PLUREL

Land Use Relationships
In Rural-Urban regions

Module 2

June 2010

PERI-URBAN LAND USE RELATIONSHIPS – STRATEGIES AND SUSTAINABILITY ASSESSMENT TOOLS FOR URBAN-RURAL LINKAGES, INTEGRATED PROJECT, CONTRACT NO. 036921

D2.4.3a

Land use projections based on Moland output

Part A: The Hague test case

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Document status:

Draft:	completed
Submitted for internal review:	completed
Revised based on comments given by internal reviewers:	completed
Final, submitted to EC:	completed

SIXTH FRAMEWORK PROGRAMME

Contents

Contents 1

List of figures 2

List of tables 4

Abstract 6

Objectives 6

Methodology 6

Results 6

1. Introduction 7

2. Study site 7

2.1 Deviations from original plans 9

2.2 Legend 10

3. Model set-up and calibration 12

3.1 Data preparation 13

3.1.1 Land use 14

3.1.2 Zoning 16

3.1.3 Suitability 20

3.1.4 Transportation and accessibility 22

3.2 Calibration 23

3.3 Scenario descriptions 27

3.3.1 Business as usual 28

3.3.2 Peak oil 29

3.3.3 Fragmentation 30

3.3.4 Baseline scenario configurations 30

3.4 Strategies 31

3.4.1 Configuration, Strategy 1 32

3.4.2 Configuration, Strategy 3 34

3.4.3 Configuration, strategy 4 35

4. Results 36

4.1 Business as Usual 37

4.2 Peak Oil (B1) 41

4.3 Fragmentation (B2) **43**

4.4 Scenario comparisons **46**

4.5 Change statistics for RUR divisions **58**

4.6 Strategies (policy alternatives) **59**

Annex A 62

Annex B 65

Annex C 68

List of figures

Figure 1. Representation of the underlying tasks behind running scenarios in Moland. 7

Figure 2. The two main settlements of the South-Holland province 9

Figure 3. Raw data for 1995 provided was transformed to 100m resolution and with a shortened, aggregated legend. 14

Figure 4. Raw data for 2004 provided was transformed to 100m resolution and with a shortened, aggregated legend. 15

Figure 5. The zoning map provided for the South-Holland province........ 16

Figure 6. The conflict between different sources of data requires adjustment before ingestion into the model. In this example, the conflict between Natura 2000 designated areas, the zoning map for the post and the current land use for the port area........17

Figure 7. Areas which are urban according to the 2004 land use maps sometimes conflict with protected areas according to the zoning maps. In these cases, the urban areas are allowed to stay but not expand further into protected areas. 19

Figure 8. The digital elevation model provided (left) was replaced by the SRTM dataset 21

Figure 9. The suitability map for arable land provided by Alterra, whereby 1=least suitable and 10=most suitable........ 21

Figure 10. The transportation network for Leiden, a city within the test case area. 22

Figure 11. The accessibility map for urban areas, used for the calibration and the BAU and B2 scenarios. 24

Figure 12. Adapted SRES scenario key variables (taken from d1.3.2.)........ 27

Figure 13. The trends in population for the test case used to configure the three baseline scenarios. 31
Figure 14. The horizontal and vertical configuration rules for three policy strategies. 32
Figure 15. The map used to configure Strategy 3 represents parcels eligible for and receiving subsidies for the Green and Blue Services initiative for the BAU scenario. 35
Figure 16. The map used to configure Strategy 4 represents parcels adhering to the Agrarian Banking System for the BAU scenario. 36
Figure 17. The original map from 2004 and the resulting land use map for the business as usual scenario for 2040. 38
Figure 18. The resulting land use map for the peak oil (B1) scenario for 2040. .. 41
Figure 19. The resulting land use map for the fragmentation (B2) scenario for 2040. 44
Figure 20. The difference maps showing the areas that are equal and those that are unequal between the three baseline scenarios and associated kappa coefficients for each couple. 47
Figure 21. A zoom on the abandoned airport in the NW part of the province. 48
Figure 22. A zoom on The Hague region, differences in model outcome............ 49
Figure 23. A zoom on the Rotterdam port region, differences in model outcome 50
Figure 24. A zoom on the NNE part of the province, differences in model outcome 51
Figure 25. Differences in the greenhouses class for the three baseline scenarios. 53
Figure 26. Differences in the pasture class for the three baseline scenarios........ 54
Figure 27. Differences in the work locations class for the three baseline scenarios. 55
Figure 28. Differences in the urban class for the three baseline scenarios. 56
Figure 29. Differences in the vacant land class for the three baseline scenarios. 57
Figure 30. The RUR typology and NUTS 3 regions of the South-Holland province 59
Figure 31. The differences for the BAU baseline scenario and the 3 strategies on land use for 2040.. 60

Figure 32. The differences for the B1 baseline scenario and the 3 strategies on land use for 2040....60
Figure 33. The differences for the B2 baseline scenario and the 3 strategies on land use for 2040.... 61

List of tables

Table 1. The land use legend for The Hague test case....11
Table 2. The model parameter set up for The Hague test case.... 12
Table 3. Data used for calibration of Moland urban land use model for The Hague region 13
Table 4. A summary of zoning map classes 18
Table 5. The layers integrated into the suitability maps....20
Table 6. Accessibility parameters used to build accessibility maps for calibration, the business as usual and the B2 scenarios....23
Table 7. Calibration results for two bogus runs and the calibration run....25
Table 8. Past and projected trends in employment per economic sector for South Holland province for the 3 baseline scenarios 30
Table 9. The stakeholder definition of the Green and Blue Services strategy (Strategy 3) in terms of parcels adhering to the initiative and subsidies received per hectare....34
Table 10. The stakeholder definition of the Land banking strategy (Strategy 4) in terms of parcels adhering to the initiative and percent farmers adhering to the initiative....35
Table 11. The changes in land use classes from 2004-2040 for the BAU scenario. 39
Table 12. The expansion of residential areas for the BAU scenario between 2004 to 2040....39
Table 13. The expansion of non-residential areas for the BAU scenario between 2004 to 2040....39
Table 14. The farmland land use changes for the BAU scenario for 2040....40
Table 15. The results of the categorical land use change analysis for the BAU scenario, corrected for the probability factor in a random model....40
Table 16. The changes in land use classes for the B1 scenario, from 2004 to 2040. 42
Table 17. The changes in residential urban surfaces for the B1 scenario 42
Table 18. The changes in non-residential urban surfaces for the B1 scenario 42

Table 19. The changes in farmland for the B1 scenario..43
Table 20. The results of the categorical land use change analysis for the B1 scenario, corrected for the probability factor in a random model........................43
Table 21. The changes in land use classes from 2004-2040 for the B2 scenario. 45
Table 22. The expansion of residential urban surfaces for the B2 scenario between 2004 to 2040. 45
Table 23. The expansion of non-residential urban surfaces for the B2 scenario between 2004 to 2040. 45
Table 24. Change in nature and farmland classes...46
Table 25. The results of the categorical land use change analysis for the B2 scenario, corrected for the probability factor in a random model........................46
Table 26. The overall changes in land use classes for each of the scenarios. 52
Table 27. The percent change of grouped land use classes according to theme for the RUR divisions...58
Table A1. The suitability layers are compared to the land use layers using a contingency table. The percent land use occupying the area of the suitability class (normalized by total area of that class) of the percent...62
TableB1. Probability statistics of simulation results *i* given the original land use type *j*..65
Table B2. Probability that actual land use is *i* given the original land use type is *j* 66
Table B3. Probability of agreement results between simulation and actual data for simulated year, given the initial land use 67
Table C1. Statistics for the Business as usual scenario for 2040 per RUR region (m^2) 68
Table C2. Statistics for the B1 scenario for 2040 per RUR region (m^2) 68
Table C3. Statistics for the B2 scenario for 2040 per RUR region (m^2)............69

Abstract

Objectives

The objective of this test case series is to produce scenario runs for different test cases using the MOLAND land use model. Each test case is unique in its geography, society and policy choices. The land use model handles each test case independently with unique datasets as provided by Alterra. A list of common indicators was designed in order to ensure the inter-comparability of the eclectic set of cases. In this paper, a stand-alone draft for now, which will eventually be amalgamated with other test cases, we look at the behaviour of the South-Holland province (aka “The Hague test case”, although many cities are a part of the test case area) according to three scenarios. Each of these scenarios is run on its own and with three “strategies” or policy alternatives, for a total of 12 model runs.

Methodology

Three scenarios were run for the South-Holland province (Netherlands) from 2004 to 2040: ‘Business as usual’, ‘Peak oil’ (B1) and ‘Fragmentation’ (B2). The parameters for the scenarios were set in collaboration with local stakeholders at several meetings spanning 2008-2010. Three of four strategies defined by the stakeholders were also run on top of these scenarios. Strategy 1 refers to 80% of new construction happening in already existing urban areas and is run by allowing construction of new residences inside of the already existing urban fabric. Strategy 2 is the “Discourse development” whereby making green space important is emphasized. This strategy is not included in the scenarios. The third strategy refers to green and blue services. This strategy is run using arbitrarily chosen parcels of a given percentage (stipulated by Alterra). The fourth and final strategy, referring to the Agrarian banking system, is also run using arbitrarily selected parcels as part of the incentives. The number of parcels used in this scenario was dependant upon the number stipulated by Alterra.

The methodological sequence included discussions with stakeholders, data acquisition and manipulation, ingestion into the Moland model and calibration; and scenario parameter setting and running. The final step was to extract statistics from the results and to prepare the data for export to allow stakeholders to perform their own analyses.

Results

Results in this report show the statistical differences between the three different baseline scenarios and their three “strategies”, or policy alternatives. Only the differences in the baseline scenarios are shown spatially, but differences in all combinations are shown graphically.

Classification of results / outputs:
For the purpose of integrating the results of this deliverable into the PLUREL Explorer dissemination platform as fact sheets and associated documentation please classify the results in relation to spatial scale; DPSIR framework; land use issues; output indicators and knowledge type.

Spatial scale for results: Regional, national, European	Regional
DPSIR framework: Driver, Pressure, State, Impact, Response	Driver/Pressure/State/Impact/Response
Land use issues covered: Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation	Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation
Scenario sensitivity: Are the products/outputs sensitive to Module 1 scenarios?	Yes
Output indicators: Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions	None
Knowledge type: Narrative storylines; Response functions; GIS-based maps; Tables or charts; Handbooks	GIS-based maps; tables and charts

How many fact sheets will be derived from this deliverable:	**1**

1. Introduction

Moland is a land use modelling tool used within the PLUREL project context to model the dynamic urban expansion for selected case studies. Based on cellular automata, the model is able to capture the complexity and random nature of urban growth and its implications on peri-urban and rural land while being able to handle large geographical areas. The model is described in detail elsewhere (Barredo *et al*, 2003; Walsh & Twumasi, 2008; Petrov *et al* 2009).

Moland requires a good knowledge of the principles driving the model in order to achieve a reasonable calibration as well as to drive scenarios realistically. As shown in figure 1, the majority of the work occurs before the actual running of scenarios with the model.

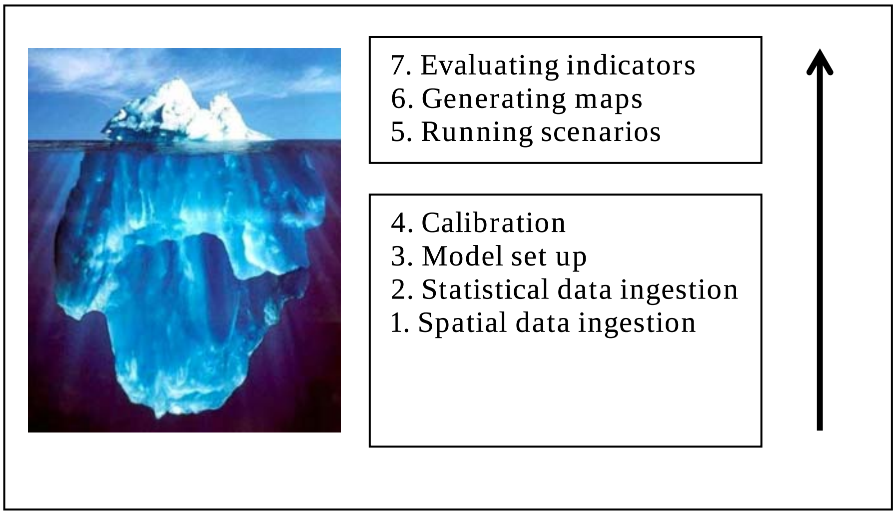


Figure 1. Representation of the underlying tasks behind running scenarios in Moland.

This report brings the reader through the various phases of modelling with Moland, with focus on The Hague case-study-specific details and analyses of results.

2. Study site

The Hague test case is one of six test case regions for the PLUREL project. This particular test case is a valuable learning tool for several reasons:

- The province is heavily zoned

- There are several ecologically sensitive areas, including around the Rotterdam harbour area
- The harbour has approved plans to expand westward, towards the water
- Some of the harbour area within Rotterdam centre are zoned to become for residential and workplaces in the near future
- There is a large region of glass greenhouses (Westland) whose purpose for now is to meet demands in the horticultural industry, but these demands fluctuate in the scenarios, causing abandonment and diversification in use
- The "services" sector of The Hague is not heavily influenced by the other economic sectors such as industry and commerce; but these three are amalgamated in the land use map
- There are several building restrictions due to low altitude, the canals and ecologically sensitive areas
- Dutch population awareness and consciousness about environment and conservation of natural, semi-natural and agricultural land: Conservation is regarded as a priority

The South Holland province is divided into six Nuts 3 regions and includes 95 settlements. Figure 2 shows the two main settlements of the province: The Hague and Rotterdam.

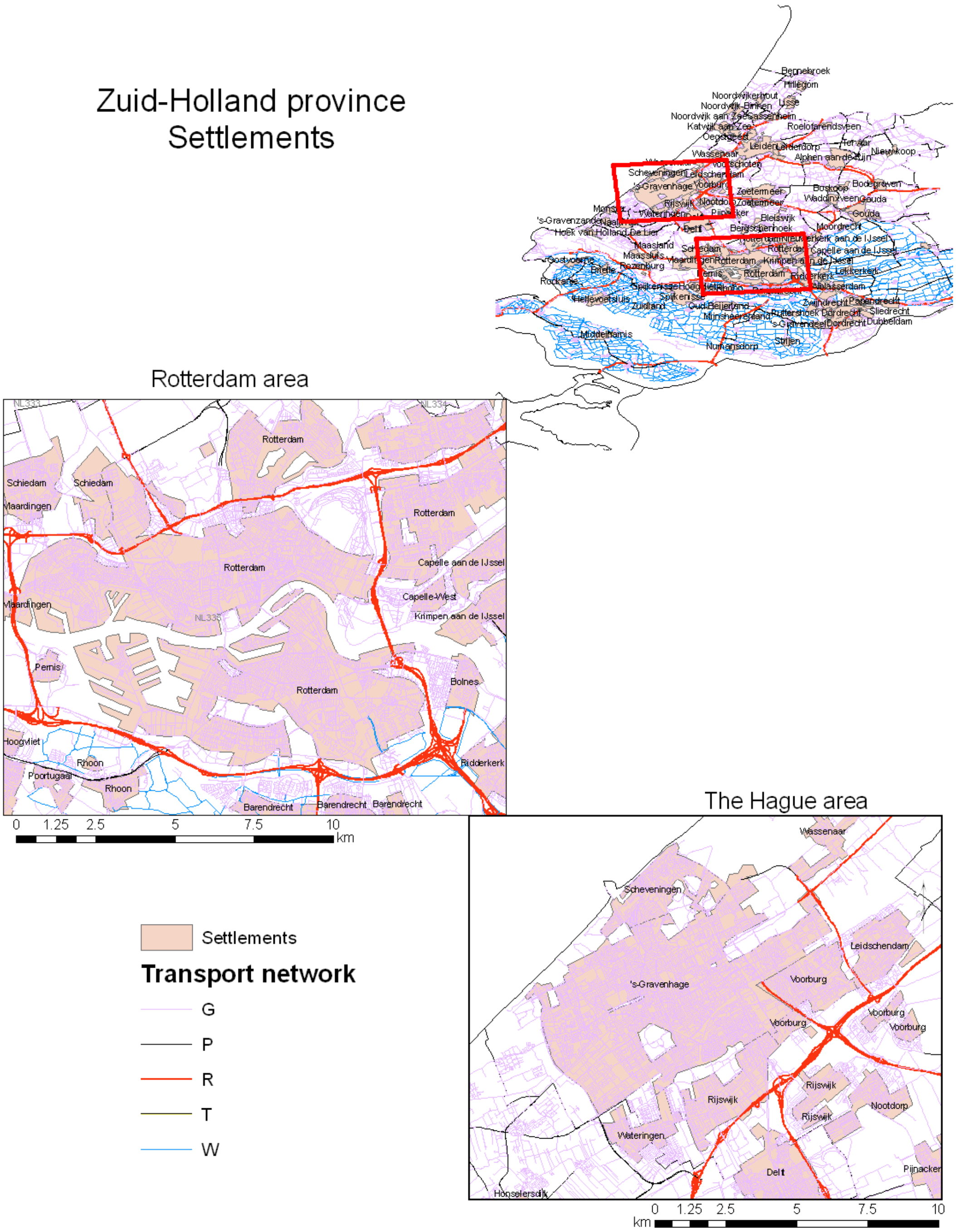


Figure 2. The two main settlements of the South-Holland province

2.1 Deviations from original plans

While Moland is a tool that can assist in regional planning because the impacts of scenario parameters can be seen on the surrounding area's land use; it is not an urban planning tool to be used to assist in the detailed plans within the confines of a city. For this reason, and several others cited below, the spatial resolution was degraded from 25m to 100m. Other reasons include:

1. The study area had grown throughout the project to encompass the South-Holland province in its entirety, thus a 25m resolution would have been too fine for the model to manage;

2. The legend inconsistencies were less apparent when the land use maps were aggregated to a 100m resolution and the level of precision in the legend did not correspond to the level of spatial precision (i.e. a high spatial precision would require detailed information about the urban content. The legend contains only one urban class)

2.2 Legend

The legend applied for The Hague test case was agreed upon by the stakeholders during the workshop held in The Hague in December 2009. This legend was amended to suit the needs of the model. Table 1 details the legend and describes the reclassification scheme needed in order to calibrate and run the model. The main reasons for adjustments are due to inconsistencies in the classifications from the base year (1995) to the simulation start year (2004). The original land use classes for 1995 and 2004, which were provided to the JRC, are shown in section 3.1.1. The land use maps were converted from 25m to 100m resolution and reclassified as shown in table 1 with 14 classes + 1 'noData' class.

Also in table 1 is the Moland land use category to which the class belongs. This is fundamental to the modelling process because it determines the behaviour of the cells within the model. Vacant classes can be built upon and may expand without explicit increase in land use demand; functional classes are the active classes with explicit land use demands assigned; and feature classes are unchanging unless the zoning maps or subsequent manual adjustments in the land use maps for any given time step are made.

Table 1. The land use legend for The Hague test case.

Original ID	Original description	Reclassified ID	Reclassified name	Moland Class
1	grass	**0**	pasture	vacant
78	pasture/farmland			
2	corn	**1**	arable	vacant
3	potatoes			
4	beets			
5	grains			
6	remaining agriculture plants			
9	orchard			
11	broad-leaved forest	**2**	ParkWoodland	feature
12	coniferous forest			
43	forest in marsh area			
77	Forest/orchard			
24	bald ground in bup in periphery	**3**	bare soil urban fringe	vacant
72	available land, harbour			
10	bulb	**4**	bulbs	function
8	greenhouse horticulture	**5**	greenhouse	function
88	work location	**6**	work location	function
18	urban area	**7**	urban	function
85	urban in port			
19	built-up in rural area	**8**	ruralResid	function
22	forest with dense bup	**9**	woodlandResid	function
26	bup in agrarian area	**10**	farmsteads	function
76	pier/dock/deposit	**11**	port	function
73	buildings in harbour			
79	pier/dock			
71	airport	**12**	airport	feature
20	broad-leaved forest in bup area	**13**	urban green	feature
21	coniferous forest in bup area			
23	grass in bup area			
25	head ways and rail ways	**14**	road and rail	feature
81	road			
31	open sand in coast area	**15**	sensitive water areas	features
46	bald ground in nature area			
30	tidal salt marsh			
32	open dune vegetation			
33	dense dune vegetation			
41	remaining marsh vegetation			
42	reed vegetation			
45	remaining open grown over nature area			
75	coastal zone			
16	sweet water	**16**	water	feature
17	salt water			
86	water			
35	dune heathland			
87	wetland			
		17	OUTSIDE	feature

3. Model set-up and calibration

The Moland regional model is appropriate if there are several competing centres of gravity (jobs, residence, economic sectors). For The Hague test case, the regional model was applied because of competing economic sectors. Ideally the area would have been divided into competing regions but insufficient statistics in economic sectors were available at a sub-provincial class thus the regional model was run, with all the added benefits of being able to configure economic sectors, but only one region was introduced in the model. Table 2 shows the general configuration of the model:

Table 2. The model parameter set up for The Hague test case.

