25-6-2014

Comparing valuation methods for ecosystem services in Amstelland

Applying ecosystem service valuation methods to evaluate land-use changes

Erin Kennedy
2163780

Bachelor thesis Earth Sciences & Economics
Course code: AB_450254, 12 ECTS
Supervisors: Eric Koomen & Peter Mulder

vrije Universiteit amsterdam

Table of contents

1. Introduction 1
   1.1. Motivation & problem 1
   1.2. Study area description 2
   1.3. Methods 5
      1.3.1. Land-use changes analysis 5
      1.3.2. Valuation methods 6
2. Results 9
   2.1. GIS analysis and transition matrices 9
   2.2. Value transfer 11
   2.3. Contingent valuation 12
   2.4. Pricing approach 15
   2.5. Valuation comparison 24
3. Discussion 25
   3.1. Application and performance 25
   3.2. Reflection on method 25
4. Conclusion 27

References 28
   Literature 28
   Websites 29
   Spatial data sources & models 29

Attachments ....
   Contingent valuation survey ....

1. Introduction

1.1. Motivation & problem

Amstelland is a traditionally agricultural region that lies south of the city of Amsterdam. The oldest developed part of this region is Ouder-Amstel, which was developed in the middle ages and predates Amsterdam. Through expansion of the metropolitan region of Amsterdam and Amstelveen, this region has been under strong pressure from urban expansion during the past decades. As a result, several groups, including Groengebied Amstelland and the organization Beschermers Amstelland have sprung up to try to preserve the open rural nature of the landscape by investing in recreation, stimulating the agricultural economy and trying to influence policy-making decisions.

The demand for land in Amstelland is very high. Only the spatial policies and zoning regulations in place prevent this region from becoming urbanized under market pressures. For groups that try to preserve the historic characteristics of this region, estimating changes in ecosystem service valuations could be a useful tool to influence policy decisions or stimulate subsidies to preserve traditional land uses. These values are often ignored or underestimated when making cost-benefit analyses of proposed changes (Atkinson, Bateman & Mourato, 2012).

One explanation for this could be that methods to value ecosystem services can be costly and time-consuming to apply. Another possible explanation is that there is uncertainty about the validity of outcomes. In order to gain insight into both the problems and possibilities of using these methods and the validity of the outcomes, this thesis applies and compares three methods of ecosystem service valuation to the region of Amstelland. For this goal, the following research question has been explored:

How well can the ecosystem service valuation methods of value transfer, contingent valuation and the pricing approach perform for the area Amstelland in assessing the impact of land-use changes?

The first method is *value transfer*; where previously defined coefficients from other studies are applied to a new region. The second method is *contingent valuation*, where value changes are assessed by means of a survey about potential changes and willingness to pay (WTP). The third method is the *pricing approach*, where available data and literature are used to determine the market value, replacement costs (substitutes) and avoided costs of negative effects of environmental change.

To answer the research question, a number of subquestions have been explored. First, it is important to understand what the most important land-use changes have been in the region. For each of the valuation methods, the possibility for exploring impacts of land-use changes is examined. Additionally, it is important to understand how these valuations are made, the strengths and weaknesses of each method and how realistic the outcomes are. Finally, a comparison of all of the results is made to provide insight into the overall applicability and performance of each of the methods.

In section 1.2 is a short description of the historic, political, physical & economic characteristics of the study area. In section 1.3, the data and methods used in the research are described. Chapter 2 covers the outcomes of the land-use change analysis and the valuation methods. Chapter 3 discusses the relevance of the outcomes for the research question and reflects on the methods used. This is followed by a conclusion in chapter 4.

1.2. Study area description

The five municipalities included in the study area are Amstelveen, Ouder-Amstel, Uithoorn, Aalsmeer & Diemen. These are shown in Figure 1. Amsterdam has been excluded from the analyses because the urban nature of the city is at odds with the rural character of the other municipalities, though residents of Amsterdam are important consumers of the ecosystem services of Amstelland.

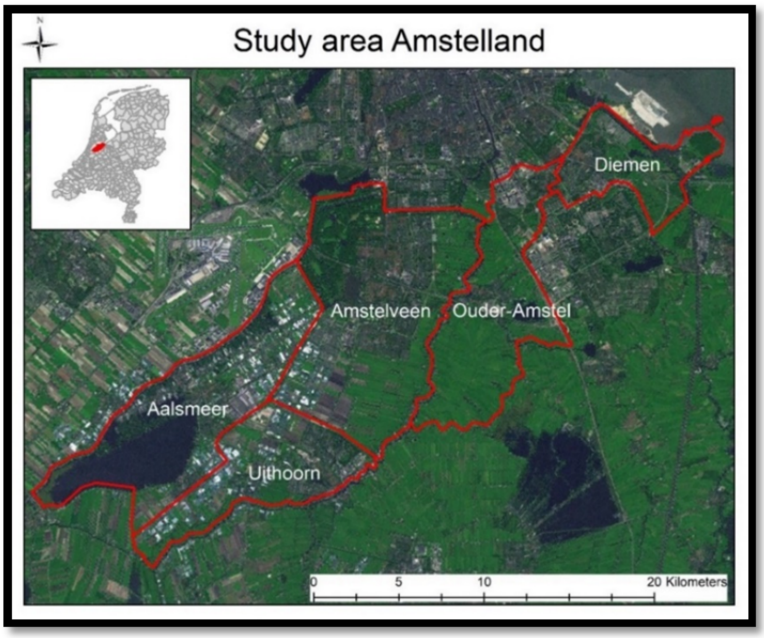

Figure 1: Study area Amstelland

Part of the land use in this region can be attributed to the physical characteristics of the landscape. During the Holocene, a high sea level led to clay deposits that in some parts of the western region still lie on the surface, which made this area suitable for arable farming. The warm climate also yielded a high plant growth, which led to the formation of a large amount of peat that remains in the east. This area was originally used for crops, but problems with ground subsidence and flooding led to this land mainly being converted to pasture (Haartsen & Brand, 2005). The spatial pattern of arable farming and pastures is still present in the landscape today.

Population has been growing in all five of the municipalities during the past decades. With the exception of Diemen, each of the municipalities had a brief period where the population decreased, particularly in the period of 1980-1985. Diemen has shown the highest overall population growth. The population change per five years for each municipality between the years of 1965 and 2010 is given in Figure 2.

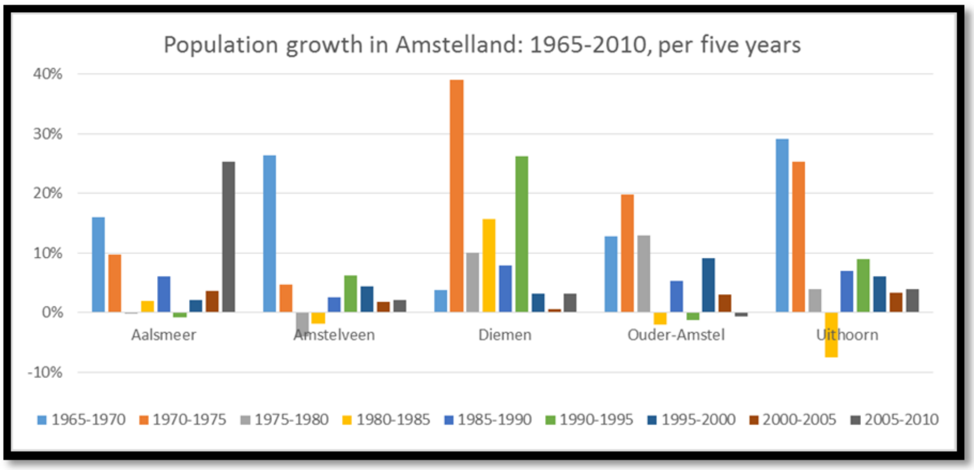

Figure 2: Amstelland population growth, 1965-2010 (cbs.nl)

At the same time, agriculture, forestry and fishing have been steadily decreasing in North Holland, as well as in Amstelland. Figure 4 shows the decrease of the share of these sectors as part of the total added economic value in North Holland.

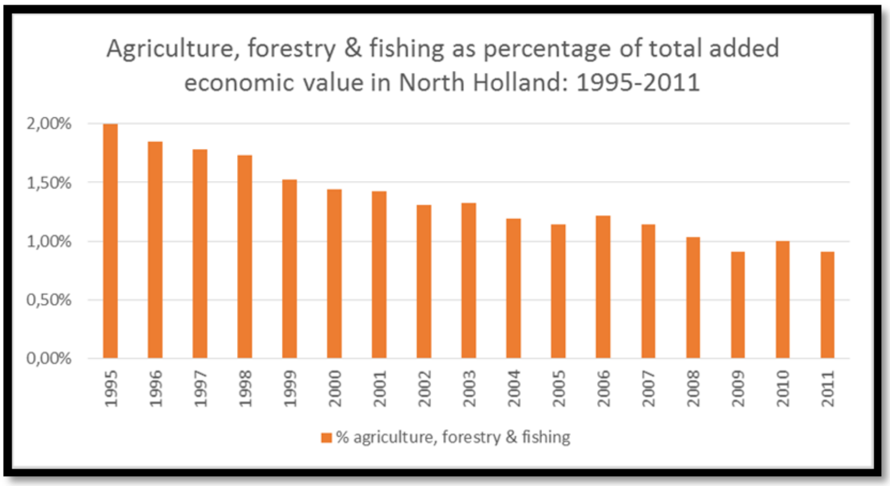

Figure 3: Added economic value agriculture/forestry/fishing (cbs.nl)

Parts of Amstelland are found in two spatial planning zones with restrictive policies to preserve the natural values of the region; the national buffer zone *Amstelland-Vechtstreek* and the *Green Heart*. Additionally, some of Amstelland belongs to the national Ecological Main Structure (Overbeek, de Graaff & Selnes, 2011). Despite these protections, there was a large increase in urbanization between 1960 and 2000 in Amstelland. This trend is shown in Figure 5 in the land-use maps for these two periods.

