Adding more detail to Potential Flood Damage Assessment

An object based approach

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July 2013

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1. Introduction

§1.1 Problem statement

In the past years much research has been done to asses the risk of floods. Due to increasing proof of climate change and -to a lesser extent- the continual subsidence of the Dutch soil, it has become increasingly more likely that floods may occur. The recent events in Germany have shown that these risks are still very real.

The goal of this thesis, however, is not to asses the likelihood of floods. Rather, this study aims to asses the potential damage of a flood, should one occur. In the past, researchers have used predominant land use based maps to determine the value of the flooded area. Unfortunately, these maps can be somewhat misleading due to its nature of determining land use by dominance. For example, an area might consist of 40% grasslands, 30% woods and 30% industrious activities, this area would be defined as a grassland.

Because of this inherent problem, it has been suggested that an object based approach might give more accurate predictions. This thesis will be a preliminary study to asses the differences between both methods and consider whether there is added value in using an object based approach to assessing flood risk.

§1.2 Objective

In this thesis the assumption is made that adding more detailed information to the models, that are typically used for assessing potential flood damage, will contribute to its accuracy. This hypothesis will be tested by creating two separate models, one using the typical land use based approach and one with added objects in the form of houses from now on deemed the object based approach.

The main question for this study is:

"How does an object based approach differ from a land use based approach, can it be beneficial in assessing potential flood damage?"

Which will be answered by first answering the following subquestions:

a. What are the advantages and disadvantages of the land use based approach?
b. What are the advantages and disadvantages of the object based approach?
c. What are the most notable differences found in the results?

But first the theoretical background will be discussed to show how flood damage has been calculated in prior research, deriving from the theoretical background, the methodology that was used to make the analysis of this thesis will be discussed. The results will contain a great number of maps to make them more visible, the subquestions will be answered in the discussion after which a conclusion will be reached.

2. Theoretical framework

§2.1 How is flood risk determined in prior researches?

In general, risk is defined by the formula: R = P(probability) x C(consequences) (Kron, 2002). For flood risk this is no different, but it is subdivided into three components: Hazard, exposure and vulnerability (De Moel, 2012). These components will be discussed in short:

Hazard has traditionally been defined as the temporal recurrence of river discharge and the associated dike breach probability. Recent studies have found that these static return rates are a poor indication for determining the hazard of flood risk in the future, as they are susceptible to change. Most notably due to anthropogenic change of the Earth's climate -otherwise known as the increased greenhouse effect, as this influences the amount of evapotranspiration, precipitation and consequently the amount of river discharge of a basin (Milly et al., 2008). The implication of these climate changes is that we should not put too much trust on historical records of river discharge and need to adjust them accordingly. Coastal regions, like the Netherlands, suffer an even greater chance of floods due to sea level rising (Morss et al., 2005).

Exposure is a quantification of the amount of people, buildings and land types that are susceptible to flooding. The actual amount of land -although susceptible to subsidence- normally does not change much. However, due to the expected sea level rising, caused by the green house effect, more land could become vulnerable to floodings (Morss et al, 2005). Additionally, the economic centre of the Netherlands is located in the most at risk part of the Netherlands, which is likely to expand in both total amount of people as total amount of buildings. Especially under the global economy scenario these expansions will be great (Dekkers et al., 2012).

Vulnerability is dependent on the precautions that are taken by governments and construction companies. As future urban expansion in the Netherlands is mostly expected in inundation zones (De Moel et al., 2010) -and therefore at risk of floodings- precaution methods as building on mounts could be taken to counter this. Increased wealth adds to vulnerability as well, as electronic goods become much more prevalent.

In effect, the probability factor is represented by the hazard component and the consequences are represented by the exposure and vulnerability components (Kron, 2002). For insurance purposes a method was developed by the Federal Insurance Agency (located in the USA) in 1968. This method involved quantifying the consequence components into depth/damage curves (Smith, 1994). These factors have later been recalculated for best representation of the Dutch situation (Klijn et al., 2007) and are still being used today.

However, after the 2005 hurricane Katrina in New Orleans, a study by Pistrika and Jonkman (2009) showed that these depth/damage curves are a poor predictor for flood damage on a -very- local scale. This was due to factors like point of breach, water velocity and water load, that greatly influenced which buildings were destroyed and which were not.

The strive for making a more accurate potential flood damage estimation is the root of this study. Which will be tested with adding detailed information as houses and house sales prices to the equation.

3. Methodology

§3.1 Approach

The main purpose of this thesis is to make a comparison analysis of two different approaches to assessing flood risk. These are the -classical- land use based approach and the -new- object based approach. Both methods use land use types as an input variable, with the object based approach adding more detail to urban areas. This has been done by adding an object variable in the form of the total amount of houses per hectare, replacing the urban land use type of the classical land use based approach.

Using GIS-systems -in this case ArcGIS- input variables as land use, inundation depth, the associated depth/damage curves, amount of houses and house prices can easily be aggregated to perform an analysis of the amount of damage that would occur, should a flooding happen. As occurrence rates are of no value -as assumed is that a flooding will happen- to the comparison of flood damage estimations done in this thesis, they are not included. As such it is no longer fair to speak of flood risk, but rather of potential flood damage.

Two different models, one for each approach, have been created to be able to perform a fair comparison of the two different approaches. These models will be discussed in greater detail later on in this paragraph. Even though these models do result in a monetary value of damage per hectare, it should be noted that these are estimates and should not be considered exhaustive. The values are used as a means to determine differences between the two approaches.

One of the major benefits of GIS is the ability to adjust input variables as new data becomes available. Having made the aforementioned models, it would only need minor adjustments to accommodate new data and perform a new analysis. This has been done multiple times during this thesis to create a best-as-possible outcome, as new information and data became available.

The resulting maps are used to make the actual comparison between the approaches. This can simply be done by subtracting one from the other and using a zonal tool to calculate the sum of all the damage in a particular area. Analysis of the differences is done by comparing these maps and the associated graphs. The process can be divided into three parts:

Preparation and adaptation of the acquired data
ArcGIS can be a great application for combining and manipulating data. Sadly this comes at a cost; all data must be in the right format and have the right properties. This means that a great deal of effort has to be put into making your data ready for analysis, such as using the same extent, grid size and projections across the data.

Creating representative maps of potential flood damage
To calculate the potential damages it is needed to create models that can automatically modify the input sources to reflect the maximum damage and depth/damage factors. This is done by reclassifying each land use type to the maximum damage for that land use type and doing the same for the inundation depth and the associated depth/damage factors. Multiplying these will result in a map that only contains cells that are affected by flooding and represent a monetary value of potential damage.

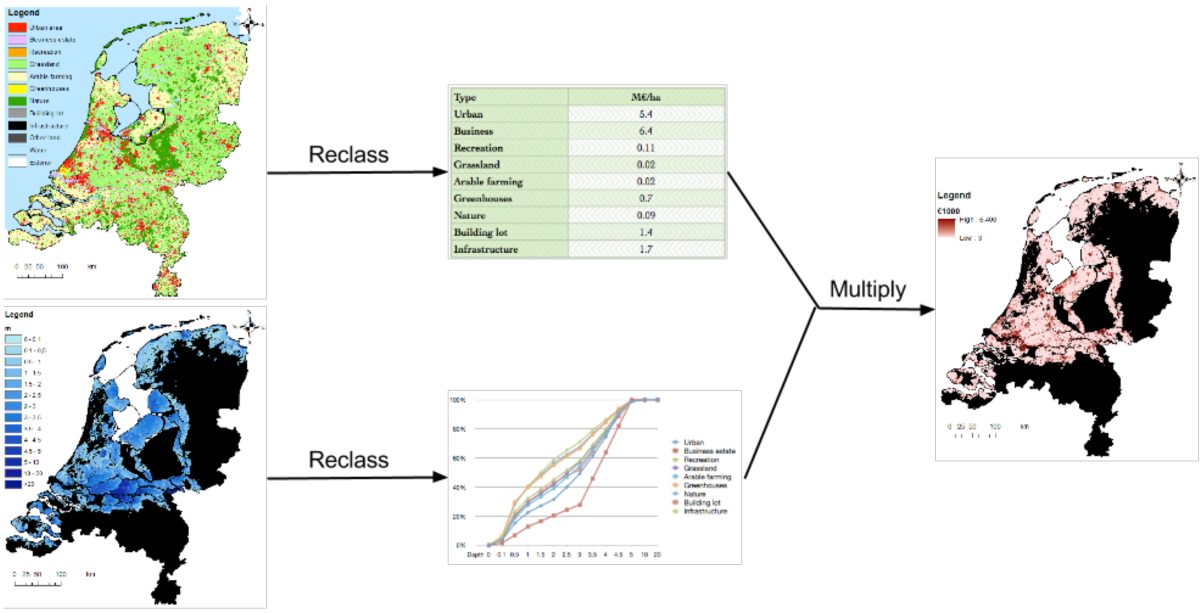

Figure 3.1: A simplified representation of how the predominant land use model works

The same can be done for the object based approach, although an additional model is created to accommodate the additional input data for house density and property prices. The results of this model are then inserted in the original model, replacing the values of urban land use.