Resolution		100m
# columns		925
# rows		758
Spatial reference		ETRS 1989 LAEA
Extent	Top	3261198.86497015
	Bottom	3185398.86497015
	Left	3895691.12465563
	Right	3988191.12465563
# regions		1
# vacant states		3
# functional states		8
# feature states		7
Economic sectors, job density associated		Industry, commerce and services
Economic sectors, no job density associated		• Dairy farming • Horticulture • Port
Population sector with population density associated		Residential

3.1 Data preparation

The data received from The Hague region is summarized in table 3:

Table 3. Data used for calibration of Moland urban land use model for The Hague region

Application	Description
Land use, First time step for calibration	Original: raster format 25m, t0=1995 (figure 3)
Land use, Second time step for calibration; first time step for simulation	Original: raster format 25m, t1=2004 (figure 4)
Regions map	Vector format
Digital elevation model, used in land use suitability mapping	Elevation model, 100m (figure 8)
National zoning	77 vector layers
Local zoning	Vector format (figure 5)
Transportation network	Vector format (figure 9)

3.1.1 Land use

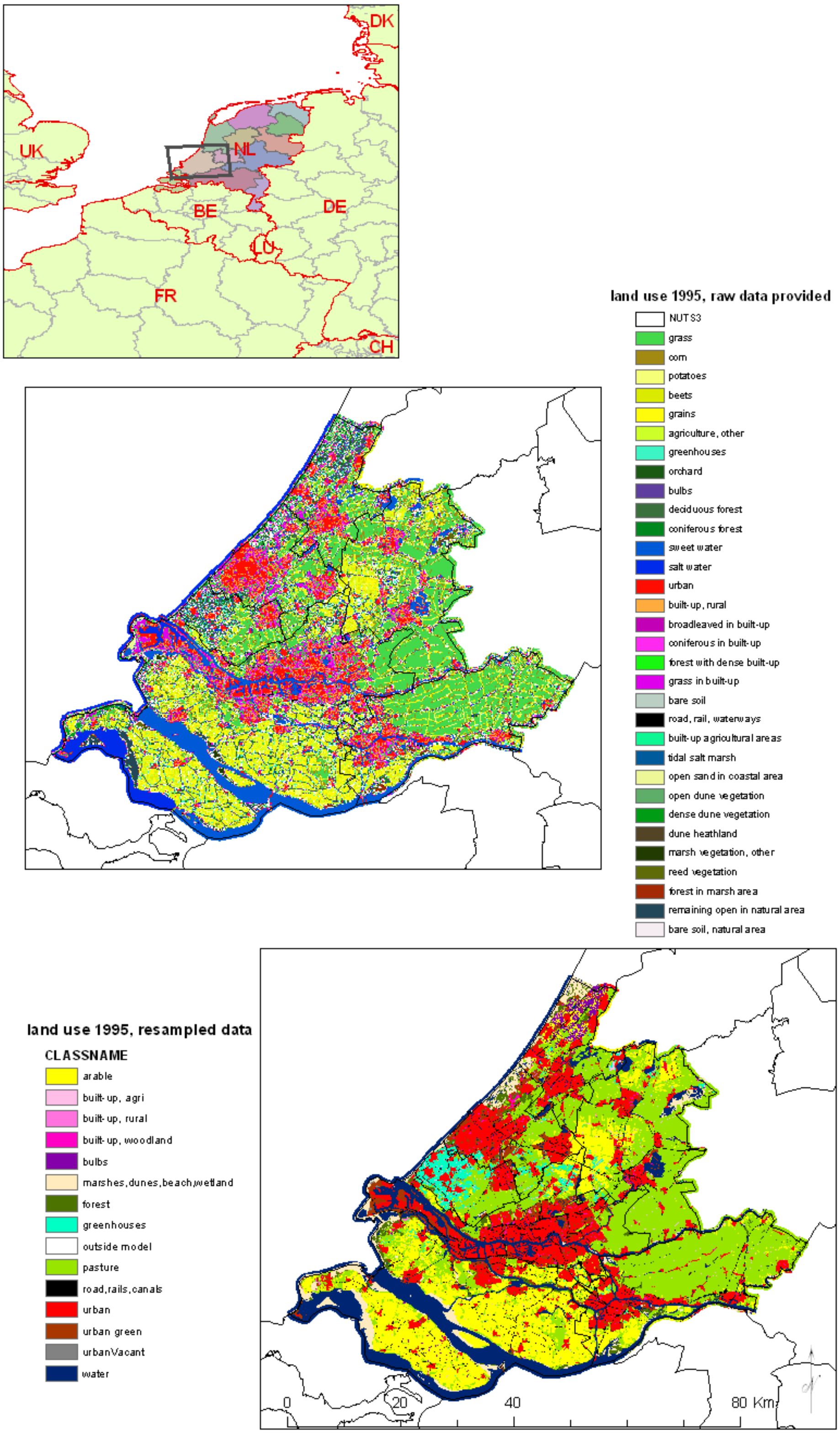


Figure 3. Raw data for 1995 provided was transformed to 100m resolution and with a shortened, aggregated legend.

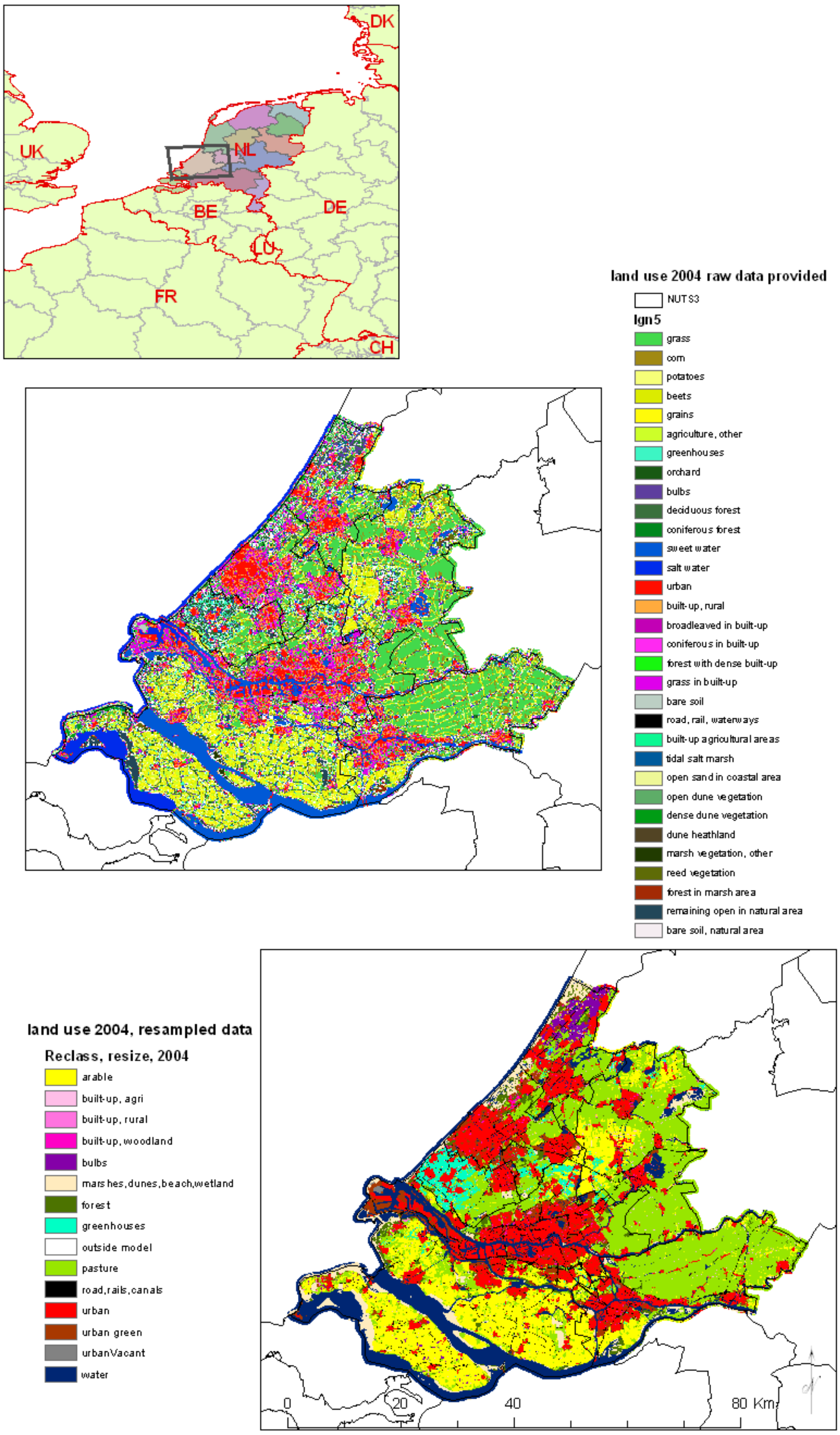


Figure 4. Raw data for 2004 provided was transformed to 100m resolution and with a shortened, aggregated legend.

3.1.2 Zoning

The zoning maps play an important role in the model. They determine whether or not a land use is allowed for a specific geographical location. Figure 5 shows the zoning map provided for the year 2004 until the end of the scenario runs. This zoning map was applied, upon request, to all three scenarios.

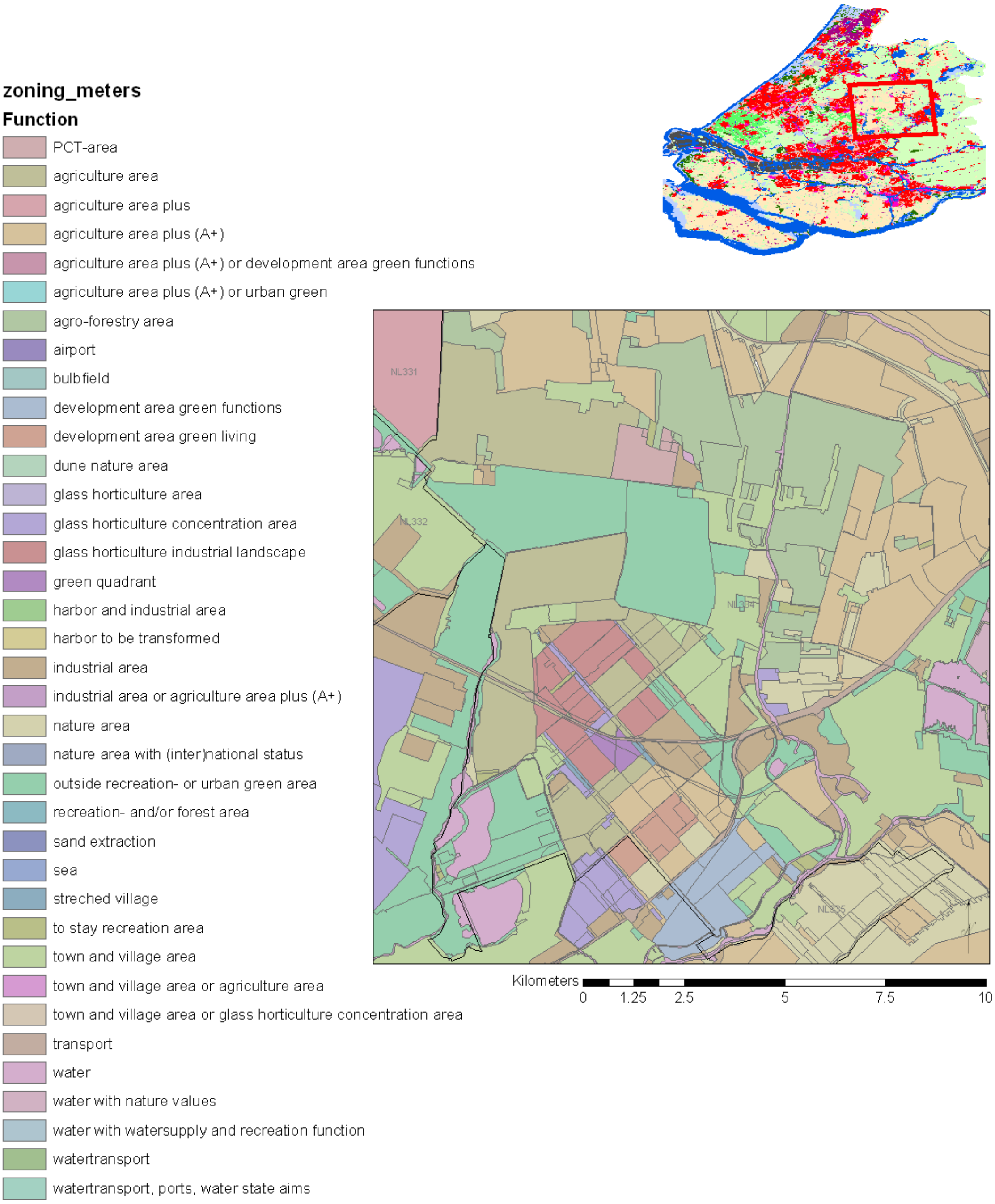


Figure 5. The zoning map provided for the South-Holland province.

The zoning map which was provided was amended in order to apply to specific land uses and to include the *actual* land use. This is important because otherwise the model reallocates land uses as of year 1 (2004). This is a problem for certain classes which are not usually allowed to change location, such as existing urban and port areas (see figure 6, for example) because these become re-allocated at time=0.

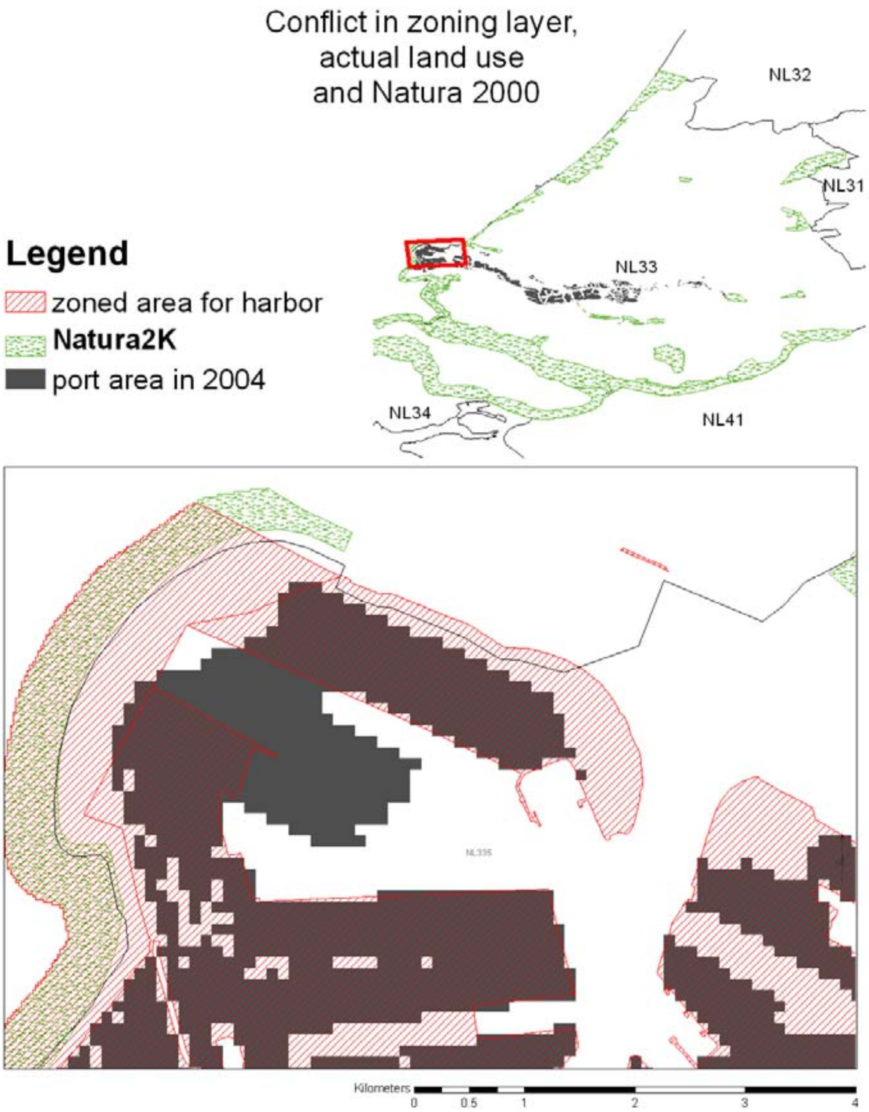


Figure 6. The conflict between different sources of data requires adjustment before ingestion into the model. In this example, the conflict between Natura 2000 designated areas, the zoning map for the post and the current land use for the port area.

Other transformations included zoning out Natura 2000 sites for building. This could not be applied to built up land use classes. A summary of the final zoning classes are listed in table 4:

Table 4. A summary of zoning map classes

Function	Zoning: "Allowed" from T0 to end of simulation	Zoning: "not allowed" from T0 to end of simulation
PCT-area	arable	
agriculture area	arable	
agriculture area plus	arable	
agriculture area plus (A+)	arable	
agriculture area plus (A+) or development area green functions	arable	
agriculture area plus (A+) or urban green	arable	
agro-forestry area	semi-natural and arable	
airport	airport	
bulbfield	bulbs	
development area green functions	semi-natural	
development area green living	semi-natural	
dune nature area		protected
glass horticulture concentration area	greenhouses	
glass horticulture industrial landscape	greenhouses	
green quadrant	semi-natural	
harbor and industrial area	port	
harbor to be transformed	Urban and port	
industrial area	workplaces	
industrial area or agriculture area plus (A+)	Workplaces and arable	
nature area	semi-natural	
nature area with (inter)national status		protected
outside recreation-or urban green area		
recreation- and/or forest area	semi-natural	
sand extraction		
sea		protected
streched village	urban	
to stay recreation area		protected
town and village area	urban	
town and village area or agriculture area	urban	
town and village area or glass horticulture concentration area	Urban and greenhouses	
transport	protected	protected
water with nature values	protected	protected

water with water supply and recreation function	protected	protected
water transport	protected	protected
water transport, ports, water state aims		

The protected areas, according to the zoning map provided and to Natura 2000 sites, were used to absolutely forbid building in these areas. In the cases where there were conflicts with the areas currently labelled as built up areas within protected areas, the built up areas were introduced manually but not allowed to expand. Figure 7 shows an example of such a case:

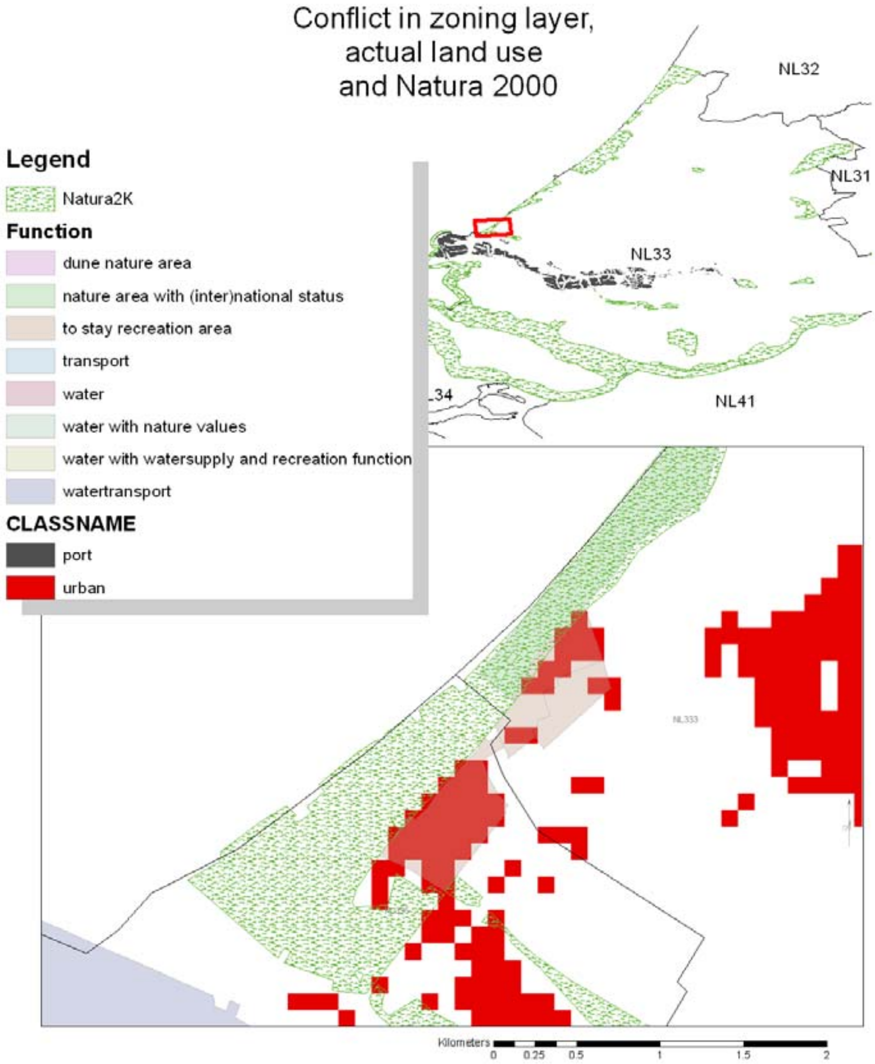


Figure 7. Areas which are urban according to the 2004 land use maps sometimes conflict with protected areas according to the zoning maps. In these cases, the urban areas are allowed to stay but not expand further into protected areas.