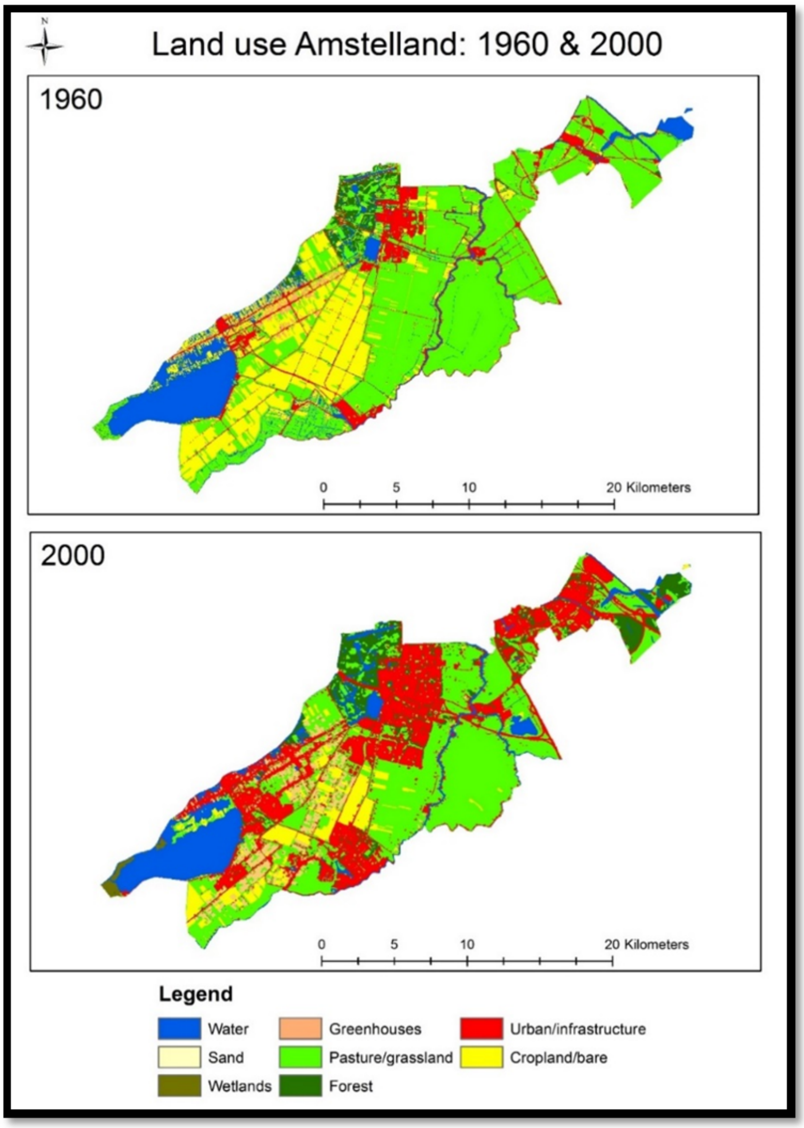

Figure 4: Land-use changes Amstelland, 1960-2000

1.3. Methods

1.3.1. Land-use changes analysis

As a first step it was necessary to compare the changes in area per land-use category between time periods; the years 1960 and 2000 are compared. The data available were the raster land-use map of the HGN1960 (Historisch Grondgebruik Nederland) with a 25m resolution and the HGN2000 with a 50m resolution. Due to the different scale, the LGN2000 (Landelijk Grondgebruiksbestand Nederland) is used instead. The LGN2000 has a total of 40 different land-use classes, while the HGN1960 only has 8. Therefore, the first step was to reclassify the LGN2000 into land-use classes corresponding with the HGN1960. Afterwards, the two maps were clipped to the study area and the values were analyzed to compare the total area per class for 1960 and 2000.

In order to explore specific transitions taking place, the HGN 1960 was reclassified with the category values multiplied times a hundred. Both rasters were then added using raster math. The resulting raster has values between 101 and 808. The value in the hundreds place identifies the original land-use class and the value in the ones place corresponds with the new land use. This was then converted into a transition matrix showing the extent of each transition. This method is shown in Figure 6.

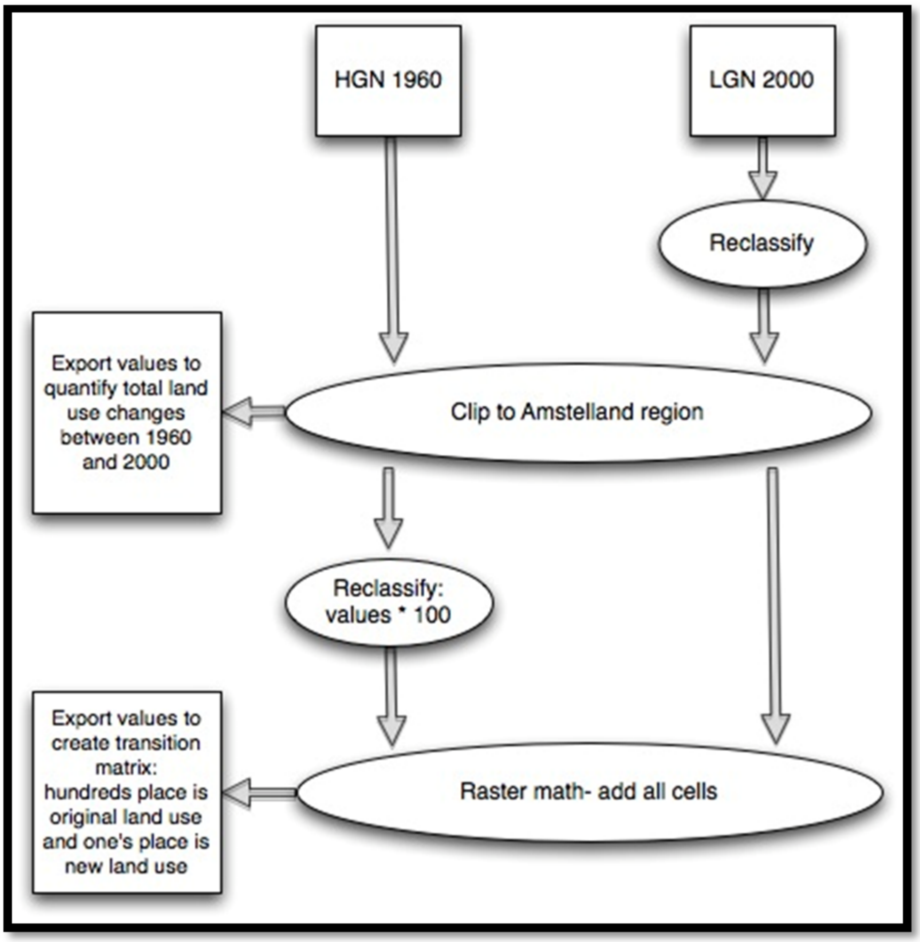

Figure 5: Method for land-use transition matrix

1.3.2. Valuation methods

There are many valuation methods for ecosystem services. Figure 6 shows the most commonly used methods, how they are interrelated and the valuation methods that were chosen for this research. These are described in the following section.

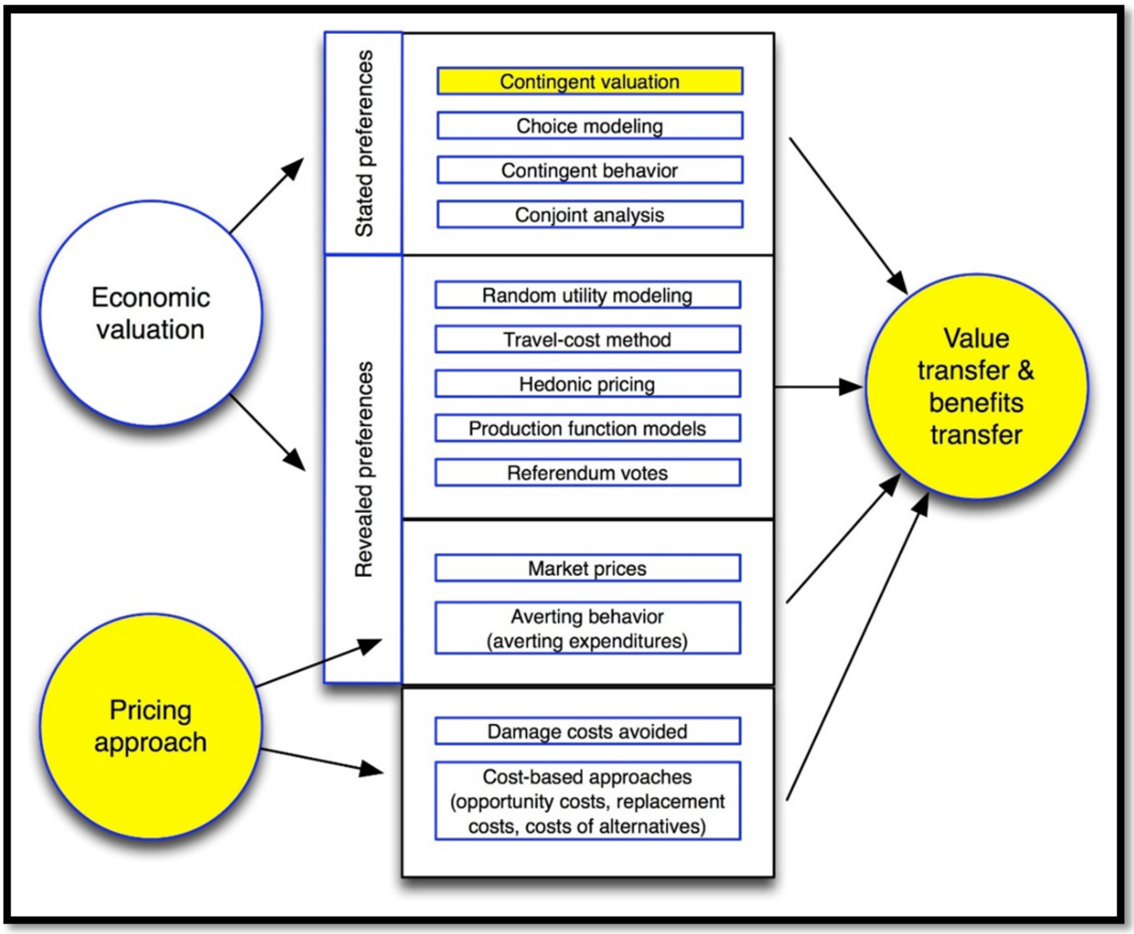

Figure 6: Ecosystem service valuation methods, methods used in yellow

Value transfer

Value transfer studies are done by estimating the value of ecosystem services on the basis of previous research for one or a few ecosystem services. These valuations are applied to a new study region. The coefficients determined in this way are often applied directly to land uses in new regions for which the original research was not intended, as a quick estimation of the ecosystem services.

In this research, valuations from two different often cited studies were selected to be applied to the land use areas of 1960 & 2000 to compare changes in ecosystem services. The hypothesis is that this method will provide a very weak estimate of the true value, but can be applied the most easily. With an understanding of factors that decrease the validity of this method, some of the problems with the valuation may be controlled for or the values altered to provide a better estimate.

The first study compared is the well-known study of Costanza et al. (1997). In this study, experts collaborate in determining the total value of ecosystem services per land cover class. The total valuations provided in this study are the most commonly applied coefficients used for valuation in other studies, though the validity is hotly contested. The second value transfer study used is that of Troy & Wilson (2006). This study is also often used for applying valuation coefficients to new study regions. In the research of Troy & Wilson, a systematic review of specific ecosystem services is done to determine ecosystem service values in study areas with different characteristics. The valuations for the most similar of these three regions will be applied to Amstelland.