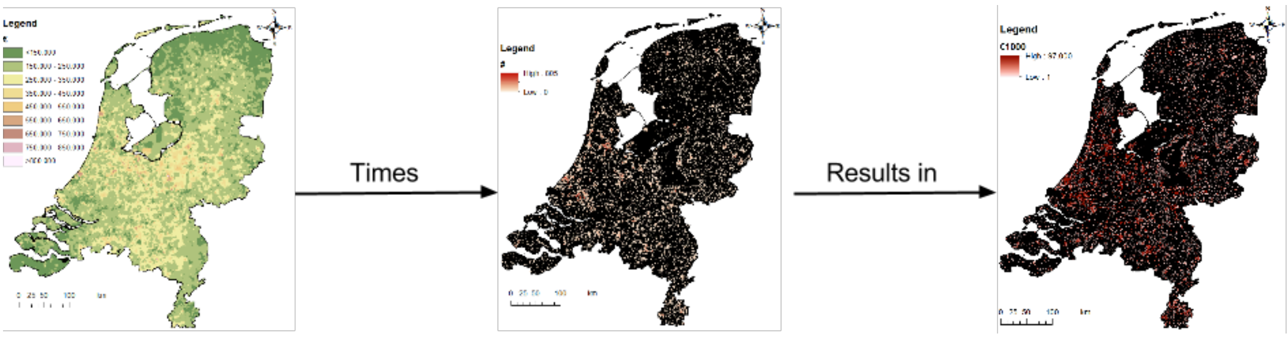

Figure 3.2: A simplified representation of how the object based potential damage is calculated

Analysis of the acquired maps and scatter plots
Final analysis of the resulting maps is done by comparing the resulting potential damage maps from the two approaches. Further analysis is done by subtracting the potential damage values found in the land use based approach from the potential damage found in the object based approach. This makes under- and over appreciation of the land use approach visible. In all cases the results are accumulated per COROP-region so differences between the two methods can more easily be seen.

§3.2 Data collection
For the analysis the following spatial data was needed:
- Predominant land use maps
- House density maps
- Inundation depth map
- House sales prices

Most of the data was provided by the VU University Amsterdam, based on work by E. Koomen. All the maps share the same cell size, projection and extent, which is needed to correctly calculate and compare each cell in the maps.

The predominant land use maps consist of eleven different land use types and are provided for the years 2000 and 2008. Due to the fact that predominant land use maps are created by calculating which land use type is the most common for each cell, a lot of urban land use cells are not covered by the buildings data set. Looking at these parts on Google Earth reveals that most parts are actually parks, out of city allotment gardens infrastructure and business estates. As the buildings data set can be considered complete, this implies that the remaining urban land use cells should't have the same maximum damage value as was used in the predominant land use approach. Further research of a more detailed land use map -with 25m x 25m grid cells- showed that approximately 54% of these leftover urban areas were parks and out of city allotment gardens -these were valued as recreation-, 25% were infrastructure and the remaining 21% were business estates. Multiplying these with their associated maximum damage values gives a very rough -placeholder- value of €1.84 million of maximum damage to these areas. This value was only used in the object based approach.

Table 3.1: Recalculation of leftover urban areas for the object based approach

Type	Count	Share	M€/ha	Relative value (M€)
Recreation	47742	54%	0.11	0.06
Infrastructure	21878	25%	1.7	0.42
Business estates	18717	21%	6.4	1.36
Total	88337	100%		1.84

The house density maps are also provided for the years 2000 and 2008 and consist of values from 1 to 805. These maps are only used in the object based approach.

The inundation map had to be recalculated into cm, to fit the depth/damage factors discussed below. The inundation depth combined with the depth/damage curves and land use maps are the basis of the two approaches, as seen in figure 3.1.

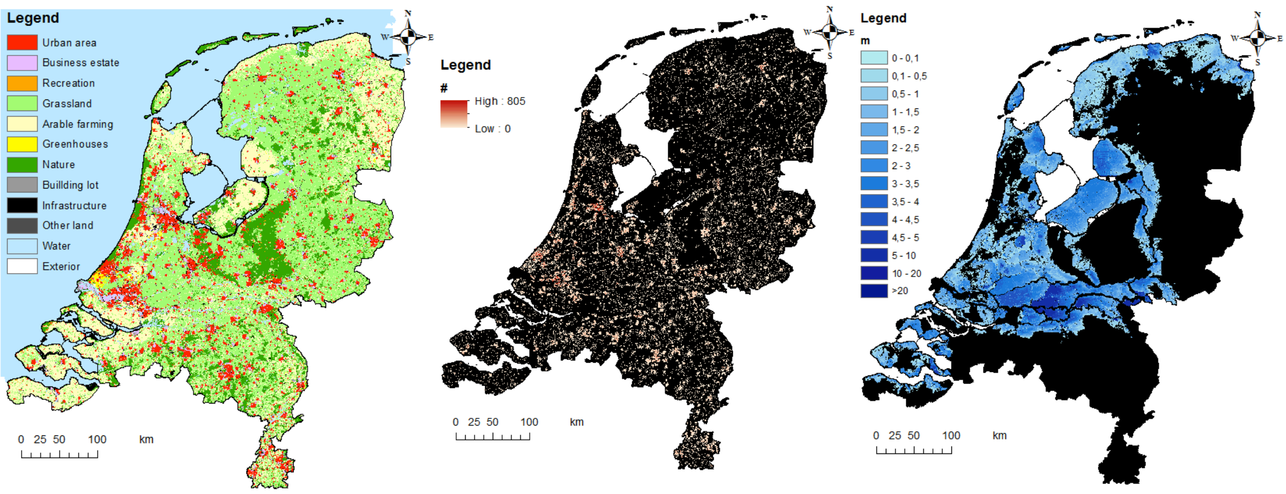

Figure 3.3: Examples of the input data: Predominant land use (left), building density (middle) and inundation depth (right), as provided by the VU

Finally, house sales prices are needed to calculate the potential damage for the object based approach. These house sales prices where provided by the Dutch Association of Estate Agents (NVM), this is the leading association when it comes to real estate market prices for the Netherlands. The data represents all actual sales of houses for the year 2000 and were previously converted to Euros. From this raw data, it was required to create an interpolated map of the house sales prices as 144 thousand data points is quite extensive, it is by no means exhaustive as the total amount of households in the year 2000 was almost 6.6 million (as can be found on CBS Statline). The missing data is filled by interpolation of the data points, which is done by inverse distance weighting (IDW). IDW is a process in which the twelve nearest data points are being evaluated and weighted according to there distance from the x,y position on the map. This is done for every x,y coordinate until a complete map has been created. The results, however, cannot be considered as an absolute truth. The resulting map is a mere indication of what the average local house prices are likely to be, based on the surrounding house prices. The results can be seen in figure 3.4.