3.1.3 Suitability

Land use allocation for vacant classes is determined through "suitability maps". Suitability maps express the physical suitability of a site for the land use classes. The suitability maps are created from a number of different layers, summarised in table 5:

Table 5. The layers integrated into the suitability maps.

Erosion risk	Soil erosion estimates (t/ha/yr), reclassified to 5 classes using Jenk's Natural Breaks algorithm. High class value=high risk
Water shortage	Water deficit during the growing season (mm), reclassified to 5 classes using Jenk's Natural Breaks algorithm. Low class value=high water deficit
Soil depth	Soil depth based on European soil database (cm), reclassified to 5 classes using Jenk's Natural Breaks algorithm. Low class value = shallow
SWAP – water availability	Soil water availability to plants (mm), reclassified to 5 classes using Jenk's Natural Breaks algorithm. High class value = high water availability.
Clay content	Soil clay content (%),values in jumps of 10% from 0-50%
Peat	Presence of peak in European soil database (y/n)
Elevation	Elevation above sea level (m), reclassified to 5 classes using Jenk's Natural Breaks algorithm
Current land use	Land use in 2004

Each layer could be used in a different way for each of the different land use classes. For example, soil depth, clay content and peat concerned the arable land class but not the vacant urban class. All datasets, with the exception of the elevation (see figure 8) and land use were created and made available by the JRC.

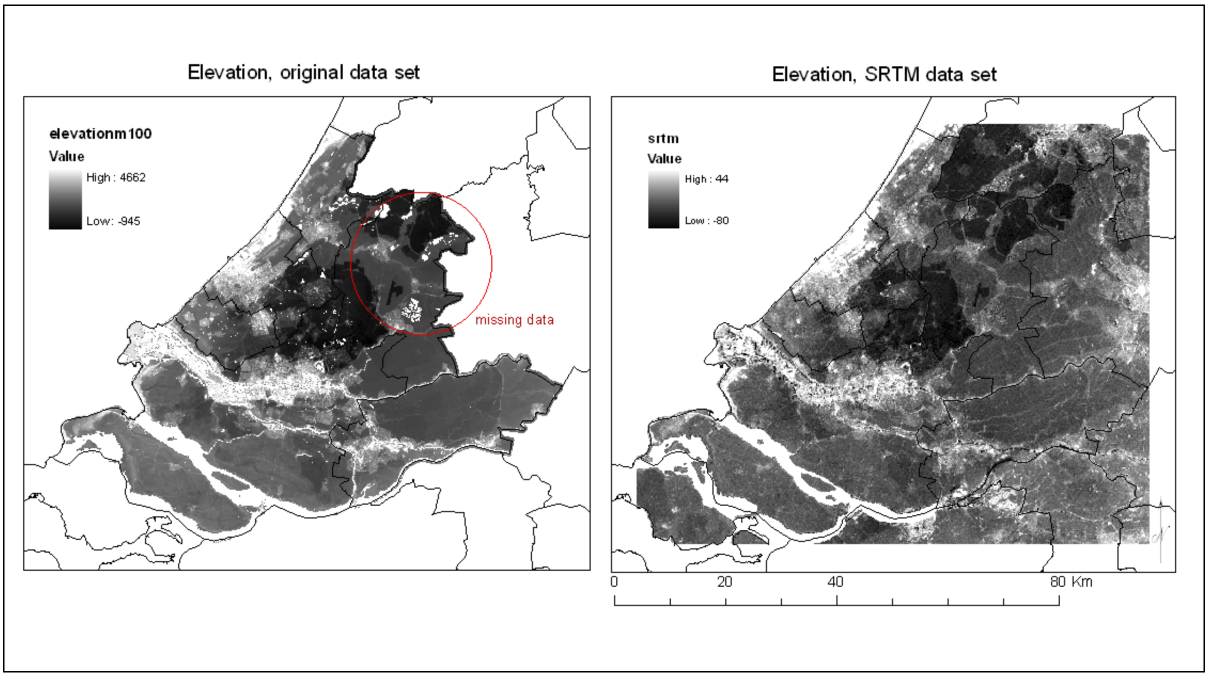


Figure 8. The digital elevation model provided (left) was replaced by the SRTM dataset (right).

Alterra improved the suitability map for arable land by adding local knowledge of the land use description and geographical area (figure 9):

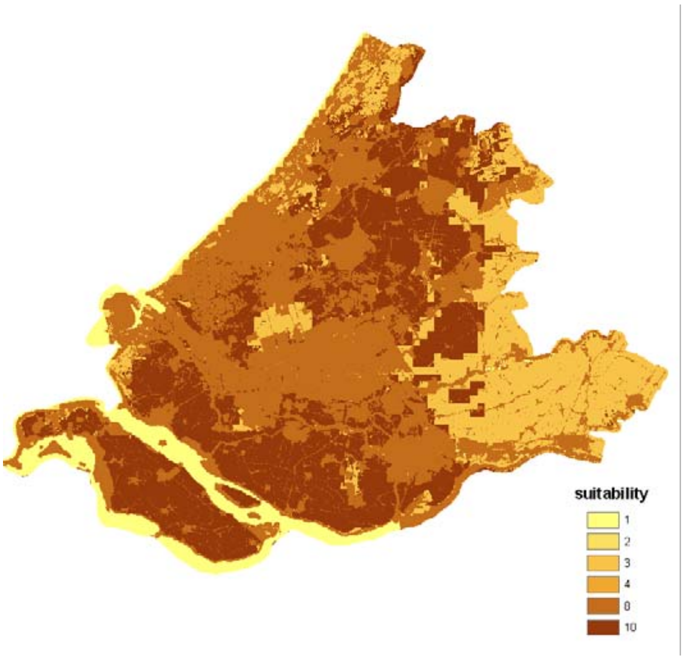


Figure 9. The suitability map for arable land provided by Alterra, whereby 1=least suitable and 10=most suitable.

3.1.4 Transportation and accessibility

The transportation network shapefiles were merged (roads, railway, waterways, railroad stations and airport) into a single shapefile (figure 10).

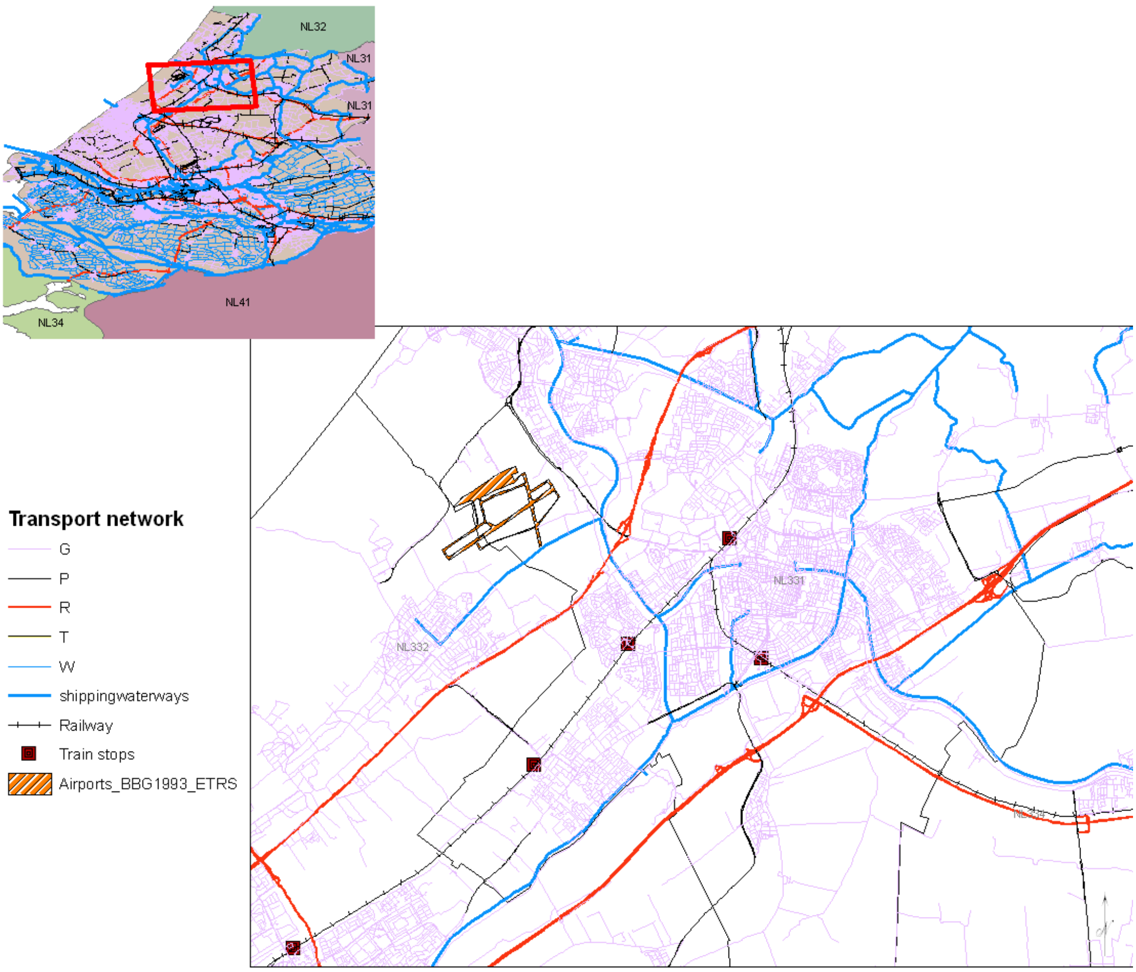


Figure 10. The transportation network for Leiden, a city within the test case area.

The airports were integrated into the land use map after a few minor changes: the vacant areas in between runways were filled in and labeled as part of the airport, otherwise other land uses could pop up between runways and two airports that are present in the 2004 land use maps were replaced with urban classes because they are no longer in use. The planned new highway between Rotterdam and Delft was added in 2015. From that date, the model takes this road into consideration as it would other highways.

3.2 Calibration

Suitability maps for vacant classes were created in Geonamica's Overlay tool and added were then checked and adjusted by Alterra. The output of suitability map making is a continuous grid from 0-10 whereby the increasing gradient indicates an increasing suitability (0= not suitable, 10=suitable).

The values assigned to the suitability maps were based on two things: expert knowledge and data behaviour. In order to assess data behaviour, the land use maps for both 1995 and 2004 were used to extract land use class statistics per suitability layer. This data was processed in a way which accounted for the relative size of each land use class as well as the relative size of each suitability class. Thus the percent land use occupying the percent suitability class was taken into consideration when assigning suitability levels per land use class. The data is shown in Annex A.

The following step was to verify the impact of the suitability maps on the calibration dataset. The land use allocation in the calibration run was compared with the true allocation. Based on this analysis, the overestimations and underestimations of the suitability maps per land use class are identified and are adjusted in small increments in order to arrive to a good fit with true data.

As described earlier, the transportation network was ingested into the model. Road, rail, airport and water transportation were all merged into the same shapefile and the necessary column "acctype" was created in the file dbf. The transportation maps can be updated at anytime during the simulation (this can be done either through uploading a whole new transport network or simply adding features on the existing transport network). The weight and spatial influence of each of the transportation types was described for each land use type. Table 6 shows the accessibility parameters for the baseline and B2 scenarios. The B1 scenario has different values due to the importance of oil prices. An example of the accessibility map for urban areas is shown in figure 11.

Table 6. Accessibility parameters used to build accessibility maps for calibration, the business as usual and the B2 scenarios.

		(importance/ Distance decay)				
Land use	**Implicit access to built-up/non-built-up**	*Highway*	*Major road*	*Rail*	*Train station*	*Water transport*
Bulbs	0.5/1	0.1/100	0.8/100	0/0	0.8/10	0.1/10
greenhouse	1/1	0.1/50	1/100	0/0	0.1/50	0.5/0.1
Work location	1/0.8	0.1/200	1/50	0.5/-2	1/50	0.4/5
urban	1/0.8	0.1/150	1/50	0.1/-5	1/50	0.9/5
Rural residence	0.8/1	0.1/200	0.9/50	0.3/-4	0.5/10	0.5/50
Woodland residence	0.8/1	0.1/200	0.9/50	0.3/-4	0.5/10	0/0
Farmstead	0.8/1	0.1/200	0.8/50	0.5/-4	0.5/10	0.8/50
Port	1/1	1/200	1/200	1/200	1/200	1/20

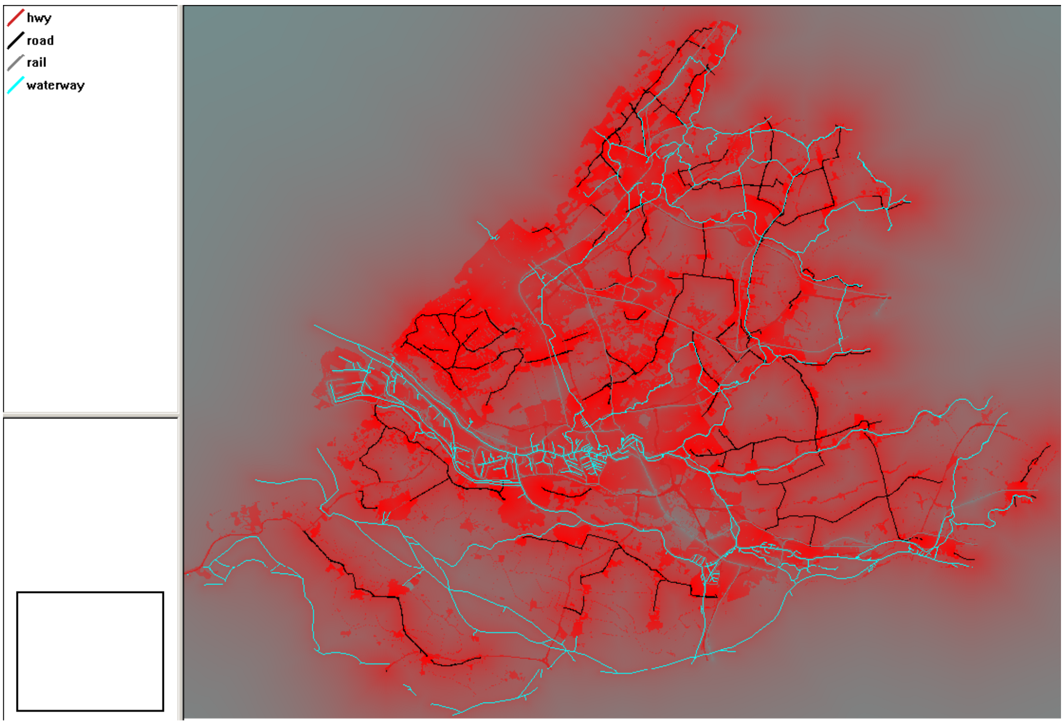


Figure 11. The accessibility map for urban areas, used for the calibration and the BAU and B2 scenarios.

Two bogus simulations were run in order to assess the calibration:

1. The "random constraint model", whereby the correct amount of land use change is allocated for T2 (2004), but in random locations (Hagen-Zanker and Lajoie, 2008[1]). For decreasing classes, pixels are taken away at

[1] Hagen-Zanker, A. and Lajoie, G. (2008) Neutral models of landscape change as benchmarks in the

random and replaced with LU classes that are increasing. Kappa statistics are computed from the random constraint.

2. The "no change model", whereby the initial land use map is used as the no change model to compare simulation results (Pontius and Malanson, 2005[2]). No change is typically more accurate than the simulation results (even if there is no simulation involved). The calibration is considered good when the model results are better than the null model results.

The actual calibration dataset, with suitability maps, accessibility maps and neighbourhood influence ingested was run and modified according to results given by the Kappa simulation model(van Vliet, 2009 – 12th Agile International Conference on GIScience "Assessing the Accuracy of Changes in Spatial Explicit Land Use Change Models" Hannover), a method which takes the total amount of change into consideration. This method was developed because it is known that Kappa accuracy is proportional to the number of changes occurring in an area. Thus fewer changes translate into higher accuracy, and since land use tends to persist rather than change over time, the models usually look very good. A sort of normalization of total changes can be made to assess the true accuracy of the calibration. According to the author of the paper, a value of 0.02 is good (personal communication, July 2009). Results are shown in table 7. Kappa values of -1 signify that the is no agreement at all; kappa values of 1 represents perfect agreement and a kappa value of 0 means that the agreement is exactly as can be expected by chance. The kappa value is computed from a contingency table of map A vs map B; in this case, map A=2004 true land use map and map b=2004 simulated land use map.

Table 7. Calibration results for two bogus runs and the calibration run.

Run	*Kappa (corr)*
Random constraint	-0.06329
No change model	-0.03706
Calibration	0.191345

A high degree of confusion which foils better statistics arises in the land use classes which are misclassified from one year to the next. This occurs for urban

assessment of model performance. Landscape and Urban planning 86 (3 – 4): 284 – 296.

2 Pontius Jr., R.G. and Malanson, J. (2005) Comparison of the structure and accuracy of two land change models. International Journal of Geographical Information Science 19 (2): 243 – 265.

green in particular, whereby fields, even those within airport and port boundaries, are classified as “urban green” but more importantly, land use classified as “pasture” in 1995 are reclassified as urban green in 2004 if they border with urban areas. This kind of behaviour is either due to misclassification or a true conversion. If the latter case is true, then the land use class “urban green” should be used as a functional class and not as a feature.

The probability values for a given land use being converted to another is shown in Annex B.

3.3 Scenario descriptions

Four scenarios are outlined within the PLUREL module 1 (taken from PLUREL deliverable 1.3.2):

- ***A1-techno***. Rapid development in ICT leading to reduced commuting and transport needs, with no constraints on the location of new build (WP1.4),
- ***A2-climate.*** Climate change reaches a tipping point leading to impacts including rapid sea level rise, flooding and water resource constraints (WP1.3).
- ***B1-econ.*** An energy price shock leading to rapidly increasing energy and transport costs and consequent changes in mobility and trade flows (WP1.1),
- ***B2-demog.* A** pandemic disease leading to major population declines and behavioural shifts within society (WP1.2),

These scenarios were adapted to suit the mandate of the PLUREL project as shown in figure 12. A full description of the adapted scenarios can be found in the PLUREL deliverable 1.3.2.

Scenario framework – key variables

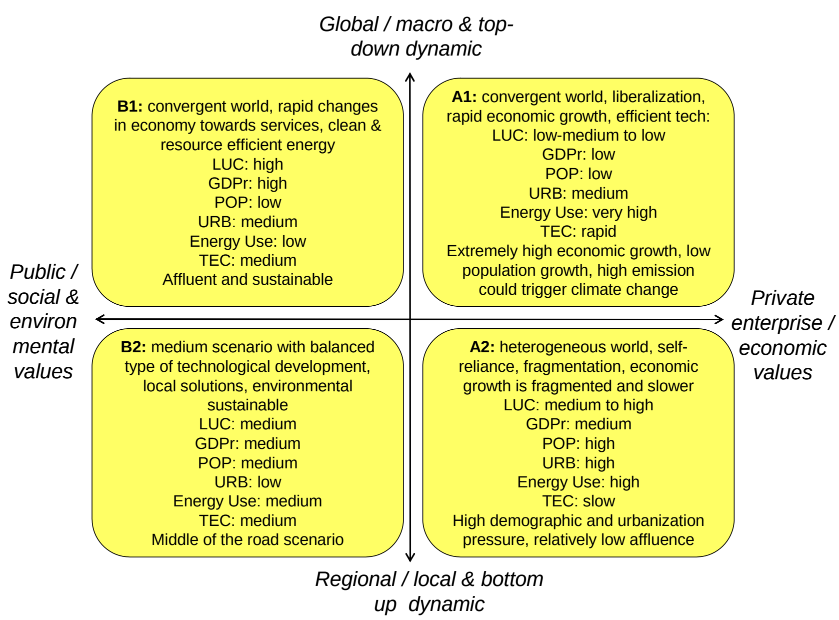


Figure 12. Adapted SRES[3] scenario key variables (taken from d1.3.2.)

[3] SRES: "Special report on Emissions Scenarios". A report prepared by the Intergovernmental Panel on Climate Change.

According to the July 2009 version of the working paper WP 3.4 "PLUREL scenario workshop The Hague Region 11 and 12, May 2009", two scenarios were retained for The Hague test case: Peak oil (B1) and Fragmentation (B2). The business as usual scenario was also run in addition to these two scenarios. A description of the B1 and B2 scenarios and their expected outcomes is detailed in the above-cited PLUREL working document. In this document, the original and detailed qualitative descriptions are summarised under the appropriate scenario heading.

All scenarios are to run to 2040. This means that the length of the run is 36 years. Although the reasons for this duration are clear and highly justifiable, it is important to note that such a long time frame increases uncertainty in the outcome. This is of course open for discussion. Since storylines are not meant to be predicative, and scenarios are based on storylines, uncertainty could be considered as being irrelevant. The philosophical debate can be left aside for now, however it is important for the reader to consider the possible implications of such a long temporal window for the model run.

