^2$, while IPCC data is originally in ha. It is possible and expected that this slightly influences the comparison of data.
- Differences in land classification rules could result in some deviation between both dataset.
- If all area of land in Drenthe is summed for the CBS dataset, 1989 and 2006 have an equal size of 268000 hectares, while the 2000 dataset holds 200 hectares more.

Still, the differences that are found in Table 3.4 are definitely too large to be explained by only these uncertainty factors. Further, it is also remarkable that IPCC data over 2000-2006 is much more in line with CBS data, than it is over 1990-2000. For time span 2000-2006, data on settlement and agricultural land deviates somewhat, though equal trends are clearly shown. The comparison of both datasets for the 1990-2000 time span creates quite some confusion. For example, settlement shows strong decrease for the CBS data, while an increase that is even 4 times as large was found for IPCC data. A huge difference between the datasets for the increase of forest area is also strange.
Some of this curiosity for the 1990-2000 dataset was cleared by reading through the attached descriptions on CBS land classes (see Appendix II). There it is stated that till 1993 unpaved and semi-paved roads were assigned to CBS class roads, which is IPCC class settlement. After 1993, where these unpaved or semi-paved roads lie in forest or agricultural area, it is accounted to one of these classes. It seems that large differences are explained by these changed classification rules. By extracting a selection of all unpaved roads from the Top10 topographic map[10], it becomes clear that it already concerns some thousands of hectares, depending on which road

[9] CBS data over time span 1989-2000
[10] source: Dutch Cadastre

width is applied. If the area of semi-paved roads is added to this, this indeed could explain a significant part of the difference between the IPCC and CBS datasets.

For the difference in total land area between 2000 and the other two years was no explanation found.

### 3.3.4 Impact of land change size on the European research project

The PhD research by Fuchs (2010) on the relation between land changes and greenhouse gases on a European level, holds a spatial resolution of 1 x 1 km. This means that each pixel in that dataset represents 100 ha. If it is for now assumed that each raster pixel holds the value of the land class of which the area is most represented, a land change should have a size of at least 50 ha to force a land change if the other land is all of the same, but another class. From the original land changes dataset, only 21% of all land changes would have impact on the 1 x 1 km resolution, representing 61% of all changed area. This scenario, with at least 50 ha of a land change covering one unit, will of course only so now and then occur. On the other hand, in quite some cases an area classified equal to the new changed land class is nearby, or more than one other land classes complete the pixel coverage. A lower area is then needed to force a change. With a scenario by which land changes of 25 ha could already force a change at 1 x 1 km resolution, this would result in 50% of all land changes (86% of all changed area) meeting this threshold.

Better understanding of the impact of a 1 x 1 km resolution can be obtained by comparing the original IPCC land changes dataset with a dataset that is the difference between:

- The 1990 IPCC dataset at 1 x 1 km resolution, and
- The 2006 IPCC dataset at 1 x 1 km resolution, where

the 2006 dataset is created by taking the 1990 IPCC dataset and update all of its area that is indicated as a land change in the original IPCC land changes dataset. The 1 x 1 km units are created by assigning the land class of which the area is most represented within that unit.

Which then becomes clear, is that instead of the 10.840 ha changed land that was already presented in section 3.2, only 9.100 ha (84%) remained. More concerning is the deviation per land class against the in section 3.2 presented numbers: cropland (70%), forest (115%), grassland (55%), settlement (90%) and others (30%). Except for forest, all land classes are underestimated, of which grassland and others are heavily underestimated. Only 42% of all land change locations intersect with these changed units. Of these, 18% are covered by units that changed into another land class than the new land class of the original land change.

## 3.4 Definition of assessment

The previous sections of this chapter emphasize the need for assessing the completeness and correctness of land changes on the geometry, as well as on its thematic and temporal attributes. The required assessment is defined by a list of instructions on how the land changes dataset must be updated:

- Validation, and if necessary improvement, of the positional accuracy of land changes in the dataset
- Validation, and if necessary improvement, of completeness of the dataset by adding missing land changes (drawing its shape) and deleting invalid land changes.
- Validation, and if necessary improvement, of the thematic information (land classes)

- Validation, and if necessary improvement, of the temporal information.
- Specifying more detailed temporal information
- Providing supportive information

### 3.4.1 Geometric assessment

The delineation of land changes can be improved in many cases. There were examples shown of missing land changes, but also of mapped land changes that in reality are no changes. More concrete, it means that tools are needed to adjust the shape of existing land changes, to draw new land changes and to delete existing ones. It is considered as an absolute must to have this functionality available in the VGI assessment website. More on the functionality and design can be found in the next chapter.

### 3.4.2 Thematic assessment

Assessment of land change attributes consists of updating incorrect information and adding new information. In the case of existing land changes, it means that locations for which is thought that its land class is incorrect, it should be adjusted. Other information that could be useful for this and further research, and therefore will be collected, is information about the contributor, supportive information and a comment box with room for own remarks from the contributor. One by one, the thematic attributes are listed below with some explanation. For the latter three items it is not necessarily that these only contain thematic information.

1. **Land class**

| *Attribute field* | *Data type* | *Allowed values (domain)* |
|---|---|---|
| land_old | Text | ”Forest”, ”Cropland”, ”Grassland”, ”Settlement”, ”Others” |
| land_new | Text | ”Forest”, ”Cropland”, ”Grassland”, ”Settlement”, ”Others” |

It would be too complex to ask from people who participate in the VGI assessment to classify the land changes based on the CLC nomenclature. With the provided descriptions it should be possible to classify former and current land within the IPCC nomenclature.

2. **Upload supportive material**

| *Attribute field* | *Data type* | *Allowed extensions* |
|---|---|---|
| - | File | .pdf, .doc, .jpg, .png, .gml, .zip, .etc. |

Any documents which contain explanatory or clarifying information on a land change can be uploaded by a contributor. It does not matter if it concerns someone who is ‘involved’ as a professional or amateur. As long as it is considered to be useful, one can upload a map, report, presentation or this could even be a spatial dataset, which is more likely to be the case for a professional.

3. **Reference to explanatory content**

| *Attribute field* | *Data type* | *Allowed values* |
|---|---|---|
| reference | text (url) | all, with maximum number of characters: 250 |

Contributors could provide a reference to online available content by pasting the URL in a textbox, if this location contains information on a land change of which it is considered to be of interest to be aware of.

4. **Information about contributor**

| *Attribute field* | *Data type* | *Allowed values (domain)* |
|---|---|---|
| type_contributor | Text | “owner”, “nearby living“, “professional”, “involved otherwise”, “interested in topic”, “others” |

This item concerns information about the contributor in relation to a specific land change that is updated. It could indicate the reliability for specific content that is updated. Further it is interesting to see which types of contributors are most willing and capable to assess land changes. By asking contributors to indicate to which group they belong, there should be gained some more insight in this. Thereby should the division in “types” of people who are directly approached and asked to contribute to this project, of course be taken into regard.

5. *Comment box*

| *Attribute field* | *Data type* | *Allowed values* |
|---|---|---|
| comment | Text | all, with maximum number of characters: 250 |

This textbox provides the opportunity for people to add a short comment. This could be anything, but of course it is aimed to collect specific information that is not covered yet by one of the earlier items of this section.

### 3.4.3 Temporal assessment

Information on the time span in which a land change took place is already available, thus can be assessed on its correctness. One of the objectives is also to gather more detailed information, i.e. the precise year when a change took place.

6. **Time span of land change**

| *Attribute field* | *Data type* | *Allowed values (domain)* |
|---|---|---|
| change_period | Text | “1990-2000”, “2000-2006” |

It is important to have correct information about the time span in which a certain land change took place. First of all, for analysis on the quality of each of the two land changes datasets, but also for further research, where initially time steps of 10 years are used. For land changes that took place in 2000-2006, this can later on be translated to changes in time span 2000-2010.

7. **Year of land change**

| *Attribute field* | *Data type* | *Allowed values (range)* |
|---|---|---|
| change_year | Numeric | range: 1988 - 2006 |

The earlier mentioned PhD research in progress by Fuchs (2010) is currently focussing on 10 year intervals. It is interesting to see whether it is feasible to acquire more detailed information about the precise moment of a land change. If known by a contributor, the precise year of a land change can be provided.

# 4 Design and development

The design and development of the VGI web mapping application is subject of discussion in this chapter (see Figure 4.1). Section 4.1 starts with a more general study on key factors and requirements for successful VGI web mapping. Then, four web mapping solutions are analysed in section 4.2 on its suitability for this particular VGI objective. For the solution that is chosen to be used during the pilot, the design is worked out and elaborated in section 4.3 with an explanation of the choices that were made and the (working of) provided functionality. The chapter ends with the strategy to be followed for monitoring during the case study (section 4.4) and for gaining publicity (section 4.5) so that people participate.

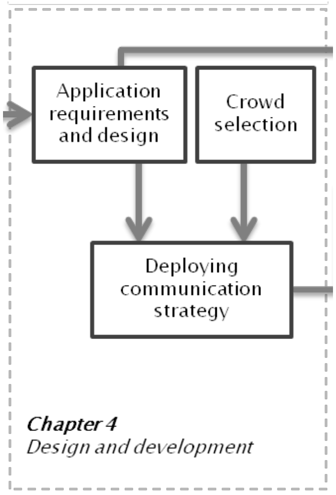

*Figure 4.1* Phase 2

## 4.1 Key factors for successful web-mapping

There are many studies that had its focus on describing the aspects that are important, and therefore should be taken into regard, when performing citizen science projects that deal with VGI and/or web-mapping activities. By analyzing those, it is aimed to answer the following questions:

- What motivates and drives citizens to participate in VGI projects?
- Which features of a web-mapping application do users appreciate or dislike?
- How could a desired level of data quality be assured?

The next three sections elaborate on these issues.

### 4.1.1 VGI motives

To start with the first question, the success of online VGI applications depends of course on the motivations of people to participate. There was found a number of reasons of which is expected that these are driving factors for people to participate in this particular VGI project:

- Personal involvement with supported product/topic (Goodchild 2007; Coleman et al. 2009);
- Altruism (Goodchild 2007; Coleman et al. 2009);
- To achieve desired political outcomes (Flanagin and Metzger 2008);
- To support others within a community (Flanagin and Metzger 2008; Coleman et al. 2009).

This list makes clear that there appear to be sufficient reasons for citizens to participate, i.e. that this approach could be successful if properly worked out.

### 4.1.2 Functionality and usability

It is then interesting to get a clear picture of the expected functionality by those volunteers, and to focus on optimization of the usability for an application that could be used for land changes assessment.

However, the diversity of volunteers, for example in technological experience, knowledge, interests or motives, makes it quite challenging to build an application that is considered to be acceptable for all, or at least the majority (Nivala et al. 2008; Newman et al. 2010). Most of the issues found from usability studies on web-mapping sites that were performed by Nivala et al. (2008) and Newman et al. (2010) also count for this project. It can be concluded that it is important to realize that:

1. Distractive animations are considered very annoying.
2. The reason for contributors to visit such a site is the web map. The overload with advertisements, images and links (often placed at prominent locations) is found very annoying and prevents the visitor from finding the relevant information.
3. Functional buttons and icons should not be distributed all over the screen.
4. The map view must have a reasonable format, and certainly not be too small.
5. The navigation functionality should be clear. For example, it was found that the now commonly known “fixed” sliders for zooming are preferred in web maps above the standard GIS industry magnifier zoom in and zoom out buttons.
6. The visibility of system response to chosen actions should be short, and also data rendering must be fast.
7. Difficult and time-consuming registration and login facilities should be avoided if possible.
8. Links to other content should preferably not be opened in the same browser window, with as a result that the map disappears.
9. Complicated functionality, of which the working is not fully understood by the users, results in more frustration, compared to a situation of not having that functionality. Sometimes a *less is more* approach could better be applied.
10. The purpose of the website and role of contributors should be clearly communicated.
11. Adding *fun features* fosters motivation and continued involvement.
12. Provide information that helps with map interpretation.
13. Allow users to play around in a “testing” environment.
14. Facilitate communication between volunteers.
15. Outcomes and results should be shared with the contributors.

Since besides functionality and usability also the costs is an important factor in this project approach, especially when it is decided to apply this approach on a wider scale, it is interesting to cite Earthy (1996) here, who states that a user-centred design could also provide financial benefits by reduced production costs, support and use. Further, he states that it could improve the product quality. How quality could be even more improved is explained in the next section.

#### 4.1.3 Data quality

Data quality in case of citizen science projects always depends on the ability of, and decisions made by, each contributor. Nevertheless, data quality could be improved by providing clear instructions on what is asked from the contributors and how they are expected to do their tasks. Further, more technical issues that influence the quality of outcomes are in this project for example the availability of useful aerial images, consistency that could be forced by providing predefined lists with values from which to choose. Geometric quality can be improved by providing functionality that facilitates the contributor in the drawing process (snapping, add/delete vertices, et cetera).

## 4.2 VGI mapping application suitability analysis

Taking into regard the findings from the previous section, four different web-mapping applications are compared and evaluated to find out which one best facilitates the land change assessment. These four applications are (1) Google Earth, (2) Google Maps, (3) OpenLayers (extended with GeoExt) in combination with GeoServer, and (4) the ArcGIS Application Programming Interface (API). The first two application have only predefined functionality that can be used in combination with own data. The latter two applications require some knowledge of code writing to customize the application. From the available code libraries, one can use different components to compose a custom application that can be implemented in a website.

Most important aspect in this comparison is the fact whether these applications provide the required functionality (weight is 45%), since this is the most crucial part. Secondly, the level of user convenience (weights 35%) is determined. Once someone gives it a try, a pleasant experience is probably the key factor for potential contributors to decide whether to put energy in it, or not. Technology, which plays a role more at the background (e.g. costs, standardization) and is not 'experienced' by contributors, is taken into consideration with the lowest weight (20%). It has been decided as this, since the research focus should be more on the assessment itself, than on the application design.

For all three assessment categories, a number of items has been evaluated and compared for each application. This is elaborated on in the next sections. Thereafter, ratings are given to each item, from 1 (very poor) up to 5 (outstanding). The scores are listed in a table at the end of each section and summarized for an overall verdict, that is presented by Figure 4.3 in section 4.2.4.

### 4.2.1 Functionality

A comparison on the functionality that is provided with each solution shows that the OpenLayers solution outperforms all other applications, as can be seen in Table 4.1. Both Google applications score clearly lower. After this table, a discussion on each item follows to explain where the rates are based on.

| Functionality | Google Earth | Google Maps | OpenLayers, GeoExt & GeoServer | ArcGIS API |
|---|---|---|---|---|
| Geometric editing (25%) | 4 | 4 | 4 | 5 |
| Attribute editing (25%) | 3 | 4 | 5 | 5 |
| Data support (20%) | 2 | 2 | 5 | 3 |
| Styling and design (20%) | 2 | 2 | 5 | 4 |
| User community (10%) | 1 | 1 | 3 | 3 |
| **Functionality score (45%):** | **2,65** | **2,90** | **4,55** | **4,20** |

***Table 4.1*** *Functionality scores for each application*

*Geometric editing*

The dataset with land changes can be imported by both Google Earth and Google Maps. In there, existing features can be deleted, new features can be added to the dataset, and the shape of existing features can be adjusted. Also OpenLayers and ArcGIS API do both have good functionality for feature shape editing and adding or deleting land changes. ArcGIS API provides most advanced editing tools, such as cutting and auto complete features. All four provide functionality to add or delete vertices. OpenLayers and ArcGIS API further enable resizing and rotation of shapes and OpenLayers additionally provides snapping.

*Attribute editing*
Assessment of land change attributes with the OpenLayers application is here facilitated by the GeoExt extension. ArcGIS API provides somewhat comparable functionality for this. Editing the land change attributes in Google Earth and Google Maps is possible, but less convenient compared to the earlier discussed two. Both Google solutions provide a pop up display box to see the attribute information. Though, editing this information in a structured way is, especially in Google Earth, not really user friendly.

*Data support*
Google Maps provides very limited functionality for adding external maps. Only KML layers, a format that supports vector editing, can be displayed on top of the basic Google Maps layers. The same counts for Google Earth, in which overlays of other image files and some WMS layers is also supported. OpenLayers offers, from the four compared applications, by far the most variety in data support. OGC standards, such as GML and the Web Services WMS and WFS (including Transactional) are supported, but even so are the base maps of Google Maps, OSM, Bing Maps, Yahoo Maps and ESRI map services. Additionally, map tiling is supported. Especially the WFS Transactions functionality is of interest in this project, since this is the open standard for online vector editing, which is required for the land changes assessment. ArcGIS API is somewhat comparable to OpenLayers regarding the support of datasets. Just one significant difference is that ArcGIS API does not support WFS Transactions. Having assessable vector data in this web-map solution requires ArcGIS Server, which is a quite expensive product.

*Styling and design*
This item concerns the whole view of the browser window, which means not only the map itself, but also the area around. For each four, it is possible to have customized representation styles applied to a dataset. OpenLayers and ArcGIS API both provide functionality to extend the map view with own items, such as a layer switcher, scale bar, display of the coordinates for the mouse position on a map and especially in OpenLayers numerous other items.
The main difference concerns the area around the map itself. Where Google Earth and Google Maps both have a fixed design (ready for use), OpenLayers and ArcGIS API only offer a framework, to which the proper content is to be provided by oneself. It is then up to the developer to implement this in a website, which requires additional efforts and skills. For someone with such design skills it is preferable to have the freedom to build the design completely customized and in line with own preferences. It enables for example to provide information on the project, to provide instructions and so on.