Contingent valuation

For the contingent valuation, 120 respondents in the five municipalities of the study region are surveyed about their willingness to pay (WTP) in order to preserve a given area of a certain land use type. The land use types considered in the valuation are croplands and pasture/grassland. Four different versions of the survey are used (see attachment) to determine the WTP for the two land-use types and to control for issues related to the payment vehicle (means of hypothetical payment).

Respondents are shown a map of the relevant land-use transitions in Amstelland (figure 7) and told how much the land use in question has decreased since 1960. They are then given a scenario where either a yearly tax or donation would preserve a certain area of the given land-use type and asked if and how much they would be willing to contribute for this preservation. To avoid potential problems with the elicitation method (manner where a price is chosen for the proposed scenario), the payment card method is used. Respondents are given a list of possible values for the contribution or tax to choose from.

Additionally, demographic data and recreation expenditure estimations are collected. These are used to test the representativeness of the sample and look for correlating factors. The average WTP is then extrapolated to the entire population and area of the land-use class. The hypothesis is that this method is relatively easy to implement and more accurate than value transfer, but factors related to the survey itself can lead to biases in the results.

Pricing approach

The third method to value ecosystem services in the region is by directly determining the value through market prices, monetization of the replacement costs of substitutes and avoided costs of the negative effects of environmental changes. This is done by first determining a list of ecosystem services that are relevant in the study region. Then, values are determined per hectare for each of these services on the basis of literature and spatial & economic data and totaled for the region. The hypothesis is that this process will be the most time-consuming, but also the most accurate method of valuation for the region.

2. Results

2.1. GIS analysis and transition matrices

More than half of the area of Amstelland has changed land use in the period 1960-2000. After the land-use transitions were analyzed in ArcGIS and exported, the following table was made of the transitions between 1960 & 2000 (Table 1). The five largest transitions were the categories of *pasture* to *urban/infrastructure* or *forest* and the category *croplands* to *pasture*, *greenhouses*, or *urban/infrastructure*.

Table 1 : Land-use transition matrix Amstelland, largest transitions given in blue

1960 2000-->	**Water**	**Sand**	**Wetlands**	**Greenhouses**	**Pasture/grassland**	**Forest**	**Urban/infrastructure**	**Croplands/bare**	**Total area 1960 (ha)**
Water	1.339	0	6	9	172	111	144	28	1.808
Sand	0	0	0	0	0	0	0	0	0
Wetlands	18	0	10	0	10	6	2	2	47
Greenhouses	2	0	0	63	29	1	52	2	149
Pasture/grassland	178	0	51	134	4.049	**289**	**2.021**	151	6.873
Forest	47	0	1	1	40	262	49	1	400
Urban/infrastructure	59	0	0	7	141	30	1.088	7	1.332
Croplands/bare	49	0	4	**467**	**765**	58	**829**	678	2.850
Total area 2000 (ha)	1.691	0	72	680	5.206	757	4.185	868	13.459

The LGN2000 was reclassified to correspond with the HGN1960. The categories were straightforward to reclassify, with two exceptions; '*grass in built up area*' and '*forest in built up area*'. The intuitive way to classify these is as grass and forest, but this choice leads to the unlikely result of some of the urban area being classified as transitioning to grass and forest. The alternative of classifying these as urban was less logical however; large parts of the Amsterdamse Bos would be shown as transitioning to urban, so these were classified as grass and forest.

In the following land-use transition maps per municipality (Figure 7), only the five largest land-use transitions are shown, both to avoid the confusion that might result from 64 transition categories and because these transitions account for nearly 75% of the change in this time period.

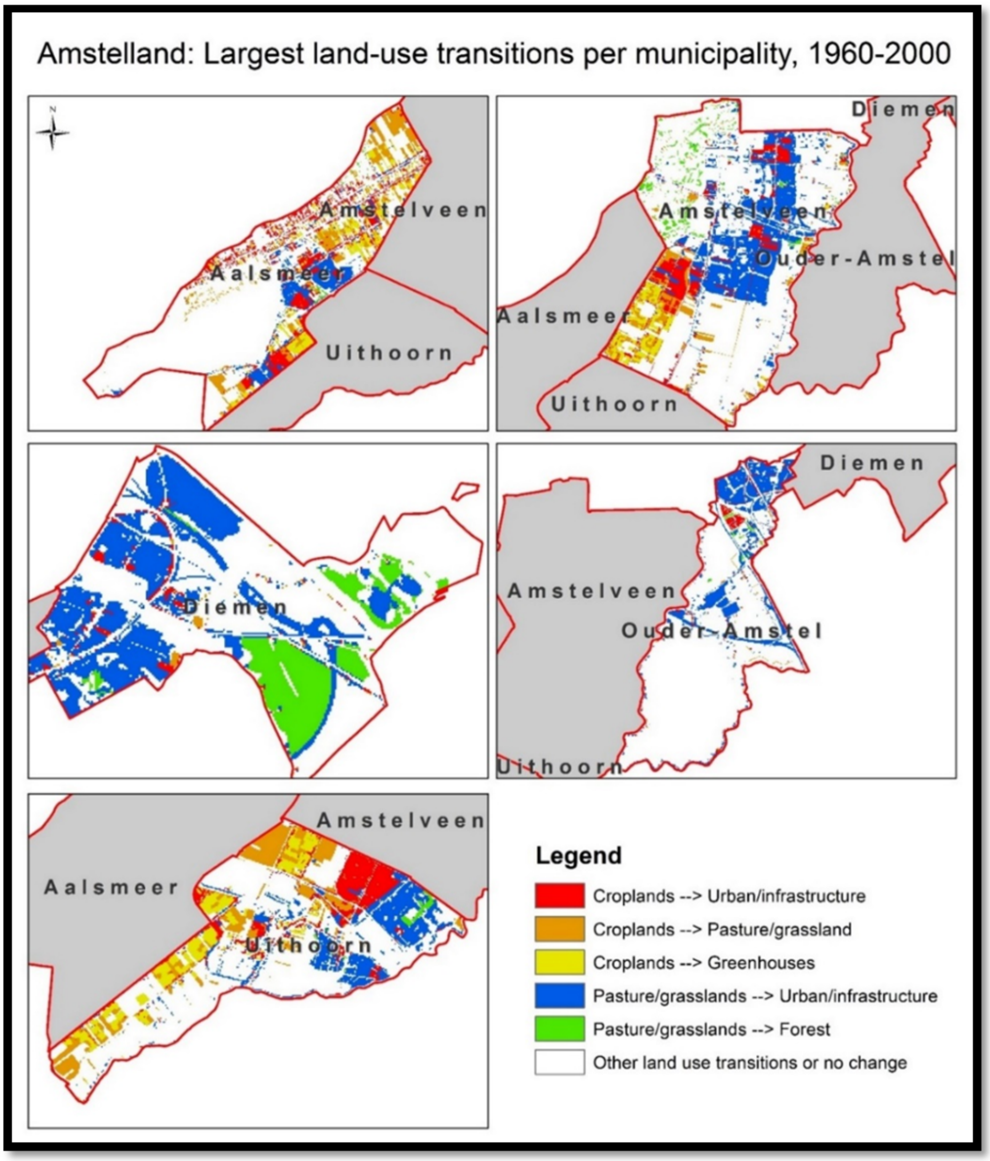

Figure 7: Largest land-use transitions Amstelland

The percentage and net change in area per land-use class are given in Table 2. The two land-use categories with the greatest net decrease were croplands and pastures, though as a percentage change the decrease in pastures is less significant. The area of urban & infrastructure increased rapidly in this period, while the percentage increase in forests and greenhouses was very large.

Table 2: Area and percentage of land-use changes Amstelland

Land use type	1960 (ha)	2000 (ha)	Percentage change in period	Total change (ha) 1960-2000	Average change (ha) per year
Water	1.808	1691	-6,5%	-117	-3
Sand	0	0	0,0%	0	0
Wetlands	47	72	53,8%	25	1
Greenhouses	149	680	**355,7%**	531	13
Pasture/grassland	6.873	5206	-24,3%	**-1.667**	**-42**
Forest	400	757	**89,1%**	357	9
Urban/infrastructure	1.332	4185	**214,1%**	**2.853**	**71**
Croplands/bare	2.850	868	**-69,6%**	**-1.983**	**-50**

2.2. Value transfer

To standardize for inflation and currency, the coefficients of the two value transfer studies used were converted to €2014 using the consumer price index to adjust for inflation (www.bls.gov) and a conversion rate of $1 = €0.73, from the date May 12th, 2014. The values for both studies after the standardization are given in Table 3.

Table 3: Value transfer coefficients after standardization

Land use type	Costanza (1997), value per hectare in €2014	Troy & Wilson (2006), value per hectare in €2014
Water	9.864	2.356
Sand	-	-
Wetlands	22.727	37.056
Greenhouses	-	-
Pasture/grassland	269	3.313
Forest	351	2.359
Urban/infrastructure	-	-
Croplands/bare	107	3.327
Conversion factor used	1,1607	0,9709

The outcomes of applying the valuations to the land-use areas of Amstelland is given in Table 4. The last row shows the total estimates for both studies and time periods, as well as the change in overall valuation. Both valuations show a large decrease in the value of ecosystem services per year. However, the valuation of Troy & Wilson shows a much larger decrease in total value. This is attributed mainly to the fact that this study values the services of croplands and pastures much higher than that of Costanza. Since losses in these land-use categories are characteristic for the region, the coefficients of Troy & Wilson result in a decrease in valuation of almost tenfold the decrease with the values of Costanza.

Table 4: Value transfer outcomes

Land use type	1960 (ha)	Costanza, 1960 value	Troy & Wilson, 1960 value	2000 (ha)	Costanza, 2000 value	Troy & Wilson, 2000 value	Costanza, change 1960-2000	Troy & Wilson, change 1960-2000
Water	1.808	€ 17.830.975	€ 4.259.736	1.691	€ 16.680.012	€ 3.984.776	-€ 1.150.962	-€ 274.959
Sand	0	-	-	0	-	-	-	-
Wetlands	47	€ 1.066.725	€ 1.739.332	72	€ 1.640.570	€ 2.675.005	€ 573.844	€ 935.673
Greenhouses	149	-	-	680	-	-	-	-
Pasture/grassland	6.873	€ 1.850.677	€ 22.767.019	5.206	€ 1.401.884	€ 17.245.972	-€ 448.793	-€ 5.521.047
Forest	400	€ 140.300	€ 944.305	757	€ 265.352	€ 1.785.980	€ 125.052	€ 841.676
Urban/infrastructure	1.332	-	-	4.185	-	-	-	-
Croplands/bare	2.850	€ 304.356	€ 9.483.356	868	€ 92.642	€ 2.886.618	-€ 211.713	-€ 6.596.737
Total valuation		€ 21.193.033	€ 39.193.747		€ 20.080.461	€ 28.578.352	-€ 1.112.572	-€ 10.615.395

Ideally, the error of the value transfer is calculated when applying the valuations to a new region, though Brouwer (2000) claims that this is rarely done. Furthermore, when such a validation test is implemented, it often shows large potential errors. Figure 8 gives the transfer error found by Brouwer in seven different studies where a validity test was performed. Due to this error, ecosystem service estimates derived from studies of factors in other regions should be considered with a high degree of skepticism.