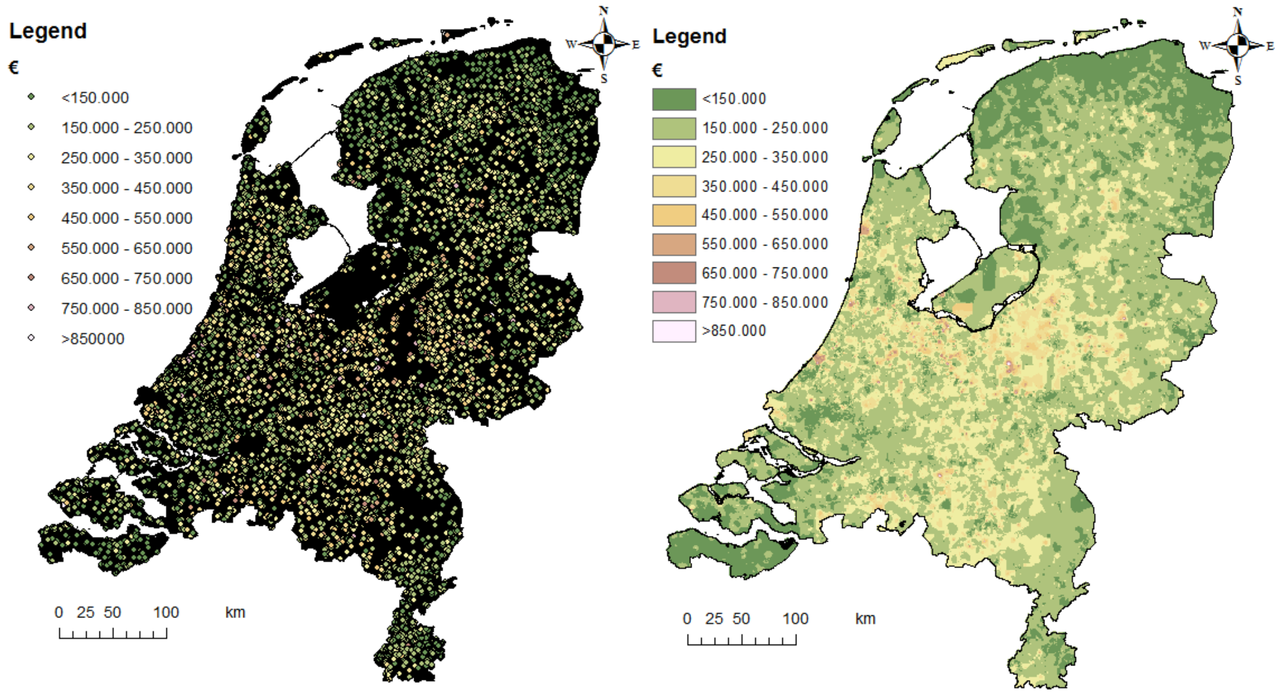

Figure 3.4: House sales prices provided by the NVM on the left, interpolation of these data points on the right

Besides the spatial data, depth/damage relations are needed to be able to calculate the potential damage of an area. These relations were also provided by the VU, see figure 3.5, and consist of nine different land use types. The other two land use types -water and other land-, respectively have a value of zero or no known value and are therefore abandoned.

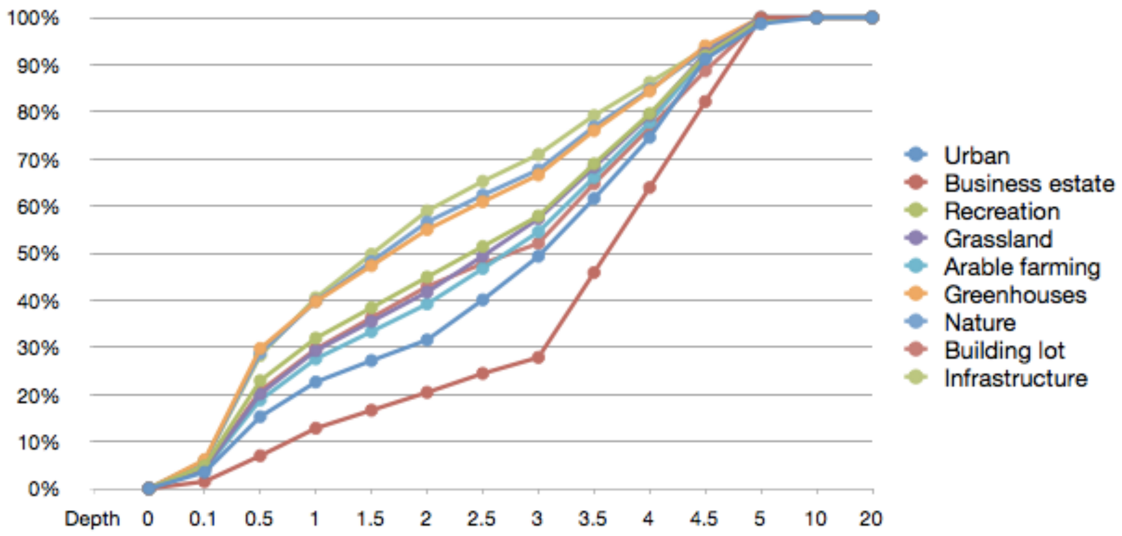

Figure 3.5: The depth/damage curves for each individual land use type (Source: VU)

The corresponding maximum damage values -see table 3.2- originate from a standard source for flood risk assessment in the Netherlands as used, for example, by Klijn et al. in 2007. These values are based on the reconstruction, replacement or market values for the affected land use types and are based on price points in the year 2000 (Klijn et al., 2007).

Table 3.2: The maximum damage (2000) for each individual land use type (klijn et al., 2007)

Type	M€/ha
Dense urban	9.65
Green urban	4
Rural	3.9
Business	6.4
Recreation	0.11
Grassland	0.02
Arable farming	0.02
Greenhouses	0.7
Nature	0.09
Building lot	1.4
Infrastructure	1.7

The maximum damage value and factors for urban land use had to be recreated as the original data from Klijn et al. (2007) subdivided urban land use into three types: dense urban, green urban and rural. This is due to the fact that the provided predominant maps discussed earlier in this paragraph do not subdivide urban land use. A representative value has been created by multiplying each of the three urban types with its relative share, see Table 3.3.

Table 3.3: Recalculation of urban maximum damage

Land use type	Current (ha)	Share	M€/ha	Relative (M€/ha)
Dense urban	83,643	26%	9.65	2.5
Green urban	180,107	56%	4	2.2
Rural	60,706	19%	3.9	0.7
Total	324,456	100%		5.4

4. Results

§4.1 Land use based approach

The potential damage maps clearly show the urban areas as deep red -signifying high damage potential- and low damage potential for all other areas. This is to be expected, as the difference between maximum damage per land use is quite steep, ranging from €6,4 million for business estates and €5,4 million for urban areas to a mere €20.000 for grasslands and arable farming areas.

The results for 2000 and 2008 can be seen in figure 4.1, differences are subtle, the most differences are the result of an increased urbanisation in 2008 and -to some degree- by different interpretations to what the predominant land use is (e.g. some urban areas in 2000 are deemed recreational areas in 2008).

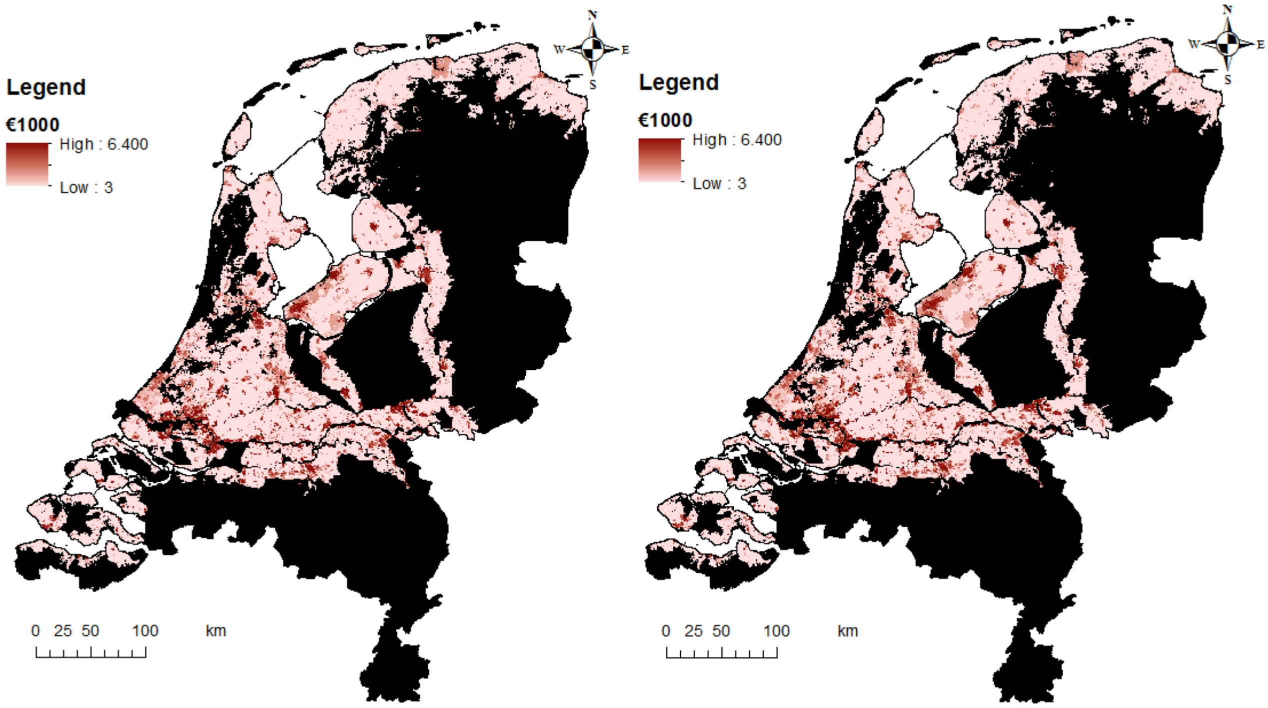

Figure 4.1: Potential damage for 2000 and 2008, using the land use based approach

The total amount of damage becomes more apparent when aggregated per region -for which the COROP-division has been chosen-, as can be seen in figure 4.2. As expected, the most potential damage is found in the lowest and the most urbanised regions of the Netherlands. Most notable are the Rijnmond, Utrecht and Flevoland areas. Changes between 2000 and 2008 show that urban growth centres as Utrecht do noticeably incur more potential damage over time.