*User community*
None of the four applications provides a built in forum, discussion/message board or something comparable. This can also not be implemented in the main browser window for both Google applications. A website with an OpenLayers or ArcGIS API map application could be designed in such as way that it facilitates something of the above.

### 4.2.2 User convenience

Table 4.2 reveals that the user convenience of Google Maps, but especially Google Earth, was found significant worse than that of OpenLayers and ArcGIS API, mostly caused by the level of disturbance and distraction.

| User convenience | Google Earth | Google Maps | OpenLayers, GeoExt & GeoServer | ArcGIS API |
|---|---|---|---|---|
| Preparation (30%) | 2 | 4 | 5 | 5 |
| Simplicity / learning curve for contributors (25%) | 3 | 5 | 5 | 5 |
| Familiarity of the design (15%) | 4 | 5 | 3 | 3 |
| Distraction / disturbance (30%) | 2 | 1 | 5 | 5 |
| **User convenience score (35%):** | **2,55** | **3,50** | **4,70** | **4,70** |

***Table 4.2*** *User convenience scores for each application*

*Preparation*

No preparatory actions are asked from contributors before starting to assess with the OpenLayers and ArcGIS API. This is also the case for Google Maps, however this application requires a Google account to log in first, which is considered as a drawback. Google Earth requires a one-time installation of the software, which is seen as a major drawback compared to the other applications that make use of the standard web browser.

*Simplicity / learning curve for contributors*

For contributors who have to work with the application, none of the applications really requires a learning process to work with it, though it is to be expected that both Google applications take some more time before (the working of) all functionality is discovered and fully understood in comparison to the other two applications. OpenLayers, Google Maps and ArcGIS API both have in general easy to use tools for modifying the shape of features, as well as their attributes. By picking a feature (in Google Maps after clicking the 'edit' button), the attributes are shown and vertices become highlighted for adjustment. In Google Earth, the edit functionality is somewhat hidden. One must first right-click on a feature and then choose for properties. A new window opens, in which attribute information can be updated, and by which also the shape editing mode is 'activated'.

*Familiarity of the design*

From the four discussed applications, it may be assumed that Google Maps provides the most familiar interface. The popularity of, and familiarity with an application could create some sort of assumed reliability and confidence in the application. This could, in combination with the knowledege on how to use the application, be a stimulus for contributing. To a lower extent, this also counts for Google Earth. The Openlayers and ArcGIS API applications do both have a less familiar interface, but most people are nowadays experienced with the basic understanding and functionality of web-maps and web-mapping, which in essence works similarly for all applications. Further, these two applications could possibly benefit from expressing some more professionalism and more specific dedication to the assessment task.

*Distraction / disturbance*

As said earlier already, the OpenLayers and ArcGIS API applications can be fully customized for land change assessment. During the assessment there is no distraction or disturbance by irrelevant information, animations or advertisement. Both Google Maps and Google Earth applications provide all kind of irrelevant functionality and information around the map view. By clicking on this, it moves to this application or service and with that away from the land change assessment.

With Google Maps and Google Earth, apart from polygons (for representing land changes), one could further add lines and points, which is irrelevant functionality for this land change assessment and cannot be turned off, see Figure 4.2, example 1. In Google Maps, there is the curiosity of showing only a maximum of 50 randomly distributed features by once, similar to the maximum number of displayed results on a page in Google search (see Figure 4.2, example 2). This is highly inconvenient, it means that there should be assessed a total of seven pages (i.e. views) with land changes in this project. Each time a page is chosen, the view goes back to the maximum extent.

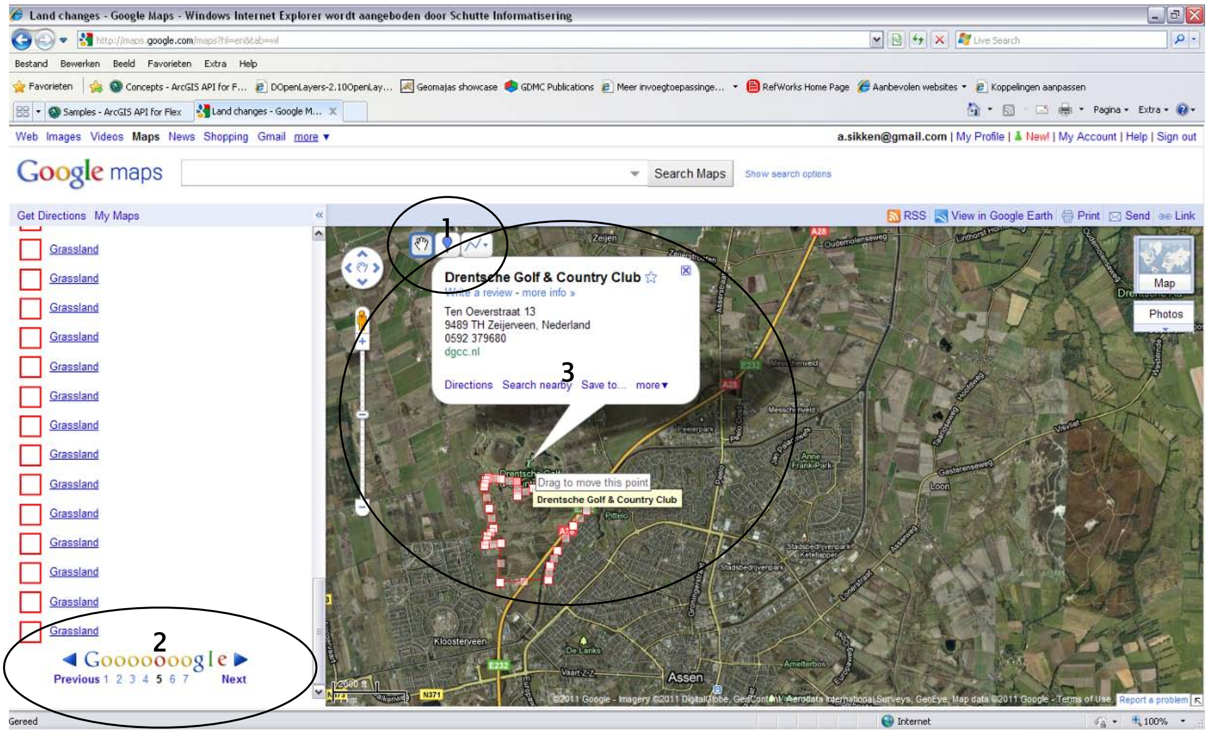


*Figure 4.2 Examples of disturbance in Google Maps*

Further, the map view provides all kind of distractive and irrelevant information (see Figure 4.2, example 3). It can be turned off, but then also orientation labels disappear.
Somewhat annoying in Google Earth is that the opened “properties” window, which has quite a large size, covers a large part of the map view with the features that are foreseen to be adjusted. This properties window should first be shifted aside manually each time, which makes shape editing somewhat unpleasant compared to ArcGIS API, Google Maps and OpenLayers.

### 4.2.3 Technology

*The overall scores of the four applications on technology were quite comparable to each other (see Table 4.3). Only ArcGIS API fails on investments, due to its expensive solutions, as becomes clear from the discussion below.*

| Technology | Google Earth | Google Maps | OpenLayers, GeoExt & GeoServer | ArcGIS API |
|---|---|---|---|---|
| Reliability / stability (25%) | 4 | 4 | 4 | 4 |
| Application investments (20%) | 4 | 4 | 5 | 2 |
| Application development learning curve (20%) | 4 | 4 | 3 | 3 |
| Saving, restoring and undoing edits (20%) | 4 | 4 | 4 | 4 |
| Open standards / open source technology (15%) | 2 | 2 | 5 | 2 |
| **Technology score (20%):** | **3,70** | **3,70** | **4,15** | **3,10** |

***Table 4.3*** *Technology scores for each application*

*Reliability / stability*

All four applications seem to pass for this "test". For none of them there was noticed a chance of data loss or otherwise computer troubling during the assessment because of instability or a malfunctioning application. Only, for map tiling in OpenLayers it appeared that loading of some tiles sometimes took a 'long' time.

*Application investments*

Google Earth, Google Maps and OpenLayers do not have any restricted functionality to be repealed by purchase license, neither use costly accessories on which their applications depend. This gives these applications a higher rating than ArcGIS API. The latter application only allows vector data to be edited with ArcGIS Server, which requires a high investment.

*Application development learning curve*

For both Google applications there is hardly a learning curve for developers, mainly because there is almost nothing to configure. For ArcGIS API and OpenLayers it is required to have some basic understanding of scripts. A great benefit of OpenLayers is that many examples are made free available by the developers community for usage (as components) in an own design.

*Saving, restoring and undoing edits*

ArcGIS does not provide a 'save' button for its API, the modifications are automatically processed. However, with 'undo' and 'redo' buttons, one is able to restore modifications, of course as long as the browser window is opened. Google Maps has function buttons for cancelling attribute – or shape editing, though the one for shape editing is somewhat hidden. Further, Google Maps provides a 'save' button. In Google Earth, modifications for shape and/or attributes can be confirmed or cancelled by clicking these buttons in the properties window. In OpenLayers one is able to create buttons for saving and cancelling edits by script writing in JavaScript.

*Open standards / open source technology*

OpenLayers is the only one from the compared four solutions that is completely in line with open standards and open source. The other three do all score low on this point, due to only supporting WMS (ArcGIS API and Google Earth) and/or KML (Both Google applications) and only some customizable components are open source (ArcGIS API).

### 4.2.4 Overall outcomes

Before drawing the final conclusion, there will be looked at some of the more crucial items to make a final choice between the OpenLayers and ArcGIS solutions. Since there is hardly any difference in functionality and user convenience, which becomes clear from Figure 4.3, a closer look at the technology shows that exactly the two most crucial points, costs aspect and "open" technology, determine the difference in final score in advantage of OpenLayers. With that information, it does hardly leave any room for discussion on which application preferably to use.

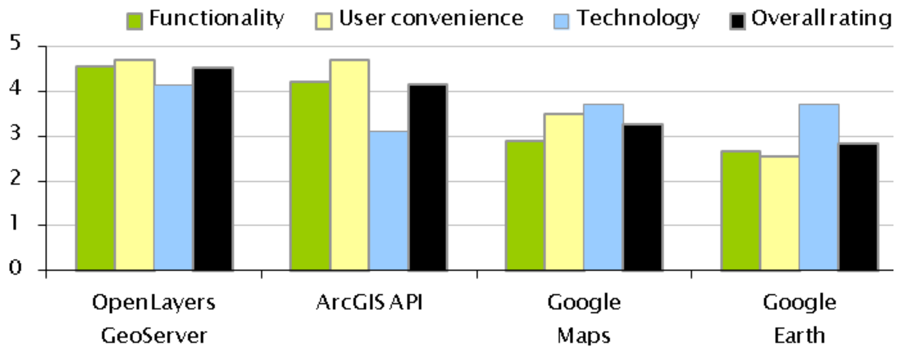


*Figure 4.3 Final scores for all four applications on suitability*

## 4.3 Land change web-mapping and website design

A land changes assessment website is created by registration of the web domain *http://www.landchanges.eu*. For news and updates, a Twitter-account *@landchanges* is registered. The assessment website is developed with HTML, CSS and JavaScript. It is successfully tested on compatibility with Internet Explorer (6 and higher), Chrome, Firefox, Safari and Opera. Further, it is of course a must to have this VGI application constantly online. For the case study, a solution for that was found by placing the datasets, and installing GeoServer, on the WUR server.

### 4.3.1 Web design

Before the website was built, some research is done on the desired dimensions for the assessment website are and how to make the website compatible with as much of the various browsers and their versions. Useful statistics on this are provided by w3schools[11]. Though their website warns not to rely only on the presented statistics for web development, it does provide at least some insight in developments over time and for the current state of e.g. browser popularity, browser versions, operating systems and browser screen resolution (see also Figure 4.4).

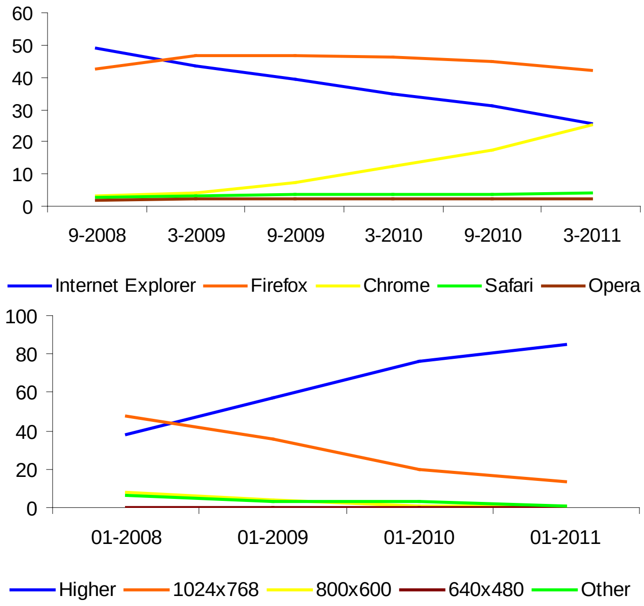


*Figure 4.4 w3schools statistics on browser popularity (top) and screen resolution (bottom)*

[11] http://www.w3schools.com

Especially for Internet Explorer (IE) it was found that quite some people still use older browser versions (IE 6 or IE 7) that have a major drawback by not supporting the newest technology. Despite this, sites that have been developed for IE 8 or higher and made compatible with other browsers, work well by over 90% of computers.
The trend in screen resolution shows that websites being designed for 1024x768 resolution nowadays are displayed without a need for scrolling to 99% of its visitors. This counts for "traditional" desktops, though there is an increasing use of smartphones, tablets and netbooks with smaller displays. Because of the unique approach and the extent of specialism it would ask in the design phase, it is decided not to involve this latter group in this project.

Figure 4.5 shows the components that together form the website. Project details are communicated by the title and project info mouse over button (1). Corresponding items are grouped together, e.g. the assessment instructions (2), the action buttons (5) and the land class descriptions (8). Updates, news and outcomes are communicated by tweets (7) and the map view itself (4) is prominent placed (centred and covering about 40% of the view). Once a land change is selected in the map view, its attributes can be modified in the table view (6). Some extended functionality (3) is made available by supporting English, as well as Dutch language, and by providing functionality to open this land change assessment project with software packages QGIS or uDig, which could be more convenient to work with for certain people. No specific functionality has been added for uploading supportive materials, which was one of the assessment items, because the required specialism on how to create this was not available. In case a contributors want to share a document, this is still possible via e-mail (if not too large size).


*Figure 4.5  Website components*

The user demands from section 4.1.2 were as much as possible applied during the design process. Explanations, information, instructions and descriptions are shown on top of the website, by mouse overs. The most important reason for this solution is that a visitor never leaves the main site. See for two examples Figure 4.6, showing an instruction button (map navigation) and a land class (grassland).

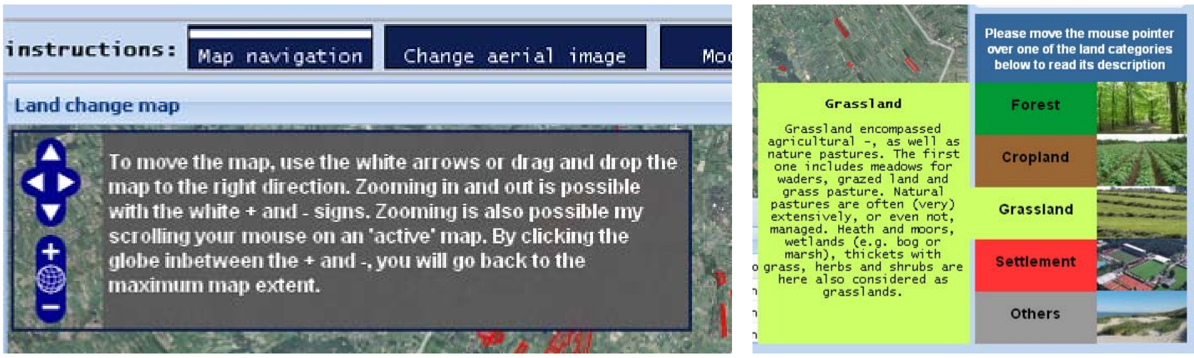


*Figure 4.6 Mouse over result for an instruction (left) and a land class (right)*

### 4.3.2 Land changes assessment API

The core of this assessment website is formed by components 4,5 and 6 (see Figure 4.5). The technology it uses is OpenLayers, with GeoExt extension. This technology is all open source, which makes the design fully customizable with JavaScript, e.g. the dimensions can be adjusted, new functionality can be added and unnecessary functionality can be dropped. The assessment functionality that is made available within this project, is listed in Table 4.4.

| | |
|---|---|
| **Map navigation** | |
| Move the map | ▪ Into N, E, S or W direction by click one of the four white arrows in the upper left corner of the map view;<br>▪ By once click (and hold) the map and move it into any desired direction. |
| Zoom in | ▪ Clicking the + icon in the upper left corner of the map view;<br>▪ By once click the map view and "scroll up" the mouse wheel;<br>▪ By double click the map view. |
| Zoom out | ▪ Clicking the – icon in the upper left corner of the map view;<br>▪ By once click the map view and scroll down the mouse wheel. |
| Go to maximum extent | ▪ By clicking the globe icon in the upper left corner of the map view. |
| Go to specific extent | ▪ By holding the shift key and select an area within the map view with the mouse. |
| **Aerial images usage** | |
| Switching layers | ▪ Aerial photo taken at the begin of a land change time span<br>▪ Aerial photo taken at the end of a land change time span |
| **Editing land changes** | |
| Shape modification | ▪ Adjust shape by moving vertices;<br>▪ Simplification of a shape by deleting redundant vertices;<br>▪ Extension of a shape by adding new vertices;<br>▪ To prevent from overlap or gaps in between shapes, snapping functionality is added to match adjacent borders. |
| Attribute modification | ▪ Modify fields by selecting another value from drop down list<br>▪ Provide information by filling or overwriting text field |
| Delete item | ▪ Delete an item from the dataset by selecting a land change and click the "delete selected item" button. |
| Create new item | ▪ Add a new land change to the dataset by clicking the "create new |

| | |
|---|---|
| | item" button, then drawing the shape and adding attribute data, and finalize by clicking once more the "create new item" button. |
| Saving edits | ▪ Edits can be processed and stored to the dataset by clicking the "Save changes" button. |
| Cancel editing | ▪ Modifications can be made undone by clicking the "Cancel editing" button. |
| Download project to edit in: | ▪ uDig format<br>▪ QGIS format |

***Table 4.4*** *Available functionality for land change assessment*

The land changes dataset contains areas that changed within one of the two time spans 1990-2000 and 2000-2006. This means that for this project aerial images from these years are needed to support the VGI assessment.