Table 1
Transfer errors found in studies testing the validity of environmental value transfer

Study	Valuation technique[a]	Environmental good	Transfer error (%)[b]
Loomis (1992)	TC	Sport fishing	5–40 5–15
Parsons and Kealy (1994)	TC	Water quality improvements[c]	4–34 1–75
Loomis et al. (1995)	TC	Water-based recreation	– 1–475
Bergland et al. (1995)	CV	Water quality improvements[d]	25–45 18–41
Downing and Ozuna (1996)	CV	Saltwater fishing	1–34 –
Kirchhoff et al. (1997)	CV	White water rafting	24–56 6–228
Brouwer and Spaninks (1999)	CV	Biodiversity on agricultural land	27–36 22–40

[a] TC, travel cost study; CV, contingent valuation study.
[b] Minimum–maximum transfer errors found in the studies. The upper range refers to the absolute transfer errors based on unit value transfer and the lower range to the absolute transfer errors based on value function transfer.
[c] For different types of lake recreation.
[d] Primarily for use by local residents, such as recreation.

Figure 8: Transfer error study outcomes (Brouwer, 2000)

2.3. Contingent valuation

In the week of May 19th-23rd 2014, 120 contingent valuation surveys were done in the study region. Since the survey was carried out during working hours when certain groups may be underrepresented, the first step was to check how representative the sample is for Amstelland. In Table 5 is a comparison of demographic factors of the sample and population of Amstelland. Children under the age of 15 were not surveyed. Besides the discrepancy due to this, the only other large difference is the ratio of married to unmarried respondents.

Table 5: Representativeness of surveys Amstelland

Category	Percentage Amstelland	Percentage Amstelland survey	Percentage difference
Men	48,4%	45,7%	-2,7%
Women	51,6%	54,3%	2,7%
Age: under 15	17,5%	0,0%	-17,5%
Age: 15 to 20	5,8%	8,6%	2,8%
Age: 20 to 25	6,2%	5,2%	-1,0%
Age: 25 to 45	25,1%	30,2%	5,1%
Age: 45 tot 65	27,6%	30,2%	2,6%
Age: 65 +	17,8%	25,9%	8,0%
Unmarried	48,2%	37,4%	-10,8%
Married	39,4%	49,6%	10,2%
Partner	12,5%	13,0%	0,6%

The percentage of respondents who support preservation of croplands or grassland is given on the left side of Table 6. The average WTP per payment vehicle is given on the right side of the table. The percentage in favor of preservation and the average willingness to pay (WTP) were lower for the donation version of the survey.

Table 6: Percentage & WTP per payment vehicle

Land use	**% in favor of preservation by payment vehicle**		**Average WTP for all respondents by payment vehicle (per 30 ha)**		
	Tax	Donation	Tax	Donation	Both payment vehicles
Croplands	69,0%	32,1%	€ 8,21	€ 4,36	€ 6,21
Grassland	56,3%	40,7%	€ 5,67	€ 4,67	€ 5,31

Other demographic factors were compared with the average WTP and are given in Table 7. While the WTP differs per category, there is not a linear relationship visible where it might be expected, for example with increasing income or money spent on outdoor recreation. However, the number of respondents per category was extremely low. With a larger sample size, more of a relationship might be visible.

Table 7: Average WTP to preserve 30 hectares of croplands or grasslands, per factor category

Factor category	**Average WTP**	**# of respondents**
Age group: 15-20	€ 4,70	10
Age group: 20-25	€ 0,00	6
Age group: 25-45	€ 6,41	35
Age group: 45-65	€ 7,43	35
Age group: 65+	€ 4,53	30
Males	€ 6,98	53
Females	€ 4,72	63
Married	€ 6,11	57
Partner	€ 7,47	15
Single	€ 4,70	43
No children	€ 5,47	70
Children	€ 6,18	46
Income category: 0-20.000	€ 6,17	18
Income category: 20.000-30.000	€ 4,21	19
Income category: 30.000-40.000	€ 6,85	27
Income category: 40.000-50.000	€ 5,97	16
Income category: 50.000-60.000	€ 11,71	7
Income category: 60.000+	€ 5,00	6
Outdoor recreation (Euro/mo.) : <20	€ 4,63	38
Outdoor recreation (Euro/mo.) : 20-40	€ 4,67	27
Outdoor recreation (Euro/mo.) : 40-60	€ 9,20	20
Outdoor recreation (Euro/mo.) : 60-80	€ 7,42	13
Outdoor recreation (Euro/mo.) : 80-100	€ 5,00	4
Outdoor recreation (Euro/mo.) : 100+	€ 7,50	8

The next aspect analyzed was the difference between the WTP values between municipalities for croplands or grassland. These results are shown on the left side of Table 8. With the exception of Amstelveen and Diemen, large differences between croplands and grasslands were seen. Additionally, the WTP varies considerably between municipalities.

Table 8: Average WTP per municipality and net change in the area of croplands & grassland

Municipality	**Average willingness to pay per municipality (per 30 ha)**			**Net change per land-use class**	
	Croplands	Grassland	Difference in WTP	Croplands	Grassland
Aalsmeer	**€ 6,25**	€ 3,58	€ 2,67	**-772**	-21
Amstelveen	€ 5,53	€ 3,73	€ 1,80	-599	-617
Diemen	€ 5,25	€ 5,00	€ 0,25	-34	-544
Ouder-Amstel	€ 5,00	**€ 7,94**	-€ 2,94	-57	**-434**
Uithoorn	**€ 9,58**	€ 4,38	€ 5,21	**-521**	-50

On the right side of table 8 are the net changes in area for grasslands and croplands. There does appears to be a relationship between the area of a land use lost in a municipality and the willingness to pay to preserve that land use. Uithoorn, for example, has the highest WTP for croplands and a very low WTP for grassland, while this municipality lost 521 hectares of croplands and only 50 hectares of grasslands. The results for Aalsmeer are similar. Conversely, Ouder-Amstel lost 434 hectares of grasslands and had the highest WTP value for this land use. For Amstelveen and Diemen, there is little relationship to be seen.

However, these are new growth areas and newcomers may not be as familiar with changes that have taken place in the municipality.

In Table 9, the total WTP per hectare of cropland or grassland is calculated in two ways. First, the average WTP per municipality is multiplied with the population of that municipality and added (Amstelland total). Second, the overall average for Amstelland is multiplied with the total population (Amstelland average). The outcomes are very similar, though for grassland the value determined by the multiplying the population per municipality is lower. This is because Ouder-Amstel valued grasslands the highest but also has the smallest population. In 2008, the cost per hectare of agricultural land was €46.700 (Kuhlman et al. 2010). These values come very close to the cost of purchasing agricultural land and thus appear to be very high, though other costs also play a role.

Table 9: WTP values per hectare, calculated in two ways

Region	Average WTP per person, per ha		Population (2012)	Total WTP value per ha	
	Croplands	Grassland		Croplands	Grassland
Aalsmeer	€ 0,208	€ 0,119	30.364	€ 6.326	€ 3.627
Amstelveen	€ 0,184	€ 0,124	83.363	€ 15.376	€ 10.374
Diemen	€ 0,175	€ 0,167	24.935	€ 4.364	€ 4.156
Ouder-Amstel	€ 0,167	€ 0,265	13.232	€ 2.205	€ 3.503
Uithoorn	€ 0,319	€ 0,146	28.307	€ 9.043	€ 4.128
Amstelland total				€ 37.313	€ 25.787
Amstelland average	€ 0,207	€ 0,177	180.201	€ 37.283	€ 31.878

Additionally, many studies have shown that there is a large discrepancy between stated and actual willingness to pay. Mohammed (2012) outlines three methods to mitigate this *hypothetical bias* in contingent valuation. The first two are *cheap talk* to make the respondent aware of the bias and think realistically about their WTP and *uncertainty adjustment*, where respondents are asked afterwards how sure they feel in their answers. Both of these methods have shown mixed results in correcting the bias. The third method Mohammed mentions is the *pledge method*, where respondents are actually invoiced afterwards for the stated value, which is a more effective method to uncover hypothetical bias.

For example, a study by Veisten & Navrud (2006) compares the outcomes of a hypothetical payment question about preserving biodiversity and the subsequent payments made. In this study, only 32%-43.7% of the respondents agreed to pay the stated amount during the follow up. If this can be taken as indicative of the discrepancy between stated and actual WTP, the actual valuation per hectare of grassland might be between €8.251 and €13.930 and from €11.930- €16.305 for croplands.

For the total value of Amstelland with contingent valuation, the values per hectare were multiplied with the area of that land use in 2000. These valuations are given in Table 10. In addition to the base WTP values from the survey, an adjusted value of 38% of the stated value is given, which can be considered a correction for hypothetical bias.

Table 10: Adjusted WTP values

Croplands	Stated WTP	Average survey value	€ 32.361.614
		Total survey value	€ 32.387.812
	WTP adjusted for hypothetical bias	Average survey value	€ 12.297.413
		Total survey value	€ 12.307.369
Grassland	Stated WTP	Average survey value	€ 165.955.110
		Total survey value	€ 134.249.200
	WTP adjusted for hypothetical bias	Average survey value	€ 63.062.942
		Total survey value	€ 51.014.696

As Figure 9 illustrates, the WTP is dependent on scarcity of a certain landscape; scarce landscapes are valued more. Due to this, determining a valuation through stated preferences makes it impossible to apply the valuations determined in the present to land-use area of the past, as was done with the value transfer method.

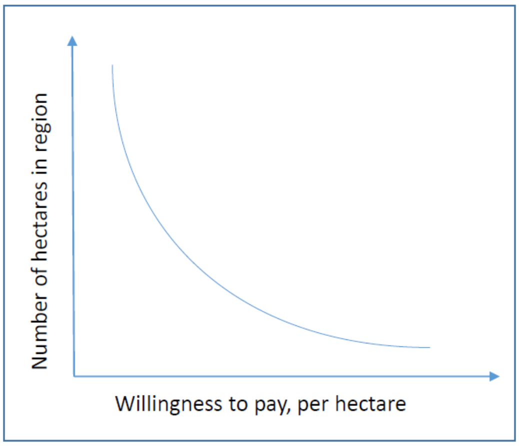

Figure 9: Relationship between scarcity and WTP

In 1960, when Amstelland was dominated by croplands and pastures, there would have been little desire to preserve it. The relationship seen between the decrease in a municipality of a certain land use and the stated WTP values highlights this issue. For this reason, the values determined through a contingent valuation survey are also only relevant for marginal future changes. However, it would be interesting to repeat the survey several years apart and explore the relationship between the WTP and the area and changes of land uses in more depth.