3.3.1 Business as usual

The "Business as usual" scenario is run in order to test the calibration robustness and to eventually tweak the trends observed for the calibration period. Two sources were used in the set up of the BAU scenario: National trends for the past decade according to the national statistics office CBS (http://www.cbs.nl) for population numbers and projections; and Eurostat for employment figures in the economic sectors.

The following is a brief description of the parameters used to run this scenario for The Hague:

- Non-linear extrapolation of horticulture sector trends from current statistics
- Non-linear extrapolation of population trends. The population reaches a peak in 2020 then is on a slight decline. For the Strategy 1 run, thus the density of living space is stable at 80 persons /ha until 2020 but is slightly lower after 2020 (74 persons/ha).
- Employment increase in port sector

- Dairy farming industry is steady
- As of 2008, the port had the go-ahead to expand by 20%; assuming this trend went ahead, the port was further expanded in 2030 by another 10%.
- Building of new individual houses is limited in the peri-urban and hinterland
- Densification along roadside and in current urban areas
- Small decrease in population, as forecasted by the national statistics office
- Accessibility: workplaces attracted to roads; individual houses such as farmsteads are not. These remain near the city centre
- Zoning: local zoning maps provided and Natura 2000 areas.

3.3.2 Peak oil

This scenario, as described by SRES, is characterised by a society whose priorities are in services and informatics rather than industry and production. Emphasis is placed on social issues and environmental sustainability. The population is described as reaching a peak growth and the decline after 2020. Building is restricted using the same zoning restrictions as for the BAU scenario.
The following is a brief description of the B1 scenario for The Hague test case.

- The services-based areas of The Hague and Delft prosper while Rotterdam is on the decline due to a slightly shrinking port, which in turn is due to the rising costs in petroleum and its derivatives
- The greenhouse industry suffers from increasing transportation costs, but does not collapse entirely
- Port activity remains somewhat steady, as for the BAU scenario, there is a shift towards the water from the city center of Rotterdam, thus leaving land available for other uses.
- Some housing appears in hinterland but growth is limited due to strong incentives to maintain “natural” areas such as agricultural areas, pasture and bulbs.
- New land. There is mention of new land being created using “sand supplements”. These are unfortunately not integrated into the model because the location of these areas is unknown and would probably not have an impact on land use changes because it occurs offshore.

3.3.3 Fragmentation

This scenario, as described by SRES, is characterised by what is described as being a “transition” period. The following is a brief description of the amendments to this scenario for The Hague test case:

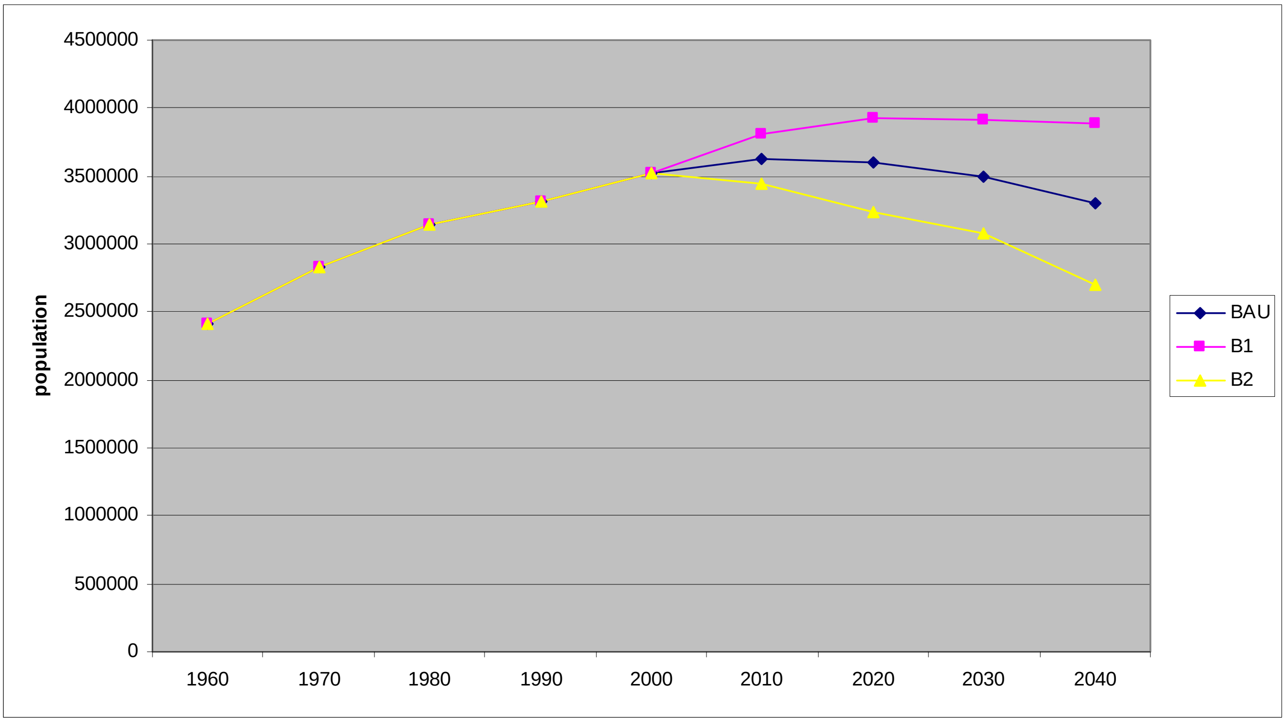
- Economically void scenario, whereby greenhouses are abandoned and, in some cases, filled with other functions but the port remains stable
- The Hague suffers decline but the Delft region is maintained intact due to good business in the technology and R&D.
- Gated communities arise in and near the Delft-Rijwijk-Nootdorp triangle (rural residential class)
- Only the Delft area is left intact in terms of work locations, other areas are desecrated

3.3.4 Baseline scenario configurations

The baseline scenarios, described in the July 2009 version of the working paper WP 3.4 “PLUREL scenario workshop The Hague Region 11 and 12, May 2009” and restructured during a meeting in Ispra in August 2010, were translated into terms the model could digest. Data was described on intervals of decades in order to configure the model. Table 8 shows the input used for the economic sectors and figure 13 shows the input for the population sector.

Table 8. Past and projected trends in employment per economic sector for South Holland province for the 3 baseline scenarios

		2004	2010	2020	2030	2040
Industry, commerce, Services /ha	BAU	12860	12900	13000	13100	13200
	B1	12860	12900	13260	13624	13992
	B2	12860	12800	12700	12600	12500
Port /ha	BAU	5834	6000	6200	6400	6400
	B1	5834	6000	6200	6400	6400
	B2	5834	6000	6200	6400	6400
Horticulture /ha	BAU	12978	12970	12975	13000	13200
	B1	12978	12970	12975	13000	13200
	B2	12978	10000	8500	7700	6489
Dairy farming /ha	BAU	1052	1052	1052	1052	1052
	B1	1052	1052	1052	1052	1052
	B2	1052	1052	1052	1052	1052



	1960	1970	1980	1990	2000	2010	2020	2030	2040
BAU	2407127	2831816	3145288	3318885	3517795	3625052	3600179	3490816	3296963
B1	2407127	2831816	3145288	3318885	3517795	3806305	3927795	3909714	3890416
B2	2407127	2831816	3145288	3318885	3517795	3443799	3236561	3071918	2703510

Figure 13. The trends in population for the test case used to configure the three baseline scenarios.

3.4 Strategies

Three different strategies were presented by the stakeholders. The purpose of running the so called "policy alternatives" in addition to the baseline scenarios, was to test the impacts of policy in three different contexts: business as usual, peak oil, or fragmentation. Two rules therefore had to be applied. The first is a horizontal rule whereby the method in which the strategies were configured should always be consistent and mutually exclusive. The second, vertical rule, involves the consistency in the demand set. This implies that the demand set for the economic and residential sectors remains consistent from the parent baseline scenarios to its child policy alternatives (figure 14).

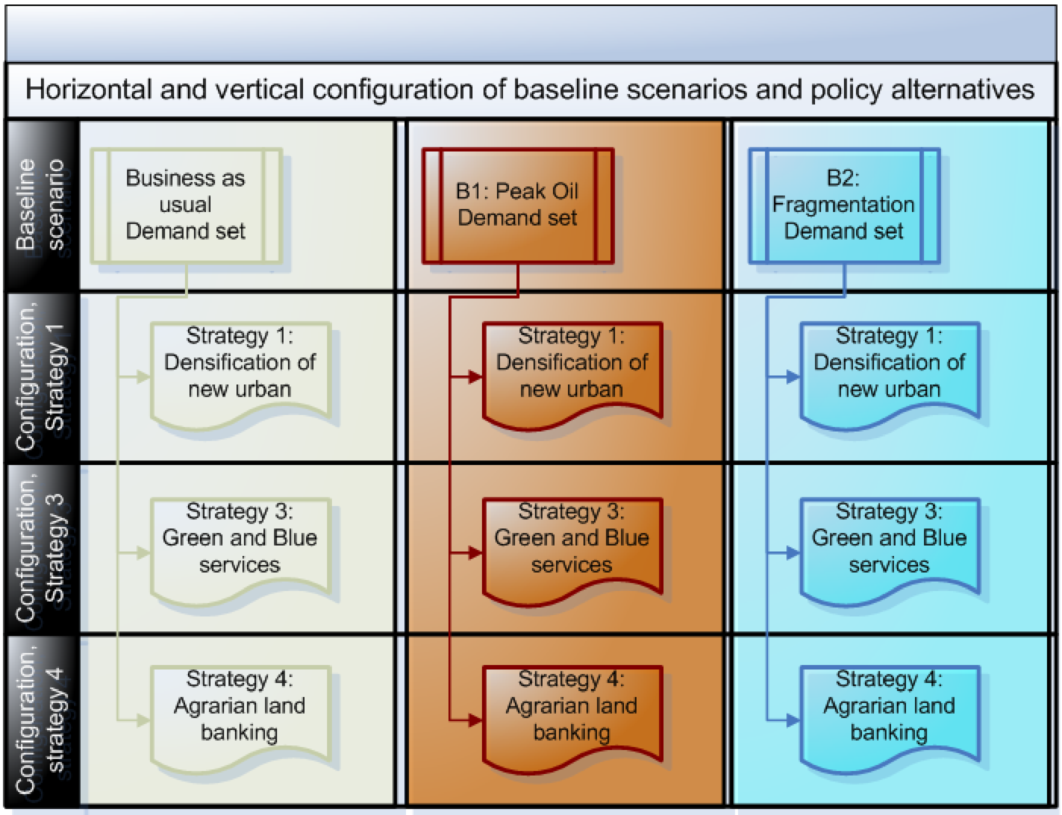


Figure 14. The horizontal and vertical configuration rules for three policy strategies.

3.4.1 Configuration, Strategy 1

"Strategy 1" involved increasing the density of the workplaces and residential areas (urban areas). In this strategy, at least 80% of new construction should take place within the urban fabric. At the initial state (t=0), the number of cells is read from the land use map and is cross-checked with the user-entered statistics of population and employees in the industry, commercial and services sector. Initial densities are assigned. For every simulation step thereafter, *W* is updated (Moland user's manual, p.34):

$$^{t+1}W_{K,i} = {}^{t}\delta 1_{k}\,{}^{t}W_{K,i} \bullet {}^{t}Wreg_{K,i} \bullet {}^{t}Wcel_{K,i} \qquad \text{(eq. 1)}$$

where

Wreg is a term for densification at a regional level;

Wcel is a term for densification at a cellular level

δ1 is the absolute influence of the current land productivity

Wreg and *Wcel* each have a number of parameters allowing the model to be more or less influenced by the demand over supply, crowding, transition potential, suitability and zoning, accessibility and total capacity of the region. By manipulating these parameters for the Industry, Commercial and Services economic sector, we influence the land use class “workplaces”. In order to influence the density of the workplaces, we can manipulate the influence of parameters “growth transition potential”. Other parameters such as “crowding” and “demand over supply” play a role in influencing density at regional level.

The parameters are also influenced for the population sector, thus influencing the classes “urban” and the three residential classes (farmsteads, luxury homes and rural residences). It would be possible to calculate the densities of the population if the proportion of the population residing in the “residential” cells were known, but this is not the case. An assumption is therefore made with respect to the population densities: The urban class has a higher density than the residential farmsteads, luxury homes or rural residences. In this way, the model can be configured to allocate a growing population to fewer, high density cells rather than to distribute the population in the lower density residential classes. The change in the population density of the region is calculated as (Moland user’s manual, p.37):

$$\Delta^t W_{p,i} = \ln({}^t W_{p,i}) - \ln({}^{t-1} W_{p,i}) \qquad \text{(eq. 2)}$$

where

${}^t W_{p,i} = density\ of\ population\,(p), at\ time\,t;\ for\ region\ i$

The actual allocation of population to cells is dependant on the amount of land available, but if cells are assigned different “holding capacities”, it is possible to allocate the same demand into fewer cells. So for example, for the urban class, the amount of cells required for the allocation of the demand for residences is allocated as follows

$$ {}^t N_{urban,i} = {}^t \varepsilon_{urban,i} \bullet {}^t N_{p,i} \qquad \text{(eq. 3)}$$

where

${}^t \varepsilon_{urban,i}$ = the relative proportion of residential cells of type “urban” at time = t

$$ {}^t N_{p,i} = \frac{{}^t D_{p,i}}{{}^t W_{p,i}} \qquad \text{(eq. 4)}$$

where

D = demand; W = land productivity as in eq. 1; and N = number of cells required

The same is done for the less densely packed residential classes.

3.4.2 Configuration, Strategy 3

Strategy three was dealt with by allocating a percentage of total parcels, as defined by Alterra, to receive subsidies. Subsidies were defined as being received per hectare (thus the larger parcels received more subsidies). Table 9 shows the definition of this strategy for the three different scenarios as presented by Alterra.

Table 9. The stakeholder definition of the Green and Blue Services strategy (Strategy 3) in terms of parcels adhering to the initiative and subsidies received per hectare.

Green-Blue Services	BAU	B1	B2
% of total area	20	20	30
Number of parcels (of total 25363)	5073	5073	7609
Subsidies €/ha yr	1000	100	100
Chance of staying above normal	1.2	1.2	1.05

This table was translated to maps as follows: For 20% of the 25363 parcels of arable land and pasture potentially included in the strategy and thus eligible for subsidies, only a certain percentage adhere. This percentage differs depending on the scenario. For example, for the BAU scenario, 20% of parcels adhere to the strategy; for the B2 scenario, 30% of parcels are included in the strategy. In addition to this criterion, there is the multiplicative criterion set by Alterra which represents the likelihood of the land owners not adhering to the strategy initiative, will continue with their activities. For example, 30% of parcels adhere to the subsidies for the B2 scenario, but in any case, the remaining 70% are 5% more likely to remain pasture or arable with respect to the baseline scenario. In this schema, the larger parcels, assumed to belong to the same land owner, receive more money. For example whereas a parcel of 120 ha is worth 120 000 Euro according to the BAU scenario, a 1ha parcel is only worth 1000 Euro for the same scenario; and the non-subsidized parcels receive 0 Euro. This information is ingested into the land use model through the suitability map layers. Since the model handles values between 0-1, it was necessary, due to the large discrepancies between the large and small parcels (max = 129 ha; min = 1ha), to implement a non-linear rescaling method whereby the square root of the values were used to assign a value to a parcel to represent the likelihood of it remaining intact (likelihood = suitability). In order to bring the values between 0-1, the results are divided by the maximum value.

Different maps were generated to differentiate the situation between BAU and B1 scenarios and the B2 scenario. Figure 15 shows the map generated for the BAU scenario.

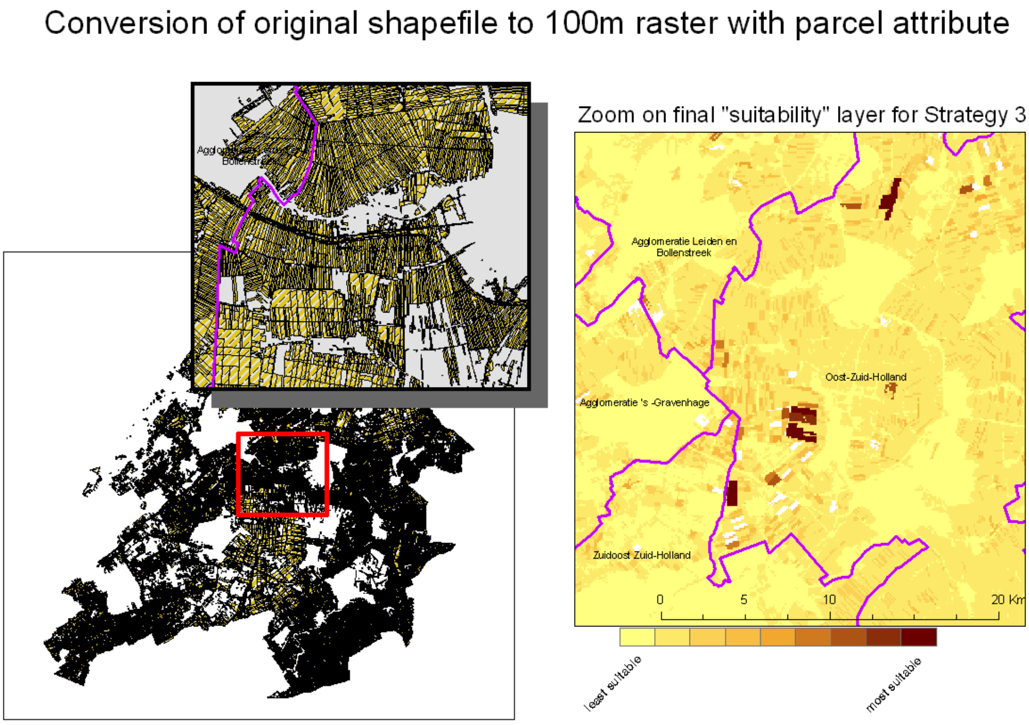


Figure 15. The map used to configure Strategy 3 represents parcels eligible for and receiving subsidies for the Green and Blue Services initiative for the BAU scenario.

3.4.3 Configuration, strategy 4

For “Strategy 4”, largely the same parcels were selected as for strategy three in order to make the strategies comparable. In this case, rather than the subsidies, the measure of success is in the percent of participating farmers. As shown in table 10, the percent of parcels adhering to the agrarian land banking system.

Table 10. The stakeholder definition of the Land banking strategy (Strategy 4) in terms of parcels adhering to the initiative and percent farmers adhering to the initiative.

Land Banking	BAU	B1	B2
% of total area	10	20	0
Number of parcels (of total 3574)	358	715	0
% farmers	50	80	0
Chance of staying above normal	1.5	2	0

Different maps were again generated to differentiate the situation between BAU and B1 scenarios (for the B2 scenario, no Agrarian Banking initiative was planned). Figure 16 shows the map generated for the BAU scenario.

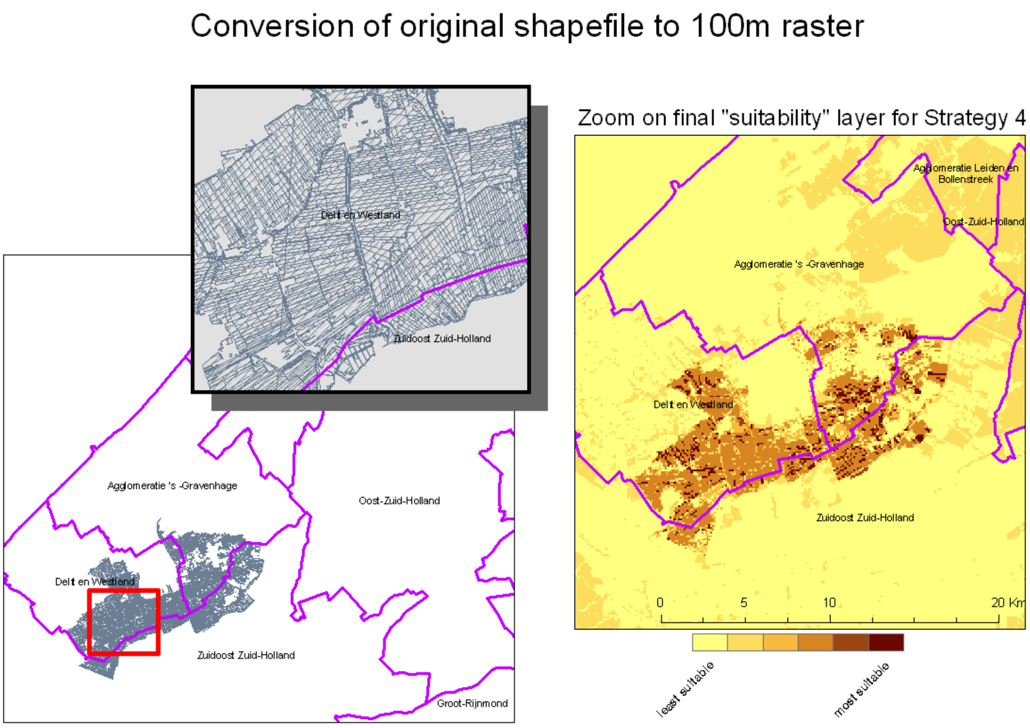


Figure 16. The map used to configure Strategy 4 represents parcels adhering to the Agrarian Banking System for the BAU scenario.