*Aerial image 1990*
An aerial image for 1988-1990 was not found among the available datasets within the GIMA participation institutes. After searching further, an aerial image from 1989 was only found as hard copy. This book, published by Robas Produkties & Topografische Dienst, contains 307 photos that cover the whole province at scale 1:14.000, which is enough detail for the project objective. After contacting the current source holder, the Dutch Cadastre, and providing some explanation on the project and purpose of use, it was agreed to use the images from this book for this MSc thesis for free. However, as a hard copy book, the possibilities are quite limited and it still is impossible to use it for the VGI assessment. It was therefore decided for the case study to cover the land changes over 1990-2000 for two Municipalities, by scanning some pages, georeferencing and creating a WMS service.

*Aerial image 2000*
There has been produced an aerial image in 2000 by Eurosense. This dataset is available within the WUR domain, but Eurosense answered to our request that it is not allowed to use it for the VGI part of this project, because of the Web 2.0 component.

*Aerial image 2006*
For 2006 there is an existing WMS service available, provided by the Geospatial Data Service Centre[12], with an aerial image that is also made available by Eurosense. This service will be one of the layers to facilitate contributors.

All datasets (land changes and aerial images) should preferably be implemented as OGC Web Services (OWS), which is the Open Standard for serving web maps, being established by the Open Geospatial Consortium (OGC). The aerial image for 2006 is already available as a free WMS service. The one of 1989 is served as a Web Map Service (WMS), which implicates that on each request only the requested part of the map is to be generated and displayed as an image format (e.g. .PNG, .JPG, .GIF) in the map view. The dataset with land changes is served as a WFS-T service. Web Feature Service (WFS) technology is able to exchange features in GML format

[12] http://gdsc.nlr.nl/gdsc/nl/services/wms

(Geography Markup Language). Its editable variant is WFS-T (Transactions), which allows anyone who visits the land change assessment website to edit the dataset.

One important drawback of WFS technology is that, on a request, it generates and transfers quite a lot of data to describe the spatial characteristics and attribute information of each individual feature in the dataset. It handles a few hundred of land change shapes without any problem, but on a European scale it definitely will not work, since it then concerns huge amounts of data to be generated and transferred. A solution to this problem is found by representing the land changes dataset initially as a WMS image, similar to the aerial images. Once clicking within the area of a land change, it requests the information for only that land change and the selected item becomes editable. This efficient solution works quite well, though it unfortunately creates a problem, by disabling snapping functionality (there are no other vector features to snap to).
Because the case study only concentrates on land changes in Drenthe, it is decided to apply the "inefficient" method, in order to keep the snapping functionality working for now.

## 4.4 Monitoring strategy

On beforehand, it is good to realize that persons with malicious intentions have also access to a VGI initiative and could possibly damage the project. Data can be deleted and false contributions can be made intentionally. For personal or political motives and reasons, persons could try to create scepticism or make the project fail. It depends on the type of negative intention, how easily or difficult such input can be traced (Coleman et al. 2010). Most difficult to trace are unintended false contributions (without malicious intention) by people who sincerely believe that they provide useful and correct contributions. On a frequent base, the land change dataset will be stored on a local drive. A model is designed with ArcGIS ModelBuilder to extract different overviews of changes that are made to the dataset.

Website statistics are registered by Google Analytics[13]. The project is also monitored to notice when visitors are faced with a critical problem, of which was not thought of during the design process, or for which the importance was obviously incorrectly estimated.

Only in case of critical mistakes or intentional abuse to the dataset there follows intervention.

## 4.5 Publicity and interaction strategy

By the moment the website is launched for the case study, its existence is not known yet by any people. To gain sufficient activity and response within the short time of this pilot, three user groups will be actively approached by sending them an e-mail. The message contains a short introduction, explanation of the objective and of course a link to the assessment website www.landchanges.eu.
Visitors of the land changes assessment website are informed during the pilot on progress and developments by a twitter-feed.

[13] http://www.google.com/intl/nl/analytics/

# 5 Case study

The case study (Figure 5.1) is discussed in this chapter, first by elaborating on some choices that needed to be made specifically for this pilot, concerning the datasets and the people to be approached. Then, in section 5.2 the visits and visitor characteristics that were registered during the first weeks after the assessment started are presented and analysed. The feedback that was received from visitors on the concept and design is included in section 5.3.


*Figure 5.1 Phase 3*

## 5.1 Preparations

Regarding the spatial extent of the case study, the design should focus primarily on people with a certain interest in the province of Drenthe. This encompasses its citizens and its land owners with their local knowledge, but

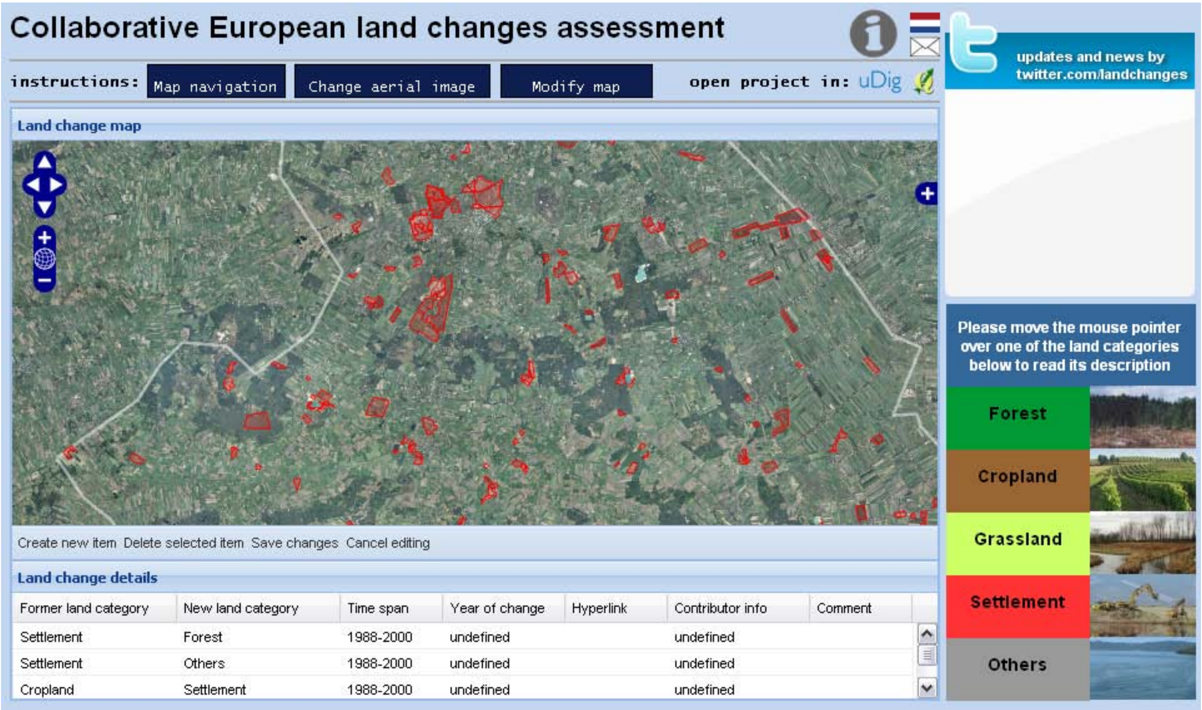


*Figure 5.2 Land changes assessment website*

also people from elsewhere, being somehow professional involved with land developments in Drenthe. Figure 5.2 illustrates exactly what is shown to people as the starting point when they enter the assessment website. The white outline in the map is the provincial border for Drenthe. All red surfaces in the map represent the land changes that took place in Drenthe. By clicking on one of these, the corresponding row with attribute information is highlighted in the attribute table that is shown right under the map.

It is further decided to facilitate the assessment of land changes by


*Figure 5.3 Aerial image of Drenthe, 1989*

making parts of the aerial image (AI) 1989 available. There were 58 pages from the hardcopy book (Figure 5.3) being scanned and georeferenced to cover the two Municipalities Assen and Coevorden, which is equal to roughly 1/5 of the total provincial size. With a GDAL tool for faster rendering of Geotiff images[14], the loading time of the 1989 aerial image enormously improved in comparison to the original configuration. Nevertheless, the time needed (in terms of a few seconds) for displaying the image is still significant compared to nowadays negligible rendering time for popular base maps (e.g. Google Maps).

Now the design is made ready for the pilot, the focus can shift toward the people that will be approached. It is assumed for the province of Drenthe that citizens, aged between 15 and 60, nowadays almost all have daily access to Internet and most of them have probably been confronted with various kind of internet applications in the past.
Although the assessment is open to everybody, it was decided to actively contact a selection of 61 persons because of their expected willingness and capability to participate and providing useful feedback. These 61 persons can be subdivided into three different groups.
The first group exists of 27 people to be in general categorized as friends and family without experience is this field. Interesting is further to mention that roughly three-quarter of them can be seen as locals with respect to the case study area.
The second group is formed by 20 GIMA involved/related people, of which is expected that they have a certain level of experience in this field. On the other hand, the knowledge of the study area by this group is for most of them probably limited or even absent.
A selection of 14 colleagues form the third group. Their experience with this topic, as well as their knowledge of this area, is estimated somewhere intermediate if compared with the other groups.

The moment by which the three groups were contacted was slightly spread over time, so that it creates a possibility to monitor the behaviour of each group. The VGI assessment "officially" started the 1st of September when an e-mail was sent to the first group. The second group was approached on September 6 and the final group on September 10.

## 5.2 Visitors

The number of visitors on each day during the first two weeks of September 2011 are shown by Figure 5.4. A total of 77 visits was counted, of which 42 were categorized as new visitors and 35 as returning visitor. If we now relate this to the number of persons that were approached (61) it looks like roughly 2/3 of them did take a look at the VGI assessment website. However, this would be a too simple conclusion, because it must be considered here that except for the first person, who is seen as a new

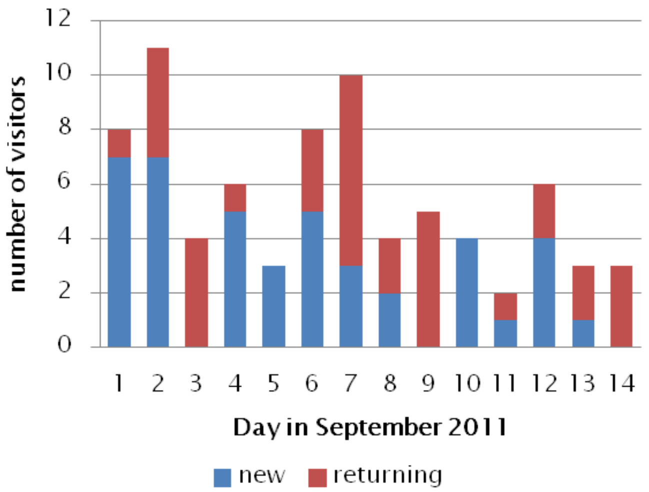

*Figure 5.4 Website visitors for the first half of September*

[14] http://docs.geoserver.org/latest/en/user/production/data.html

visitor, every next person who enters the website from the same domain will be marked as a returning visitor. Examples are the group of colleagues that was approached (all working in the same building) and the approached persons at WUR. Thus, one may assume that the number of unique (new) visitors is in reality higher than the above presented and the returning visitors slightly lower. This is the consequence of the method by which statistics were gathered with Google Analytics. Although it probably happens less frequent, it also works the other way around. If one visits the website at the office, and the next day this same person visits the website again, but this time from home, his returning visit will be marked as again a new visit. Apart from all the new visitors there is quite a high number of returning visitors, with the same remark as just was made on the method by which statistics were gathered.

Figure 5.5 shows how often people visited the website. Half of the unique visitors visited the website only once. After that point, the frequency of visits is low. Except for the category 26-50 visits, which is a remarkable high percentage and difficult to explain.

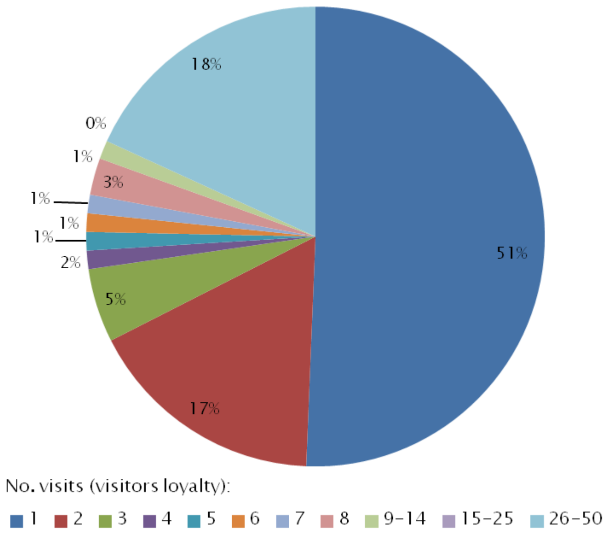


***Figure 5.5*** *Visitors loyalty (number of visits)*

The lack of scale, in terms of the limited number of people that was reached, becomes evidently from the statistics over the three weeks that then followed, when a total of just 7 new visitors and 3 returning visitors was counted. Further, no new contributions were made to the dataset during these weeks. To that latter point, people possibly refrained from participation because no longer any activity was observable (messages/news).

One of the remarks that is listed further on in section 5.3.1 concerned incorrect displaying of the website. Choices for the design were partly based on statistics about browser types and screen resolutions (see section 0). Now it can be evaluated if, with the information about visitors, those made choices are legitimated.

It is noticed that those 42 unique visitors used 16 different screen resolutions. If we now look again at the defined treshold for screen resolution on which the design was based, for 90% of visitors the website should have been shown correctly (with standard browser configuration). This is less than expected based on statistics over February, 2011. According to Figure 5.6, 10% of unique visitors had a deviating screen resolution, of which for non of them this concerned an older, traditional resolution. Those other visitors were most likely using devices as netbooks, tablets or smartphones. Of this category, two indeed concerned an Iphone.

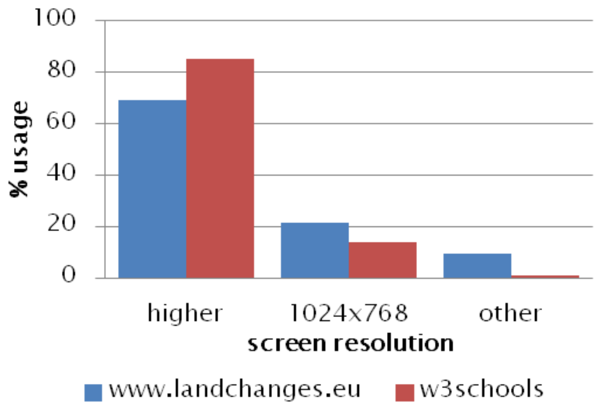


***Figure 5.6*** *Screen resolution of website visitors*

Another issue during the design phase was the browser compatibility. Lots of efforts were put into having the website compatible with all browser variants and versions to reach an as large as possible audience. If we look at Figure 5.7, we see that statistics from February 2011 significantly deviate from the ones that are collected for unique visitors of the website www.landchanges.eu. Since the website was made compatible with all listed browsers in Figure 5.7, this did not have any impact on the outcomes. However, it is interesting to see that Internet Explorer and Safari were significantly more used for visiting the website, and Firefox significantly less than the statistics from w3schools suggest. Only, compatibility with Internet Explorer 6 was not neccesary (0 visitors) and for 7 (1 visitor) one could reconsider if it was worth it, to put that much efforts in realizing compatibility.