2.4. Pricing approach

For the pricing approach, the first step was to create a comprehensive list of ecosystem functions and the associated services and possible valuation methods. This was done by adapting the services and classification used in the published research of de Groot, Wilson & Boumans (2002) and DEFRA (2007) and is summarized in Table 11.

Some ecosystem services were assumed irrelevant for the region, such as drinking water and genetic and medicinal resources, as no use of these resources is made in the region. Other services produced in the region, such as the use of the landscape as cultural, artistic and spiritual inspiration are difficult to quantify with the pricing approach. For these, targeted contingent valuation surveys might be a better estimator. Lastly, the estimation of some services requires data that is not available at this time, for example many of the services that would make use of the factor income pricing method.

In the following section are the methods and calculations per ecosystem service, followed by a summary table of the total value of the ecosystem services included in the pricing method and the sources used for valuation.

Table 11: Ecosystem functions, services and pricing methods, priced services of this research given in green

Functions		Goods & services	Pricing methods
Provisioning	Water	Water for consumption	Direct market pricing, replacement costs
Provisioning	Medicinal resources	Drugs, chemical models & tools, test organisms	Direct market pricing, factor income, replacement costs
Provisioning	Genetic resources	Improve crop resistance to pathogens & pests	Direct market pricing, factor income
Provisioning	Raw materials/energy	Fuel, lumber, fertilizer, minerals	Direct market pricing, factor income, contingent value
Provisioning	Food	Seafood, game, crops, other animal products	Direct market pricing, factor income, contingent value
Supporting	Nutrient dispersal & cycling	Maintenance of healthy soils, productive ecosystems	Replacement cost, avoided cost, factor income
Supporting	Seed dispersal	Maintenance of productive ecosystems	Contingent value, replacement costs
Supporting	Primary production	Grass production for grazing, maintenance of productive ecosystems	Factor income, replacement costs
Supporting	Habitat & biodiversity	Maintenance of biological & genetic diversity, maintenance of commercially harvested species	Direct market pricing, contingent value, replacement costs
Regulating	Gas regulation	Carbon sequestration, Uvb-protection from O3	Avoided cost, replacement cost
Regulating	Climate regulation	Maintenance of a favorable climate	Avoided cost, replacement cost
Regulating	Air purification & detoxification	Pollution control/detoxification, dust filtration	Replacement cost, avoided cost, factor income
Regulating	Water purification	Natural water purification	Avoided cost, replacement cost
Regulating	Biological control	Control of pests/diseases, crop damage reduction	Replacement costs, factor income, direct market pricing
Regulating	Soil retention	Maintenance of arable land, prevention of damage from erosion	Avoided cost, replacement costs, factor income
Regulating	Pollination	Pollination of crops, pollination of wild vegetation	Replacement costs, factor income, avoided costs
Regulating	Soil formation	Maintenance of arable land	Avoided cost, replacement cost, factor income
Regulating	Disturbance regulation & water regulation	Storm protection, flood protection, transport medium, drainage & natural irrigation	Avoided cost, replacement cost, contingent value, direct market pricing
Cultural	Cultural (art, film, etc.)	Medium or inspiration for cultural products	Contingent value, direct market pricing
Cultural	Spiritual & historical	Heritage values, religious meaning	Contingent value, hedonic pricing, travel costs
Cultural	Recreation	Eco-tourism, outdoor sports & activities	Direct market pricing, contingent value, travel costs, hedonic pricing
Cultural	Science & education	School excursions, research	Direct market pricing, contingent value, travel costs
Cultural	Aesthetic values	Enjoyment of scenery	Contingent value, hedonic pricing, travel costs

Raw materials & energy

It is plausible that many products are gathered from the study area, such as wood from the forests with sustainable nature management or plant litter to be used as fertilizer. However, there is no data available on these flows. Instead, only the value of reed gathered from wetlands with nature management are considered. This value is given in a report by the Ministry of Agriculture, Nature & Food Quality (LNV, 2006) as an average yearly production of 250 bundles per hectare, with a value of €2 per bundle. The total calculation of this service is found in Table 12.

Table 12: Value of reed

Hectares reed	60
Bundles (per year, per ha)	250
Price per bundle	€ 2
Total value of reed	€ 30.000

Food

For food production, the largest value for the region comes from the benefits to agriculture. However, any estimation of these services from economic data would encounter some problems. First, there would have to be data available on not only the revenues, but also the inputs in both terms of cost and effect. Estimating how much of the remaining profit is due to the efforts of a specific farmer, complete with their own set of traits and practices, would prove to be impossible. Secondly, some factors that indirectly lead to food production (soil formation and net primary production) are discussed in following sections and inclusion of agriculture might have resulted in double counting.

For this section, only the ecosystem services values for wild game and fishing are estimated. For wild game, values for production of game per hectare nature and €/kg from the LNV report (2006) are used. These are average values for the entire country; the actual amount of wild game consumed in this area is unknown. For fishing, information on the weight of fish caught in the region was unavailable. Additionally, controlling for inputs and efforts would again be an issue. For this reason, the costs of fishing permits are used as a proxy for the willingness to pay for access to this resource.

Fishing permits cost between €10-€30 (www.sportvisserijnederland.nl) and the percentage of residents per municipality with fishing passes is also known (www.zorgatlas.nl). Using this information and the population per municipality (CBS.nl) an estimation is made of the total value of fishing permits. It should be noted that this value is certainly an underestimation, both because the lowest price of the fishing pass is used and because residents in outlying areas with few local fishing possibilities may purchase permits to fish in the Amstelland waters. The results for the values of game, fishing permits and total value for this ecosystem service function are given in Table 13.

Table 13: Value of fishing & game

Average game (kg/ha forest/grassland)	2,77
Number of hectares forest/grassland (not urban)	4.482
Price per kg game	€ 10
Total value game	€ 124.151
Population with fishing permit Aalsmeer	797
Population with fishing permit Amstelveen	1.635
Population with fishing permit Diemen	530
Population with fishing permit Ouder-Amstel	465
Population with fishing permit Uithoorn	773
Minimum cost fishing permit	€ 10
Total value of fishing permits	€ 42.004
Total value of fish & game	€ 166.156

Primary production

It is not possible to estimate the full benefits of primary production as the basis for most other ecosystem services. However, the production of grass is considered here as an input for grazing animals. An average cow consumes 12-18 kg of feed or grass per day (www.agrifirm.com) and under a *pasture only* scenario, 12-15 kg of the necessary feed comes from grass with between 1-3 cows per hectare. The maximum grazing period is 202 days per year (Smolders & Plomp, 2012). Two cows consuming 12 kg grass per day for 202 days a year in one hectare leads to a yearly production of 4,85 tons/ha/year. In the study region there are 5.498 cows (CBS.nl). Replacement costs per ton of alternative feed ranges from between €67,50-€120 (www.productschapakkerbouw.nl).

Using this information, there are two ways to calculate the value of grass production using the replacement cost of alternative feed. The first is to estimate only the benefit based on the number of cows in the region. The second method is to calculate the total value of all the grass produced in the region based on the area of grassland. Both methods and the outcomes are shown in Table 14.

Table 14: Value of primary production

Number of cows	5.498
Grass required per cow per day (ton)	0,012
Number of grazing days/year	202
Replacement cost (euros per ton)	€ 67,50
Total value of service	€ 899.583
Grass production per hectare per year (ton)	4,85
Hecares grassland/pasture in area	4.142
Replacement cost (euros per ton)	€ 67,50
Total value of service	€ 1.355.987

Gas regulation

The effect of carbon sequestration is examined for the ecosystem function of gas regulation, though the effect of land use on other gasses could be examined. The values of the LNV report (2006) for sequestration per land use and the market value of carbon sequestration per ton are applied to the area. The results are shown in Table 15.

Table 15: Value of carbon sequestration

Land-use class	Area per land use (ha)	Carbon sequestration (tons)	Value per ton carbon	Total value per land use
Deciduous forest	1.075	1,37	€ 49,5	€ 72.901
Coniferous forest	33	2,19	€ 49,5	€ 3.577
Grassland/pasture	5.138	2,00	€ 49,5	€ 508.662
Reed	60	6,80	€ 49,5	€ 20.196
Total value carbon sequestration (euros)				€ 605.336

Air purification & detoxification

For the category of air purification & detoxification, values for removal/filtration rates of pollutants by different land-use classes and the health costs per kg pollutant from different studies were applied to the land-use areas to estimate avoided costs. The outcomes are shown in Table 16.

The particulate matter (PM_{10}) capture rate of Oosterbaan, Tonneijck & de Vries (2006) was used. In this study, the capture rate is estimated for a study region in the Netherlands based on concentrations of PM_{10} and biological processes. Coniferous trees are not found in this study region, but are estimated to capture three times the volume of deciduous trees. Removal rates of nitrogen dioxide and sulfur dioxide from the study of Yang, Yu & Gong (2008) for the classes of grass and deciduous trees are used, with the assumption that coniferous trees remove an equal amount of this pollutant.

Health costs per kilogram PM_{10}, sulfur dioxide & nitrogen dioxide are estimated in the study of Spadara & Rabl (2000). However, the value of sulfur dioxide removal from the LNV (2006) report are applied instead for this category, because the value of removal in urban vs rural settings differs, which could provide a more precise estimate. In Spadara & Rabl, the value is €9.95/kg and in the LNV report this is €4/kg (rural) & €11/kg (urban).