4. Results

Several indicators, which had been agreed upon by stakeholders for the different case studies, were calculated for The Hague test case. Some were not possible to calculate. For example, it was not possible to assess population numbers or population densities in the absence of statistics associated to densities for the residential land use categories urban, built-up rural, built-up woodland and built-up agricultural land (farmsteads). The following is a list of the indicators that could be calculated for The Hague, and a description of the interpretation for The Hague:

1. Total amount of new urban land. This includes the workplaces, the port, the airports and the urban land but not the "vacant" land because this class is also used to describe land vacated by the diminishing horticulture industry in the B2 scenario.
2. Amount of urban land by RUR typology (figure 30). See above for land use classes included in the calculations.
3. Amount of new urban land per new inhabitant. The density of residential classes is a parameter used to manipulate scenarios and is therefore not an indicator, but rather a driver.
4. Lost valuable nature. Based on discussions with stakeholders, "valuable natural lands" include forest, natural coastal areas and other natural and semi-natural waterfront areas; and water itself. The areas associated with water and its flora are protected in these scenarios and therefore do not change; the forest land use class is susceptible to change.
5. Lost farmland. "Farmlands" include pasture, arable and bulbs.

In this report, a small description of the outcomes of each of the scenarios is made and the maps are shown. The raw data, shown in Annex C, includes the statistical breakdown of land use classes for the RUR typology.

4.1 Business as Usual

Figure 17 shows the resulting land use map for the business as usual scenario, run until 2040.

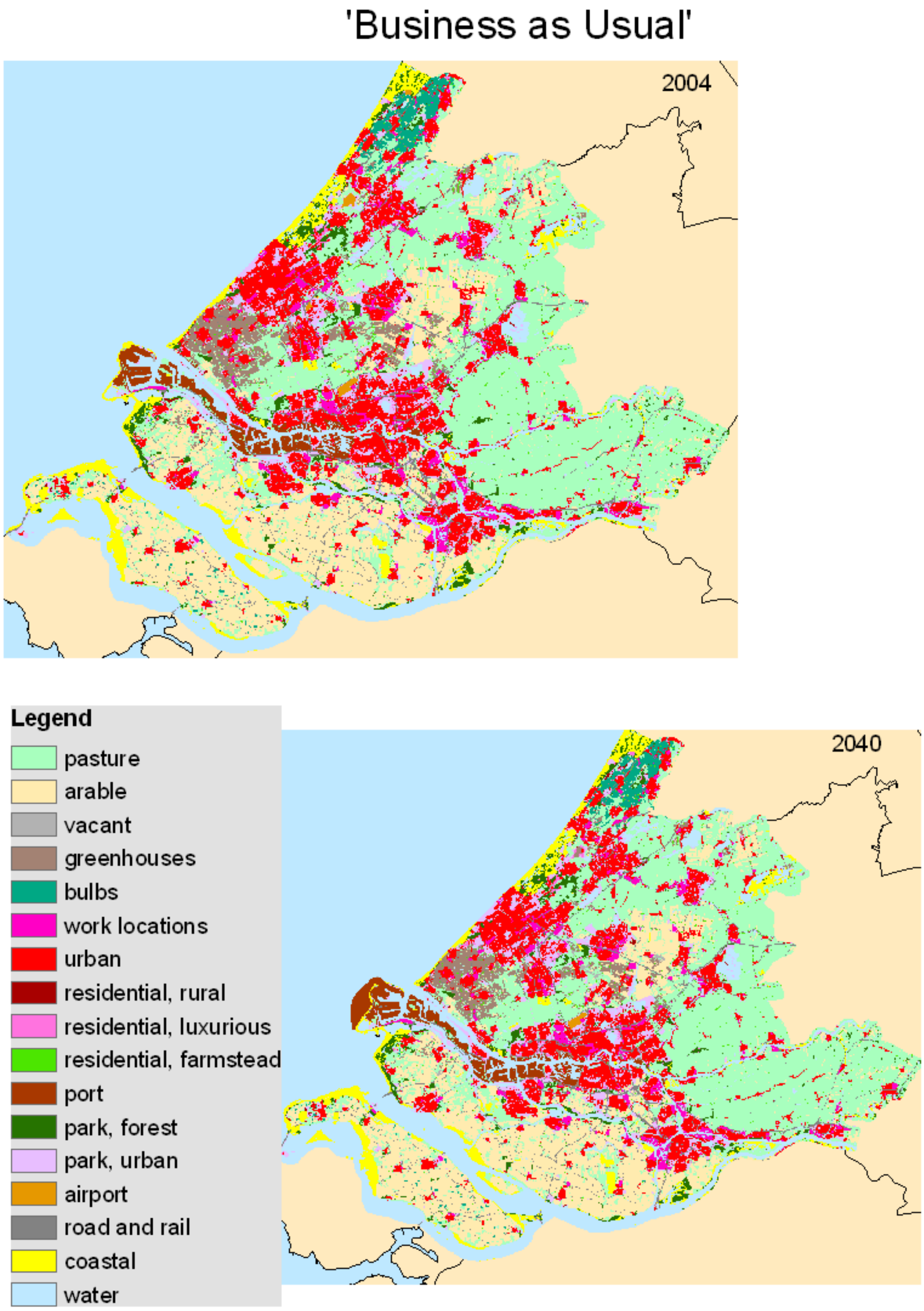


Figure 17. The original map from 2004 and the resulting land use map for the business as usual scenario for 2040.

Table 11 summarises the changes in land use for the province from 2004 to 2040 according to the BAU scenario:

Table 11. The changes in land use classes from 2004-2040 for the BAU scenario.

	2004	2040	Change %
pasture	104167	102759	-1.35
arable	60048	59754	-0.49
vacantUrban	874	2	-99.77
greenhouses	8950	9102	1.70
bulbs	4028	4098	1.74
workLocations	7432	7776	4.63
urban	45309	46764	3.21
ResidRural	600	621	3.50
ResidLuxury	1555	1603	3.09
Residfarmsteads	2105	2105	0.00
port	5834	6400	9.70
parkForest	7513	7513	0.00
parkUrban	17237	17236	-0.01
airport	270	270	0.00
roadsRail	10078	10078	0.00
ReedsSandMarsh	14688	14613	-0.51
Water	50087	50081	-0.01

Table 12 summarises the growth in cells with residential uses for the scenario and table 13 shows the non-residential urban land expansion.

Table 12. The expansion of residential areas for the BAU scenario between 2004 to 2040.

residential	lu2004 /ha	lu2040 /ha
90% of urban	40778.1	40897.8
ruralResidences	600	602
woodlandResid	1555	1570
50% farmsteads	1052.5	1052
TOTAL	**43985.6**	**44121.8**
Change in amount of new residential urban land	136.2 ha	0.31%

Table 13. The expansion of non-residential areas for the BAU scenario between 2004 to 2040.

non-residential urban land	lu2004 /ha	lu2040 /ha
workLocations	7432	7662
10% of urban	4530.9	4544.2
port	5834	6400
TOTAL	**17796.9**	**18606.2**
Change in amount of new non-residential urban land	809.3 ha	4.55%

The loss of farmland between 2004 and 2040 is -0.39% for the BAU scenario (table 14).

Table 14. The farmland land use changes for the BAU scenario for 2040.

Farmland	lu2004	lu2040
arable	60048	59946
pasture	104167	103605
bulbs	4028	4028
TOTAL	**168243**	**167579**
Change in amount of farmland	-664 ha	-0.39%

An in depth analysis was done on all baseline scenarios adopting the method presented by Pontius *et al* (2004[4]) whereby the net gain, loss and exchange of land types, which are regrouped into simplified thematic areas, are analyzed based on the frequency of exchange amongst themselves. The contingency table analysis shows that there is a no land "swapping" in this scenario, therefore all changes seen are net changes. Furthermore, when there is a gain of built-up land, it comes at the expense of vacant land (0.21% higher probability than in a random model). No other conclusions can be drawn from this scenario outcome when compared to the random model outcome. Table 15 summarises the gain, loss, swapping and net change in each land use meta-class:

Table 15. The results of the categorical land use change analysis for the BAU scenario, corrected for the probability factor in a random model

	gain	loss	total change	SWAP	abs value 'net change'
built-up	0.78	0.00	0.78	0.00	0.78
natural	0.00	0.00	0.00	0.00	0.00
farmed	0.00	0.51	0.51	0.00	0.51
vacant	0.00	0.27	0.27	0.00	0.27
total	0.78	0.78	1.56	0.00	1.56

[4] Pontius Jr., Shusas, E., McEachern, M (2004). Detecting important categorical land changes while accounting for persistence. Agriculture, Ecosystems and Environment 101: 251-268.

4.2 Peak Oil (B1)

The results for the B1 scenario are shown in figure 18.

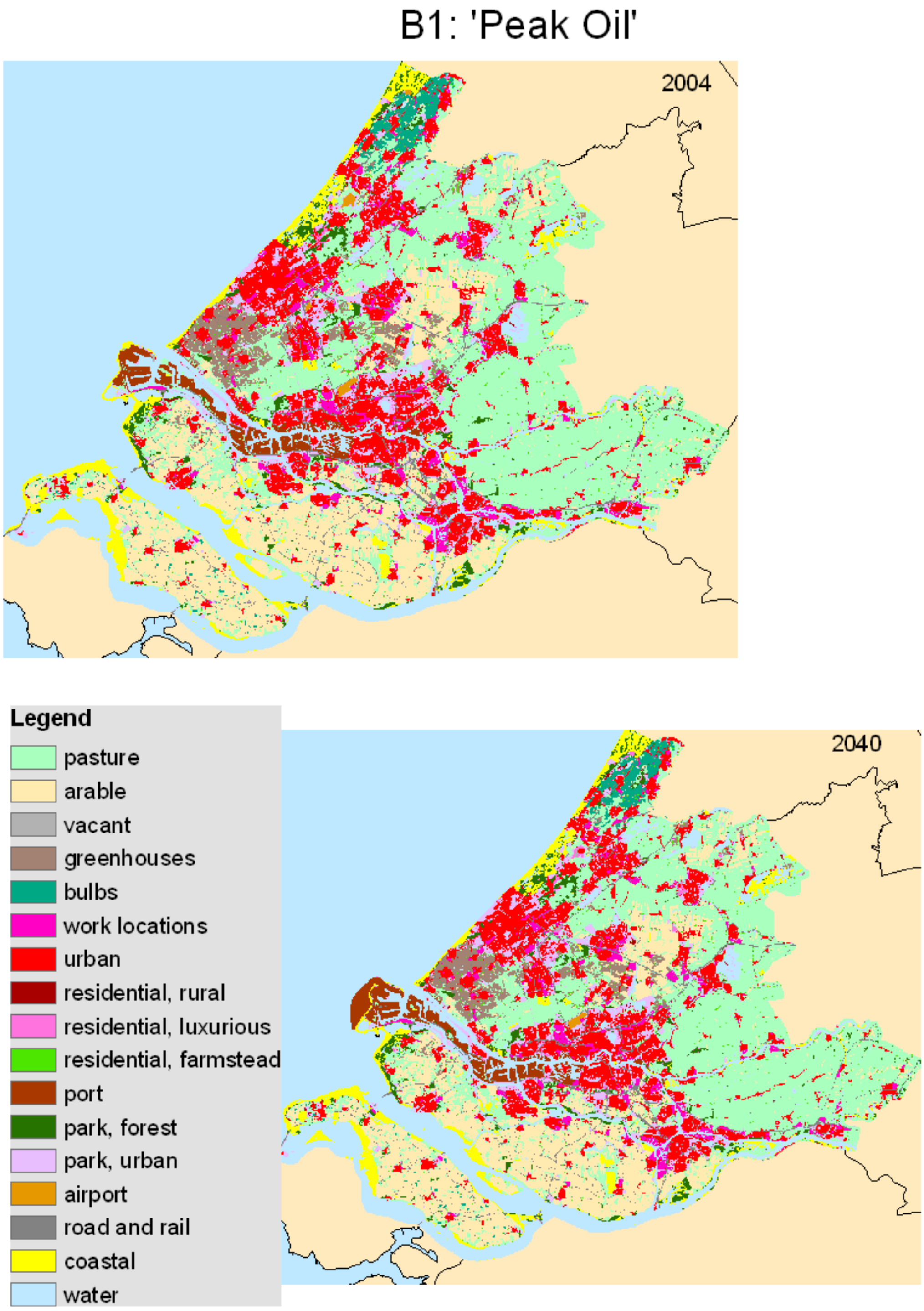


Figure 18. The resulting land use map for the peak oil (B1) scenario for 2040.

The changes from one land use class to another between 2004 and 2040 according to the B1 scenario are summarised in table 16.

Table 16. The changes in land use classes for the B1 scenario, from 2004 to 2040.

	2004	2040	Change %
pasture	104167	103596	-0.55
arable	60048	58577	-2.45
vacantUrban	874	82	-90.62
greenhouses	8950	9102	1.70
bulbs	4028	4098	1.74
workLocations	7432	8019	7.90
urban	45309	46751	3.18
ResidRural	600	626	4.33
ResidLuxury	1555	1628	4.69
Residfarmsteads	2105	2105	0.00
port	5834	6400	9.70
parkForest	7513	7513	0.00
parkUrban	17237	17236	-0.01
airport	270	270	0.00
roadsRail	10078	10078	0.00
ReedsSandMarsh	14688	14613	-0.51
Water	50087	50081	-0.01

Tables 17 and 18 summarise the main changes in residential and non-residential urban classes between 2004 and 2040.

Table 17. The changes in residential urban surfaces for the B1 scenario

residential urban land	lu2004	lu2040
90% of urban	40778.1	42075.9
ruralResidences	600	626
woodlandResid	1555	1628
50% farmsteads	1052.5	1052.5
TOTAL	**43985.6**	**45382.4**
Change in amount of new residential urban land	1396.8 ha	3.18%

Table 18. The changes in non-residential urban surfaces for the B1 scenario

non-residential urban land	lu2004	lu2040
workLocations	7432	8019
10% of urban	4530.9	4675.1
port	5834	6400
TOTAL	**17796.9**	**19094.1**
Change in amount of new non-residential urban land	1297.2 ha	7.29%

The loss of farmland is quantified as being -1.17% for this scenario (table 19):

Table 19. The changes in farmland for the B1 scenario

Farmland	lu2004	lu2040
arable	60048	58577
pasture	104167	103596
bulbs	4028	4098
TOTAL	**168243**	**166271**
Change in amount of farmland	-1972 ha	-1.17%

The net gain, loss and exchange of land types, which are regrouped into simplified thematic areas, are analyzed based on the frequency of exchange amongst themselves (Pontius *et al* 2004). The contingency table analysis shows that there is a no land "swapping" in this scenario, therefore all changes seen are net changes. Furthermore, when there is a gain of built-up land, it comes at the expense of vacant land (0.01% higher probability than in a random model). No other conclusions can be drawn from this scenario outcome when compared to the random model outcome. Table 20 summarises the gain, loss, swapping and net change in each land use meta-class:

Table 20. The results of the categorical land use change analysis for the B1 scenario, corrected for the probability factor in a random model

	gain	loss	total change	SWAP	abs value 'net change'
built-up	1.05	0.00	1.05	0.00	1.05
natural	0.00	0.00	0.00	0.00	0.00
farmed	0.00	0.68	0.68	0.00	0.68
vacant	0.00	0.37	0.37	0.00	0.37
total	1.05	1.05	2.10	0.00	2.10

4.3 Fragmentation (B2)

The fragmentation scenario was the most difficult to configure in that the economic drivers were difficult to identify. It appears that in this scenario, the main economic drivers of the region are on the decline. Yet some activity is still expected in the Delft region from the R&D sector. The scenario is characterized by degraded city centers and the appearance of "gated communities", a term which we took the liberty to interpret as meaning an increase in the rural and woodland residential classes. It was technically not possible to assign a different economic sector to greenhouses, as the scenario description implies, so this class results as vacated on the maps although in the scenario definition, the greenhouses are converted to other uses. Urban area was allowed to take over the greenhouses to a certain extent. Figure 19 shows the resulting land use map for this scenario:

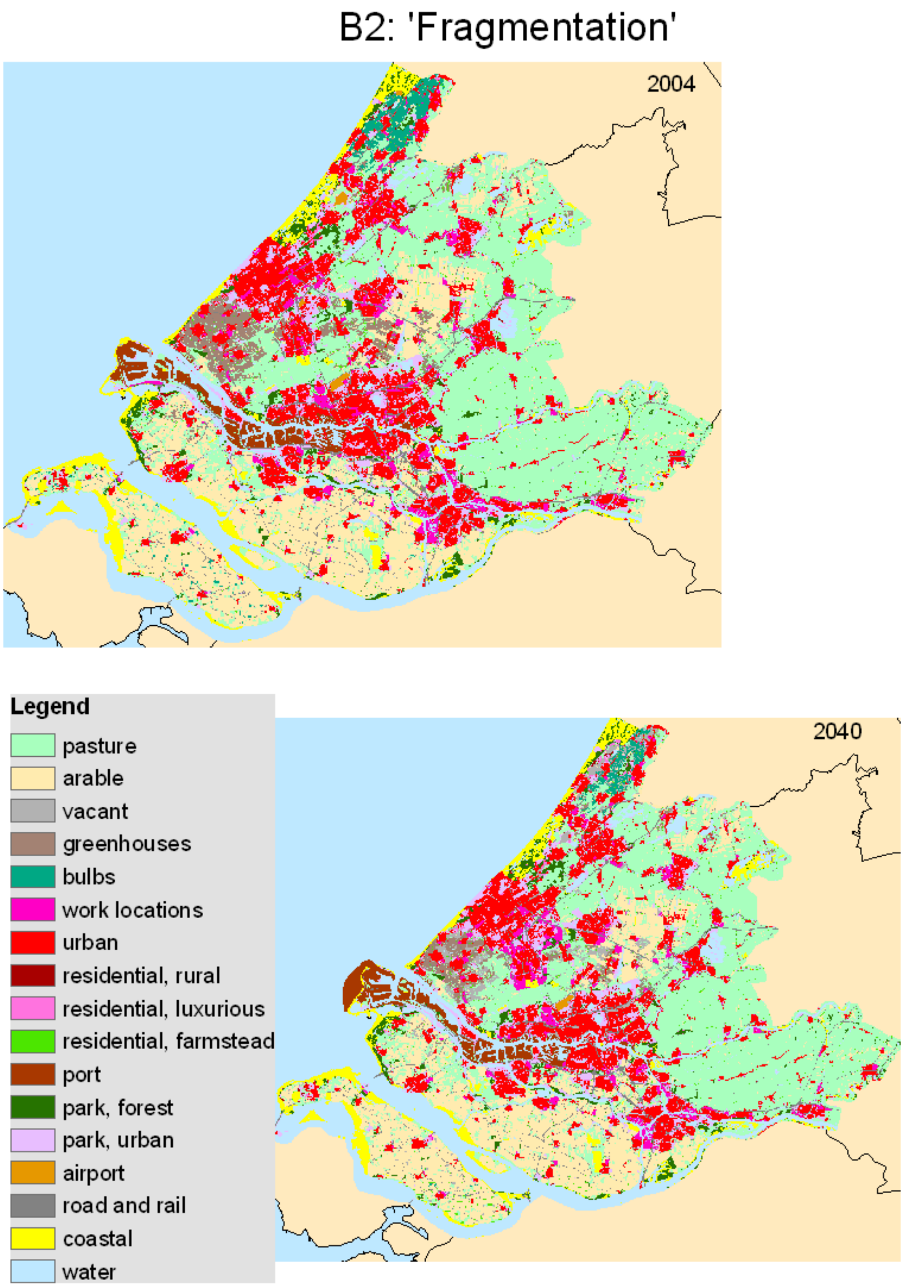


Figure 19. The resulting land use map for the fragmentation (B2) scenario for 2040.

Table 21 summarises the changes in land use for the province from 2004 to 2040 according to the B2 scenario. The increase in vacant areas is massive.

Table 21. The changes in land use classes from 2004-2040 for the B2 scenario.

	2004	2040	Change %
pasture	104167	103368	-0.77
arable	60048	58586	-2.43
vacantUrban	874	7351	741.08
greenhouses	8950	4478	-49.97
bulbs	4028	2011	-50.07
workLocations	7432	7575	1.92
urban	45309	46628	2.91
ResidRural	600	608	1.33
ResidLuxury	1555	1598	2.77
Residfarmsteads	2105	2381	13.11
port	5834	6400	9.70
parkForest	7513	7513	0.00
parkUrban	17237	17236	-0.01
airport	270	270	0.00
roadsRail	10078	10078	0.00
ReedsSandMarsh	14688	14613	-0.51
Water	50087	50081	-0.01

For the B2 scenario, the amount of new residential and non-residential urban land is summarised in tables 22 and 23:

Table 22. The expansion of residential urban surfaces for the B2 scenario between 2004 to 2040.

residential urban land	lu2004	lu2040
90% of urban	40778.1	41965.2
ruralResidences	600	608
woodlandResid	1555	1598
50% farmsteads	1052.5	1190.5
TOTAL	**43985.6**	**45361.7**
Change in amount of new residential urban land	1376.1 ha	3.13%

Table 23. The expansion of non-residential urban surfaces for the B2 scenario between 2004 to 2040.

non-residential urban land	lu2004	lu2040
workLocations	7432	7575
10% of urban	4530.9	4662.8
port	5834	6400
TOTAL	**17796.9**	**18638**
Change in amount of new non-residential urban land	840.9 ha	4.72%

The loss of farmland between 2004 and 2040 is -2.54% for the B2 scenario. (table 24):

Table 24. Change in nature and farmland classes.