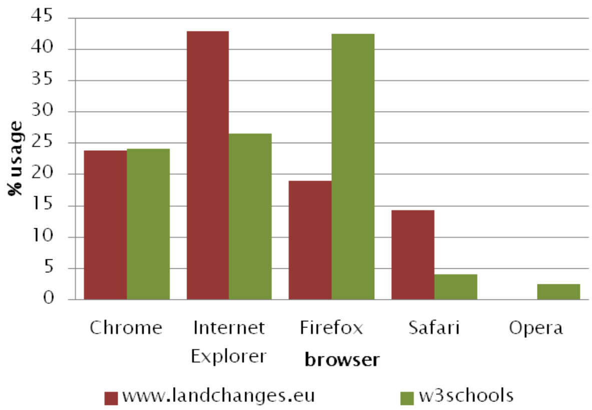

*Figure 5.7  Browser usage of website visitors*

Neither the website statistics nor the collected information from pop-up questions provided sufficient information to make reliable statements about the knowledge of visitors about the study area. Hence it is difficult to relate this aspect directly to the made contributions, being discussed in the next chapter.

## 5.3 Feedback

This section elaborates on the feedback that was received from visitors of the website. Feedback was received by e-mail, in some cases oral, but also collected by the more general pop up questions that are shown by opening (see Appendix III, 5 responses) and leaving (See Appendix IV, 2 responses) the website. A remark on this latter one must be made, because in quite some cases visitors stated not having seen any questions, or not the ones that should pop up at leaving the website. This is likely to be explained by automatic pop up blockers.

First the comments on the design are discussed, then followed by some more VGI concept related remarks.

### 5.3.1 Design

*Orientation*

During the first days after the first user group was approached, several persons made comments about having difficulties with the orientation. It appeared that only having an aerial image as base map really hindered the assessment. From this group with mainly locals, at least four persons told that they struggled with navigating to their own area. One person gave an example where it also really influenced the assessment, in a situation of not being 100% sure about the location of an assessed land change, where confirming map labels would have taken away these doubts.

To overcome this problem, recent OSM data was added to the project. The website was extended by a layer with streets (lines and labels) and places (labels). Due to the dependence on an external person managing the WUR server, this was fixed on the first possible moment, which was September 5. After this date, no further comments on the orientation were received, which indicates that the current configuration meets the requirement on this point.

*Speed*

From each user group, there were one or more persons with a remark that the assessment website responded slowly. These comments and some tests revealed that this cannot be only ascribed to slow internet connection, though it is obvious that especially the time needed for loading the datasets (WFS and WMS layers) is to some extent related to the internet connection and thus caused "trouble" for some. It became further clear that some of the nowadays used personal computers still lack capacity for fast and fluently loading and responding of this assessment website. Tests showed that on such computers it takes for example unpleasantly long time for loading the datasets, displaying of website elements or responding to actions. Examples are selecting a land change or restructuring on resizing the website, when auto-adjustment of map and attributes is performed with an annoying delay.

*website*

Some other suggestions and remarks that were received, concerning the website design, are here point wise listed:

- An interesting suggestions was made about the status of modifications. One way to implement this, could be by giving each modification automatically a "proposed" status. There are then multiple ways to process this further. For example with editors/moderators who approve such proposed modifications, or make it for everyone possible to judge by assigning an agree/disagree. At a certain number of agrees the modification is then automatically approved.
- From few people it became clear that they encountered problems with editing the map, especially when adding a new land change. After drawing one should again press the "add land change" button to finish the process. This was, despite that it was described in the instructions, not always immediately clear and was experienced as illogically.
- There were people who indicated that, when just arrived at the website, it took some time before all information and instructions were found and well understood.
- It was once mentioned that it would be less confusing if only the details of a selected land change appear right under the map, instead of a whole series, as with the current design. This is something that could be considered, since it will have other benefits, such as a larger map area, while no negative consequences are seen so far.
- One noted that the website was not properly aligned, especially text elements like the title. This is caused by a relatively low screen resolution, a relatively large browser font size or a zoomed in browser display. It was nevertheless decided to reduce the font size of this title element for lowering the chance of an incorrect alignment.
- To have (more area of) aerial images from 1989 and 2000 available to facilitate the assessment would be welcome.

### 5.3.2 VGI concept

There was also received some feedback that is more focused on the VGI concept itself:

- The most important one of all received comments is the one of people who were not able to participate because they did not understood the provided project objective. By reading the introduction in the e-mail and visiting the website it still did not become clear what was expected from them or how it worked. In many cases, additional textual or oral explanations made it clear at a later moment. Nevertheless, it asks for a critical review on the (form of) provided information and instructions.

- Other given reasons for not participating concern not having (sufficient) local knowledge of this specific area, and not having (sufficient) knowledge of determining the right land classes.

Received feedback was certainly not all about “trouble”. Some of the more positive comments:

- Many people declared that the project objective was clear to them, and that they were (easily) able to process changes, although not everyone who said this also really participated.
- There were some people who made a compliment about the concept and see it as an interesting new method that could be successful.

# 6 Assessment results

It becomes clear from Figure 6.1 that this chapter fully concentrates on the updates that were made to the land changes dataset. The contributions are extensively analysed on the geometric assessment in section 6.1 where there is looked at the positional accuracy for delineation and area coverage. The results from assessment on the thematic aspects of the land changes datasets are analysed and discussed in section 6.2, where also the results for temporal assessment are included in section 6.2.2.

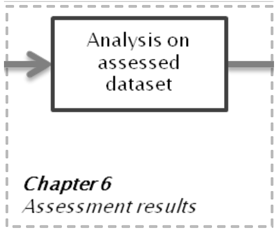


*Figure 6.1 Phase 4*

First of all, an overall impression of the contributions can be obtained from Figure 6.2. This image shows the locations of updates, categorized on being updated by geometry, attribute or both. The updates were made somewhat distributed over the province, although some concentration of updates can be found around the cities Emmen (lower right corner) and Assen (northern area with AI 1989 coverage). During the first two weeks of September 2011, there were

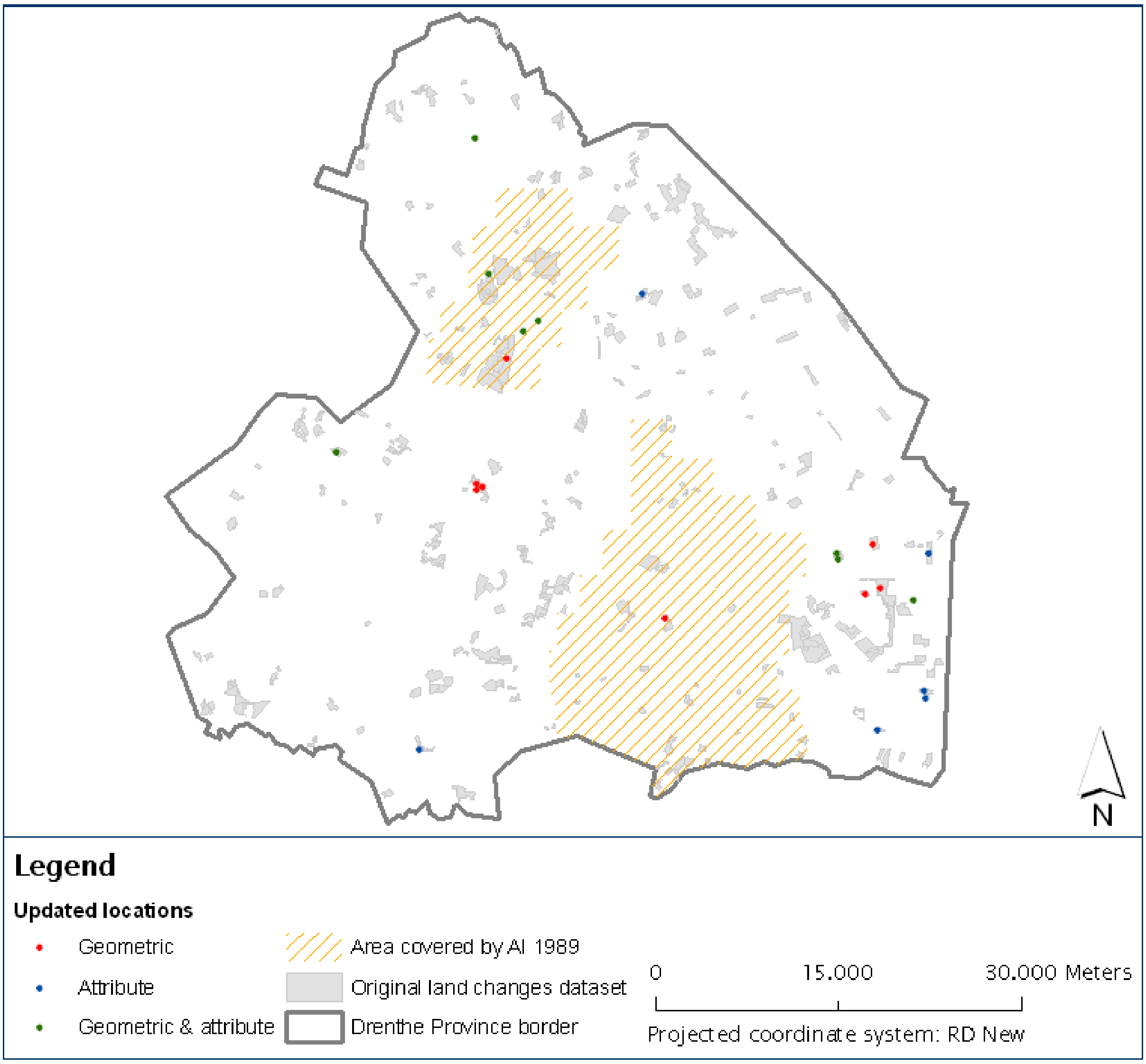


*Figure 6.2 Spatial distribution of contribution*

made contributions to 23 locations. In 5 cases it concerned new added land changes, once a land change was deleted from the dataset and the remaining 17 were all updates of existing land changes.

The verification of updates starts with one contribution that is left out of the analysis in the sections below, because it deviates too much from all the other contributions. Nevertheless, it holds the most important assessment aspects (geometry, attributes and temporal) of this VGI assessment task. It is therefore being used as an introduction to the analysis that follows in the next sections.
One contributor added the red dotted shape that is shown on the left side of Figure 6.3. By the comment that was made on it, it was explained that this shape outlines the global contours of new developed nature together with the redesigned course of the Runde stream (over a length of 20 kilometer). It was also mentioned that the exact location needed to be better defined. The result of this refinement is shown in the righter part of the same figure, where in total 194 hectare of land was found that had been transformed between 1989 and today. The green bordered areas have a size of 94 hectares and changed within the time span 1989-2006 from agricultural land (cropland) toward partly grassland, forest and settlement.
A similar transformation took place in the orange and blue bordered areas. Only, these locations changed after 2006 and should therefore not be added to this dataset. Of this "invalid" area, the blue part (8 hectares) would probably never have been mapped in CLC. Although it is clearly a land change, it does not meet the CLC criteria for being at least 100 meter wide.

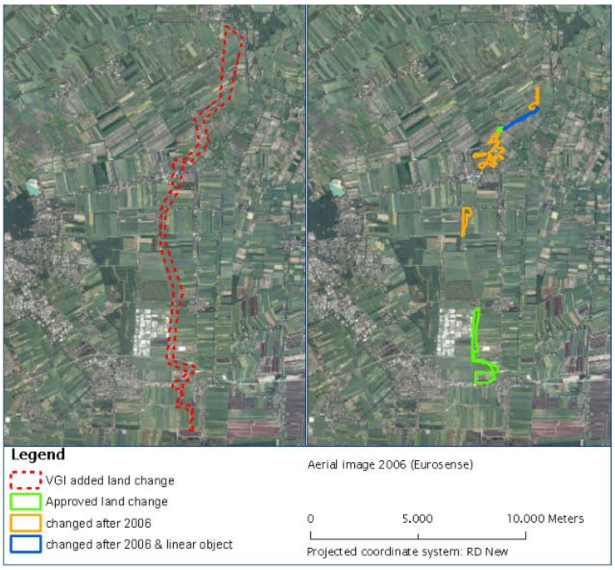

***Figure 6.3*** *VGI update (left) & its correct shape (left)*

The same manner, from visitors of www.landchanges.eu it was asked to assess the land changes dataset with this critical view, by making similar evaluations and considerations as were just made above. The outcomes of this assessment are discussed in the next sections, where a distinguish was made between geometric updates, attribute updates and time-related updates.

## 6.1 Geometric assessment updates

During the assessment pilot, 4 locations were added, 1 location was deleted and for 11 locations the outlines of land changes were adjusted. Shapes of land changes were thus adjusted at 16 locations. Of these updated locations, the majority can be seen as an improvement, which means there were also contributions that should thus be categorized as a deterioration. For both categories, there is quite some variation if we look at the impact of each individual adjustment.
This is concluded by first creating a new layer with the correct position for each location that was adjusted. Next, the original land changes and the adjusted ones were compared with the correct dataset. Two criteria are used to determine whether an adjusted shape is categorized as an improvement or a deterioration. The first one is the size, more precisely the accuracy of an area

compared to the correct area. Secondly, the percentage of the outline of a land change that is within 10 meter from the correct outline. Similarly, this is done with the margin set to 20 meter.

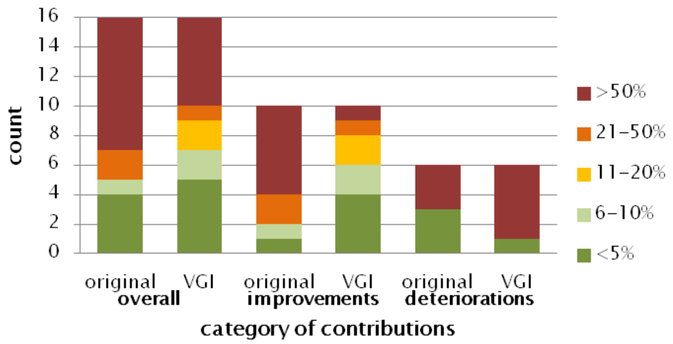


*Figure 6.4 Accuracy of updates by % of correct area*

The area of reshaped land changes is significantly more accurate than their original shape, as visualized by Figure 6.4. Of all reshaped land changes, 43% deviates less than 10% from the area of the correct shapes. This applies to 31% of the original land changes. Furthermore, of the improved land changes, the number of land changes that deviates more than 50% of the correct area was decreased from 6 to 1. From the 10 improved land changes, the number that deviates less than 10% from the correct area increased from 2 to 6.

A typical difference was also found for the deteriorated land changes. Two locations changed from the most accurate towards the lowest accuracy category, which can easily be explained by new created land changes that appeared not to be valid land changes in reality, thus being falsely mapped. An example of such a contributions is given by Figure 6.5.
The reason why this falsely new mapped land change was added is difficult to determine. For the other, there was made a supportive comment that the original buildings were removed and new buildings were placed. This indeed is true, though that still does not mean it should be considered as a land change.
Another land change being marked as deterioration could somehow also be seen as improvement, since the absolute area that was mapped is little less worse than in the original dataset. It is the most northern one of the three represented land changes on the top and middle images of Figure 6.6. It is nevertheless marked as a deterioration, because the contributor


*Figure 6.5 Invalid added land change, with AI 2006 (left) and 1989 (right)*

actually should have decided to delete this land change, since it is not a land change at all.
If we take a look at the other two reshaped areas on Figure 6.6, based on only AI 2006, there were made appropriate improvements (middle image) to the original dataset (top image) by

following clear contours, which seems to be logically and indeed is attractive to do in this situation.

Although, if we see the correct land changes (bottom image), it seems that the missing of AI 1989 during the assessment becomes painfully clear for these locations.

An observation of the delineation accuracy for locations that were reshaped (see Figure 6.7) learns that the VGI assessment, especially with a margin of 20 meter, resulted in a clearly increased overall accuracy. Nevertheless, the overall precision of the VGI delineation seems to be degraded on the highest level of accuracy for the 10 meter margin, despite the decrease of the lowest accuracy category. This can mainly be explained by the phenomenon that was already outlined above, new locations that were falsely mapped. If the margin "within 10 meter" from the correct outline is doubled up to 20 meter, the locations that deviate less than 5% from the correct datasets increases from 6% to 31% for all reshaped locations, as Figure 6.7 indicates. If we compare the accuracy for both margins, it could be concluded that the assessment did not completely live up to the expectation that was pronounced in section 3.3.2.

If the delineation accuracy of VGI assed data and its original equivalent is compared with the random selection from section 3.3.2, as is done in Figure 6.8, one sees that the delineation of land changes towards forest and settlement is quite well improved during VGI. That settlement performs somewhat lower is explained by one land change that was dramatically digitized in the original dataset, and still is after being updated. Without this particular land change, the VGI accuracy scores for settlement would also rise above 90% with an applied margin of 30 or 50 meter. It is further noticed that, for both forest and settlement, the random selection scored slightly lower than the land changes that were selected and updated by contributors.