Table 16: Value of air purification &detoxification

Land-use class	Area (in ha)	Particulate matter filtration (kg/ha)	Value per filtered kg PM	Total value per land use for PM filtration	Nitrogen dioxide removal (kg/ha)	Value per removed kg nitrogen dioxide	Total value per land use for nitrogen dioxide removal	Sulfur dioxide removal (kg/ha)	Vaue per removed kg sulfur dioxide	Total value per land use for sulfur dioxide removal
Grass/pasture outside urban area	4.142	18,2	€ 15,40	€ 1.161.644	23,3	€ 15,70	€ 1.515.208	6,5	€ 4,00	€ 107.694
Grass in urban area	996	18,2	€ 15,40	€ 279.329	23,3	€ 15,70	€ 364.347	6,5	€ 11,00	€ 71.214
Cropland	857	6,1	€ 15,40	€ 80.786		€ 15,70	€ 0		€ 4,00	€ 0
Deciduous forest outside urban area	263	36,4	€ 15,40	€ 147.344	35,7	€ 15,70	€ 147.164	10,1	€ 4,00	€ 10.608
Deciduous forest in urban area	462	36,4	€ 15,40	€ 259.194	35,7	€ 15,70	€ 258.876	10,1	€ 11,00	€ 51.314
Coniferous forest outside urban area	10	109,3	€ 15,40	€ 16.099	35,7	€ 15,70	€ 5.360	10,1	€ 4,00	€ 386
Coniferous forest in urban area	23	109,3	€ 15,40	€ 39.037	35,7	€ 15,70	€ 12.996	10,1	€ 11,00	€ 2.576
Forest in wetland area	12	36,4	€ 15,40	€ 6.769	35,7	€ 15,70	€ 6.761	10,1	€ 4,00	€ 487
Forest in dense urban area	351	36,4	€ 15,40	€ 196.869	35,7	€ 15,70	€ 196.627	10,1	€ 11,00	€ 38.975
Reeds	60	21,7	€ 15,40	€ 20.062	10	€ 15,70	€ 9.440		€ 4,00	€ 0
Total value per pollutant				€ 2.207.132			€ 2.516.778			€ 283.255
Total value air purification & detoxification (euros/year)							€ 5.007.165			

Water purification

Drinking water is not extracted from the surface waters of the area, but clean water is necessary, for swimming water quality among other things. The LNV report (2006) estimates values for water purification per land use for nitrogen, carbon, heavy metals and phosphorus. For phosphorus, these values are only valid if the vegetation is removed, which may not be the case in the study area. The removal of heavy metals and carbon is only relevant for around 20 years until maximum saturation is reached. For these reasons, removal of phosphorus, heavy metals and carbon is not included. For nitrogen, only removal by vegetation is estimated, though organisms in the water also lead to purification. In Table 17, the values from the report (2006) are applied to estimate nitrogen removal by vegetation for the area found within a 5 meter buffer of surface water (Top10NL map of surface water).

Table 17: Value of nitrogen removal

Land-use class	Area within 5 meters of water (ha)	Nitrogen removal (kg/ha/year)	Value of nitrogen removal (euro/kg)	Total value of nitrogen removal
Grass/pasture	1.162	20	€ 2,2	€ 51.124
Deciduous forest	214	15	€ 2,2	€ 7.046
Coniferouse forest	362	25	€ 2,2	€ 19.910
Reed	14	102	€ 2,2	€ 3.160
Total value of nitrogen removal				€ 81.240

Pollination

In the research of Sandhu, Wratten, Cullen & Case (2008), the cost of renting bee hives for pollination is used to estimate the value of this ecosystem service for crops that are dependent upon pollination. Taking a similar approach, the replacement cost is estimated with the cost of beehives rental. The suggested price for beekeepers to charge for rental is €60/hive per 3 weeks for outdoor pollination. The number of hives necessary to pollinate one hectare of crops is between €2-€10 (www.bijenhouders.nl). Since most of the pollinated crops in the region are in the lower range with regards to the number of hives, the value of pollination is estimated at €120 per hectare.

Data from CBS.nl was used to estimate the area of pollination-dependent crops in the study region. The data only lists the larger categories (e.g. fodder crops) on the municipal level. Examples of the crops that fall under these categories are found in national statistics data from CBS. Using the crop types and the research of Morse & Calderone (2000) which estimates the dependency per crop on insect pollination, dependency per category is estimated. Lastly, the area per category, the estimated percentage dependency of this crop category and the beehive rental costs per hectare are multiplied. These results are given in Table 18.

Table 18: Value of pollination

Statistics category	Crop type	Pollination dependency per crop	Estimated % of category dependent on pollination	Area (ha)	Total replacement cost of pollination
Arable farming vegetables	Beans	-	25%	133	€ 3.990
	Onions	1,0			
	Corn	-			
Fruit- open ground	Apples	1,0	50%	1	€ 60
	Pears	0,7			
	Grapes	0,1			
Horticulture	Strawberries	0,2	50%	3	€ 180
	Endive	-			
	Asparagus	1,0			
	Cauliflower	1,0			
	Lettuce	-			
Fodder	Fodder corn	-	25%	138	€ 4.140
	Fodder beets	0,1			
	Alfafa	1,0			
Total replacement costs for study region (euros/year)					€ 8.370

Soil formation

Pimentel et al. (1997) & Lavalle et al. (2006) estimate that soil invertebrates bring between 10-500 tons of soil to the surface yearly per hectare of agricultural land. Pimentel et al. further estimates that 1 ton/ha of this is new top soil. This study values each ton of newly formed soil at $12 ($1997), which is €12,93 (€2014). This price is used to estimate the value of new soil formation per hectare of agricultural land in the study region and the results of this are shown in Table 19. Soil formation is also an important ecosystem service in non-agricultural areas, but is excluded from this calculation.

Table 19: Value of soil formation

Land-use class	Area (ha)	Tons soil/ha	Value per ton (euros)	Total value (euros)
Cropland	857	1	12,93	11.078
Grass/pasture	4.142	1	12,93	53.557
Total value for soil formation				64.635

Disturbance regulation & Water regulation

The value changes in flood protection and storm water are typically calculated by estimating the total risk of an area before and after a proposed land-use change (LNV, 2006). To estimate the value of this service, the risk is first calculated for a hypothetical occurrence of flooding to 1 m NAP. The damage costs are adjusted for potential infiltration of unpaved soil, using the porosity of underlying soil as a proxy for the effect of damage reduction.

The height model used was the Algemeen Hoogtebestand Nederland (AHN) with a 100m resolution. There was a large amount of height data missing, so the following script was used in raster calculator to fill in the missing data with average values for neighboring cells (result is shown in Figure 10):

```
Con(IsNull("ahnamstel.tif"), FocalStatistics("ahnamstel.tif", NbrRectangle(15,15, "CELL"), "MEAN"), "ahnamstel.tif")
```

Figure 10: Filling of missing height data

This height raster was then subtracted from a raster of the study region with a value of 100cm to find the flooding height. Negative values (above the hypothetical flooding level) were reclassified to obtain a raster of only the inundation depth. This inundation depth raster and the land-use cover raster map of 2000 (Ruimtescanner) were inputs in the Damage Scanner model (Klijn et al,, 2007) operationalized by Vrije Universiteit, which estimates the economic damage per cell based on the inundation depth and land use. This method is illustrated in Figure 11.

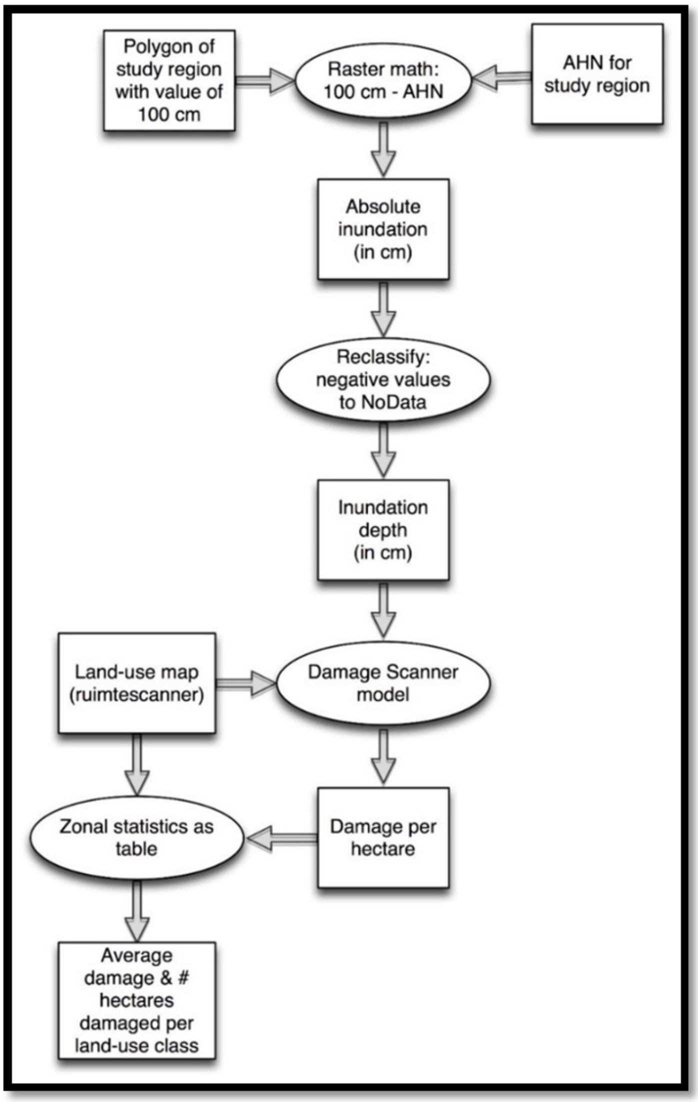

Figure 11: Method to estimate flooding damage

The damage scanner outcome was adjusted to average yearly damage based on the probability of 1:10.000 for flooding risk in the area. To estimate the benefit of unpaved soil, the percentage of soil sealing and the porosity of the soil was used. A porosity of 31% for peat and 26% for clay in another region was used Lohila et al (2003), where total porosity and the percent water-filled pore space was assumed to be similar to the study region. The percent unpaved soil and the porosity of the soil were multiplied with each other and the average yearly damage to estimate the effect of the infiltration capacity per cell. The tool *zonal statistics as table* was used to calculate the area and average damage or damage reduction per land-use class. The results are given in Table 20.

Table 20: Total yearly flooding risk and reduced damage by unpaved soil, with 1 m flooding scenario

Land-use class	Hectares affected	Average damage per hectare	Total damage per category	Hectares with reduced damage	Average reduced damage per hectare	Total reduced damage per category
Residential- High density	1.153	€ 393	€ 453.129	409	€ 54	€ 22.086
Residential- low density	1.749	€ 224	€ 391.776	770	€ 39	€ 30.030
Residential- rural	17	€ 138	€ 2.346	15	€ 36	€ 540
Recreation	271	€ 20	€ 5.420	218	€ 6	€ 1.308
Commercial	453	€ 297	€ 134.541	189	€ 56	€ 10.584
Nature/forest	765	€ 14	€ 10.710	601	€ 4	€ 2.404
Arable land	1.340	€ 16	€ 21.440	1.131	€ 4	€ 4.524
Grassland	3.890	€ 9	€ 35.010	3.688	€ 2	€ 7.376
Greenhouses	975	€ 67	€ 65.325	887	€ 10	€ 8.870
Zero grazing	4	€ 23	€ 92	4	€ 4	€ 16
Infrastructure	230	€ 113	€ 25.990	150	€ 25	€ 3.750
Total	10.847		€ 1.145.779	8.062		€ 91.488

This is an overly simplistic method to apply to flooding, since factors such as the speed of flooding and maximum infiltration capacity are not taken into account. Additionally, a flooding scenario is highly unlikely in the region, even though infiltration is important by any heavy rainfall. However, since the Damage Scanner model (Klijn et al. 2007) was developed to calculate changes in risk based on future scenarios, it would be easy to apply the model to proposed changes in an area to make comparisons.