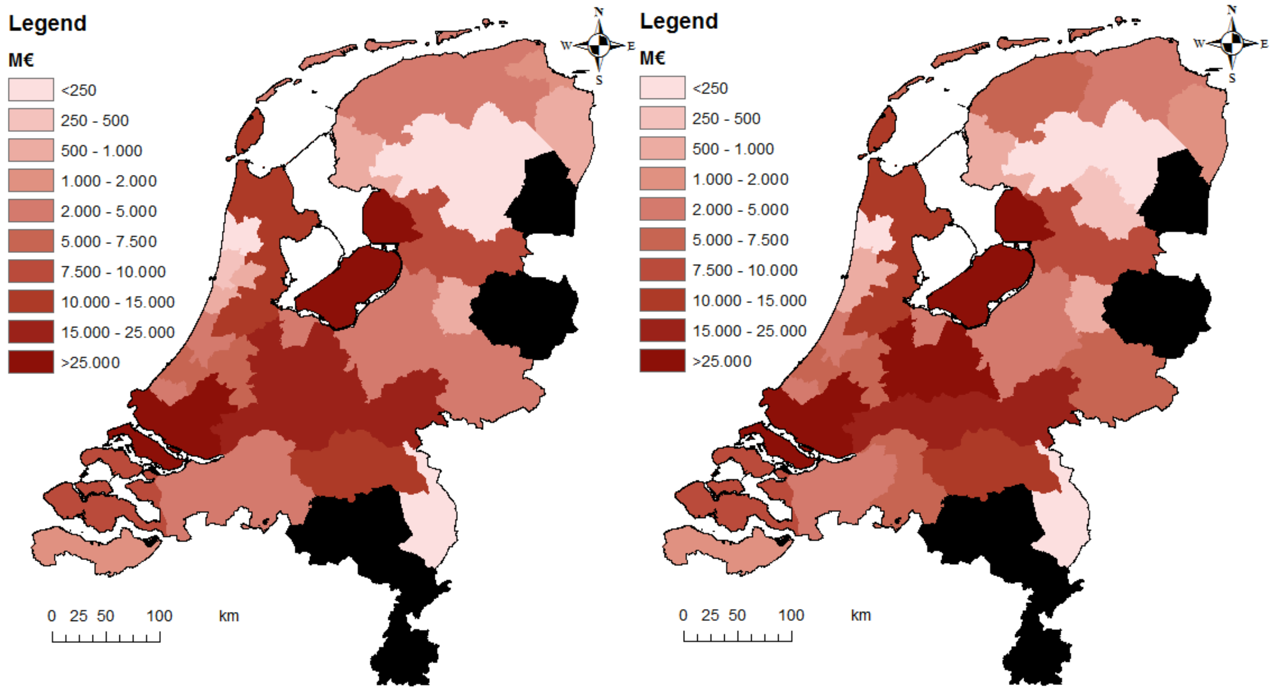

Figure 4.2: Potential damage per COROP region for 2000 and 2008, using the land use based approach

§4.2 Object based approach

In contrast to the land use based approach, the object based approach is not limited by a maximum damage value. This is due to the fact that the object based approach relies on both the regional market value of houses and the amount of houses per hectare. Both of which are subject to change and therefore does not restrict the amount of potential damage that can be reached for a certain hectare.

As a result, the highest potential damage per hectare seen in the object based approach is €97 million for both 2000 as 2008. This potential damage is reached by a combination of the local house market, the number of buildings per hectare and the flood depth that can potentially reached. These results can be viewed in figure 4.3. Again, the differences between 2000 and 2008 are subtle, the emphasis lies on urban expansion much like the land use based approach.

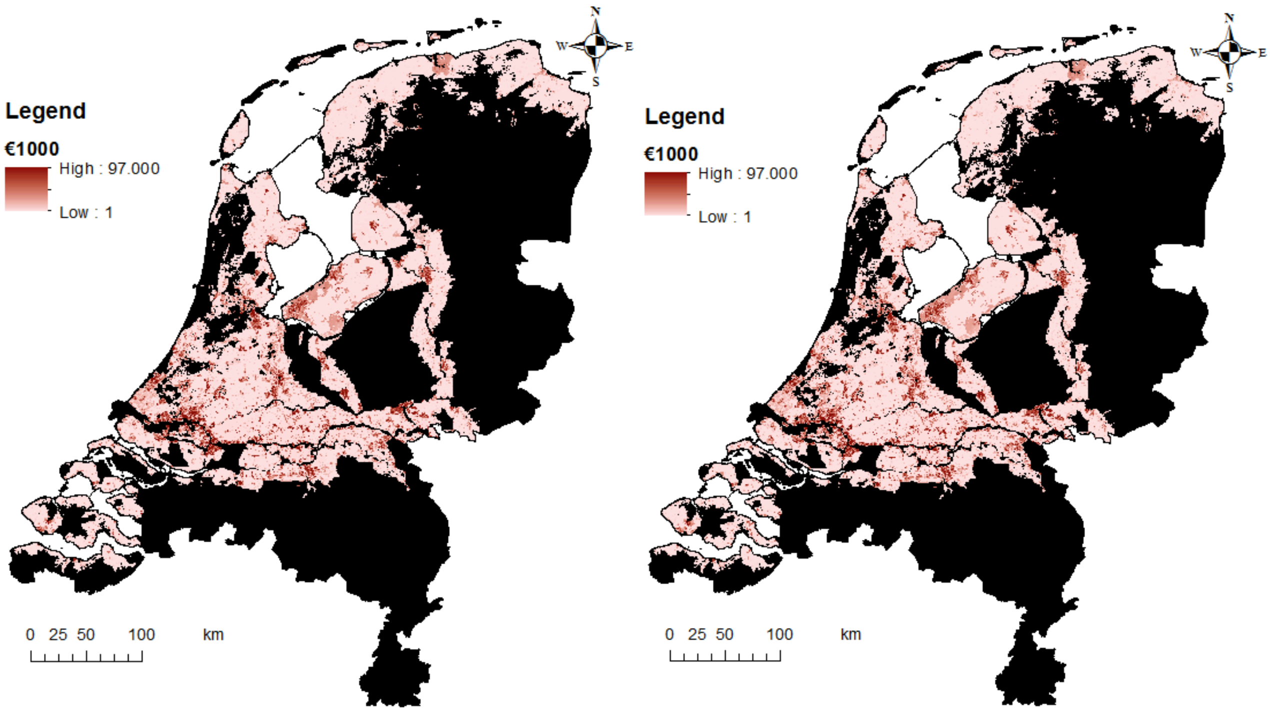

Figure 4.3: Potential damage for 2000 and 2008, using the object based approach

When viewing the total potential damage per COROP-region, figure 4.4, the regions with the most potential damage are Rijnmond and Flevoland, followed by Utrecht, Southeast-Zuidholland, Southwest-Gelderland and the Arnhem/Nijmegen regions. Between 2000 and 2008 the most noticeable difference is the increased potential damage for the Flevoland region, but not for the Utrecht region.