***Figure 6.6** Discussable VGI updates*

An analysis from a totally different perspective was made to determine the value of the 1989 aerial image, by comparing the accuracy of geometric adjusted land changes based on a

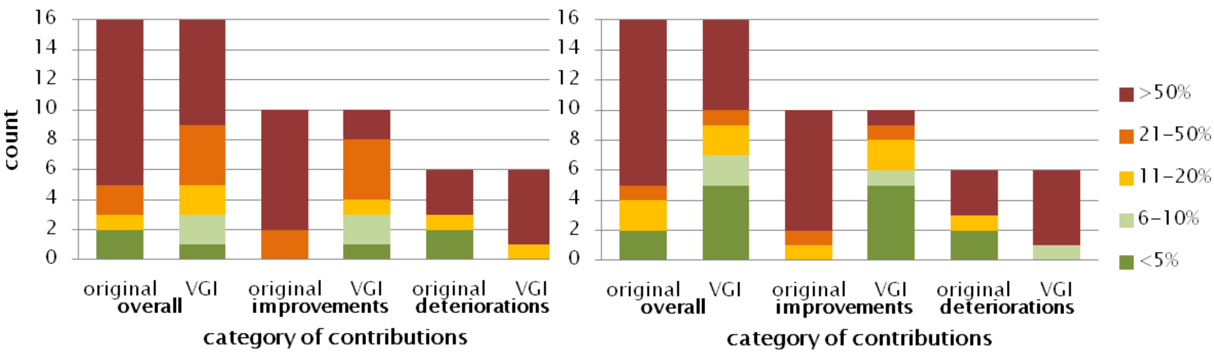


***Figure 6.7** Accuracy by % of correct delineation with margin 10 (left) & 20 (right) meter*

devidance between presence or absence of this image. In 5 situations, the aerial image 1989 was available, while for 11 locations this was not the case. Unfortunately, the comparison could only be based on this relatively low number of cases, which possibly affects the results. Figure 6.9 shows that, for locations with the presence of aerial image 1989, the improvements that were made during the VGI assessment were generally better than for the locations without the availability of AI 1989. A plausible explanation is that the correct outline could be better defined by comparing both datasets. Though it must be said here that Figure 6.9 indicates that these locations left also more room for improvements. This is most likely explained by the fact that, with both aerial images available, land changes with relatively large errors, or missing land changes were easier found.

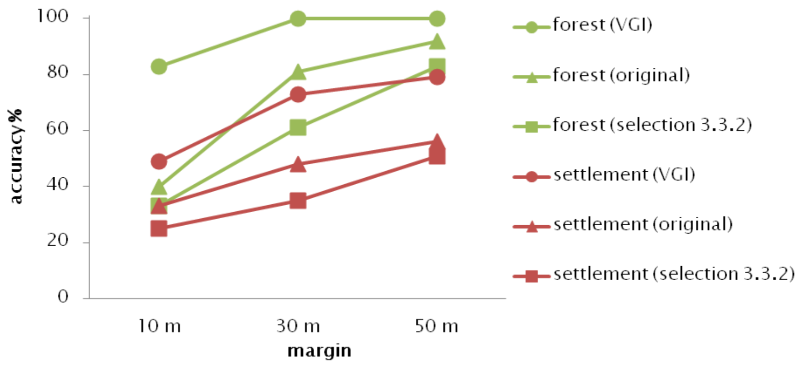


***Figure 6.8*** *Positional accuracy of new forest & settlement*

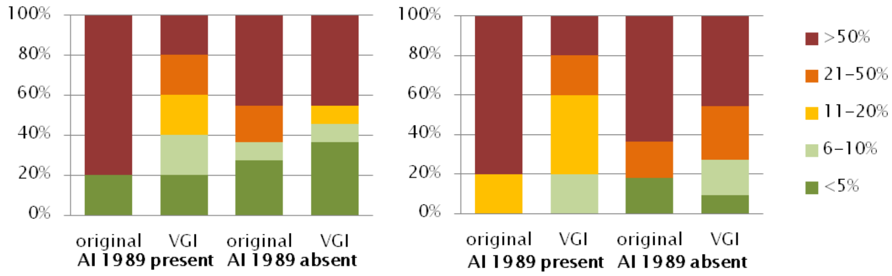


***Figure 6.9*** *Impact of AI 1989 to area (left) and delineation 10 m (right) accuracy*

One example of a justified new mapped land changes is visualized by Figure 6.10. It concerns a quite well digitized location. Only in the top left corner a small part was forgotten. The scores for this land change are 93% for area and 92% for the delineation with 10 meter margin.

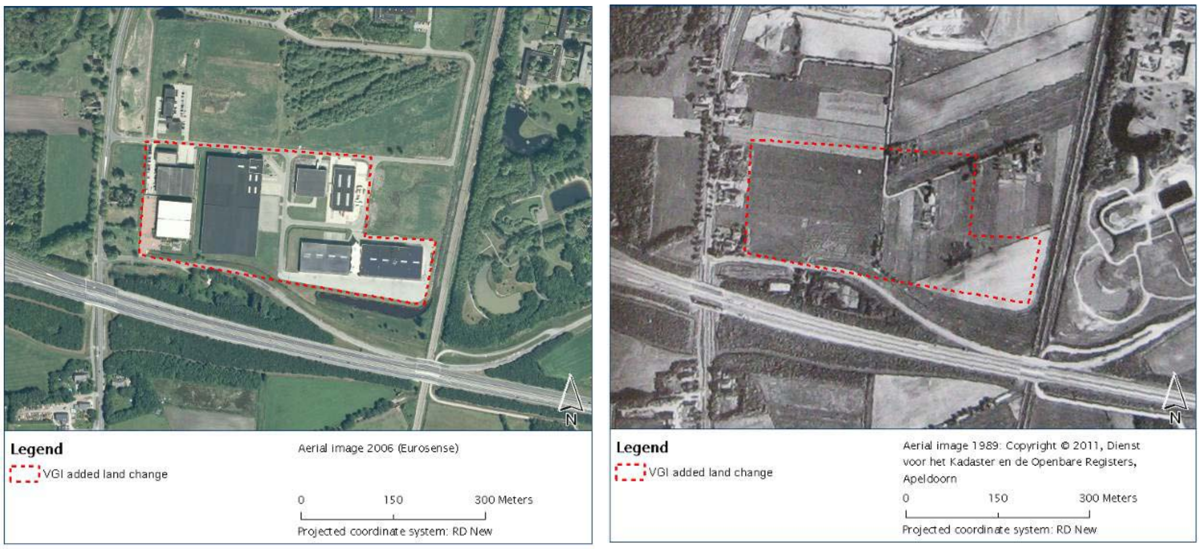


***Figure 6.10*** *Valid added land change, with AI 2006 (left) and 1989 (right)*

Up to this point, the focus was mainly on the positional accuracy of the assessment updates. Besides that, it is also interesting to see how large the impact is, i.e. the quantity of the assessment updates. The original dataset covers 645 hectares of land changes spread over the

16 updated locations. After the VGI assessment, the dataset with land changes covers only 597 hectares. It is built up by 539 hectares from the original dataset and 58 hectares of new created area. This means that 106 hectares was deleted from the originally dataset.

The 539 hectares that remained, is slighty above the correct potential of 514 hectares from the original dataset. This is caused by an area of 39 hectares that is still in the dataset, while it should have been deleted. On the other hand, 14 correct hectares are falsely deleted.

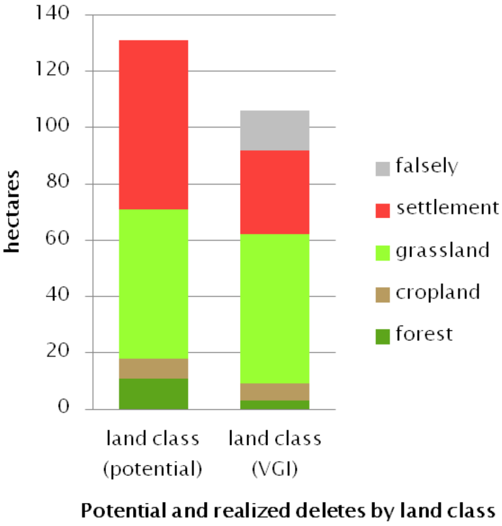


*Figure 6.11 Deleted land changes*

The correct area that should have been deleted from the original dataset is indicated as available potential in Figure 6.11. That this area should be deleted means in fact that it did not change between two of the IPCC land classes somewhere between 1990 and 2006. It concerns in total 131 hectares, of which 92 hectares (70%) really has been deleted during the VGI assessment. A 50 hectares large area (forest → grassland) that was correctly deleted appeared to be unchanged heathland. Further, Figure 6.11 shows that especially more "unchanged" settlement area could have been deleted on the assessed locations.

There is also changed land that is not yet included in the original dataset. The available potential is provided in Figure 6.12, of which 75% (15 hectares) was added during the VGI assessment.

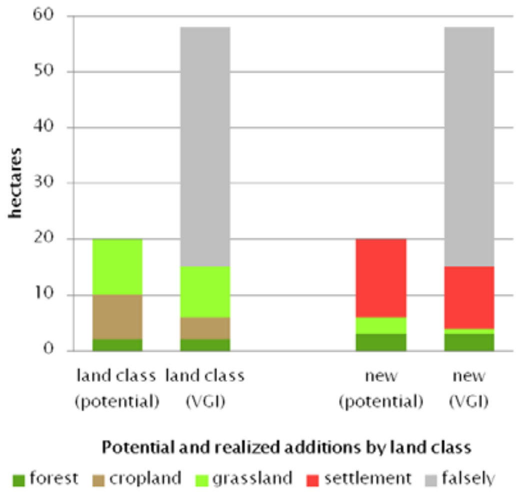


*Figure 6.12 Added land changes*

The most logical explanation would be that this area misses because of the CLC mapping rules, but this is not the case. Only less than 1 hectare could be legitimated by not meeting the CLC criteria. One large area of almost 10 hectares meets all the criteria to be included in CLC, though was inexplicably ignored. Further, it concerns 10 hectares of area that lies adjacent to existing land changes and misses due to poor digitizing quality, as already is indicated by Figure 6.7. Contributors also added 43 hectares incorrectly. Vast majority of this area concerns the falsely added new land change locations, see for an example Figure 6.5.

Together with the correct hectares from the location that was discussed during the introduction of this chapter, a sum of 152 hectares of originally uncovered land was added to the dataset, while 106 hectares of originally covered area was deleted.

This means that an area as large as 40% of the original size of these 16 locations was adjusted. If compared to the original land changes dataset, an area equal to exactly 2% of its total size changed during the VGI assessment pilot. In case the VGI assessment was done perfectly, it would have resulted in 114 added and 131 deleted hectares, which is equal to 38% of the original size of all the reshaped locations, and 1,94% of the total size of the original dataset.

Since there is both area deleted and added, the net result to the dataset is much lower. The VGI assessment resulted in an increase of 46 hectares to the dataset, while in a correct situation it should have been decreased with 17 hectares based on the 16 discussed locations.

By involving the land classes in the discussion on the assessment outcomes, one of the attributes has already been introduced. In the next section, a more in-depth analysis on the attribute updates of the land changes assessment follows.

## 6.2 Attribute assesent updates

During the VGI assessment, 27 attributes were updated on 12 locations. With 4 new added land changes, there was provided additional information, while together with 2 reshaped locations also attributes were updated. For 6 land changes only the attributes were updated.

If we look at the kind of attribute updates (Figure 6.13), it is first of all noticed that none of the contributors referred to explanatory content.

Of the 7 times that a type of contributor was assigned, this was “interested in topic” 4 times (all for new added land change). For 2, the attribute was updated with “owner” and once with “professional”. By the given fact of being new created in the same region during the same period, one could carefully draw the conclusion that the 4 new created land changes were processed by one contributor. The two updated land changes by “owner” are also lying relatively close to each other, but in another part of the province Drenthe. Given the content of the additionally provided comments (a description of the location) by its contributor, and the fact that both are water elements, these could also really well have been updated by one and the same contributor, being the owner. Which is in that perspective strange, is that both locations do have a different owner according to the ownership registration at the Dutch Cadastre.

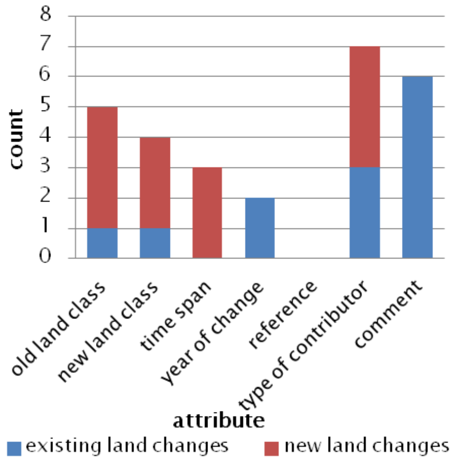

*Figure 6.13 Number of attribute updates*

However not in the same region, by two comments it was indicated that the outline of these land changes were adjusted. Strangely, further analysis learned that both locations were not reshaped, which definitely seems to be a “procedural” error that was made by the contributor. Most likely, the geometric adjustment was made but then not saved. The original dataset provides indeed clear opportunities for improvement of the delineation for both land changes. A location with a comment that more described the reason for a geometric adjustment, was also really reshaped. Of one comment, it can be said that it was not useful. It seemed to be the beginning of a comment that was somehow not completed, and therefore unclear.

### 6.2.1 Thematic

A quite important assessment item is the old and new land class. It was updated 10 times in total. Of these, 7 classifications were provided with a new added land change, while 2 concerned an adjustment of an existing land classification. Another location where a thematic adjustment was made concerns the deleted land change. Of all these, only once a misclassification was made, although it hardly can be seen as an incorrect adjustment. The location is clearly vegetated area, though belongs to an active sand mining area, which forces it to be classified as settlement. If mining activities stopped a few years ago, it would have been a correct update.

From the 22 not time-related attribute updates, 20 are considered as correct/useful, while only 2 were found incorrect/noise. These two are the earlier in this section discussed “unfinished” comment and incorrect adjustment of settlement towards grassland for the new land class.

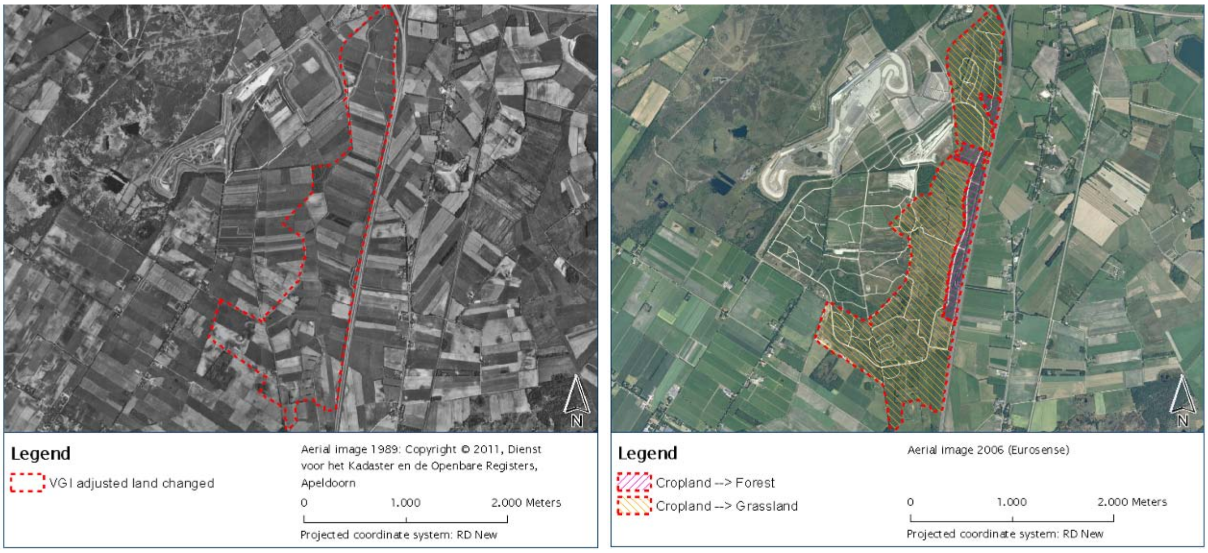


***Figure 6.14*** *Thematic refinement of a land change, with AI 1989 (left) and 2006 (right)*

For two locations that were only reshaped, also the available attributes should have been updated. For example, a more detailed land classification could have been made for the location that is shown on Figure 6.14. Here, a distinguish was found between forest and grassland for the new land class. One of the reasons why this adjustment was not made could be, considering the absence of a split tool, the complexity of actions that is needed to do this. Further, for another location the old land class had to be cropland instead of forest.