Farmland	lu2004	lu2040
arable	60048	58586
pasture	104167	103368
bulbs	4028	2011
TOTAL	**168243**	**163965**
Change in amount of farmland	-4278	-2.54

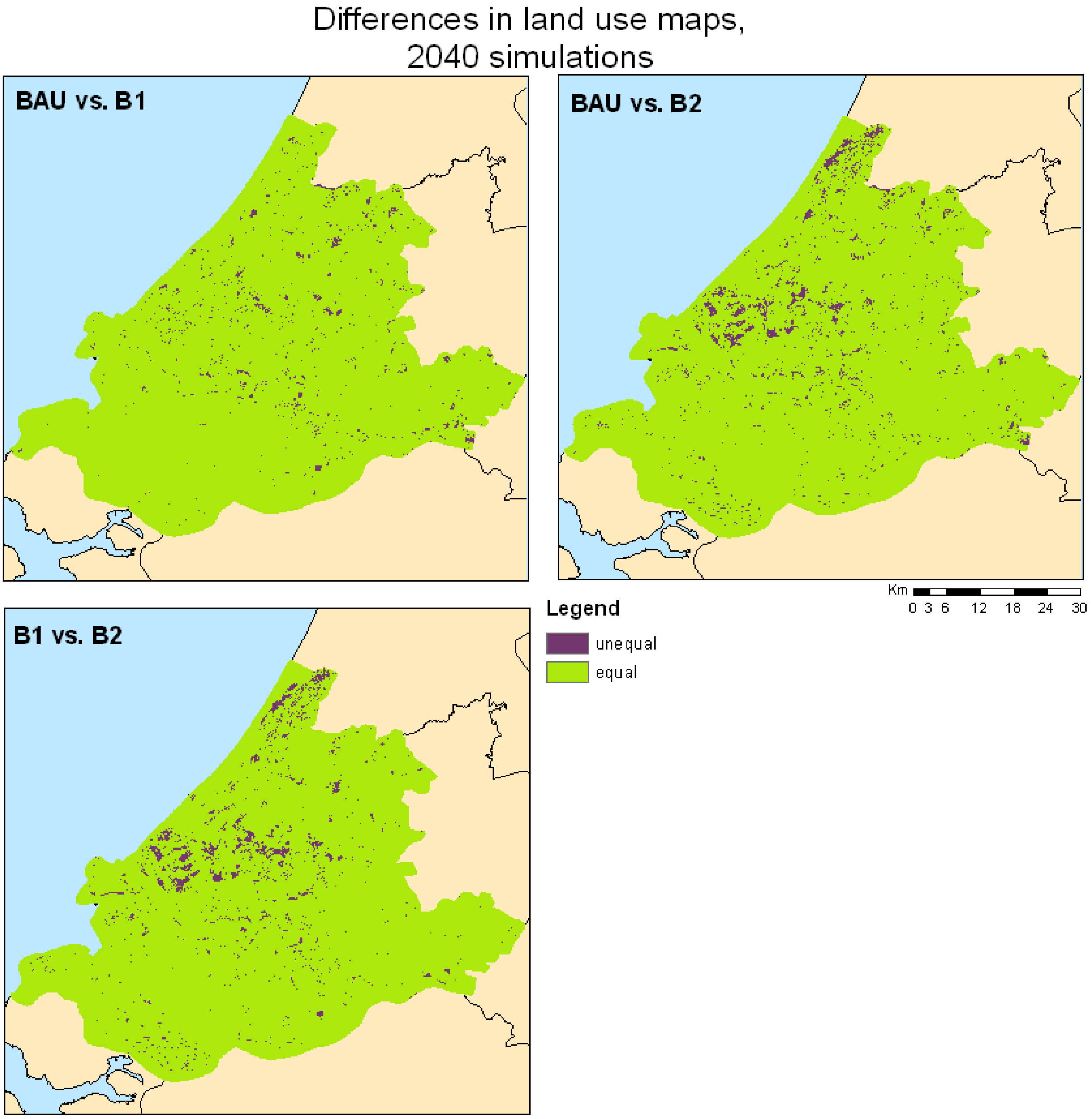
The advanced contingency table analysis shows that there is a bit of land "swapping" in this scenario within the built-up and vacant land meta-classes. The matrix also shows that when there is a gain of built-up land, it comes at the expense of vacant land (0.01% higher probability than in a random model); and vacant land will take over built up (0.27% more frequently than a random model) and farmed land (0.68% more frequently than a random model). Table 25 summarises the gain, loss, swapping and net change in each land use meta-class:

Table 25. The results of the categorical land use change analysis for the B2 scenario, corrected for the probability factor in a random model

	gain	loss	total change	SWAP	abs value 'net change'
built-up	1.33	0.28	1.61	0.55	1.06
natural	0.00	0.00	0.00	0.00	0.00
farmed	0.00	1.75	1.75	0.00	1.75
vacant	0.97	0.28	1.25	0.55	0.70
total	2.30	2.30	4.61	1.10	3.51

4.4 Scenario comparisons

When the scenario results are compared to one another in terms of the criteria set by the indicators, the differences in the outcomes are evident (figure 20).



	pasture	arable	vacant	greenhouses	bulbs	workLocations	urban	ResidRural	Luxury homes	farmsteads	port	overallKappa
b1 vs b2	0.98	0.99	0.05	0.64	0.66	0.69	0.98	0.99	0.52	0.87	0.95	0.95
bau vs b2	0.97	0.97	0.14	0.65	0.66	0.72	0.98	1.00	0.58	0.88	0.97	0.95
bau vs b1	0.98	0.97	0.02	0.89	0.97	0.86	0.98	0.98	0.61	0.97	0.97	0.97

Figure 20. The difference maps showing the areas that are equal and those that are unequal between the three baseline scenarios and associated kappa coefficients for each couple.

The following four figures show zooms or the areas most affected by changes (as indicated by figure 20). In the BAU scenario the area which was labeled as being an airport in 2004 is converted to greenhouses and some luxury house. In the B1 scenario, this same area is converted to urban and luxury residences, although some is still left vacant. In the B2 scenario, most of this land remains vacant, although a bit of urban land appears (figure 21).

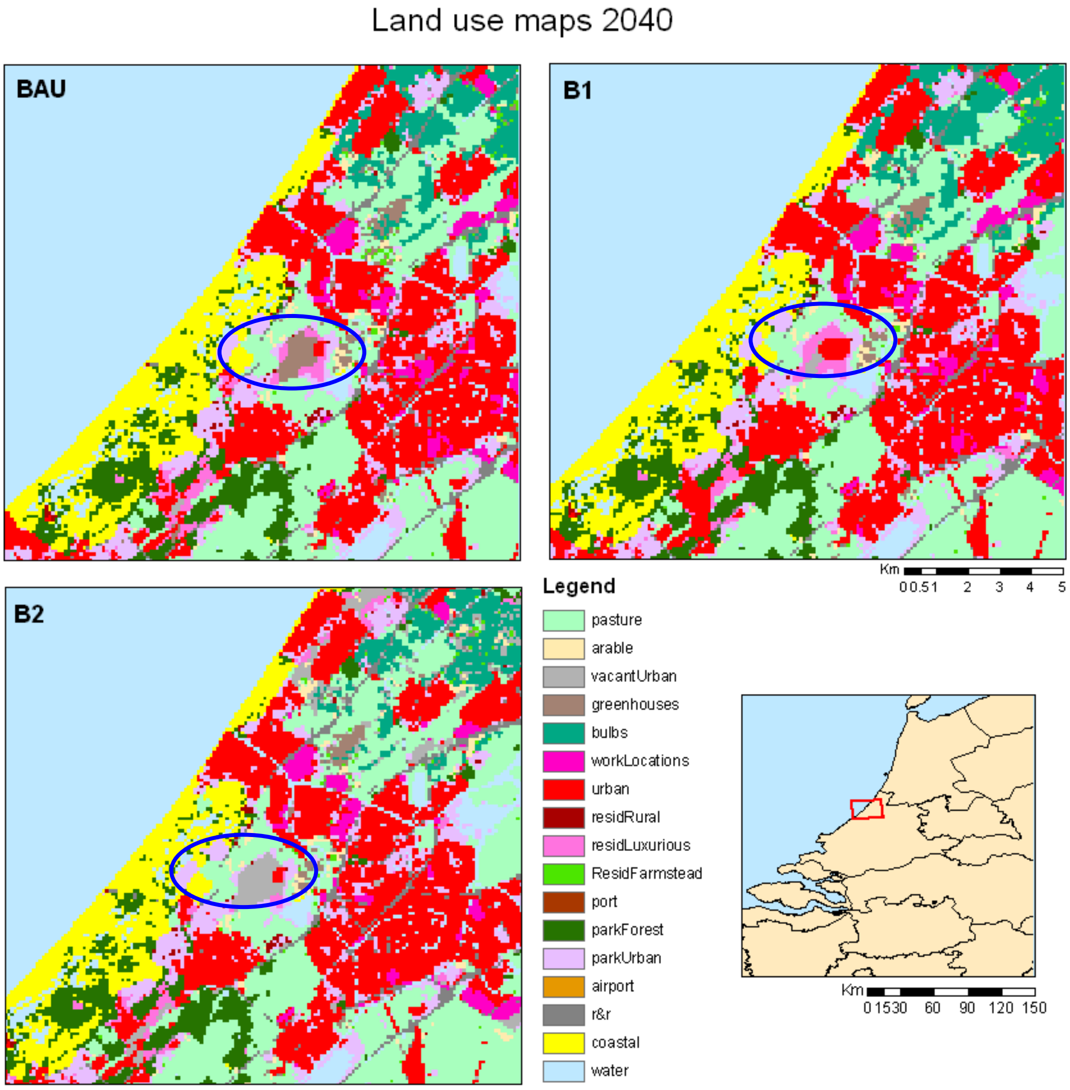


Figure 21. A zoom on the abandoned airport in the NW part of the province.

Figure 22 shows The Hague region zoom whereby the main differences are in the greenhouse densification in the B1 scenario and it's vacating in the B2 scenario; and differences in industrial area placements in all three scenarios

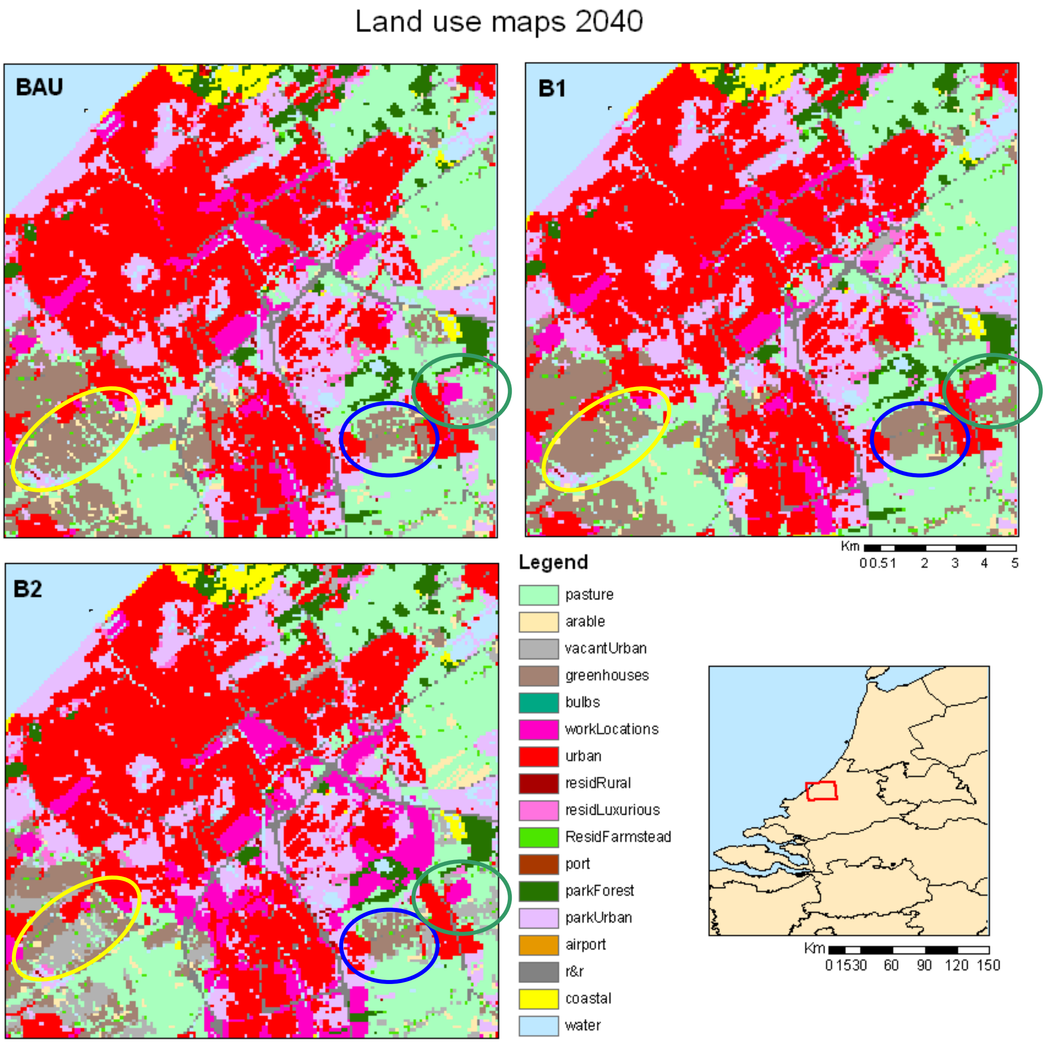


Figure 22. A zoom on The Hague region, differences in model outcome.

For the Rotterdam port area near the city center, there are differences in the way in which the progressively vacating port land is converted. In the BAU scenario, much of it is left vacant due to the decreasing population and thus the decreasing demand . A few greenhouse cells do pop up on the former port area for this scenario. For the B1 scenario, the area is converted to urban and industrial sites. The B2 scenario also shows this effect, but to a lesser degree (figure 23).

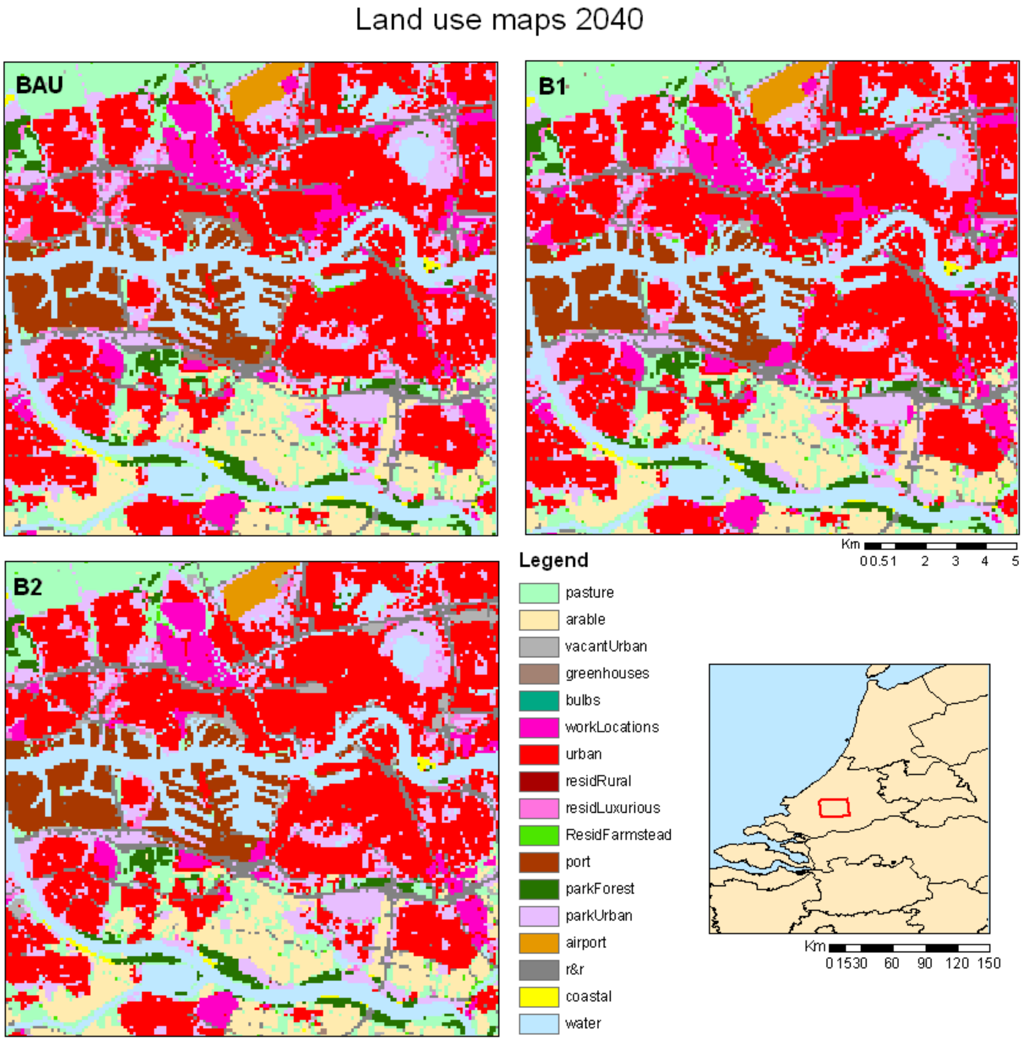


Figure 23. A zoom on the Rotterdam port region, differences in model outcome

As shown in figure 24, some changes occurring here and there are often difficult to see with the human eye, but appear in the statistics.

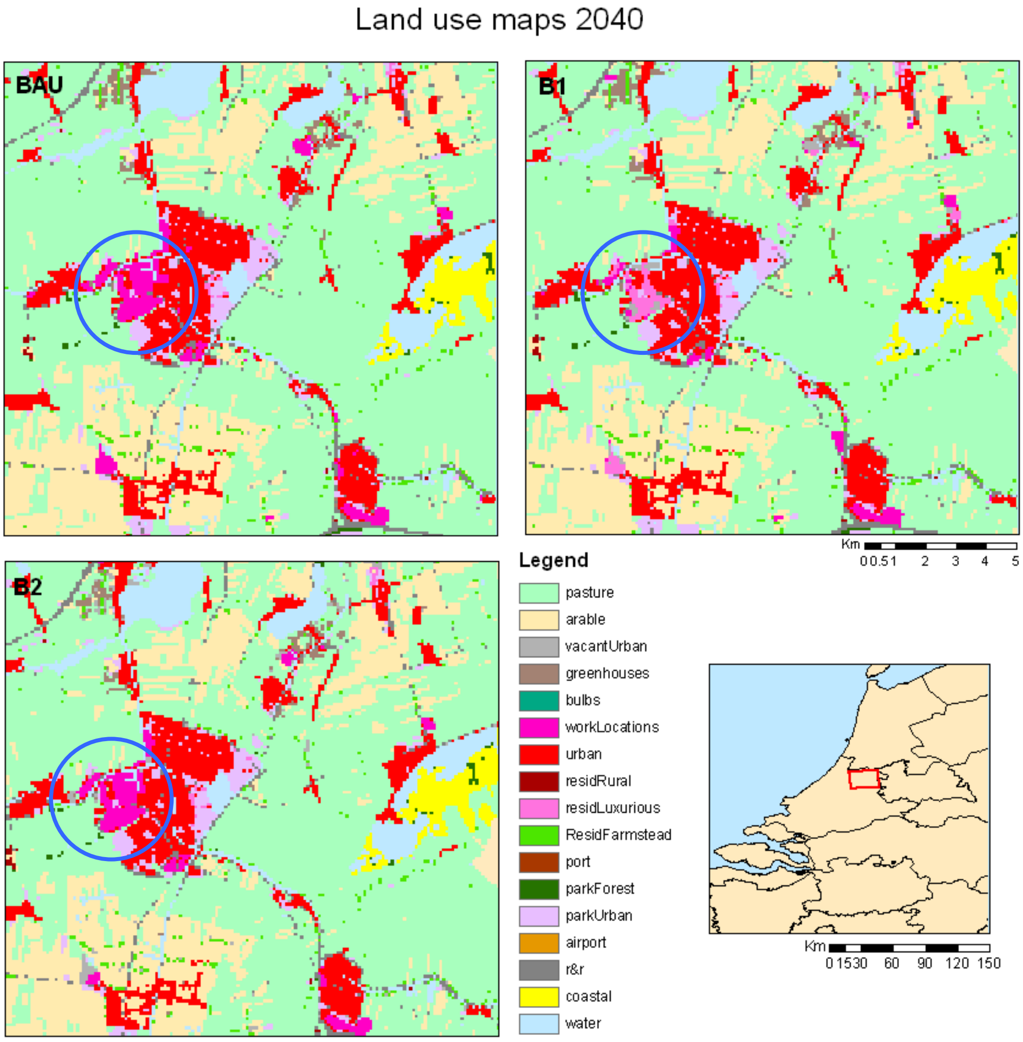


Figure 24. A zoom on the NNE part of the province, differences in model outcome

All scenarios used the same zoning restriction maps and the same suitability maps. The main differences are in the demand for land in the different scenarios and the decline in the port area in the B2 scenario. Workplaces and rural residential housing crop up in the Delft-Rijwijk-Nootdorp triangle and farmsteads appear in the B2 scenario. In terms of total land change, the B2 scenario shows drastic increase in vacant land. This can be rectified by using a more generous zoning map which allows the reallocation of land uses associated with declining economic sectors, namely the port and greenhouses. It is the zoning maps and lack of demand which prevents these areas from being reassigned. Table 26 shows the overall changes in land use for the three scenarios:

Table 26. The overall changes in land use classes for each of the scenarios.