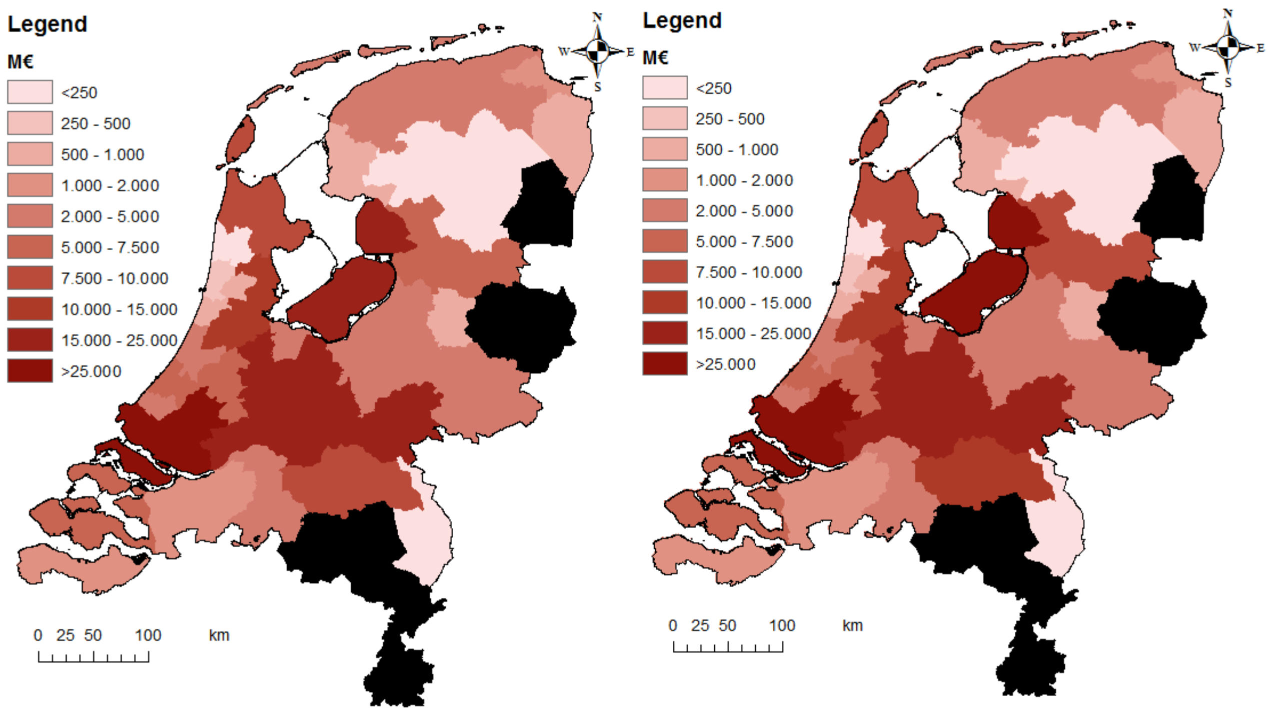

Figure 4.4: Potential damage per COROP region for 2000 and 2008, using the object based approach

The results of both approaches will be compared in the next paragraph.

§4.3 Differences between the two approaches

To show the differences between the two discussed approaches, the results from the land use based approach were subtracted from the object based approach.

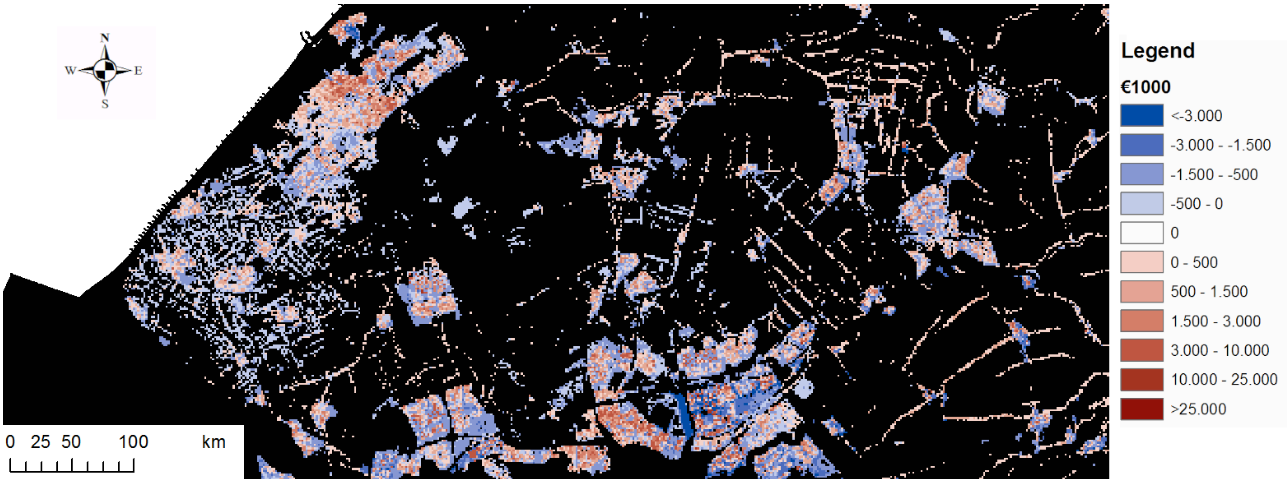

Figure 4.5: Close up of the Rijnmond (below) and The Hague (upperleft) area, showing over appreciation (blue) and under appreciation (red) of the land use based approach, compared to the object based approach

The results show that there is typically an over appreciation of the value for urban areas, when using the land use based approach. For high density urban areas like Rotterdam, The Hague and Utrecht, the opposite is true. These areas are under appreciated in the land use based approach for up to 1500%, in rare cases.

The maps also show the effect of house prices, as can be seen in the Gelderse Vallei and the IJssel area in figure 4.9, which show a higher potential damage when using the object based approach. When viewing the Gelderse Vallei in more detail, figure 4.6, it is revealed that urbanised areas generally show an over appreciation for the predominant land use approach when compared to the object based approach. The same can not be said for rural areas, these are almost all under appreciated, this is due to the fact that these rural houses do not show up as urban land use in the predominant land use maps.

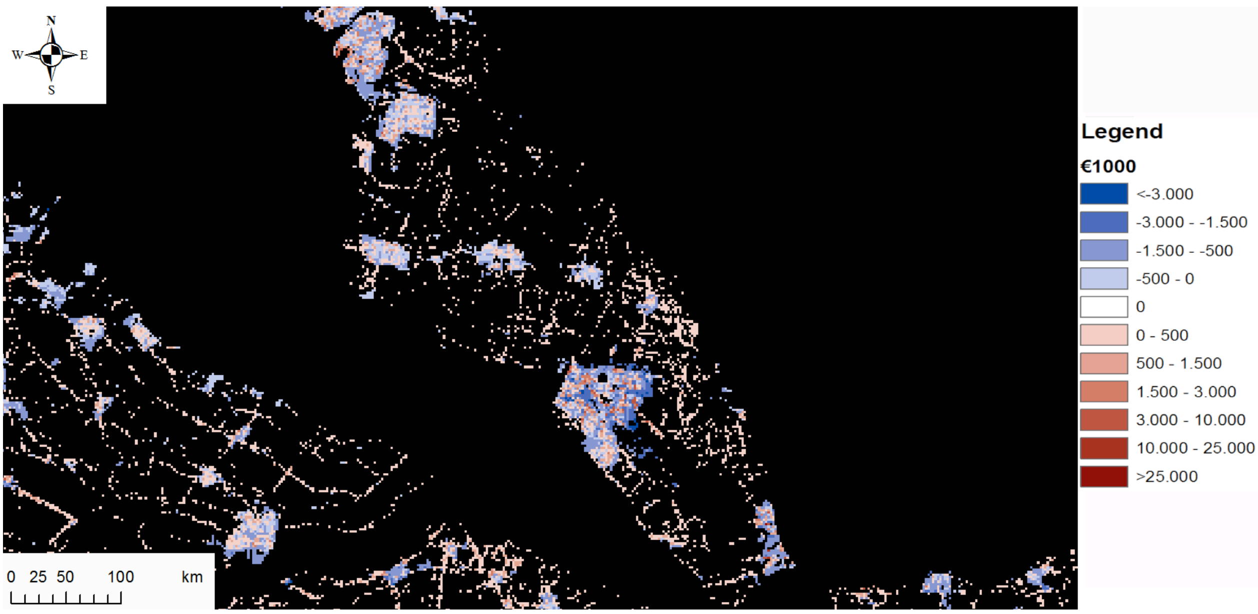

Figure 4.6: Close up of the Gelderse Vallei area, showing over appreciation (blue) and under appreciation (red) of the land use based approach, compared to the object based approach

When viewing the accumulated differences in potential damage per COROP-region, most of these differences are smoothened by the size of the chosen regions. Figure 4.7 shows that the land use based approach is over appreciating a maximal €5 million and under appreciating a maximal €1 million. This is due to high local variation which is evened out by the size of the COROP-regions.