Recreation

Direct market values for recreation are estimated based on the values given by the LNV report (2006) for profits and/or travel costs of day recreation and overnight stays, the number of hectares of natural area and information about the number of visitors in Groengebied Amstelland and the Amsterdamse Bos (www.groengebied-amstelland.nl & www.amsterdamsebos.nl).

Only the number of visitors for Groengebied Amstelland and Amsterdamse Bos are known, leaving out the recreation values for a large part of the study region. Additionally, the type of recreation for these visitors is unknown, while the LNV differentiates between the profits and travel costs for different types of day recreation (swimming, biking and walking). The lowest value (for walking visitors) is applied to the entire number of visitors. For the value of overnight stays, the average number of overnight stays per hectare nature and average profit per stay for the region "Utrecht/North Holland lake area" are applied, based on the information given in the LNV report. The estimated value of day recreation and overnight stays are given in Table 21.

Table 21: Total recreation value

Number of visitors for day recreation	9.291.000
Profit + travel costs per recreant	€ 0,15
Total value day recreation	€ 1.412.232
Number of overnight stays per ha nature	21
Profit per overnight stay	€ 1,27
Hectares nature in study area	4.494
Total value overnight stays	€ 119.761
Total value recreation	€ 1.531.993

Total valuation

The lowest value of each of the above estimated services are added to give the total value of ecosystem services in the area and are shown in Table 22. Additionally, where possible, the contribution to the values by only croplands or grasslands/pastures is estimated.

Table 22: Overall ecosystem service valuation with pricing approach & sources used for estimations

Ecosystem service	Total value per ecosystem service	Total value for only grasslands/pastures	Total value for only croplands	Sources used for estimations
Raw materials/energy	€ 30.000	€ 0	€ 0	Ministerie van LNV (2006), LGN2000
Food	€ 166.156	€ 114.733	€ 0	Ministerie van LNV (2006), LGN2000, www.sportvisserijnederland.nl, www.zorgatlas.nl, CBS.nl
Primary production	€ 899.583	€ 899.583	€ 0	Smolders & Plomp (2012), www.agrifirm.com, www.productschapakkerbouw.nl, CBS.nl, LGN2000
Gas regulation	€ 605.336	€ 508.662	€ 0	Ministerie van LNV (2006), LGN2000
Air purification & detoxification	€ 5.007.165	€ 3.499.436	€ 80.786	Oosterbaan, Tonneijck & de Vries (2006), Yang, Yu & Gong (2008), Spadara & Rabl (2000), Ministerie van LNV (2006), LGN2000
Water purification	€ 81.240	€ 51.124	€ 0	Ministerie van LNV report (2006), LGN2000, Top10NL
Pollination	€ 8.370	€ 0	€ 8.370	www.bijenhouders.nl, Morse & Calderone (2000) , CBS.nl
Soil formation	€ 64.635	€ 53.557	€ 11.078	Pimentel et al. (1997) , Lavalle et al. (2006) , LGN2000
Disturbance & water regulation	€ 91.488	€ 7.376	€ 4.524	AHN, Land-use cover map 2000 (Ruimtescanner), Lohila et al (2003) , Damage Scanner model operationalized by the Vrije Universiteit (Klijn et al. 2007)
Recreation	€ 1.531.993	€ 0	€ 0	Ministerie van LNV (2006) , LGN2000, www.groengebied-amstelland.nl, www.amsterdamsebos.nl
All ecosystem services	€ 8.485.966	€ 5.134.471	€ 104.758	

2.5. Valuation comparison

In Table 23, the total valuation from each of the methods is given. For the contingent valuation, the total value only consists of the land uses grassland and croplands. Additionally, these values are the lower values adjusted for hypothetical bias. Despite this, the contingent valuation has the highest total value. There are two factors that could account for this outcome. The first is that the contingent valuation takes into account all of the ecosystem services, including ones that are more difficult to account for with other methods, such as the historic or aesthetic values that locals benefit from. If this method is the most complete, it makes sense for it to be the highest. The second factor is that the WTP values are being applied to a larger area of land than was considered by the respondents. If the scale of preserved land in the contingent valuation survey scenario was ten times greater, it is unlikely that the willingness to pay would be ten times higher.

The pricing approach has the lowest total estimation. This is largely due to the number of ecosystem services that were not possible to estimate on the basis of available data. Furthermore, in any situation where a range of values was possible to apply, the lowest values were used. Due to this, it is surprising that the pricing approach still produced a higher valuation for croplands & grassland/pasture than the value transfer coefficients of Costanza (1997).

The outcomes of the value transfer method lie between that of the of the contingent valuation and the pricing approach valuations. The outcomes of the two value transfer studies for *grassland/pasture* and *croplands* are extremely different; for Troy & Wilson they account together for 70% of the value, while for Costanza this is only 7%. For the pricing approach, around 62% of the value is attributed to these land-use classes. For this reason, it is likely that the pricing approach and the value transfer approach of Troy & Wilson would provide a similar outcome, had the pricing approach been more complete in estimating all of the ecosystem services.

Table 23: Valuation method outcome comparison

Land-use class	Value transfer method: Costanza (1997)	Value transfer method: Troy & Wilson (2006)	Contingent valuation (CV)	Pricing approach
Total value grassland/pasture only	€ 1.401.884	€ 17.245.972	€ 51.014.696	€ 5.134.471
Total value croplands only	€ 92.642	€ 2.886.618	€ 12.297.413	€ 104.758
Total value all land-use classes (only crops & grasslands for CV)	€ 20.080.461	€ 28.578.352	€ 63.312.109	€ 8.485.966

3. Discussion

3.1. Application and performance

In general, one weakness of applying any of these valuation methods to analyze the land-use change impacts is that none of them take into consideration the issues of scale and proximity; these are especially relevant for ecosystem services related to levels of biodiversity. Another weakness is that working with low-resolution land-use maps that show the predominant class per area leads to small-scale elements being excluded. The effects of small rows of trees or small water elements for example are not examined. However, the trade-off is that analyzing the values of ecosystem services while considering scale, proximity and small-scale elements adds a high degree of complexity and requires detailed data.

For each of the methods, some of the issues related to application and performance for the purpose of analyzing the impacts of land-use changes on ecosystem services are detailed below.

Value transfer

The value transfer coefficients were the simplest to apply to land-use changes, but the accuracy of applying valuations from other regions is questionable. In the study of Costanza (1997), for example, the estimation was made based on global averages, while estimates of global average values are not particularly relevant for most areas. For example, Costanza values water very highly which is appropriate on a global scale, but less suitable in Amstelland where water is plentiful. For Amstelland, the coefficients of Costanza resulted in a lower value for cropland & grasslands than that of the pricing approach, which did not estimate all of the services of the region. The value transfer outcomes of Troy & Wilson were for the state of Massachusetts, which is more similar to Amstelland, for example in the importance of croplands and grassland and the proximity of urban areas. For this reason, these coefficients probably provide a better estimate, but should still be considered with some skepticism.

Contingent valuation

Contingent valuation is relatively easy to apply and for some ecosystem services may be the most suitable valuation method, assuming hypothetical bias is sufficiently taken into account. On one hand, the performance of this method could be high for analyzing impacts as it looks specifically at relative changes. On the other hand, this method has limitations in the application of valuations for small changes to large-scale changes. A possibility for controlling for this issue would be to design a survey in which respondents are given a scenario preserving different areas of a land-use to determine a more accurate valuation per hectare. Additionally, though it relies on far fewer assumptions than other methods, it does rely on the assumption that respondents understand what their relative preferences are.

Pricing approach

The pricing approach was the most difficult method to apply and due to lack of data also the most incomplete. Applying this method to analyze land-use changes would prove difficult as the valuations of ecosystem services depend on a number of different factors, not just the areas of land-use classes. However, this method does not suffer from the problems of applicability of value transfer coefficients or the subjectivity of the contingent valuation. Additionally, this method provides the possibility of including small-scale elements and scale as factors to determine the valuation. Inputs of time and data are the largest limiting factors for the performance and applicability of this method.

3.2. Reflection on method

The largest weakness in applying and analyzing these valuation methods, particularly for the value transfer and pricing approach, was the lack of detailed data and data on different temporal scales. For the pricing approach, this led to many unpriced ecosystem services. Another weakness was the amount of proxy data that was assumed to be representative of the value of services, for example, the value of fishing passes as a proxy for the value of fish.

The contingent valuation method produced a surprisingly large valuation when applied to the study area and population. There are limitations when applying this method to a larger scale than is considered by respondents and this is certainly an important weakness in the outcomes. This method may be better suited for valuation of one specific ecosystem service, with regards to one land-use transition, which is easier for respondents to consider.

In a follow-up study, controlling for the mentioned weaknesses of all the methods should be implemented. These include examining the transfer error of the value transfer coefficients, controlling for hypothetical bias in the contingent valuation and including small scale-elements, scale and proximity as factors in the pricing method.

4. Conclusion

The research question was: *How well can the ecosystem service valuation methods of value transfer, contingent valuation and the pricing approach perform for the area Amstelland in assessing the impact of land-use changes?* In the results, the methods are applied to value the ecosystem services and the strengths and weaknesses of these methods are specified. In the discussion, the issues of application (ease of method and input requirements of time and data) and performance (validity, sources of error and practicality) of the methods are considered.

The value transfer approach has the easiest application and in some cases applying average values for another study area to a new region may be sufficient to provide some insight in certain situations. However, the area where the values were derived should share characteristics with the new study area. Additionally, the potential errors should be examined and communicated where possible.

Relative to the value transfer approach, the contingent valuation approach requires more time and is more difficult to apply. Deriving valuations directly from the area in question increases the validity and thus the performance. However, valuations derived this way are only practical for areas on the temporal and spatial scale considered by the respondents and cannot be credibly extrapolated outside this range. This makes contingent valuation more suitable for small-scale changes that involve few different interrelated aspects, for example by the analysis of impacts related to one specific project.

The pricing approach costs the most time and effort to apply which means that application is difficult, especially when increasing the complexity to provide more accurate estimates. Data availability forms the largest obstacle. On the other hand, the accuracy of the pricing approach could be highest. Furthermore, the flexibility of this method allows for analysis of complex or large-scale changes.

In conclusion, any of these methods could perform well in estimating the impacts of land-use changes, depending on the context for application, though the outcomes should not be considered a precise monetary value. Conclusions based on these estimations should only be made in conjunction with awareness of the limitations and assumptions of each method.