Percent change in land use classes from 2004 to 2040	BAU	B1	B2
pasture	-1.35	-0.55	-0.77
arable	-0.49	-2.45	-2.43
vacant	-99.77	-90.62	741.08
greenhouses	1.70	1.70	-49.97
bulbs	1.74	1.74	-50.07
workLocations	4.63	7.90	1.92
urban	3.21	3.18	2.91
ResidRural	3.50	4.33	1.33
ResidLuxury	3.09	4.69	2.77
Residfarmsteads	0.00	0.00	13.11
port	9.70	9.70	9.70
parkForest	0.00	0.00	0.00
parkUrban	-0.01	-0.01	-0.01
airport	0.00	0.00	0.00
roadsRail	0.00	0.00	0.00
ReedsSandMarsh	-0.51	-0.51	-0.51
Water	-0.01	-0.01	-0.01

Figures 25-29 show the differences between scenario outcomes for the most relevant land use classes. A more in-depth spatial analysis could be done with the ascii files of the scenario outcomes.

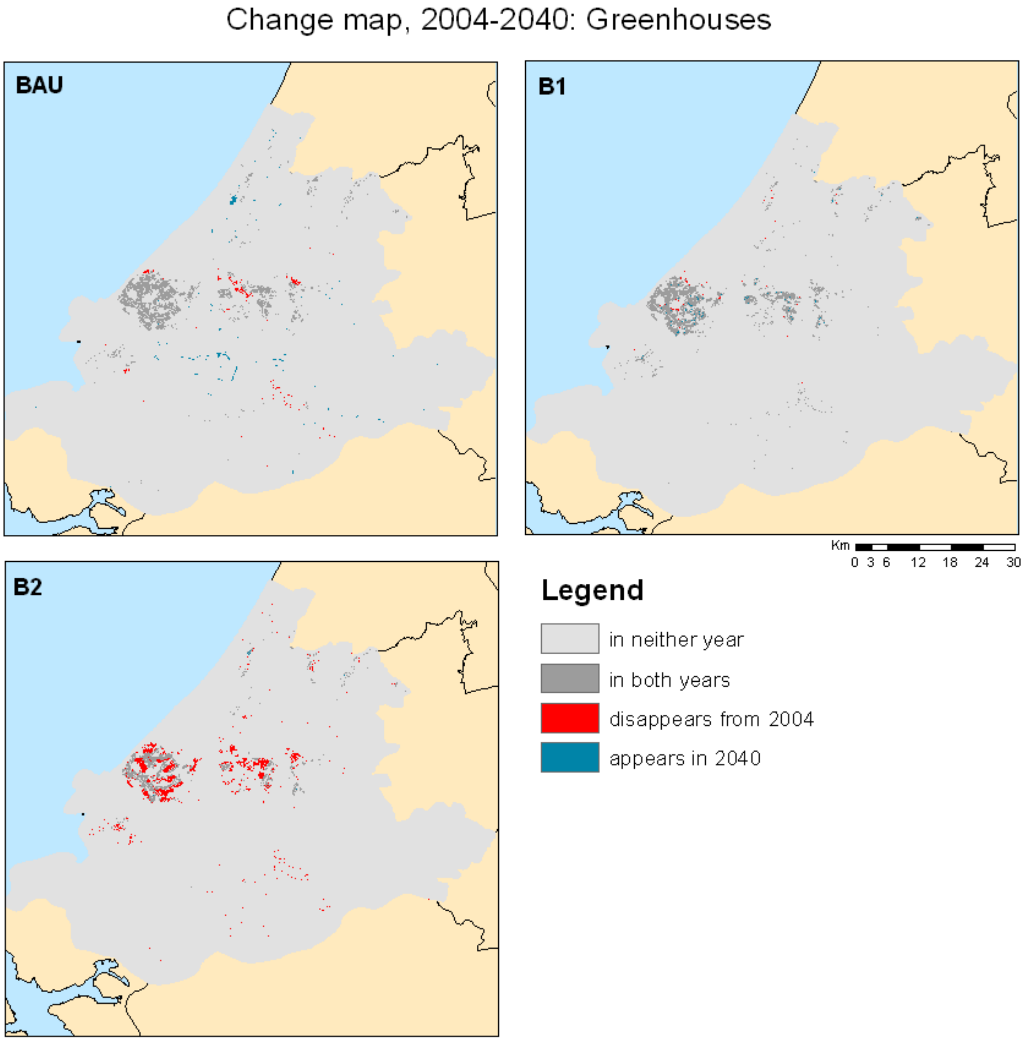


Figure 25. Differences in the greenhouses class for the three baseline scenarios.

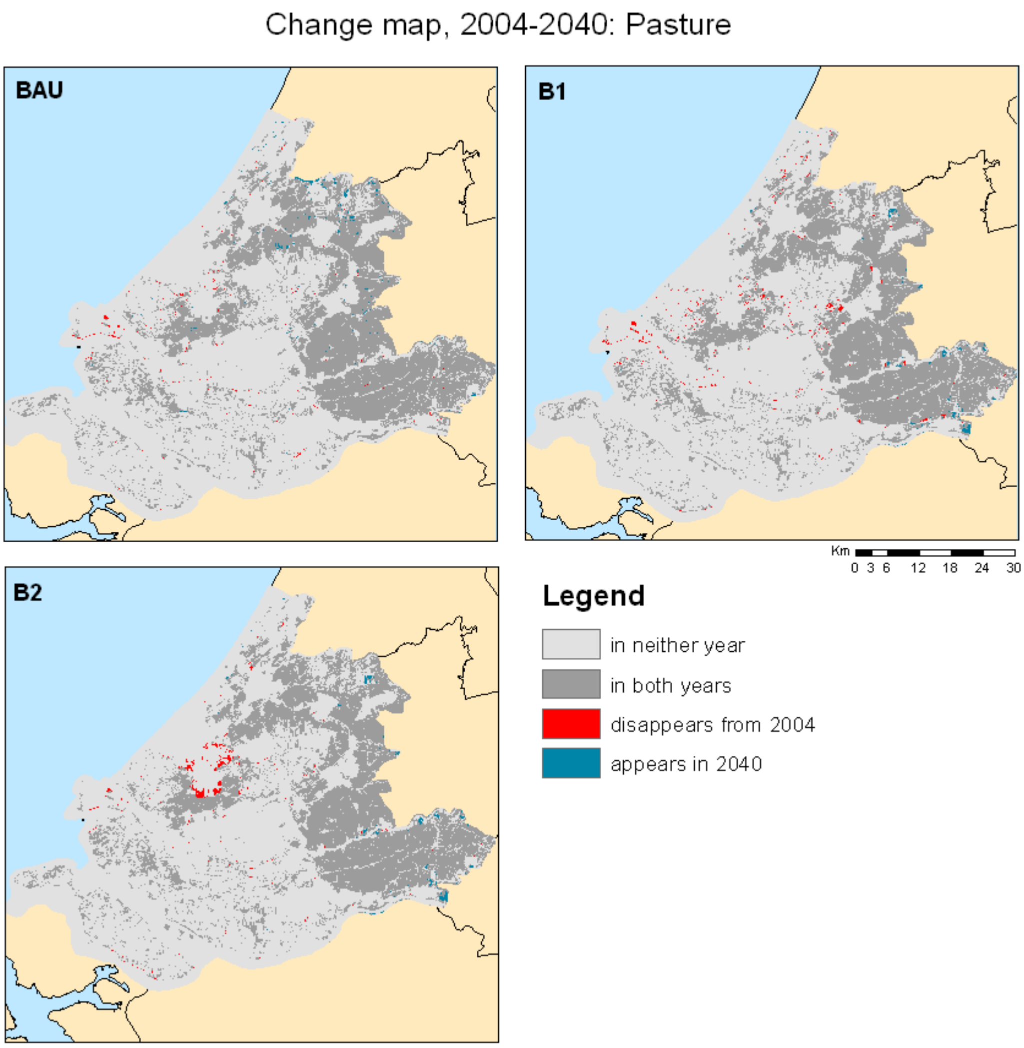


Figure 26. Differences in the pasture class for the three baseline scenarios.

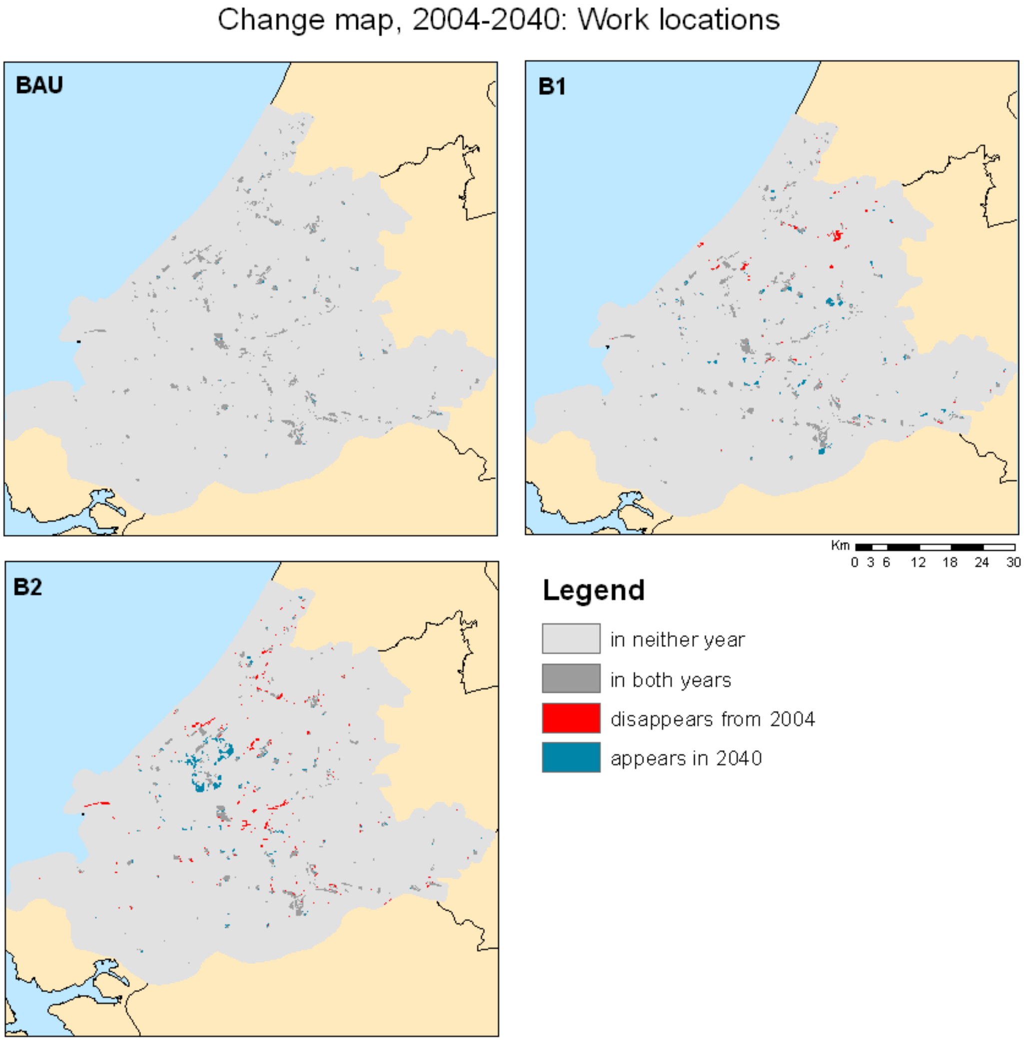


Figure 27. Differences in the work locations class for the three baseline scenarios.

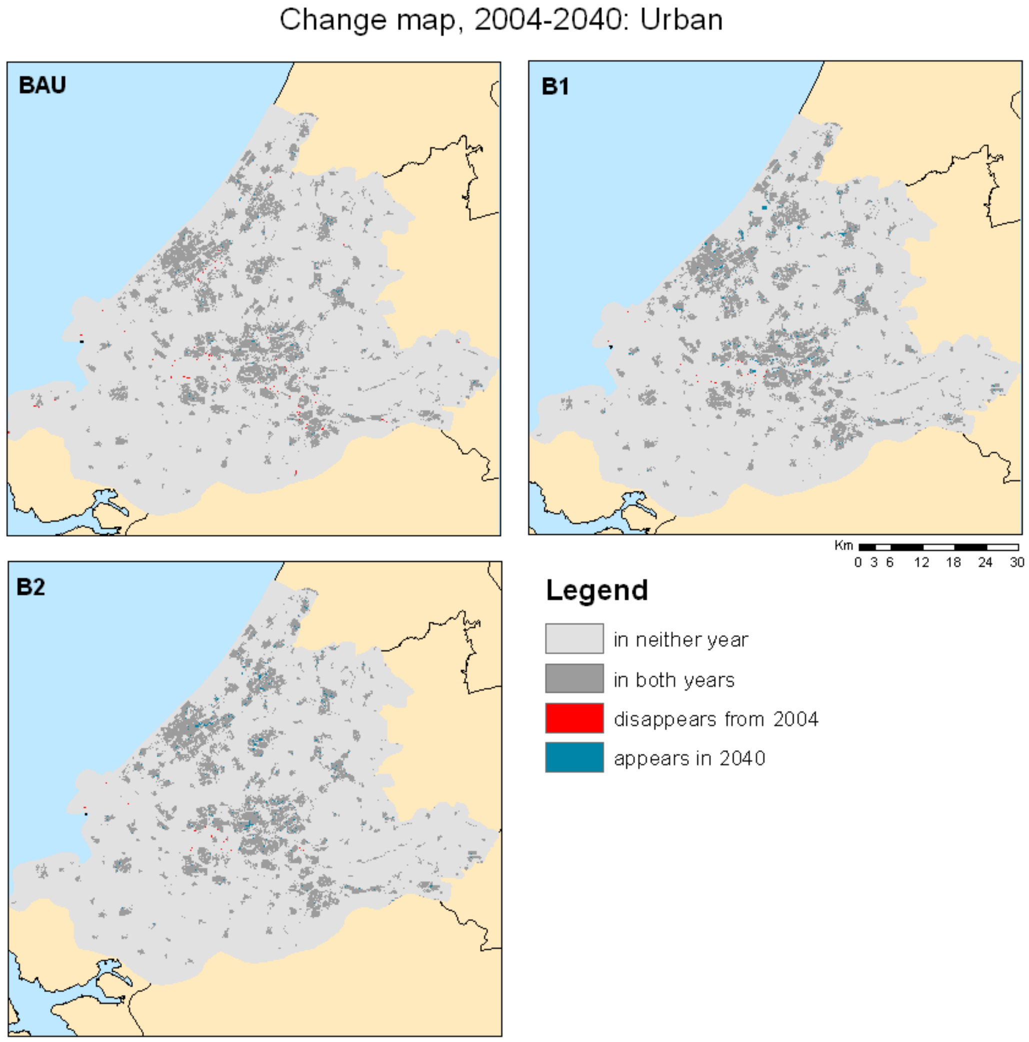


Figure 28. Differences in the urban class for the three baseline scenarios.

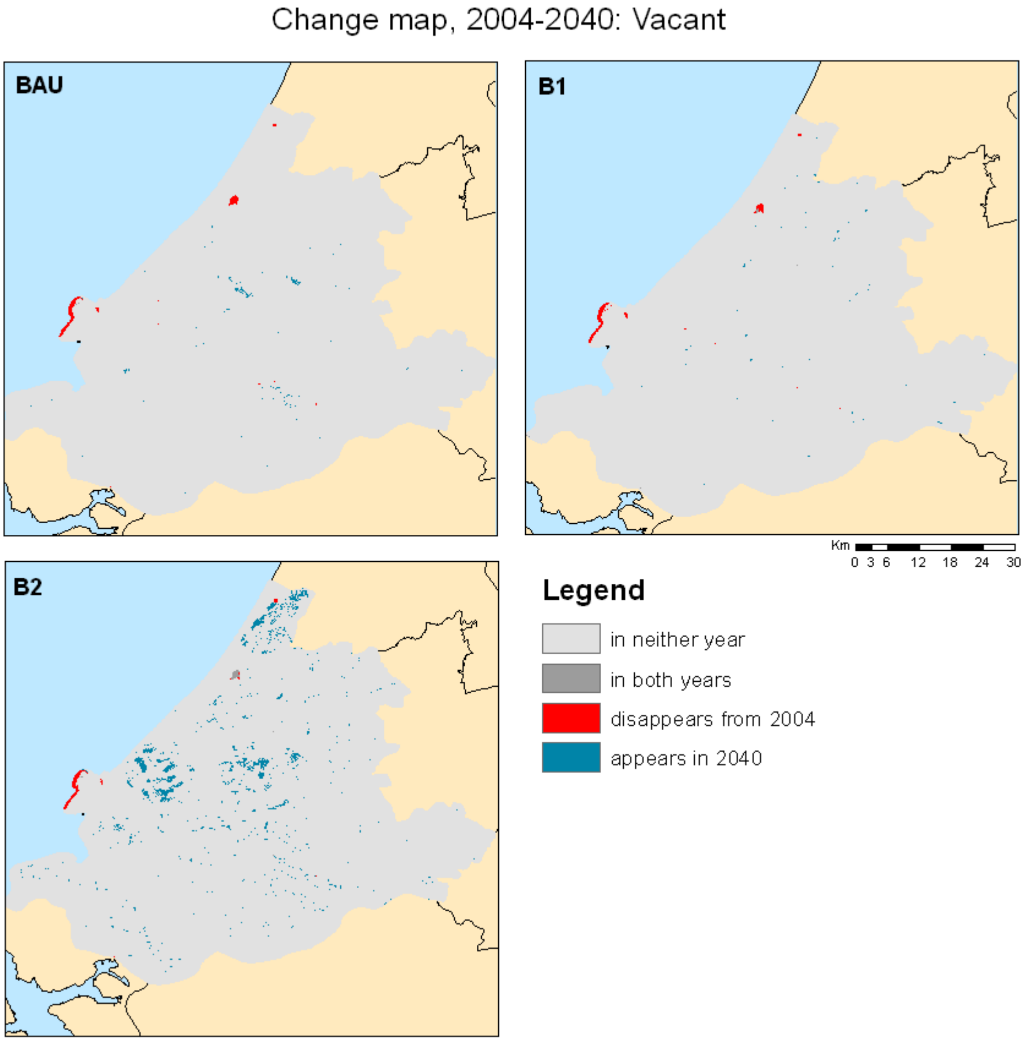


Figure 29. Differences in the vacant land class for the three baseline scenarios.

4.5 Change statistics for RUR divisions

Table 27 summarises differences in the land use changes in for the RUR divisions. These divisions are shown in figure 30:

Table 27. The percent change of grouped land use classes according to theme for the RUR divisions.