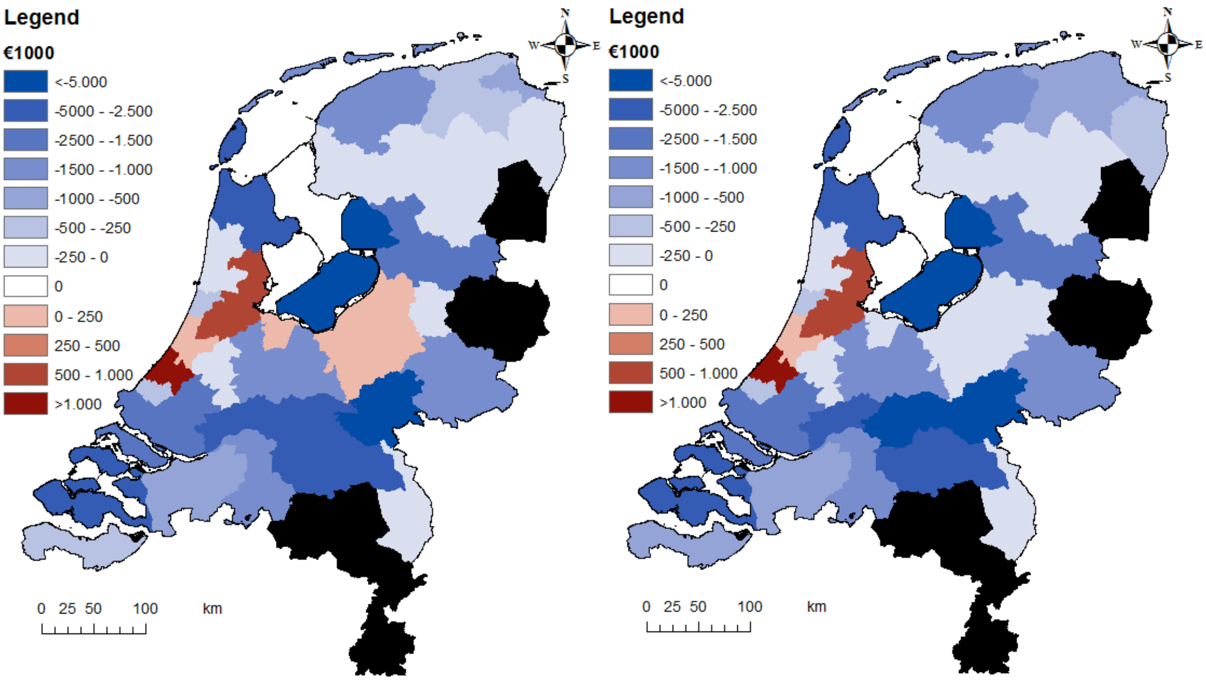

Figure 4.7: Over appreciation (blue) and under appreciation (red) of the land use based approach, compared to the object based approach, per COROP-region for the years 2000 (left) and 2008 (right)

When viewing the same data with smaller regions, this effect seems to be proven and variability between regions is much more pronounced. The results per municipality can be seen in figure 4.8 and finally per borough in 4.9.

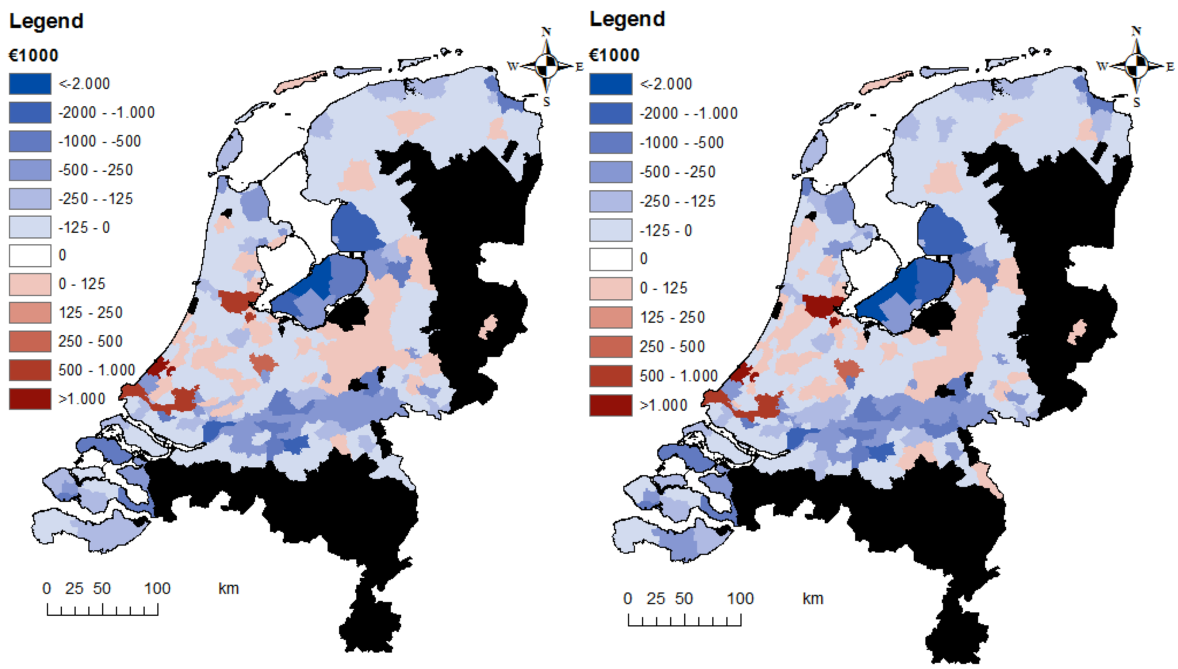

Figure 4.8: Over appreciation (blue) and under appreciation (red) of the land use based approach, compared to the object based approach, per municipality for the years 2000 (left) and 2008 (right)

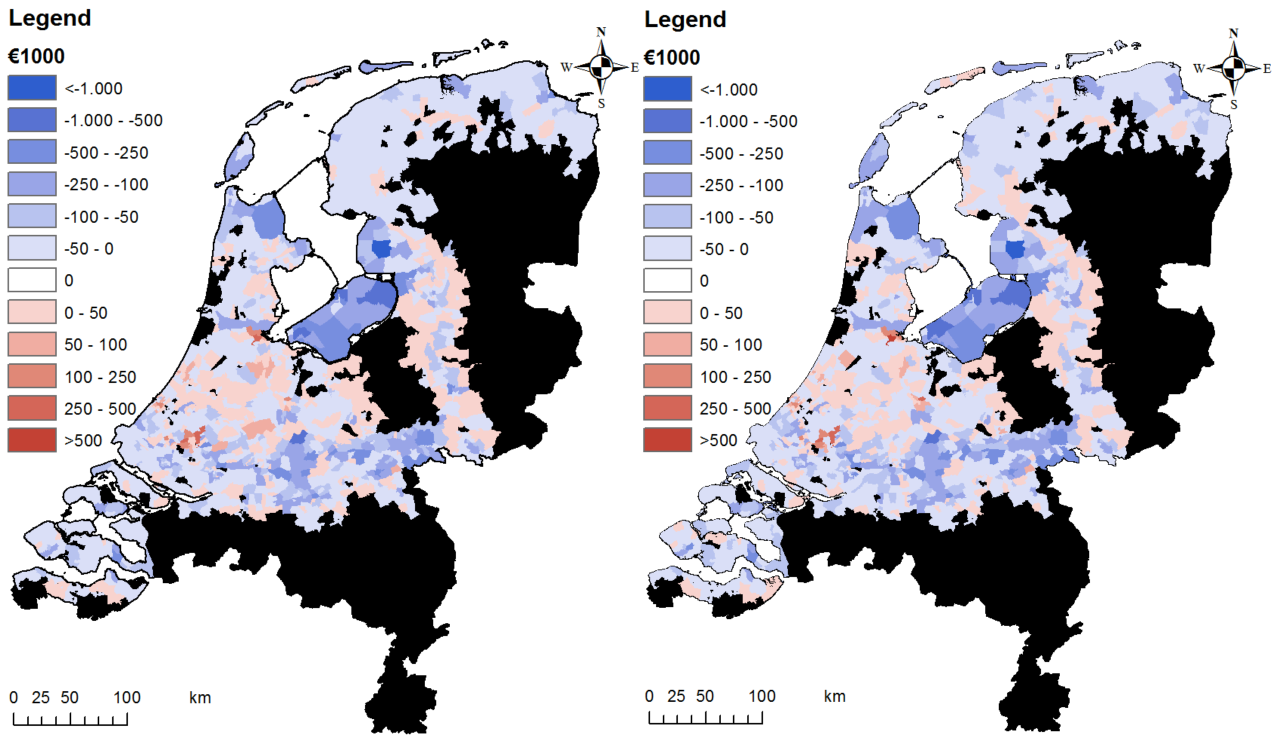

Figure 4.9: Over appreciation (blue) and under appreciation (red) of the land use based approach, compared to the object based approach, per borough for the years 2000 (left) and 2008 (right)

To compare how well the results from both approaches match, comparison graphs were created to show total potential damage per flood depth range with 50cm intervals. To prevent biased results from overlapping methodology between the two approaches -as the object based approach does still rely on land use based data for non urban areas-, only urban areas were used in these calculations.