If the geometric correctness is analyzed for the land changes that only underwent attribute updates, it was for 2 of the 6 locations already indicated by the contributor that the delineation could have been improved by VGI provided comments. Of the other 4 locations, one appeared not to be a land change at all (the location with the "unfinished" comment), one is quite well digitized and two leave some room for delineation improvement. Of this latter two, an example is shown on Figure 6.15. The left image shows the original land changes around a village. For the red outlined land change, only one of the attributes (year of change) was updated. The right image shows the slightly corrected delineation of this updated land change. Further, nearby there were found some other not updated locations (green) being quite poor delineated if compared with its correct delineation. In the area northern of the assessed one, some first contours of

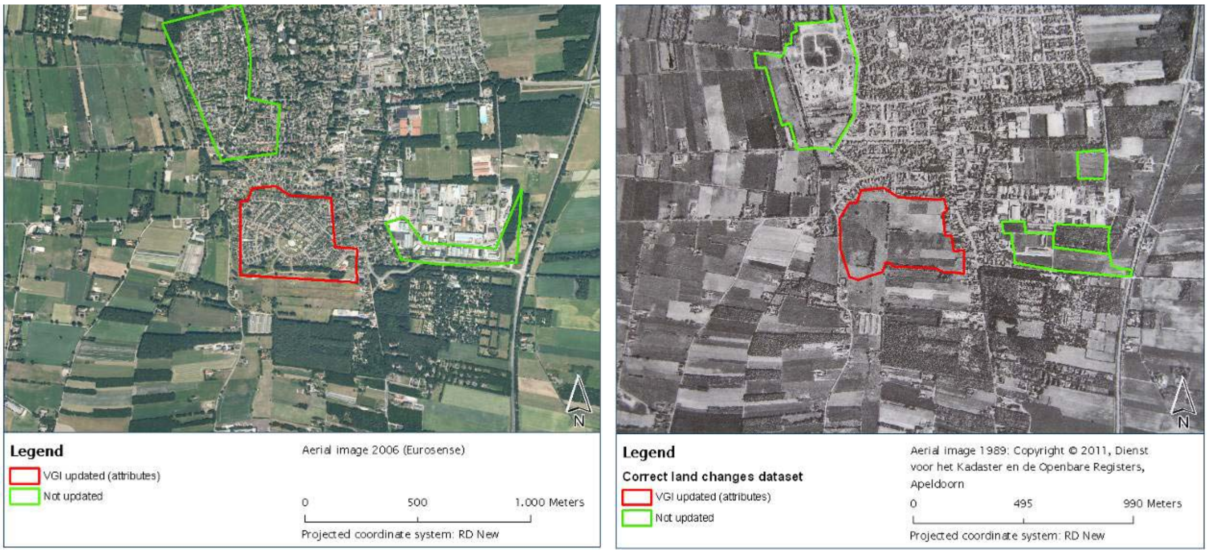


***Figure 6.15*** *Area with incompletely updated location and "ignored" locations*

planned new settlement is seen already on the 1989 aerial image, which makes it even questionable whether it belongs in this dataset. For the other two locations, the 1989 image shows partly cropland and partly forest, which clearly is transformed towards settlement in 2006. For the 6 locations with only attribute updates it was found that in total 9 hectares should have been added to the dataset, while another 63 hectares should have been deleted, which includes one invalid land change of 55 ha. This means that the 245 hectares that were found at the end of section 6.2 to be reshaped for a correct geometric representation should be extended with 72 hectares if we take into regard all locations that underwent any type of assessment.

### 6.2.2 Temporal

Not discussed so far are the temporal aspects, with the attributes time span and year of change. Where the current land class and some of the comments could for example be validated by field visits, this will not help for validation of time-related information. Validation of the time span (1990-2000 or 2000-2006) can be done by additionally checking the 2000 aerial image. But without having local knowledge or (more detailed) supportive information available, the exact year of change is more difficult to be assessed without local knowledge.
For one location, a contributor assigned 1999 for the year of change, while the time span was left unchanged at 2000-2006. A review on this land change with AI 2000 learns that the change took place between 2000 and 2006, which means that the VGI contribution incorrect is. For the other assigned year (2000) it was found to be in line with the time span 1990-2000. However, on AI 2000 the location seems to be changed for a while already, which suggests that it took place before 2000, though this cannot be said with certainty.
For all 23 updated locations, the time span was checked on correctness. Further it is indicated whether this attribute was updated. The resulting overview is given by Table 6.1.

| Assessment category | Locations count | Correct change 1990-2000 | Correct change 2000-2006 | No change |
|---|---|---|---|---|
| 1. Correct (not updated) | 11 | 7 | 4 | |
| 2. Correct (updated) | 4 | 3 | | 1 |
| 3. Incorrect (not updated) | 3 | 1 | | 2 |
| 4. Incorrect (updated) | 1 | | | 1 |
| 5. Discussable (not updated) | 4 | 3 | 3 | 1 |

***Table 6.1*** *Correctness of time span for assessed locations*

The first category consists of locations for which the time span was already correctly assigned in the original dataset. The second category exists of the deleted land change and of 3 new added land changes to which the correct time span was assigned. The third category holds 3 land changes from the original dataset with an incorrect time span that was not corrected during the assessment. To one of these, the wrong time span is assigned, while for the other 2 it was found that these were no land change locations in reality. The 4$^{th}$ category consists of a new added land change, with time span 1990-2000 assigned, which was incorrect because this location should not be considered as a land change.

There are four locations that were categorized as discussable land changes. One concerns an added land change to which no time span was assigned. This could be a correct decision in case it was left blank because the contributor was not sure about the right time span. Another reason why it can be seen correct to leave it blank is because this location appeared not to be a land change in reality. From that point of view, it would then be quite strange to decide to add this location to the dataset. The other three locations are best explained by the situation that is visualized by Figure 6.16. On the left image the original land change shape is shown with AI 2006. Based on AI 1989 (the center image) the changed area was reshaped towards the real changed area. If now AI 2000 is added (the right image), one sees that roughly the left half

***Figure 6.16*** *Land change towards settlement that is spread over both time spans*

changed between 1990 and 2000, where the right half changed between 2000 and 2006. Although the original land change had a correct time span assigned, more than half of the total changed area, although took place in the other time span, misses in this dataset. Figure 6.17 shows a comparable example. It is a land change towards forest, by which the AI 2000 clearly shows that it was partly (green shaded) afforested before 2000, while other parts are afforested after 2000, hence being spread over both time spans.


***Figure 6.17*** *Land change towards forest that is spread over both time spans*

An even more complex situation occurs when, besides a transition being geometrically spread over two time spans, also an additional thematic transition occurs. Figure 6.18 shows this situations where between 1989 (center) and 2006 (left) a transition took place from agricultural land towards settlement. The AI 2000 (right), however, indicates that this was not a straight transition. For 30 hectares it was found that it was before 2000 first transformed towards forest, which was then at a later point after 2000 being transformed towards settlement.

***Figure 6.18*** *Multiple thematic changes on one location within the assessment period*

Information that is shown by these examples could not have been noticed without local knowledge or the availability of supportive datasets, such as AI 2000.

# 7 Conclusions, discussion and recommendations

With this final chapter of the report, also the latest of all five research phases is reached (see Figure 7.1). It holds quite important sections with the conclusions in section 7.1 and the discussion and recommendations in section 7.2. The first section of this chapter also provides the answers to the research questions that were written down in section 1.4. To he three research questions we:

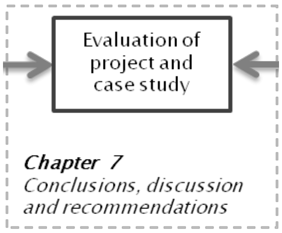


*Figure 7.1 Phase 5*

1. On which properties from the land changes dataset is assessment required?
2. How is assessment of this land changes dataset by volunteered geographic information optimally facilitated?
3. What are the conclusions that can be drawn from a case study that includes the findings from research on the first two questions?

## 7.1 Conclusions

The next sections provide the main conclusions and answers to the research questions, based on the findings that were already presented in all the previous chapters.

### 7.1.1 Answers to the first research question

The research started with an exploration of the land changes dataset to figure out what the weak points of this dataset are. Once these are found, it is defined which kind of assessment could lead to a qualitatively better dataset.

*Land changes data*

By establishment of the CLC rules for mapping land changes it was defined that land changes smaller than 5 ha and linear objects (less than 100 meter width) are not included. Further, for 1/3 of all CLC land classes, it was advised to consult ancillary data when determining the delineation of their areas. It is questioned to which extent this advise really was followed, because that should have lead to a higher level of quality. The exploration of the land changes dataset further learned that not only “small” land changes miss, but also land changes larger than 5 ha were missing. It became clear that the positional accuracy of mapped land changes in general left room for improvement and that the land changes dataset contained mapped locations that in reality are no land changes, or being highly discussable “land changes” between grassland and cropland, as quite often was found. The CLC classification also holds some more complex classes that exist of a mixture of fragmentally dispersed areas of other classes. Changes within these complex classes can be quite significant without being detected.
Where for the CLC2000 dataset a reliability score of 87% was found, for the CLC land changes dataset over 1990-2000 and 2000-2006 it is estimated that its score remains far from this.
In the area that was used for the case study, almost 11.000 ha of land changed from one to another of the classes forest, cropland, grassland, settlement and others between 1990 and 2006 according to the CLC dataset. Two-third of this area changed before 2000. Over the whole time span, most land changed towards settlement, while the former land class was in most cases

grassland or cropland. Although this sounds plausible and seems to be in line with global trends, a comparison with other land datasets (Eurostat and CBS) on these numbers strengthened the idea that the dataset leaves quite some room for further improvement.

*Assessment*
From the land changes dataset analysis on which was elaborated in chapter 2 it has become clear that the geometry, as well as the attributes (thematic, temporal and supportive) need assessment. Simply formulated, it is desired to improve the correctness and completeness of the dataset. which should be realized by:

- Validation, and if necessary improvement, of the positional accuracy of land changes in the dataset;
- Validation, and if necessary improvement, of completeness by adding missing land changes (drawing its shape) and deleting invalid land changes;
- Validation, and if necessary improvement, of the thematic information (land classes);
- Validation, and if necessary improvement, of the temporal information;
- Specification of more detailed temporal information on a new attribute;
- Providing supportive information on new attributes.

### 7.1.2 Answers to the second research question

The conception that VGI could be a successful instrument to facilitate such assessment is supported by the presence of many driving factors that were found in other VGI studies and projects. From there, also valuable information can be derived about key factors and minimum conditions that this project should meet to become successful.

*Functionality and usability*
Which became evident about functionality and usability requirements (listed in section 4.1.2), is that these in general should lead to:

- A design that is fully dedicated to the project objective, without any distractive features;
- With a logical design that is built from a user perspective;
- By which the user experiences ease and efficiency, so that the objective can be reached without undergoing complex and/or time consuming handlings/processes;
- And in which a user observes interaction on, and the added value of, participation.

Additionally, there are conditions established from the designer objective:

- Costs should be limited to the lowest possible (open source);
- For a design that is in line with international standards (open standards);
- And provides the needed functionality to perform the in section 3.4 defined assessment.

For the case study, it is further necessary that:

- Developments can be easily monitored during the case study and analysed afterwards;
- With a possibility to intervene in the design/strategy during the case study phase.

*Design and configuration*
Four potential solutions, pre-selected on the expected ability to facilitate VGI assessment of land changes, were compared on the design and functionality requirements (see also section 4.2). This suitability analysis showed that particularly items under *user convenience* and *functionality*

made that both Google solutions (Google Maps and Google Earth) were dropped. The main reason that, of the two remaining API solutions (ArcGIS and OpenLayers), a decision in favour of OpenLayers was made, is the difference in embracement of "open" technology (open source and open standards) and the consequential investment costs.

The chosen solution, the OpenLayers API with GeoExt extension for specific assessment functionality, requires a framework around it, in which all the other design components are implemented. Such a framework can be built cost free with HTML and CSS technology for overall representation in a web browser, and with JavaScript to support functionality for interaction between the user and the interface. Feeding the API with datasets could be managed by several solutions. Some datasets, such as the aerial image 2006, are free available as external web service. With an own server on which e.g. GeoServer is installed, one is able to add own specific datasets as OGC web service, of which images (WMS) and editable vector data (WFS-T), are quite essential in a project like this.
For providing updates and news messages to visitors, a practical solution was found by registering a Twitter account and adding a Twitter-feed to the framework.
All kind of statistics on visitors are collected by registration of a Google Analytics account. Although not essential, a model is built with ArcGIS ModelBuilder, by which easily and in a convenient way various overviews of contributions can be extracted.

For the case study, the above configuration was made available to the public by the website www.landchanges.eu. Since the project data was placed on a WUR-server, the registration of a web domain were the only technical costs for the complete presented design and configuration, being less than € 10,- yearly. Additionally, costs were made (€20,-) to acquire the aerial image 1989 atlas.

### 7.1.3 Answers to the third research question

The case study, assessment of land changes for 1990-2000 and 2000-2006 in Drenthe, is best facilitated by providing supportive aerial images from 1990, 2000 and 2006. A useful aerial image for 2006 was easily found with the free to use WMS service from Eurosense. For 2000 there exists also a dataset from Eurosense, but unfortunately this one was not allowed to be used in a Web 2.0 environment. The best solution for a 1990 aerial image was found with the 1989 hard copy aerial images atlas, for which its free use in this project was allowed by the Dutch Cadastre. A large number of photos was scanned and georeferenced, by which 1/5 of the provincial area is covered.

*Participation*
The case study was then initiated by contacting a selection of 61 persons. They were first divided in three groups (friends/family, GIMA community and colleagues) and successively approached. During the first two weeks, there were 77 visits to www.landchanges.eu registered. Of this number, 42 were seen as new visitors, while the remaining concerned returning visitors. Roughly half of all visitors only once visited the website, while one-fourth of all visitors brought more than 3 visits, according to the gathered statistics. During the three weeks that then followed, 7 new and 3 returning visitors were count.

*Feedback on design and concept*

Several visitors provided useful feedback on the design, of which the most critical remarks are mentioned here.

- It became within the first days clear that there was an absolute need for orientation assistance. An aerial image only appeared to be insufficient for people to (easily) navigate. This problem was successfully overcome by adding OSM data to facilitate the orientation. A custom style has been assigned to this dataset, displaying roads (lines) and labels for roads and places, with increasing representation detail on each zoom step.
- The in chapter 4 discussed design and configuration was applied to the case study. Unfortunately, some visitors reported poor performance, caused by their (probably older) personal computers with insufficient capacity or due to a too slow internet connection.
- The design could be extended by functionality to rate updates to the land changes dataset with e.g. “agree” or “disagree”. At a certain extent of agreement or disagreement, a suggested land change can be approved or rejected.

There was also received feedback that is more related to the objective or approach. Some people stated that they were not able to participate because the provided objective was not clear, because they lack knowledge of the area, or because they miss the expertise to categorize land within the right class. On the other hand, other people reported that the objective and working of the assessment was clear and that the VGI concept is an interesting and promising approach.

*Assessment results*

Contributions were made to 23 locations, consisting of assessment on the geometric, thematic and temporal characteristics of land changes.

Geometrical updates were made on 16 locations. In general, it was found that the positional accuracy significantly improved after being updated. The locations where AI 1989 was present are slightly better improved compared to locations without this supportive dataset. Some land change locations have been added or deleted, but most locations concerned geometrical refinement of land changes that were already present in the original dataset. The assessment resulted in 152 added hectares, where 106 ha was deleted. With this, vast majority of the potential area to be deleted (70%) and added (75%) on these locations was covered by the VGI project. One large area was incorrectly added, only a few hectares were falsely deleted. Additionally, at locations for which only the attributes were updated, there was another 9 ha of potential area to be added as changed land, while on these locations 63 hectare of falsely mapped area could have been deleted if the assessment was performed perfectly. The total size of the reshaped area is as large as 2% of the whole land changes dataset. If we consider only the changed locations, an area as large as 40% of its original size was reshaped.

A total of 27 attributes was updated on 12 locations. None of the contributors added (a reference to) explanatory information. It can be concluded that, from a user perspective, there seems to be no need for the new added functionality to add a reference to explanatory content, or to upload supportive materials.

Background information was provided several times in the comment box, in which also some explanations for adjustments were given. Overall, the attribute “comment” can be seen as a useful addition to the dataset for this VGI assessment pilot. Contributor info was added 7 times.

Thematic updates mainly took place together with adding/deleting locations. Twice it was updated for an originally mapped location. The conversion from the original CLC dataset towards IPCC classification for “old” and “new” land classes, in combination with the updates, led to acceptable quality for the assessed locations.

Temporal information was provided with three new land changes (the time span) and for two already mapped locations (the precise year). The assessment of these temporal attributes seems to be more complex and error-sensitive, because its specific values cannot be simply seen as the change between the 1989 and 2006 situation. It is often quite difficult to exactly define and validate a year of change for (often large) changes where a “spread” (geometrical and/or temporal) transition took places, as e.g. could be the case with new built up area with houses.

Despite numerous improvements, there were also things that went wrong during the assessment:

- Incomplete geometric updates: Two comments indicated a reshaped location, while the original shapes were left unchanged.
- Incomplete attribute update: There was added an unfinished, meaningless comment.
- Another comment revealed that, based on misinterpretation of the land change definition, new area was mapped.
- One large area, without any attributes assigned, was falsely added.
- By one contribution, a situation with conflicting attribute values arose, with time span 2000-2006 and 1999 for the precise year of change.
- It seems to be tempting to, without further thinking, follow AI 2006 contours. In one situation (Figure 6.6), the land change was obviously redefined on the contours of the AI 2006 with a promising and logically looking result. Additional availability (and use) of AI 1989 would have provided insight on which the contributors definitely would have decided different.