DIFFERENCES % change from 2004 to 2040 per scenario:			
2040 BAU	natural	farmland	built-up
protected	0.00	-9.05	3.98
urban	0.00	-5.17	0.10
peri-urban	0.00	-0.22	-0.06
rural	-0.75	-0.55	3.82
2040 B1	natural	farmland	built-up
protected	0.00	-9.51	3.78
urban	0.00	-10.69	0.10
peri-urban	0.00	-1.27	4.17
rural	-0.75	-0.99	5.82
2040 B2	natural	farmland	built-up
protected	0.00	-1.60	1.13
urban	0.00	34.00	-1.24
peri-urban	0.00	2.36	-6.62
rural	-0.75	-1.09	6.41

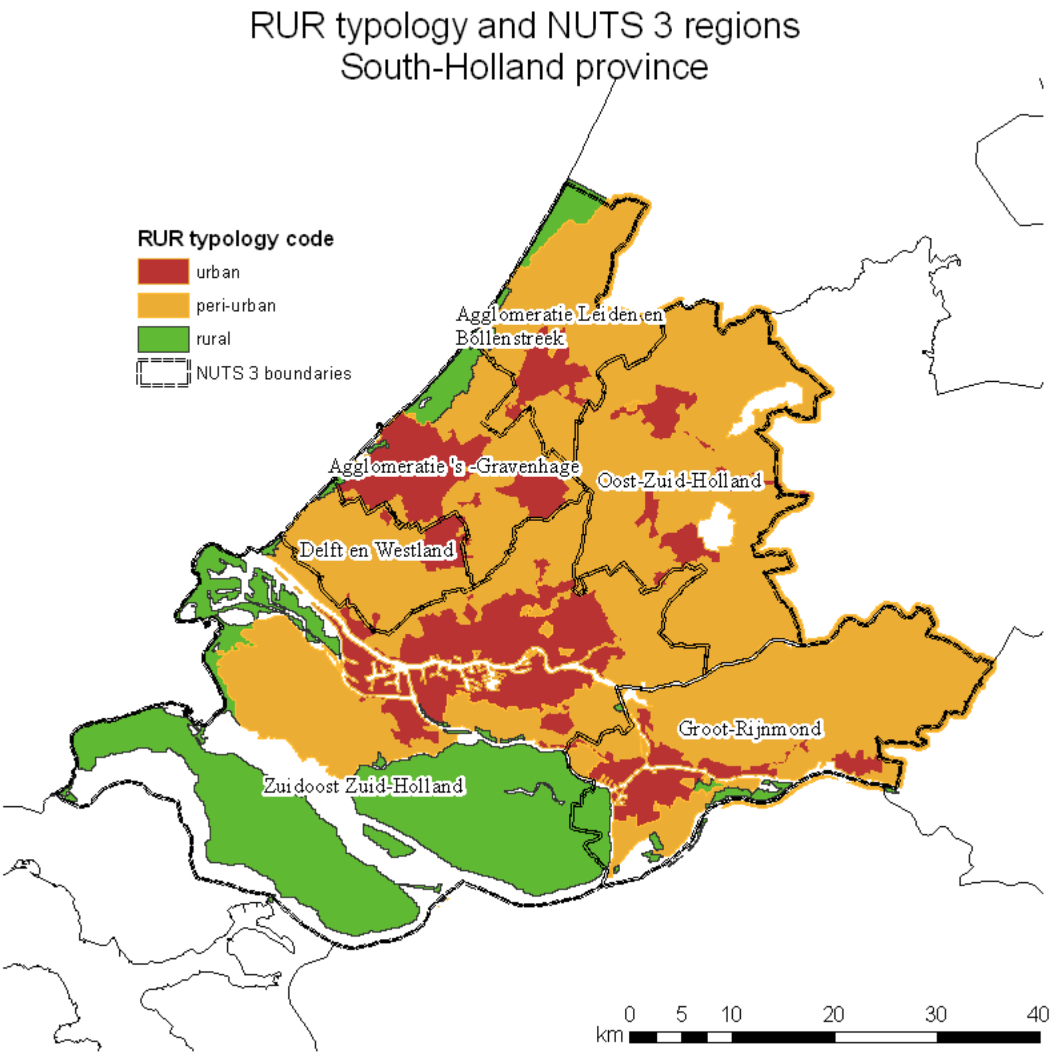


Figure 30. The RUR typology and NUTS 3 regions of the South-Holland province

4.6 Strategies (policy alternatives)

Although it is beyond the scope of this report to discuss the three strategies which were applied to each of the baseline scenarios, some statistics were extracted from the maps in order to provide a “quick view” of the effects of Strategies 1,3 and 4 on the three baseline scenarios. Figures 31-33 show the impacts of the strategies.

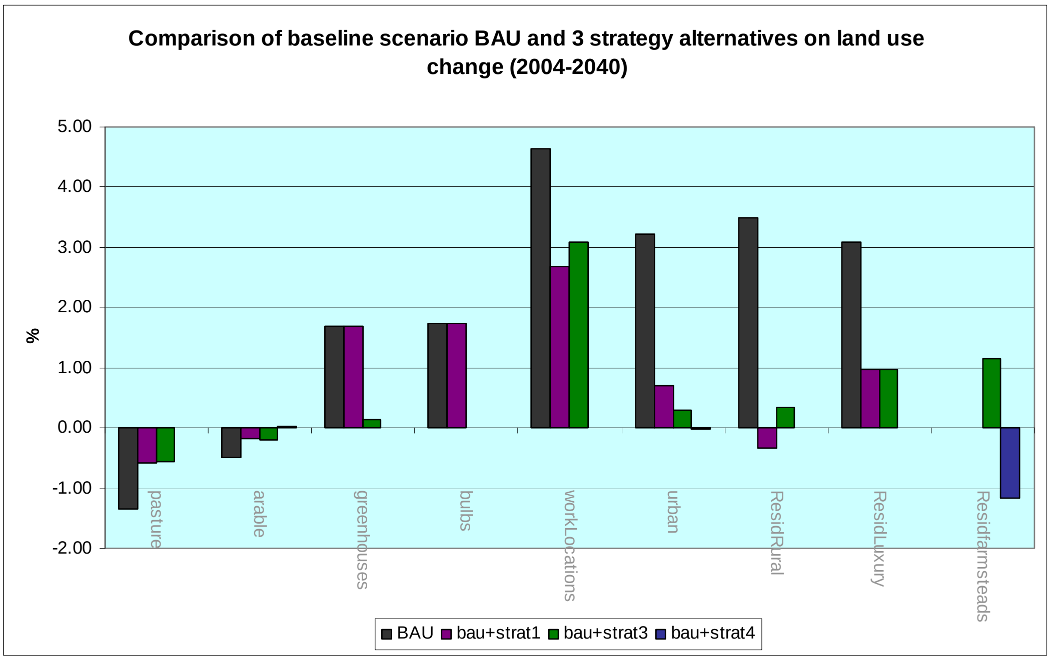


Figure 31. The differences for the BAU baseline scenario and the 3 strategies on land use for 2040.

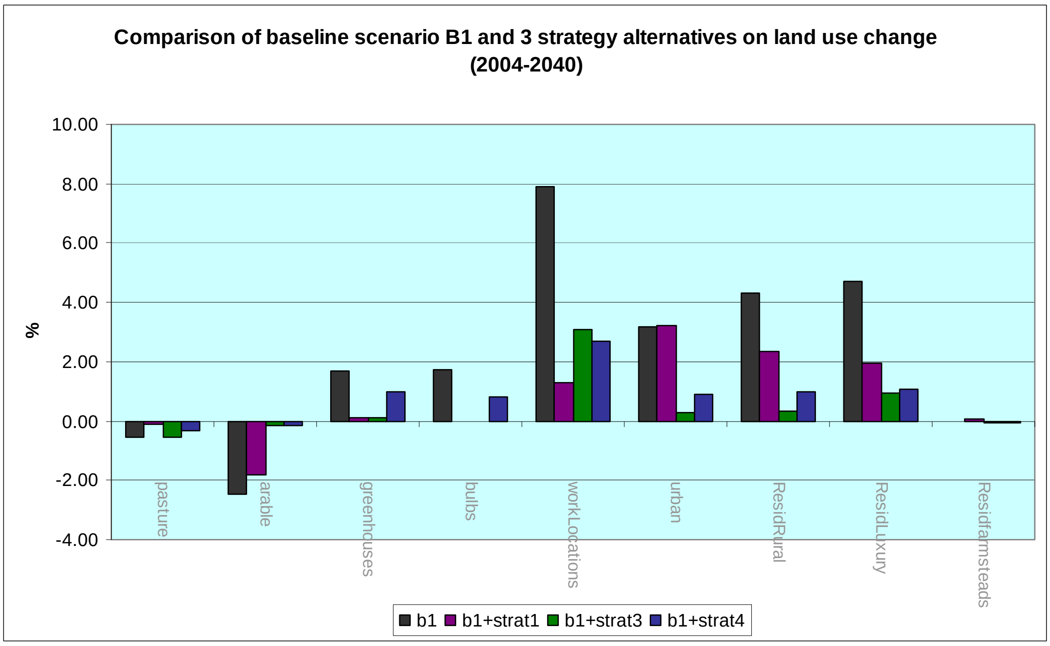


Figure 32. The differences for the B1 baseline scenario and the 3 strategies on land use for 2040.

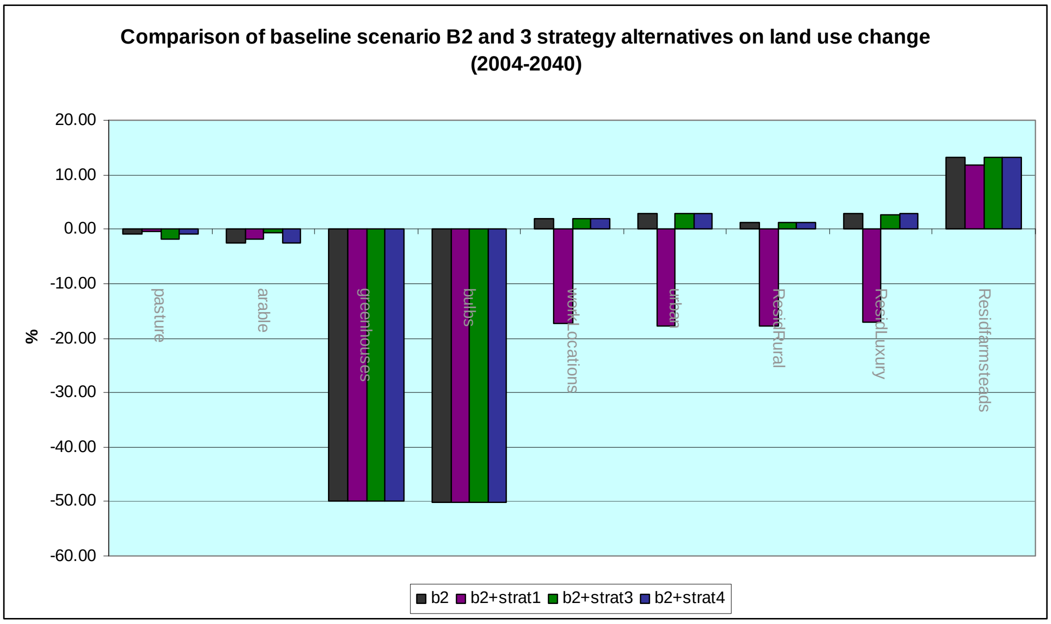


Figure 33. The differences for the B2 baseline scenario and the 3 strategies on land use for 2040.

Annex A

Table A1. The suitability layers are compared to the land use layers using a contingency table. The percent land use occupying the area of the suitability class (normalized by total area of that class) of the percent

	1995						2004				
Water availability	**class1**	**class2**	**class3**	**class4**	**class5**		**class1**	**class2**	**class3**	**class4**	**class5**
pasture%of%	2.37	8.79	9.22	1.64	6.02		1.98	8.91	9.35	1.28	5.62
arable%of%	1.47	0.01	0.15	16.42	0.22		1.42	0.01	0.09	15.54	0.21
forest%of%	0.66	0.08	0.34	0.32	0.06		0.69	0.06	0.32	0.50	0.07
urbanVacant%of%	0.00	0.00	0.02	0.02	0.00		0.00	0.00	0.12	0.01	0.00
bulbs%of%	0.01	0.00	1.62	0.01	0.00		0.01	0.00	2.24	0.02	0.01
SOIL DEPTH											
pasture%of%	0.01	13.57	6.25	0.09	7.18		0.01	13.04	6.31	0.09	6.24
arable%of%	0.10	1.04	0.01	0.00	14.56		0.08	1.15	0.01	0.00	13.26
forest%of%	0.06	0.01	0.87	0.00	0.84		0.07	0.02	0.76	0.00	1.04
urbanVacant%of%	0.02	0.00	0.00	0.00	0.03		0.00	0.00	0.00	0.00	0.07
bulbs%of%	0.00	0.00	0.01	0.00	0.81		0.00	0.00	0.01	0.00	1.24

WATER SHORTAGE											
pasture%of%	4.63	3.00	7.90	5.05	1.47		3.78	2.73	7.50	5.16	1.42
arable%of%	1.53	13.26	6.18	0.03	0.02		1.20	12.41	6.08	0.04	0.04
forest%of%	1.67	0.07	0.13	0.07	0.02		1.79	0.14	0.17	0.08	0.02
urbanVacant%of %	0.06	0.00	0.01	0.00	0.00		0.12	0.00	0.01	0.00	0.00
bulbs%of%	1.75	0.01	0.00	0.00	0.00		2.68	0.01	0.00	0.00	0.00
EROSION RISK											
pasture%of%	27.72	0.98	0.01	0.01	0.00		26.16	0.79	0.01	0.01	0.00
arable%of%	10.57	6.01	0.07	0.02	0.00		10.54	4.98	0.00	0.00	0.00
forest%of%	0.85	0.08	0.25	0.66	0.10		1.07	0.13	0.21	0.55	0.10
urbanVacant%of %	0.02	0.01	0.00	0.00	0.00		0.01	0.01	0.00	0.00	0.00
bulbs%of%	0.22	0.03	9.47	1.24	0.00		0.37	0.07	11.14	1.41	0.00
ELEVATION											
pasture%of%	4.23	22.95	2.65	0.10	0.00		3.85	21.90	2.36	0.07	0.00
arable%of%	3.02	8.88	3.49	0.02	0.00		2.66	9.07	2.98	0.01	0.00
forest%of%	0.00	0.02	0.19	1.09	4.62		0.01	0.06	0.25	1.05	4.10
urbanVacant%of %	0.00	0.01	0.01	0.02	0.00		0.00	0.00	0.01	0.06	0.01
bulbs%of%	0.00	0.10	0.58	0.03	0.00		0.00	0.15	0.91	0.04	0.00
grennhouses	0.47	0.35	1.16	0.01	0.00		0.69	0.42	1.10	0.01	0.00

urban	0.17	0.66	5.45	7.83	1.04	0.22	0.76	5.72	7.67	0.95
built-up, rural	0.01	0.01	0.05	0.05	0.01	0.03	0.01	0.05	0.06	0.01
built-up, woodla	0.01	0.03	0.12	0.21	0.20	0.01	0.02	0.11	0.20	0.22
built-up, agri	0.11	0.22	0.19	0.01	0.00	0.10	0.21	0.15	0.01	0.00

CLAY CONTENT

pasture%of%	9.12	0.40	3.76	12.05	9.30	0.38	3.03	11.55
arable%of%	0.06	0.15	18.89	0.17	0.09	0.03	18.04	0.17
forest%of%	0.01	2.67	0.28	0.13	0.02	2.39	0.47	0.14
urbanVacant%of %	0.00	0.05	0.02	0.00	0.00	0.28	0.00	0.00
bulbs%of%	0.00	4.29	0.01	0.00	0.00	6.11	0.02	0.00

PEAT

pasture%of%	9.25	12.13	8.28	12.39
arable%of%	9.64	0.05	8.88	0.09
forest%of%	0.97	0.01	1.13	0.01
urbanVacant%of %	0.03	0.00	0.04	0.00
bulbs%of%	0.42	0.00	0.64	0.00

Annex B

TableB1. Probability statistics of simulation results *i* given the original land use type *j*

	arable	forest	urban vacant	_bulbs_	_greenhouses_	_urban_	_built-up, rural_	_built-up, woodland_	_built-up, agri_
pasture	0.0197	0.0003	0.0000	0.0000	0.0015	0.0000	0.0000	0.0006	0.0008
arable	0.9777	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
forest	0.0330	0.9111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
urban vacant	0.0091	0.2500	0.6955	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
bulbs	0.2687	0.0167	0.0000	0.6545	0.0000	0.0000	0.0000	0.0000	0.0000
greenhouses	0.0102	0.0004	0.0013	0.0000	0.8990	0.0000	0.0000	0.0000	0.0174
urban	0.0102	0.0011	0.0000	0.0003	0.0002	0.9569	0.0000	0.0015	0.0000
built-up, rural	0.0226	0.0353	0.0000	0.0028	0.0000	0.0000	0.8545	0.0000	0.0000
built-up, woodland	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
built-up, agri	0.0051	0.0005	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.9760

Table B2. Probability that actual land use is *i* given the original land use type is *j*

	arable	forest	urban vacant	_bulbs_	_greenhouses_	_urban_	_built-up, rural_	_built-up, woodland_	_built-up, agri_
pasture	0.0664	0.0004	0.0001	0.0015	0.0012	0.0002	0.0000	0.0003	0.0040
arable	0.8597	0.0001	0.0000	0.0053	0.0009	0.0007	0.0001	0.0001	0.0025
forest	0.0432	0.7920	0.0000	0.0003	0.0000	0.0001	0.0001	0.0001	0.0003
urban vacant	0.0084	0.0000	0.2311	0.0000	0.0000	0.3235	0.0000	0.0000	0.0000
bulbs	0.3985	0.0005	0.0000	0.5147	0.0005	0.0007	0.0010	0.0000	0.0064
greenhouses	0.0607	0.0000	0.0001	0.0003	0.8283	0.0004	0.0000	0.0000	0.0190
urban	0.0094	0.0003	0.0002	0.0004	0.0042	0.9488	0.0002	0.0019	0.0010
built-up, rural	0.0835	0.0014	0.0014	0.0014	0.0000	0.0438	0.7525	0.0014	0.0085
built-up, woodland	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.9911	0.0006
built-up, agri	0.0632	0.0005	0.0005	0.0074	0.0023	0.0037	0.0005	0.0005	0.6800

Table B3. Probability of agreement results between simulation and actual data for simulated year, given the initial land use

	arable	forest	urban vacant	_bulbs_	_greenhouses_	_urban_	_built-up, rural_	_built-up, woodland_	_built-up, agri_
pasture	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
arable	0.8405	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
forest	0.0014	0.7216	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
urban vacant	0.0001	0.0000	0.1607	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
bulbs	0.1071	0.0000	0.0000	0.3369	0.0000	0.0000	0.0000	0.0000	0.0000
greenhouses	0.0006	0.0000	0.0000	0.0000	0.7447	0.0000	0.0000	0.0000	0.0003
urban	0.0001	0.0000	0.0000	0.0000	0.0000	0.9080	0.0000	0.0000	0.0000
built-up, rural	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.6430	0.0000	0.0000
built-up, woodland	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9911	0.0000
built-up, agri	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6637

Annex C

Table C1. Statistics for the Business as usual scenario for 2040 per RUR region (m^2)

BAU	protected	urban	peri-urban	rural
pasture	6230000	14260000	953720000	66730000
arable	1710000	2400000	249640000	334390000
vacantUrban	70000	560000	5620000	310000
greenhouses	390000	4770000	83520000	820000
bulbs	0	20000	35370000	4820000
workLocations	1700000	46270000	22290000	6090000
urban	3090000	279500000	144910000	26490000
ResidRural	250000	450000	4040000	1260000
ResidLuxury	100000	7200000	6840000	1470000
Residfarmsteads	330000	810000	17630000	2180000
port	6810000	25160000	680000	26130000
parkForest	4000000	3600000	32650000	32570000
parkUrban	6680000	71670000	73470000	19200000
airport	0	2670000	30000	0
roadsRail	1820000	32960000	47810000	17450000
ReedsSandMarsh	44760000	730000	19000000	65400000
Water	171610000	28650000	65640000	18380000

Table C2. Statistics for the B1 scenario for 2040 per RUR region (m^2)

B1	protected	urban	peri-urban	rural
pasture	6370000	13930000	943070000	65980000
arable	1530000	1760000	246480000	333390000
vacantUrban	150000	1560000	1750000	140000
greenhouses	90000	950000	89030000	930000

bulbs	0	20000	36080000	4790000
workLocations	1680000	42740000	29210000	6280000
urban	3480000	287070000	149580000	26830000
ResidRural	250000	450000	4240000	1300000
ResidLuxury	220000	7750000	6750000	1460000
Residfarmsteads	240000	900000	17400000	2430000
port	6670000	24270000	670000	27160000
parkForest	4000000	3600000	32650000	32570000
parkUrban	6680000	71670000	73470000	19200000
airport	0	2670000	30000	0
roadsRail	1820000	32960000	47810000	17450000
ReedsSandMarsh	44760000	730000	19000000	65400000
Water	171610000	28650000	65640000	18380000

Table C3. Statistics for the B2 scenario for 2040 per RUR region (m^2)

B2	protected	urban	peri-urban	rural
pasture	6540000	12590000	942920000	67270000
arable	1530000	1650000	249790000	330870000
vacantUrban	520000	9330000	58470000	4970000
greenhouses	0	190000	44340000	240000
bulbs	0	0	19500000	620000
workLocations	1140000	38980000	30680000	4750000
urban	3310000	286820000	148610000	26990000
ResidRural	250000	450000	4090000	1270000
ResidLuxury	80000	5890000	8060000	1880000
Residfarmsteads	270000	700000	17040000	5670000
port	7040000	24800000	760000	26160000
parkForest	4000000	3600000	32650000	32570000
parkUrban	6680000	71670000	73470000	19200000

airport	0	2670000	30000	0
roadsRail	1820000	32960000	47810000	17450000
ReedsSandMarsh	44760000	730000	19000000	65400000
Water	171610000	28650000	65640000	18380000