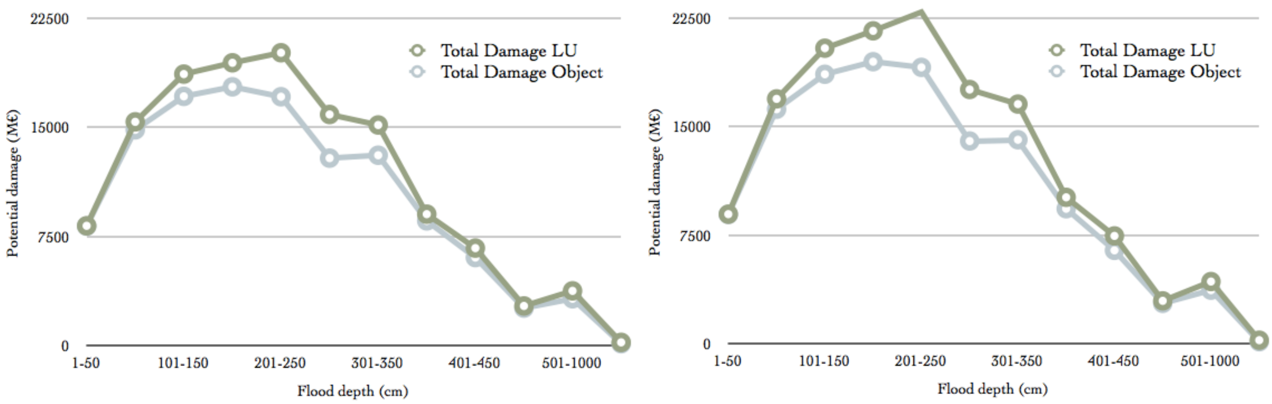

Figure 4.10: Difference in total potential damage per flood range for the years 2000 (left) and 2008 (right)

The results, see figure 4.10, show what seems to be a pretty good fit between both graphs, with the land used based approach again showing higher values as opposed to the object based approach, as was seen earlier in this paragraph. The gap seen from the 50cm to 350cm flood ranges are explained by the total amount of value that both approaches allot to urban areas, see figure 4.11. Even though the gap in figure 4.11 is the largest for the lowest flood ranges, the depth/damage factors are also the smallest for these flood ranges, which explains why both approaches return similar results in these ranges.

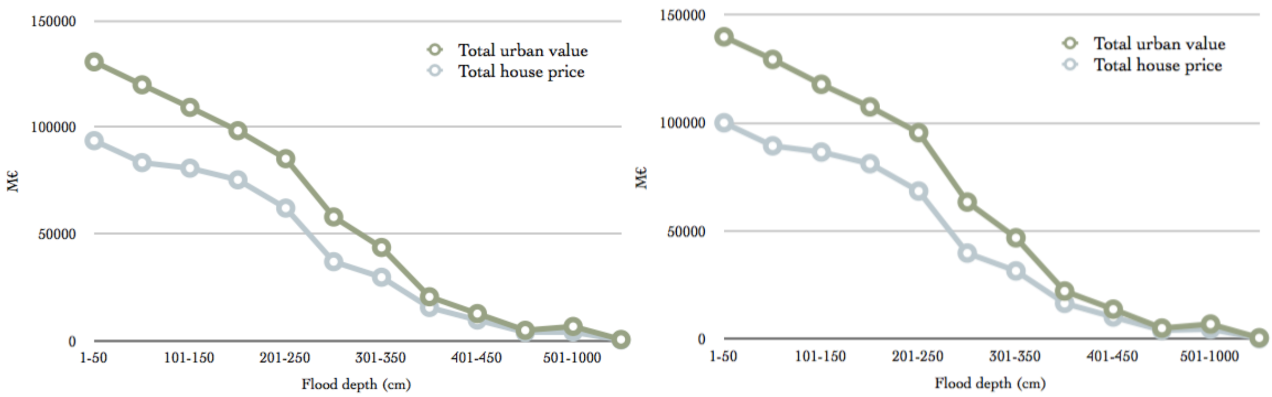

Figure 4.11: Total value of houses and urban areas per flood range for the years 2000 (left) and 2008 (right)

5. Discussion

§5.1 What are the advantages and disadvantages of the land use based approach?

The main advantages of the land use based approach are: ease of use and convenience. Predominant land use data is widely available and getting more detailed as time progresses. Higher resolution maps -of, for example, 25x25m- are not the only aspect contributing to this heightened detail, more categories become available as well. This, counterproductively, does contribute to the complexity of this approach, but could contribute to the accuracy of the predicted potential damages.

The main disadvantage is found in the method of attributing fixed maximum damage values for each type of land use, while grosso modo this could work well for quick and dirty calculations. In general it should be preferred to use data that is location specific, rather than land use type specific.

Also, as described by Smith (1994), damage factors are a poor predictor of actual damages, as many more variables as point of breach, water velocity and water load have a major influence in an area. These variables do become less important when the area size of the research increases (Pistrika & Jonkman, 2009).

§5.2 What are the advantages and disadvantages of the object based approach?

An object based approach adds the possibility of adding location specific information to a study. In this thesis the amount of houses and house sales prices were used to make urban locations more detailed and add more variation between areas by removing fixed maximum damage values for urban areas. Further research could be done by feeding more information into the model, like business estates, infrastructures, ports and their respective local values, a very accurate prediction can be made. This, however, does come at a price: much of this data is hard to acquire and often either secret or very expensive to obtain.

Like the land use based approach, the object based approach still uses damage factors to calculate potential damages per flood depth. Further research should be done to more accurately reflect damages to buildings. This could become a potential benefit of the object based approach, as different building types can be differentiated, each with its own respective depth/damage curve. This would further optimise the accuracy of potential flood damage assessments (Merz et al., 2004).

§5.3 *What are the most notable differences found in the results?*

As pointed out in the results, the land use based approach seems to over appreciate potential damage estimations in rural areas and under appreciates estimations for high density urban city areas. Newly built neighbourhoods also seem to be over appreciated by the land use model, as these areas tend to have a fairly low density of houses, and more room for gardens, streets and recreation than found in the older city centres. Proof of this is found in the 2000 and 2008 comparison maps by region, which show an increase in over appreciation of the land use model as time progresses, this can only be explained by urban expansion.

These variations in appreciation of the potential damage are best represented by smaller regions, this suggests that the object based approach is better suited for analysing smaller regions. When examining larger regions, like COROP-regions, the outcomes become smoothened with differences between the two approaches reaching from -40% to +10%. However when using municipalities as the aggregation level, changes become much greater ranging from -50% to over +100%, with a maximum of +175%. This seems further seems to proof the benefit of the object based approach at lower aggregation levels.