## 7.2 Discussion and recommendations

The chosen VGI approach to assess a land changes dataset on its completeness and correctness seems to be working. Although it must be said that so far it has been tested only in this single case study. The following discussion leads to several recommendations, indicated with a large symbol R. By following these, the success for future initiatives can be increased, while also the impact of such VGI assessment on the European research project by Fuchs (2010) becomes more evident.

### 7.2.1 Applicability at European scale

The case study in this project was carried out in the Netherlands, more specifically in the province Drenthe. As soon as the project will be transformed towards a European scale, there should be reckoned on several issues to be dealt with.

It is highly unsure, for example, that other countries have as much ancillary datasets available as there are in the Netherlands. And if there are, the case study showed that usage of these existing datasets is not always evident. It often depends on national policies and willingness of source holders to participate.

During the case study, information technology (IT) related trouble was reported. One issue concerned “speed”. Assessment data has to be generated by the WUR server (land changes and AI 1989) and is then sent over internet. Before on the user side all this data was received took so now and then more time than desirable. This is partly dependent on the internet connection speed, but possibly also a result of the configuration that was used in Wageningen, more specific the GeoServer software and configuration, used data format and the data size. Also the web design led to conflicts on personal computers with limited capacity. With JavaScript, functionality

was developed by which the assessment website always exactly fits the browser window with predefined ratios for its dimensions. This resizing solution works fine for sufficient performing personal computers, but it annoyingly delays the display of the website after browser resizing on underperforming personal computers. Finally, problems were encountered with the pop-up questions that should be shown at entering and leaving the website. In quite some cases, these were not shown because of pop-up blockers. A solution that makes use of more sophisticated technology should replace the current design on this point. On all these technical issues, it should be explored how the design could be improved. Moreover, because it is expected that the "standard of living" in other countries with respect to IT (internet infrastructure and computer capacity) is not everywhere at the same advanced level as it was for the case study. Problems are foreseen especially with people living outside urban areas in less wealthy parts of Europe. This could significantly affect the level of participation in such regions.
Also limited knowledge of the English language could withhold those people from participation. With the recommendations on this section, the impact of these issues is foreseen to be mitigated.

® *The initial design requires improvement to reduce the needed capacity for processing and data transfer.*

® *Application on European level should preferably be facilitated with the official languages for each of the covered countries.*

Another, more technical design issue that arises by applying the current configuration to a European scale, is the transfer of vector data by WFS-T. Currently, for the area of Drenthe, descriptive information on all 353 land change locations is transferred by GML. On a European level, where it concerns thousands of locations, this certainly will not work because of the large amount of data to be transferred. A working alternative, with WMS representation for land changes locations is described in section 3.3.2. In short this means that upon selection of a land change, for that single location the WFS-T is activated. The drawback is that snapping to other (vector) locations will not work any longer. Implementing the given recommendations overcomes the discussed problem.

® *The current WFS-T configuration must be replaced by the in section 3.3.2 suggested alternative if assessment is applied on a European level.*

® *A fix for the current snapping functionality should be found or developed for the alternative WFS-T solution in OpenLayers.*

There is a large difference between the scale on which land changes assessment occurs, and the scale used by Fuchs (2010) in his research on the relation between these land changes and the greenhouse gases balance on a European level. This project made clear that in the original land changes dataset numerous land changes are missing, some (large) locations are falsely mapped, and that the original land changes leave much room for improvement on the positional accuracy. Most of these adjustments are minor details if observed at a 1 x 1 km resolution. For example, 50% of all original land change locations have its size under 25 ha and this project indicates that this number is even higher in reality. Together, these represent 14% of all changed area in the original land changes dataset. Changes with a size of 25 ha are large in reality, but cover only 1/4 of a unit at 1 x 1 km resolution. It is far from sure that areas of this size force a change at 1 x 1 km resolution. It is desired to acquire more insight in the above described issue, so that the consequences become more precisely clear. The two given recommendations should minimize, and provide better information on, the impact of resolution.

*Further research is needed to determine more accurately the impact of applying a 1 x 1 km resolution to land change research.*

*Keep the resolution to be applied for European studies as high as possible.*

It may be assumed that thorough VGI assessment results in an increase or decrease of the overall size of the land changes dataset. Not only this total changed size of the dataset has a certain impact, but also the thematic (land class) characteristics of these changes. Murty et al. (2002) and Luyssaert et al. (2010), for example, provide insight in the impact of changes between land classes on the $CO_2$ balance. Comparable, it is desired to gain insight in the impact of changes between the IPCC land classes on the greenhouse gases balance, so that the impact of thematic updates to a land changes dataset become evident.

*There is a need for more insight in the impact of shifts between IPCC land change classes on the greenhouse gases balance.*

### 7.2.2 Design and approach

In the previous section there were made some recommendations already on the design if applied to a European extent. Besides that, there are other improvements that should be made on the initial design to improve the functionality and usability.
Crucial is the availability of a dataset that enables a visitor to navigate through an area. This functionality for orientation was not included yet in the design in chapter 4, but appeared to be an absolute must. It is recommended to use a cost free solution by adding the most recent OSM data with a custom style for roads (lines and labels) and places (labels) with varying levels for different scales.

*OSM data must be added to the project to facilitate orientation for participants.*

Also the aerial images were found very valuable to facilitate the assessment. One available image holds a risk that people are being seduced to illegitimately concentrate on certain contours that stand out, but are meaningless for land change assessment. Having the opportunity to compare land classes over a time span with two aerial images prevents from this, leading to better assessment quality, which has been shown by this project. By having also intermediate datasets available, even more detail can be reached, especially on temporal attributes, but also on thematic ones.
Improvement of thematic correctness could further be made much easier by adding functionality to split a shape. Thematic refinement as is indicated on Figure 6.14 is quite hard to realize with the current design.
Assessment of the temporal attributes is probably the most complex of all assessment objectives, which also counts for its validation. The assessment objective to specify the moment of a land change on the precise year sometimes leads to arbitrary values, where transitions take place over several years (Figure 6.16 and Figure 6.17). On the other hand, a time span larger than 10 years is also unadvised, since important developments could then easily be missed (Figure 6.18).

The case study showed that people are willing and capable to cooperate in such an initiative. According to the statistics that were provided by Google Analytics, 2/3 of the originally approached people checked the website. It was discussed already that the real number is probably higher. If more than one person approaches the website via the same domain, these are (except for the first one) categorized as returning visitors. This means automatically, that the 50% of people who were registered for being returning visitors would be somewhat overestimated. During the case study, the number of visits and contributions evidently dropped after there was stopped with communicating about the project via the Twitter-feed, and with actively approaching (new) contributors.
All visitors together made contributions on 23 locations. It is difficult to estimate how representative the found participation level is. Many factors play a role here. First of all, it could be possible that during the first 4 days more contributions were made if orientation data (OSM) was available from the very first beginning. It is obvious that missing this was experienced as a real problem for properly use the website. Another factor is the chosen strategy by which 61 persons were actively approached, being familiar to the researcher. On the one hand, people could interpret the approach as sharing and showing a project one is working on, without understanding the importance to really participate. On the other hand, it could also be interpreted as a moral obligation to participate. It is difficult to estimate the impact of such factors. Further, based on the availability of AI 1989 and the origin of a high number of persons from one of the user groups, more updates could have been expected on beforehand in the Municipality of Coevorden, which is the southern one of the AI 1989 covered areas.
To acquire a higher quality dataset by VGI, so that it could be used instead of the original dataset, it is obvious that a larger community of (returning) participators is needed. Haklay et al. (2010) found that, to a certain point, quality increases with the increase of contributors. With a low number of participators, for OSM an average positional accuracy of roughly 10 meter was found. Although it is debatable if mapping roads could be compared with mapping the outline of a land change, and in this research the number of participators was lower, this accuracy was not found for the average of all updates to the land changes dataset. However, there were some individual geometric updates founds that are far more accurate than 10 meter average.
In a perfect scenario, validation of updates is done by the community itself, so that slowly but surely a high accurate delineation is achieved and external expert validation is reduced to a minimum. It is not evident that this is easily managed. Haklay and Weber (2008) showed that the development of the online OSM community experienced a relatively "slow start", by which it took quite some time before the web mapping project has grown towards a solid participating community. How such a community could be established and involved for this project could probably be seen as the biggest of all challenges at this point. But there are some recommendations worth trying to explore. One of the solution could be to cooperate with other initiatives. With CLC for example, this was tried already by joining the OSM concept[15]. This sounds as a promising solution, although it is also realized that these existing initiatives do certainly not meet all of the requirements that apply to this specific project. Nevertheless, it is worth to be given a try.

*By seeking cooperation with existing projects like OSM or Wikimapia, this project could benefit from a large and experienced community.*

*New ways, by which participation results in added value (rewarding) for the contributor, should be explored to encourage loyalty.*

[15] http://wiki.openstreetmap.org/wiki/WikiProject_Corine_Land_Cover

Some of the visits during the case study were made with smartphones. With a growing popularity of apps, this could be another interesting community to involve.

The final discussed item on the design concerns the costs and investments. In section 7.1.2 it was concluded that the total project costs were under €30,- for the complete case study, with only registration costs for www.landchanges.eu and for purchase of the aerial images atlas. If one starts from scratch with a similar initiative, without the possibility to benefit from existing facilities, costs will be higher. Investments are then required on a server, a personal computer and a fast internet connection if it is chosen to manage all self. Another consideration could be to choose for one of the available hosting facilities for the "geo-configuration" by which a server and fast internet connection are no longer required, but costs have to be paid instead for the external facility.

### 7.2.3 Quality of VGI assessed land changes data

During the pilot, interesting contributions were made of which the vast majority can be seen as improvements. Because of the limited extent of the case study it proved to be necessary to have all contributions validated by an expert. Also, because some contributions were only indicative and need further exploration. One of the expectations on beforehand, supported by results from other initiatives (Nuojua and Kuutti 2008), was that new information would be collected by benefitting from local knowledge. A significant number of updates was indeed the result of local knowledge. But the outcomes made also clear that there are quite some things that can be improved to increase the quality of VGI updates. For example, if a contributor does not know the correct information on a particular attribute, it is recommended to let one assign a value "unknown" instead of leaving a field blank. This way, it becomes obvious to others that such an attribute was assessed, though still needs further assessment by someone else. Having the opportunity to leave attribute fields blank (like with the current design) is undesirable, because it is interpreted as an incompletely assessed update.

Ongoing on this topic about acceptation and reliability of data, interesting functionality could be created by letting people agree or disagree on updates. This is a provided suggestion of which was thought before, in a very early stage of the project. It had never been implemented thus far because it had been averted for its complexity. Nevertheless, its added value is recognized and it is recommended to explore how "agreement" functionality can be developed.

Another issue on which the design can be improved is preventing conflicting attribute information. This occurs e.g. with an assigned year of change that falls outside the assigned time span. Also, when the old and new land class are the same, this should not be accepted. The current design does not forestall the creation of such conflicts. It is recommended to deal with this by automatic detection of conflicting attribute values before updates are being saved. A contributor is then asked to adjust the value(s) into the permitted (and correct) combination of attribute values before updates can be saved. This solution should also prevent the earlier discussed blank fields.

*Applying the recommendations that were made in this section assures an increase of correctness and completeness for VGI assessed data.*

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# Appendix I

| CLC Class | CLC Class Name | LCCS label | Classifiers | LCCS Code | IPPC land class |
|---|---|---|---|---|---|
| 111 | Continuous urban fabric | High density urban areas | A4 Non Linear (Feature)<br>A13 Urban Areas<br>A14 High Density | 5003-13 | Settlement |
| 112 | Discontinuous urban fabric | Medium density areas // Low density urban areas | A4 Non Linear (Feature)<br>A13 Urban Areas<br>A15 Medium Density<br>A16 Low Density | 5003-14 // 5003-15 | Settlement |
| 121 | Industrial or commercial units | Industrial and/or other areas | A4 Non Linear (Feature)<br>A12 Industrial and/or other areas | 5003-8 | Settlement |
| 122 | Road and rail networks and associated land | Roads // Railways // Industrial and/or other areas built-up object: other - installations associated to roads and railways | A3 Linear<br>A7 Roads<br>A10 Railways<br>A4 Non Linear (Feature)<br>A12 Industrial and/or other areas<br>A44 Other<br>Zp122 Installations associated to roads and railways | 5002-3 // 5002-6 // 5003-8-A44Zp122 | Settlement |
| 123 | Port Areas | Industrial and/or other areas built up object: Port Area (including docks, shipyards, locks) | A4 Non Linear (Feature)<br>A12 Industrial and/or other areas<br>A32 Port area (including docks, shipyard, locks) | 5003-8-A32 | Settlement |
| 124 | Airports | Industrial and/other areas built-up object: airport | A4 Non Linear (Feature)<br>A12 Industrial and/or other areas<br>A21 Airport | 5003-8-A21 | Settlement |
| 131 | Mineral extraction sites | Extraction Sites | A2 Non built up areas<br>A6 Extraction Sites | 5004-2 | Settlement |
| 132 | Dump Sites | Waste Dumps/Deposits | A2 Non built up areas<br>A5 Waste Dumps/Deposits | 5004-1 | Settlement |
| 133 | Construction Sites | Built up areas / Bare areas | A1 Built up areas<br>B16 Bare areas | 5001 / 0011 | Settlement |
| 141 | Green urban areas | Vegetated urban areas | A6 Urban Vegetated Areas | 11176 | Settlement |
| 142 | Sport and leisure facilities | Built up areas built up object: Sports and leisure facilities | A1 Built up areas<br>A38 Sports and Leisure Facilities | 5001-A38 | Settlement |
| 211 | Non irrigated | Herbaceous crops // shrub crops | A3 Herbaceous crops<br>A2 Shrub crops | 10025 // 10013 (1) | Cropland |

| | | | | | |
|---|---|---|---|---|---|
| | arable land | | Z211 Nurseries of fruit and trees and shrubs | [Z211] | |
| 212 | Permanently irrigated land | Surface irrigated herbaceous crops // surface irrigated shrub crops // surface irrigated tree crops | A3 Herbaceous crops<br>D3 Irrigated (general)<br>D4 Surface irrigated<br>A2 Shrub crops<br>A1 Tree crops | 11500-13227 // 11495-13227 // 11491-13227 | Cropland |
| 213 | Rice fields | Graminoid crops dominant crop: cereals – rice (Oryza spp.) | A4 Graminoid crops<br>S0380 Rice (Oryza spp.)<br>(Mode1: Terrestrial and/or Aquatic or regularly flooded) | 10037-S0308 | Cropland |
| 221 | Vineyards | Broadleaved deciduous shrub crops dominant crop: fruits & nuts – grapes (Vitis vinifera) | A2 Shrub crops<br>A7 Broadleaved<br>A10 Deciduous<br>S0610 Grapes (Vitis vinifera) | 10013-1891-S0610 | Cropland |
| 222 | Fruit trees and berry plantations | Broadleaved tree crops crop type: fruits & nuts // broadleaved shrub crops crop type: fruits & nuts // broadleaved shrub crops crop type: beverage | A1 Tree crops<br>A7 Broadleaved<br>S6 Fruits & Nuts<br>A2 Shrub crops<br>S8 Beverages | 10001-3781-S6 // 10013-3781-S6 // 10013-3781-S8 | Cropland |
| 223 | Olive groves | Broadleaved evergreen tree crops dominant crop: industrial crops – olive (Olea europaea L.) // fields of broadleaved evergreen tree crops (one additional crop)(shrub crop with simultaneous period). Dominant crop: industrial crops – olive (Olea europaea L.) Second crop: fruit & nuts –grapes (Vitis vinifera) | A1 Tree crops<br>A7 Broadleaved<br>A9 Evergreen<br>S0910 Olive (Olea europaea L.)<br>C2 Intercropped (Second crop)<br>C3 One additional crop<br>C6 Shrub crops (additional crop)<br>C17 With simultaneous period (second crop)<br>S0610 Grapes (Vitis vinifera) | 10001-1-S0910 // 11345-1275-S0910S0610 | Cropland |
| 231 | Pastures | Closed to open (100-40%) Grassland | A6 Graminoid<br>A20 Closed to open (100-15%)<br>A21 Closed to open (100-40%)<br>(Mode2: Cultivated – managed and/or natural and semi-natural terrestrial vegetation) | 21461-121340 | Grassland |
| 241 | Annual | Fields of herbaceous | A3 Herbaceous crops | 11370- | Cropland |