References

Literature

- Atkinson, G., Bateman, I. & Mourato, S. (2012) Recent advances in the valuation of ecosystem services & biodiversity. *Oxford Review of Economic Policy*, 28 (1), 22-47.
- Brouwer, R. (2000) Environmental value transfer: state of the art and future prospects. *Ecological Economics*, 32, 137-152.
- Costanza, R., d'Arge, R., de Groot, R., Farberk, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Suttonkk, P. & van den Belt, M. (1997) The value of the world's ecosystem services & natural capital. *Nature*, 387.
- Department for Environment, Food and Rural Affairs (DEFRA) (2007) An introductory guide to valuing ecosystem services. London: DEFRA.
- de Groot, R., Wilson, M., Boumans, R. (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41, 393–408.
- Haartsen, A. & Brand, N. (2005) *Amstelland: land van water and veen*. Utrecht: Stuurgroep Toekomst Amstelland.
- Klijn, F., Baan, P., De Bruin, K.M. & Kwadijk, J. (2007) *Overstromingsrisico's in Nederland in een veranderend klimaat: verwachtingen, schattingen en berekeningen voor het project Nederland Later*. WL Delft Hydraulics, Report Q4290.00.
- Kuhlman,T, Luijt, J, Van Dijk, J, Schouten, AD, and Voskuilen, MJ (2010) *Grondprijskaarten 1998-2008*. Wettelijke Onderzoekstaken Natuur & Milieu report 185. Den Haag: LEI Wageningen UR.
- Lavelle, P., Decaëns, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., ... & Rossi, J. P. (2006). Soil invertebrates and ecosystem services. *European Journal of Soil Biology*, 42, S3-S15.
- LNV, Ministry of Agriculture, Nature & Food Quality (Ministerie van landbouw, natuur & voedselkwaliteit) (2006) *Kentallen waardering natuur, water, bodem en landschap: Hulpmiddel bij MKBA's*. Rotterdam: LNV.
- Lohila, A., Aurela, M., Regina, K. & Laurila, T. (2003) Soil and total ecosystem respiration in agricultural fields: effect of soil & crop type. *Plant & Soil*, 251, pp. 303-317.
- Mohammed, E. (2012) Contingent valuation responses and hypothetical bias: mitigation effects of certainty question, cheap talk, and pledging. *Environmental Economics*, 3 (3), 62-71.
- Morse, R. & Calderone, N. (2000) The value of honey bees as pollinators of U.S. crops in 2000. *Bee Culture,* 128, 1-15.
- Oosterbaan, A., Tonneijck, A.E.G. & de Vries, E.A. (2006) *Kleine landschapselementen als invangers van fijn stof en ammoniak.* Alterra-rapport 1419. Wageningen: Alterra.
- Overbeek, G., de Graaff, R. & Selnes, T. (2011) *Investeren in landschap: lessen uit de gebiedsprocessen in Amstelland, Binnenveld, Het Groene Woud & Ooijpolder-Groesbeek*. Landbouw Economische Instituut (LEI) report. Wageningen & Den Haag: LEI.
- Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., ... & Cliff, B. (1997). Economic and environmental benefits of biodiversity.BioScience, 47(11), 747-757.
- Sandhu, H., Wratten, S., Cullen, R., & Case, B. (2008). The future of farming: the value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecological Economics*, 64(4), 835-848.
- Smolders, G. & Plomp, M. (2012) Weiden van biologisch melkvee. Hoe langer hoe beter? Wageningen UR Livestock Research, report #594. Lelystad: Wageningen UR.
- Spadaro, J. & Rabl, A. (2000) Air Pollution Damage Estimates: the cost per kg of pollutant. *International Journal of Risk Assessment and Management*, 3(1), 75-98.
- Troy, A. & Wilson, M. (2006) Mapping ecosystem services: Practical challenges and opportunities in linking GIS & value transfer. *Ecological economics*, 60, 434-449.
- Veisten, K & Navrud, S. (2006) Contingent valuation and actual payment for voluntarily provided passive use values: assessing the effect of an induced truth-telling mechanism and elicitation formats. *Applied Economics*, 38, 735-756.

- Yang, J., Yu, Q. & Gong, P. (2008) Quantifying air pollution removal by green roofs in Chicago. *Atmospheric Environment*, 42(31), 7266-7273.

Websites

- http://www.agrifirm.com/agrifirm-feed/melkvee/nieuws/detail/listitemid/3144#.U5g8tfmSxpU (consulted on 09-06-2014)
- http://www.amsterdamsebos.nl/organisatie/feiten-cijfers/ (consulted on 05-06-2014)
- http://www.bijenhouders.nl/bijenwerk/bestuiving/bestuivingsadvies-2014 (consulted on 09-06-2014)
- http://www.bijenbestuiving.nl/hoeveel_bijenvolken_zijn_er_nodig_voor_bestuiving (consulted on 09-06-2014)
- http://www.bls.gov/data/inflation_calculator.htm, United States Department of Labor. Consumer price index calculator, (consulted on 08-06-2014)
- http://statline.cbs.nl/statweb/?LA=nl (consulted on various dates between 05-05-2014 to 09-06-2014)
- http://www.groengebied-amstelland.nl/content/content.asp?menu=02900005_000000 (consulted on 05-06-2014)
- http://www.productschapakkerbouw.nl/teelt/marktprijzen/5 (consulted on 09-06-2014)
- http://www.sportvisserijnederland.nl/vispas/?page=vispas (consulted on 07-06-2014)
- http://www.zorgatlas.nl/thema-s/sporten-en-bewegen/sportdeelname/sportvissen-per-gemeente/ (consulted on 07-06-2014)

Spatial data sources & models

- AHN: Actual height data set of the Netherlands (Algemeen Hoogtebestand Nederland)
- Damage Scanner: Defined by Klijn et al. (2007) listed above and operationalized by the Vrije Universiteit
- Digital soil map of the Netherlands (Bodemkaart van Nederland), available from Alterra at http://maps.bodemdata.nl/bodemdatanl/index.jsp
- HGN1960: Historic land use of the Netherlands (Historisch Grondgebruik Nederland)
- LGN2000: National land-use data set of the Netherlands (Landelijk Grondgebruiksbestand Nederland)
- Land-use Scanner map 2000 (Ruimtescanner 2000)
- Soil sealing map of the Netherlands: available from the European Environment Agency at http://www.eea.europa.eu/data-and-maps/data/eea-fast-track-service-precursor-on-land-monitoring-degree-of-soil-sealing
- Top10NL 2009 (surface water vector data), available from Kadaster at http://www.kadaster.nl/web/artikel/productartikel/TOP10NL.htm

Attachments

Contingent valuation survey

Respondents were all asked the following general questions:

Age	
15-20	☐
20-25	☐
25-45	☐
45-65	☐
65+	☐
Prefer not to answer	☐

Marital status	
Married	☐
Partner	☐
Single	☐
Prefer not to answer	☐

Income (yearly)	
0-20.000	☐
20.000-30.000	☐
30.000-40.000	☐
40.000-50.000	☐
50.000-60.000	☐
60.000+	☐
Prefer not to answer	☐

Children at home?	
Yes	☐
No	☐
Prefer not to answer	☐

Gender	
Male	☐
Female	☐

Area code of residence: ______________________

Estimated average amount spent per month on outdoor recreation (for example bike or boat rental, camping, travel costs or restaurants/cafes in nature areas:

<€20 €20-€40 €40-€60 €60-€80 €80-€100 € 100+

Then, respondents were given one of the following questions and shown the map of relevant land-use changes in Amstelland between 1960-2000 (figure 7):

1. Version grassland/tax

In the Amstelland region since 1960, grassland & pastures have decreased by around 1.700 hectares, largely replaced by urban land uses or greenhouses. An average of around 42 hectares per year is lost (close to the size of 60 football fields). Some people want to preserve the grasslands & pastures because they are culturally & historically relevant for the region, provide recreation possibilities and other ecosystem services. How important do you find the grassland & pastures for the region Amstelland (1-5, 1 is not important at all and 5 is extremely important): _____________

Would you support a proposed tax that would help to preserve 30 hectares (around the size of 45 football fields) of the grasslands & pastures per year in Amstelland? This would mean reducing the amount of this land lost from 42 hectares per year to 12 hectares per year.

YES NO

Which of the following amounts would you be willing to pay as an additional yearly tax in order to provide the resources necessary to reduce the loss of grasslands and pastures in Amstelland by 50 hectares a year?

€0.25 € 0.50 €1 €2 €3 €5 €10 €15 € 20 More than €20

2. Version croplands/tax

In the Amstelland region since 1960, croplands have decreased by around 2.000 hectares. This averages out to around 50 hectares per year (around the size of 75 football fields per year). Some people want to preserve the croplands because they are culturally & historically relevant for the region, provide recreation possibilities and other ecosystem services. How important do you consider croplands for the region of Amstelland? (1-5, 1 is not important and 5 is very important) _______

Would you support a proposed tax that would help to preserve 30 hectares (an area of around 45 football fields) of the croplands per year in Amstelland? This would mean reducing the amount of this land lost from 50 hectares per year to 20 hectares per year.

YES NO

Which of the following amounts would you be willing to pay as an additional yearly tax in order to provide the resources necessary to reduce the loss of croplands in Amstelland by 30 hectares a year?

€0.25 € 0.50 €1 €2 €3 €5 €10 €15 € 20 More than €20

3. Version croplands/donation

In the Amstelland region since 1960, croplands have decreased by 2.000 hectares. This averages out to around 50 hectares per year (around the size of 75 football fields per year). Some people want to preserve the croplands because they are culturally & historically relevant for the region, provide recreation possibilities and other ecosystem services. How important do you consider croplands for the region of Amstelland? (1-5, 1 is not important and 5 is very important) _______

Would you consider yourself willing to make a yearly donation to preserve 30 hectares of croplands per year (an area of around 45 football fields). This would mean reducing the amount of this land lost from 50 hectares per year to 20 hectare per year.

YES NO

If so, what amount would you be willing to contribute yearly to do so?

€0.25 € 0.50 €1 €2 €3 €5 €10 €15 € 20 More than €20

4. Version grass/donation

In the Amstelland region since 1960, grassland & pastures have decreased by around 1.700 hectares, largely replaced by urban land uses or greenhouses. An average of around 42 hectares per year is lost (close to the size of 60 football fields). Some people want to preserve the grasslands & pastures because they are culturally & historically relevant for the region, provide recreation possibilities and other ecosystem services. How important do you find the grassland & pastures for the region Amstelland (1-5, 1 is not important at all and 5 is extremely important): ____________

Would you consider yourself willing to make a yearly donation to preserve 30 hectares (around the size of 45 football fields) a year of grasslands and pastures? This would mean reducing the amount of this land lost from 42 hectares per year to 12 hectares per year.

YES NO

If so, what amount would you be willing to contribute yearly to do so?

€0.25 € 0.50 €1 €2 €3 €5 €10 €15 € 20 More than €20