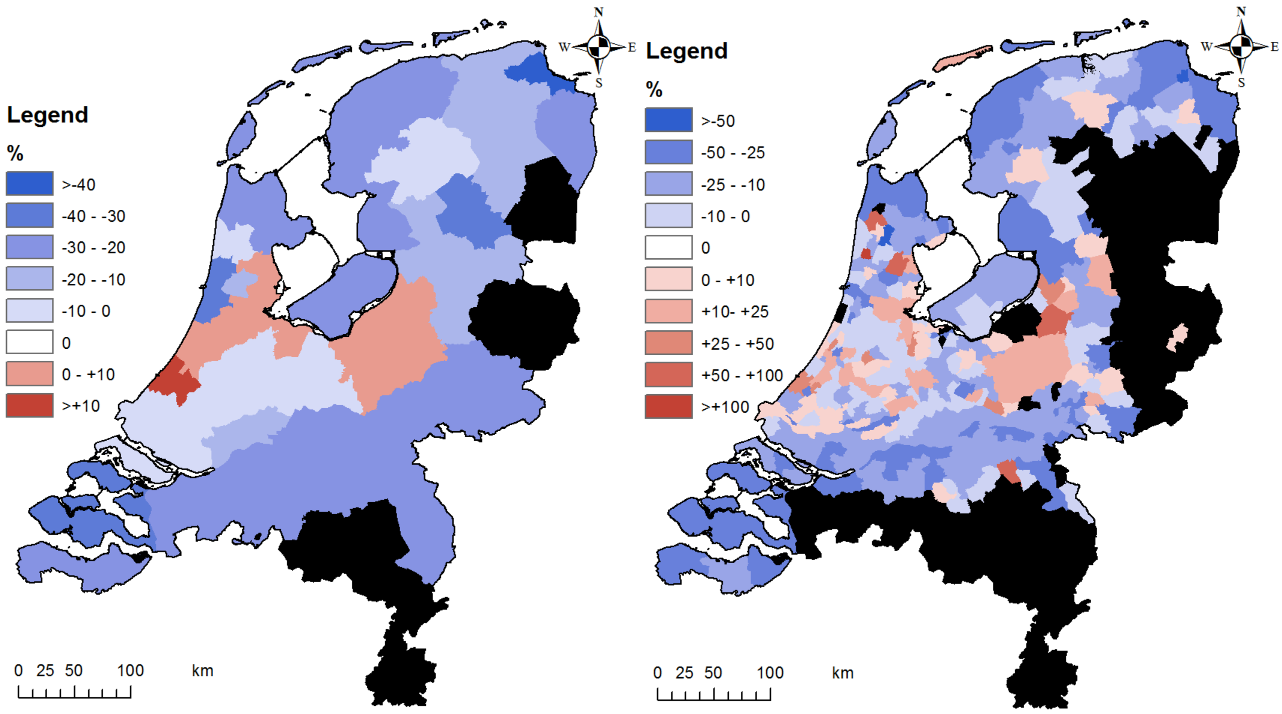

Figure 5.1: Percentile differences between the two approaches per COROP-region (left) and municipality (right), showing over appreciation (blue) and under appreciation (red) of the land use based approach for the year 2000

As seen before, figure 4.8 shows the difference in potential damages per flood range. These seem to proof that there is a general over appreciation of potential damages when using the land use based approach. This however is not as straightforward as it seems. The maximum damage values used in the land used based approach also take household possessions into account. Something that could not accurately be done within the time constraints of this thesis for the object based approach. But the main issue of over appreciation of the land use model, due to large urban areas without houses, remains.

§5.4 Validation of the results and research methods

As discussed in the methodology a certain amount of adjustments to the data were needed to fit the data that was available. Examples of these are the revaluation of the maximum damage for urban areas and the interpolation of house market prices. These results are therefore a close-as-possible interpretation of the data that was available. More accurate values would be preferred, such as market house prices on a neighbourhood or district level, when using the object based approach.

Both approaches still use damage factors to calculate the amount of damage that occurs at a specific flood depth. As stated before, on a micro level this is a less than optimal method of calculating potential damages. Not only does the point of breach strongly influence the amount of actual damage to an area, the type of buildings likely influences the actual damage as well. Not all buildings can be considered equal, as there are, for example, wooden, brick and concrete structures, which should have an effect on the resilience against a flooding. Another factor not taken into consideration is the height of buildings, tall buildings will probably have a higher resistance against floods and therefore can not be reflected with the same depth/damage factors as a two story house would be. At this moment these factors are not taken into consideration as all land use types reach almost 100% damage at a flood depth of 5m. Further research should be done to study the effects of building types and their influence on the potential damage that could be incurred.

As noted, the object based approach used in this thesis does not include household contents values, as they were not available. As the world becomes much more reliant on electronic goods and personal wealth increases, this could be an important factor in assessing potential flood damage. Further research should be done to make an educated estimation of these damage values.

6. Conclusion

In the past most studies concerning the assessment of potential flood damage have resorted to using predominant land use maps. It was shown that these maps do not give an accurate estimation of actual damages, as they are limited by maximum damage values and depth/damage factors. It was stated that adding more detailed information to the equation, might give more accurate predictions.

This thesis has described the process of calculating potential flood damage using both a land use and an object based approach. In doing so it was found that an object based approach can contribute to a more detailed assessment when looking at a micro level. However, the added effort and expenses might not be worth it when a less detailed result is required.

The object based approach contributes towards more realistic results, due to the fact that there no longer is a maximum damage constraint. This results in greater variation between very local regions and to a lesser extent for larger regions.

The concept of the object based approach does seem to merit further research, as more data can be added to the model, further optimising the results. More accurate data will also contribute to this. Within the constraints of this thesis this was sadly not possible, but this thesis has proofed that it is feasible to use objects to enhance the land use based approach.

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Appendix

Depth/damage factors belonging to figure 3.5

Depth	Urban	Business	Recreation	Grassland	Arable Farming	Greenhouses	Nature	Building lot	Infrastructure
0	0	0	0	0	0	0	0	0	0
0.1	0.034734	0.014880	0.047967	0.042828	0.040302	0.061212	0.058230	0.042251	0.056973
0.5	0.152506	0.069588	0.228976	0.200780	0.187928	0.297355	0.287257	0.207071	0.282241
1	0.226261	0.128014	0.319252	0.292893	0.275404	0.396934	0.397858	0.296269	0.405167
1.5	0.271626	0.166156	0.383937	0.354639	0.333265	0.473081	0.481810	0.362653	0.497491
2	0.315531	0.204145	0.448835	0.417043	0.391734	0.549647	0.565782	0.428914	0.589335
2.5	0.400535	0.244258	0.513805	0.493673	0.466868	0.608901	0.623012	0.477661	0.652129
3	0.492942	0.278260	0.578451	0.572838	0.544832	0.665734	0.676609	0.520390	0.709093
3.5	0.615416	0.458440	0.689194	0.682148	0.660431	0.759779	0.768050	0.646973	0.791813
4	0.745311	0.638978	0.795693	0.791806	0.777195	0.843416	0.847294	0.765556	0.862255
4.5	0.911613	0.821443	0.918758	0.923490	0.916710	0.939621	0.930479	0.886614	0.932958
5	0.986502	0.998839	0.997735	0.999508	0.999016	0.999612	0.998289	0.997711	0.997279
10	0.998942	0.999894	0.999855	0.999982	0.999944	0.999999	0.999845	0.999791	0.999777
20	1	1	1	1	1	1	1	1	1

Values for figure 4.10

2000

Flood depth	Total Damage LU	Total Damage Object	Difference
1-50	8245.516	8222.862	-0.27%
51-100	15382.164	14835.804	-3.55%
101-150	18659.505	17132.092	-8.19%
151-200	19435.304	17787.132	-8.48%
201-250	20125.554	17106.186	-15.00%
251-300	15887.096	12891.321	-18.86%
301-350	15165.469	13088.923	-13.69%
351-400	9043.774	8585.33	-5.07%
401-450	6713.7	6064.243	-9.67%
451-500	2742.453	2596.42	-5.32%
501-1000	3778.614	3238.256	-14.30%
>1000	242.747	152.557	-37.15%

2008

Flood depth	Total Damage LU	Total Damage Object	Difference
1-50	8961.869	8941.473	-0.23%
51-100	16921.515	16204.672	-4.24%
101-150	20420.251	18620.605	-8.81%
151-200	21618.164	19488.068	-9.85%
201-250	22915.889	19099.166	-16.66%
251-300	17568.804	14010.217	-20.26%
301-350	16561.445	14098.916	-14.87%
351-400	10124.636	9337.115	-7.78%
401-450	7462.112	6463.065	-13.39%
451-500	2978.093	2805.366	-5.80%
501-1000	4310.381	3713.8	-13.84%
>1000	261.948	156.433	-40.28%

Values for figure 4.11

2000

Flood depth	Total house price	Total urban value
1-50	93646	130618
51-100	83347	119840
101-150	80738	109261
151-200	75271	98323
201-250	62001	85190
251-300	36862	57843
301-350	29576	43526
351-400	15370	20410
401-450	9490	12525
450-500	3657	4678
501-1000	3871	6470
>1000	151	371

2008

Flood depth	Total house price	Total urban value
1-50	100078	139910
51-100	89387	129414
101-150	86507	117894
151-200	81126	107443
201-250	68429	95494
251-300	39715	63347
301-350	31451	46797
351-400	16449	22118
401-450	10099	13715
450-500	3896	4947
501-1000	4447	6822
>1000	160	454