| | | | | | |
|---|---|---|---|---|---|
| | crops associated with permanent crops | crops (one additional crop) (tree crop with simultaneous period) // fields of herbaceous crops (one additional crop) (shrub crop with simultaneous period) | C2 Intercropped (Second crop)<br>C3 One additional crop<br>C5 Tree crop (additional crop)<br>C17 With simultaneous period (second crop)<br>C6 Shrub crops (additional crop) | 12602 // 11370-12614 | |
| 242 | Complex Cultivation Patterns | Small sized fields of herbaceous crops // small sized fields of shrubs // small sized fields of tree crops // scattered urban areas | A3 Herbaceous crops<br>B2 Small sized fields<br>C2 Intercropped (Second crop)<br>A2 Shrub crops<br>A1 Tree crops<br>A4 Non Linear (Feature)<br>A13 Urban Areas<br>A17 Scattered Density | 11250 // 11215 // 11195 // 5002-17 | Cropland |
| 243 | Land principally occupied by agriculture, with significant areas of natural vegetation | Cultivated and Managed terrestrial areas / natural and semi-natural primarily terrestrial vegetation | A11 Cultivated and Managed terrestrial areas<br>A12 Natural and semi-natural primarily terrestrial vegetation | 0003 / 0004 | Cropland |
| 244 | Agro forestry areas | Closed to open woodlamd with herbaceous layer // continuous closed to open trees + continuous fields of herbaceous crops | A3 Trees (Main layer)<br>A20 Closed to open (100-15%)<br>B2 >30-3m (trees height main layer)<br>C1 Continuous (vegetation main pattern)<br>F2 Second and/or third layer present<br>F4 Herbaceous vegetation (second or third layer)<br>F7 Closed (>70-60%) to open (70-60%) -(20-10%) (second or third layer)<br>G4 3-0.03m (Herbaceous height second or third layer)<br>Z244 Grazing land (pasture)<br>A3 Herbaceous crops<br>B5 Continuous | 21575(1)[Z244] // 2144710027 | Cropland |
| 311 | Broad-leaved forest | Broadleaved closed to open (100-40%) Trees | A3 Trees (Main layer)<br>A20 Closed to open | 21495-121340 | Forest |

| | | | | | |
|---|---|---|---|---|---|
| | | | (100-15%)<br>B2 >30-3m (trees height main layer)<br>D1 Broadleaved<br>A21 Closed to open (100-40%) | | |
| 312 | Coniferous forest | Needle leaved closed to open (100-40%) Trees | A3 Trees (Main layer)<br>A20 Closed to open (100-15%)<br>B2 >30-3m (trees height main layer)<br>D2 Needle leaved<br>A21 Closed to open (100-40%) | 21498-121340 | Forest |
| 313 | Mixed Forest | Mixed closed to open (100-40%) Trees // Mixed closed to open (100-40%) Trees | A3 Trees (Main layer)<br>A20 Closed to open (100-15%)<br>B2 >30-3m (trees height main layer)<br>D1 Broadleaved<br>E2 Deciduous<br>A21 Closed to open (100-40%)<br>E3 Mixed<br>D2 Needle leaved<br>E1 Evergreen | 21497-129398 // 21499-129398 | Forest |
| 321 | Natural grasslands | Herbaceous closed to open (100-40%) Vegetation | A2 Herbaceous Vegetation (Main Layer)<br>A20 Closed to open (100-15%)<br>A21 Closed to open (100-40%) | 21453-121340 | Grassland |
| 322 | Moors and heathland | Closed to open (100-40%) Shrubland (Thicket) // Closed to open (100-40%) Shrubland (thicket) / Herbaceous Closed to open | A4 Shrubs (Main Layer)<br>A20 Closed to open (100-15%)<br>B3 5-0.3m (Shrubs height main layer)<br>A21 Closed to open (100-40%)<br>A2 Herbaceous Vegetation (Main Layer) | 21450-121340 // 21450-121340 / 21453-121340 | Grassland |
| 323 | Sclerophyllous vegetation | Broadleaved evergreen closed to open (100-40%) Thicket | A4 Shrubs (Main Layer)<br>A20 Closed to open (100-15%)<br>B3 5-0.3m (Shrubs height main layer)<br>D1 Broadleaved<br>E1 Evergreen<br>A21 Closed to open (100-40%) | 21517-121340 | Grassland |

| | | | | | |
|---|---|---|---|---|---|
| 324 | Transitional woodland-shrub | Closed to open (100-40%) woody vegetation // closed to open (100-40%) woody vegetation with herbaceous layer | A1 Woody vegetation (Main Layer)<br>A20 Closed to open (100-15%)<br>A21 Closed to open (100-40%)<br>B1 7-2m (Height for woody vegetation main layer)<br>F2 Second and/or third layer present<br>F4 Herbaceous vegetation (second or third layer)<br>F7 Closed (>70-60%) to open (70-60%) -(20-10%) (second or third layer)<br>G4 3-0.03m (Herbaceous height second or third layer) | 21441-121340 // 21548-121340 | Forest |
| 331 | Beaches, dunes, sands | Loose and shifting sands // bare rock and/or coarse fragments - gravels | A6 Loose and shifting sands<br>A3 Bare rock and/or coarse fragments<br>A14 Gravel<br>Z331 Gravel accumulation along stream channels | 6006 // 6002-8(1)[Z331] | Others |
| 332 | Bare rocks | Bare rock and/or coarse fragments // herbaceous sparse vegetation | A2 Herbaceous Vegetation (Main Layer)<br>A14 Sparse (20-10)-1% (Main Layer) | 6002 // 20058 | Others |
| 333 | Sparsely vegetated areas | Herbaceous open (40-(20-10)%) Vegetation | A2 Herbaceous Vegetation (Main Layer)<br>A11 Open General (70-60%) - (20-10%) (Main Layer)<br>A13 Very Open 40-(10-20%) (Main Layer) | 20037-3012 | Others |
| 334 | Burnt areas | Natural and semi-natural primarily terrestrial vegetation | A12 Natural and semi-natural primarily terrestrial vegetation<br>Z334 Burnt | 0004(3)[Z334] | Others |
| 335 | Glaciers and perpetual snow | Perennial ice // perennial snow | A3 Ice<br>B1 Perennial<br>A2 Snow | 8009 // 8006 | Others |
| 411 | Inland marshes | Closed to open (100-40%) Herbaceous Vegetation | A2 Herbaceous Vegetation (Main Layer)<br>A20 Closed to open (100-15%)<br>A21 Closed to open | 42155-60686 | Grassland |

| | | | | | |
|---|---|---|---|---|---|
| | | | (100-40%) | | |
| 412 | Peat bogs | Closed to open herbaceous vegetation / closed to open lichens/mosses // Bare soil and/or other unconsolidated materials | A2 Herbaceous Vegetation (Main Layer)<br>A20 Closed to open (100-15%)<br>A7 Lichens/Mosses<br>A5 Bare soil and other unconsolidated materials<br>Z412 Peat extracting areas | 42155 / 422606005(1)[Z412] | Grassland |
| 421 | Salt marshes | Closed to open herbaceous vegetation water quality: saline water | A2 Herbaceous Vegetation (Main Layer)<br>A20 Closed to open (100-15%)<br>R3 Saline water | 42155-R3 | Grassland |
| 422 | Salines | Shallow Artificial Perennial waterbodies (standing) Salinity: Brine // shallow artificial non-perennial waterbodies (standing) (surface aspect: bare soil) salinity: brine | A1 Artificial Waterbodies<br>B1 Perennial<br>C2 Shallow<br>A5 (Standing)<br>V5 Brine<br>B2 Non-Perennial<br>B4 (surface aspect: bare soil) | 7013-5-V5 // 7019-7-V5 | Others |
| 423 | Intertidal flats | Tidal area | A1 Inland Water<br>B3 Tidal area | 8004 | Others |
| 511 | Water courses | Natural waterbodies (flowing) // Artificial waterbodies (flowing) | A1 Inland Water<br>A4 (Flowing)<br>A1 Artificial Waterbodies | 8001-1 // 7001-1 | Others |
| 512 | Water bodies | Natural waterbodies (standing) // Artificial waterbodies (standing) | A1 Inland Water<br>A5 (Standing)<br>A1 Artificial Waterbodies | 8001-5 // 7001-5 | Others |
| 521 | Coastal lagoons | Natural waterbodies (standing) // Artificial waterbodies (standing) | A1 Inland Water<br>A5 (Standing)<br>A1 Artificial Waterbodies<br>Z521 Coastal lagoons, salt or brackish water | 8001-5(5)[Z521] // 7001-5(5)[Z521] | Others |
| 522 | Estuaries | Tidal area (flowing) Salinity: slightly Saline | A1 Inland Water<br>B3 Tidal area<br>A4 (Flowing)<br>V2 Slightly Saline | 8004-1-V2 | Others |
| 523 | Sea and ocean | Perennial natural waterbodies salinity: moderately saline // perennial natural waterbodies salinity: very saline // perennial natural waterbodies salinity: brine | A1 Inland Water<br>B1 Perennial<br>V3 Moderately saline<br>V4 Very Saline<br>V5 Brine | 8002-V3 // 8002-V4 // 8002-V5 | Others |

# Appendix II

| CBS class | Translation | IPCC land class | 1989 | 2000 | 2006 |
|---|---|---|---|---|---|
| Spoorterrein | Railroads | Settlement | 300 | 300 | 300 |
| Wegverkeersterrein | Roads | Settlement | 8600 | 6400 | 6500 |
| Vliegveld | Airport | Settlement | 200 | 100 | 100 |
| Woonterrein | Built-up (residential) | Settlement | 9800 | 9700 | 10100 |
| Bedrijventerreinen | Industry | Settlement | 2200 | 2800 | 3400 |
| Sociaal-culturele voorzieningen | Social-cultural facilities | Settlement | 600 | 700 | 700 |
| Delfstofwinplaats | Mining | Settlement | 1300 | 400 | 400 |
| Bouwterrein | Construction site | Settlement | 400 | 1300 | 1800 |
| Overige semi-bebouwde terreinen | Other semi built-up area | Settlement | 500 | 500 | 400 |
| Park en plantsoen | Urban green | Settlement | 300 | 800 | 800 |
| Sportterrein | Sport facilities | Settlement | 1200 | 1500 | 1700 |
| Overige recreatieterreinen | Other recreational area | Settlement | 2500 | 2200 | 2400 |
| Terrein voor glastuinbouw | Greenhouses | Cropland & Grassland | 200 | 400 | 400 |
| Overig agrarisch terrein | Other agricultural area | Cropland & Grassland | 198400 | 194300 | 191400 |
| Bos | Forest | Forest | 27700 | 33000 | 32600 |
| Open natuurlijke terreinen | Open natural area | Cropland & Grassland | 11000 | 10000 | 10900 |
| Binnenwater | Open water (inland) | Others | 2800 | 3800 | 4100 |

| IPCC land class | change 1989-2000 | change 2000-2006 | Total | Total | Total |
|---|---|---|---|---|---|
| Forest | 5300 | -400 | 27700 | 33000 | 32600 |
| Grassland & Cropland | -4900 | -2000 | 209600 | 204700 | 202700 |
| Settlement | -1200 | 1900 | 27900 | 26700 | 28600 |
| Others | 1000 | 300 | 2800 | 3800 | 4100 |

<u>**Description of CBS class (in Dutch):**</u>

**Spoorterrein**
Terrein in gebruik voor vervoer en transport per rail t/m 1993 werden ook terreinen t.b.v. tram en metro in deze categorie opgenomen.

**Wegverkeersterrein**
Terrein in gebruik voor vervoer en transport over hoofdwegen, t/m 1993 zijn ook onverharde wegen in deze categorie opgenomen.

**Vliegveld**
Terrein in gebruik voor vervoer en transport door de lucht.

**Woonterrein**
Terrein in gebruik voor wonen en sterk daaraan gelieerde activiteiten.

**Bedrijventerreinen**
Terrein in gebruik voor werken. Vanaf 1955 t/m 1976 alleen industrieterreinen. Vanaf 1977 een samengestelde categorie: Detailhandel en horeca, openbare voorziening en bedrijfsterrein zijn samengevoegd.

**Sociaal-culturele voorzieningen**
Terrein in gebruik door sociale en/of culturele voorzieningen.

**Delfstofwinplaats**
Terrein voor het winnen van grondstoffen uit de bodem. Vanaf 1996 exclusief water.

**Bouwterrein**
Terrein in gebruik als bouwlocatie.

**Overige semi-bebouwde terreinen**
Terrein in gebruik als stortplaats, wrakkenopslag, begraafplaats of overig semi-verhard terrein.

**Park en plantsoen**
Terrein met groenvoorziening in gebruik voor ontspanning.

**Sportterrein**
Terrein in gebruik voor sportactiviteiten.

**Overige recreatieterreinen**
Terrein in gebruik als volkstuin, voor dagrecreatie of verblijfsrecreatie.

**Terrein voor glastuinbouw**
Terrein in gebruik voor agrarische bedrijfsvoering onder staand glas.

**Overig agrarisch terrein**
1899 t/m 1939: cultuurgrond, inclusief tuinen voor eigen gebruik;
1940 t/m 1945: cultuurgrond, exclusief tuinen voor eigen gebruik;
1946 t/m 1976: inclusief smalle sloten, onverharde wegen, tuinen voor eigen gebruik;
vanaf 1977 : inclusief smalle sloten, tuinen voor eigen gebruik.
vanaf 1996 : inclusief on- en halfverharde wegen.

**Bos**
Terrein beplant met bomen bestemd voor houtproductie en/of natuurbeheer.
vanaf 1996 : inclusief on- en halfverharde wegen.

**Open natuurlijke terreinen**
Terrein in droge en natte natuurlijke staat, t/m 1959 incl. dijken, zonder wegen en natuurbaden.

**Water**
Water 1899 t/m 1949: exclusief water groter dan 75 ha;
1899 t/m 1939: inclusief vergraven grond, moeras en strand;
1940 t/m 1945: exclusief vergraven grond, moeras en strand;

1950 t/m 1966: de gegevens hebben betrekking op een herberekening van het bodemgebruik, uitgaande van de stand op 1 januari 1967.
1968: vermeerdering door indijking Zuid-Flevoland en door gewijzigde gemeentegrens Het Bildt en de Waddenzee.
1977. Toeneming door gemeentelijke indeling van Waddenzee, Eems, Dollard en Noordzee en gewijzigde interpretatie van de rijksgrens in de Eems.
Vanaf 1985 toeneming ten gevolge van het gemeentelijk indelen van de Waddenzee, delen van de Noordzee en het IJsselmeer.

**Binnenwater**
Water breder dan 6 m dat niet in open verbinding staat met de zee (IJsselmeer, rivieren, kanalen, meren e.d.).

# Appendix III

* Required

**1. Knowledge of study area Drenthe (Dutch province)** *
How well do you know the province Drenthe? If wanted, you can also use the "Other" textbox for an explanation.

- ☐ For more than 20 years I've been living in, or frequently visit, Drenthe
- ☐ For 5-20 years I've been living in, or frequently visit, Drenthe
- ☐ For less than 5 years I've been living in, or frequently visit, Drenthe
- ☐ I've been there so now and then
- ☐ I've never been there
- ☐ Other: ______

**2. Knowledge of land use** *
On a scale of 1-5, how would you score yourself on the level of knowledge about defining land use and changes in it?

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| I am an amateur | ☐ | ☐ | ☐ | ☐ | ☐ | I am an expert |

**3. Experience with web mapping applications** *
On a scale of 1-5, how would you score yourself on skills and experience with web mapping applications?

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| I am an amateur | ☐ | ☐ | ☐ | ☐ | ☐ | I am an expert |

**4. Your relation to this project** *
How did you get to this land changes assessment website? If wanted, you can also use the "Other" textbox for an explanation.

- ☐ I received a direct message from the researcher
- ☐ I was notified about this project / website by someone else than the researcher
- ☐ The project / website was mentioned somewhere on the internet
- ☐ Other : ______

**5. Your name or e-mailaddress (not required)**
Please provide your name or e-mailaddress, so that this information can be matched to the experiences afterwards. It will not be related to any of your assessment activities. And of course, your name or e-mailaddress will not be used for used for any other purposes.

______

# Appendix IV

* Required

**1. The land changes**

Could you indicate which statements apply to your experiences with the assessment website (you may select more than one)? If wanted, you can also use the "Other" textbox for an explanation.

- [ ] The project idea became clear to me by visiting this website
- [ ] I found one or more locations of land changes that contained errors
- [ ] It was not always obvious to me which class to pick for the right old and/or new land class
- [ ] Aerial images of 2000 and/or a larger area of 1990 are a "must" for reliable assessment
- [ ] Other: ______

**2. Editing the land changes map ***

Were you able to change the shape of a land change, or to add or delete a land change? If wanted, you can also use the "Other" textbox for an explanation.

- ○ I have tried it, but didn't find out how to do this
- ○ I was able to, but I must say that I haven't really processed any edits
- ○ It took some efforts, but in the end I have processed my edits
- ○ For me it was easy to improve the map on the errors I found
- ○ Other: ______

**3. Editing the land changes attributes ***

Were you able to change the attributes of a land change, or to complete missing information? If wanted, you can also use the "Other" textbox for an explanation.

- ○ I have tried it, but didn't find out how to do this
- ○ I was able to, but actually I haven't really processed any edits
- ○ It took some efforts, but in the end I have processed my edits
- ○ For me it was easy to improve the attributes on the errors I found
- ○ Other: ______

**4. Comments**

Do you have any other remarks, suggestions, or something else to say? In that case you can write it down below.

______

**5. Your name or e-mailaddress (not required)**

Please provide your name or e-mailaddress, so that this information can be matched to the provided information before. It will not be related to any of your assessment activities. And of course, your name or e-mailaddress will not be used for used for any other purposes.

______