Towards an Integrated Approach for Incorporating Socio-Economic and Biophysical Processes in Local Scale Land-Use Modelling

or

Putting Alonso into practice

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Outline

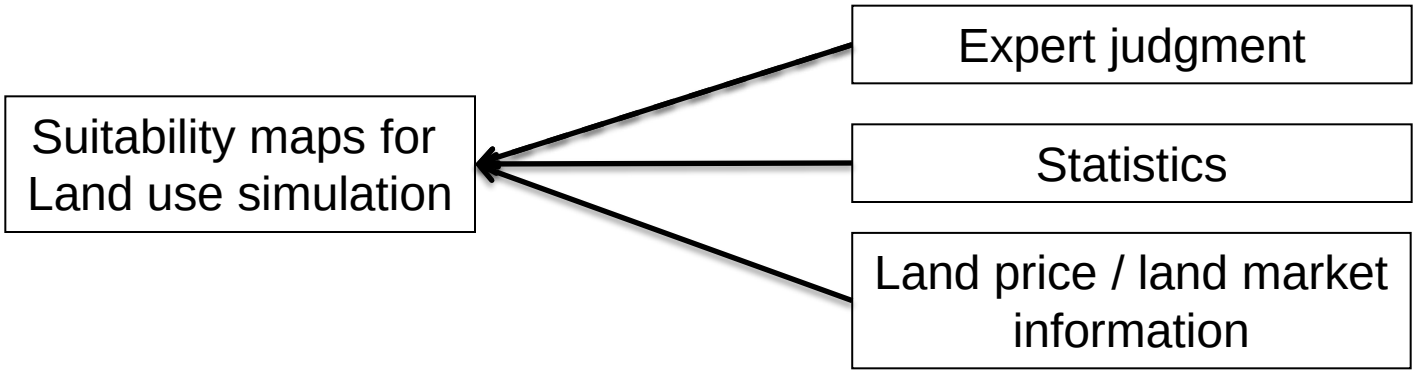
- Introduction
  - aim
  - Land Use Scanner
  - defining suitability
  - simulating future land use
- Evaluate alternative specifications for suitability
  - Multinomial Logit
  - Binomial Logit (with / without rescaling)
  - Incorporating utility-based approaches
- Results & Conclusions
- Future work

Aim of this paper

Try to improve suitability definition:

-Get closer to the factors that are actually relevant in the decision-making process of actors on the land market (segments);

-While using an economic framework in order to let the suitability maps of various sectors compete for scarce space



Introducing the Land Use Scanner

An operational information system for land-use planning since 1997

Developed by a number of institutes:

Planbureau voor de Leefomgeving

Object Vision

Geodan

LEI

vrije Universiteit amsterdam

Planbureau voor de Leefomgeving

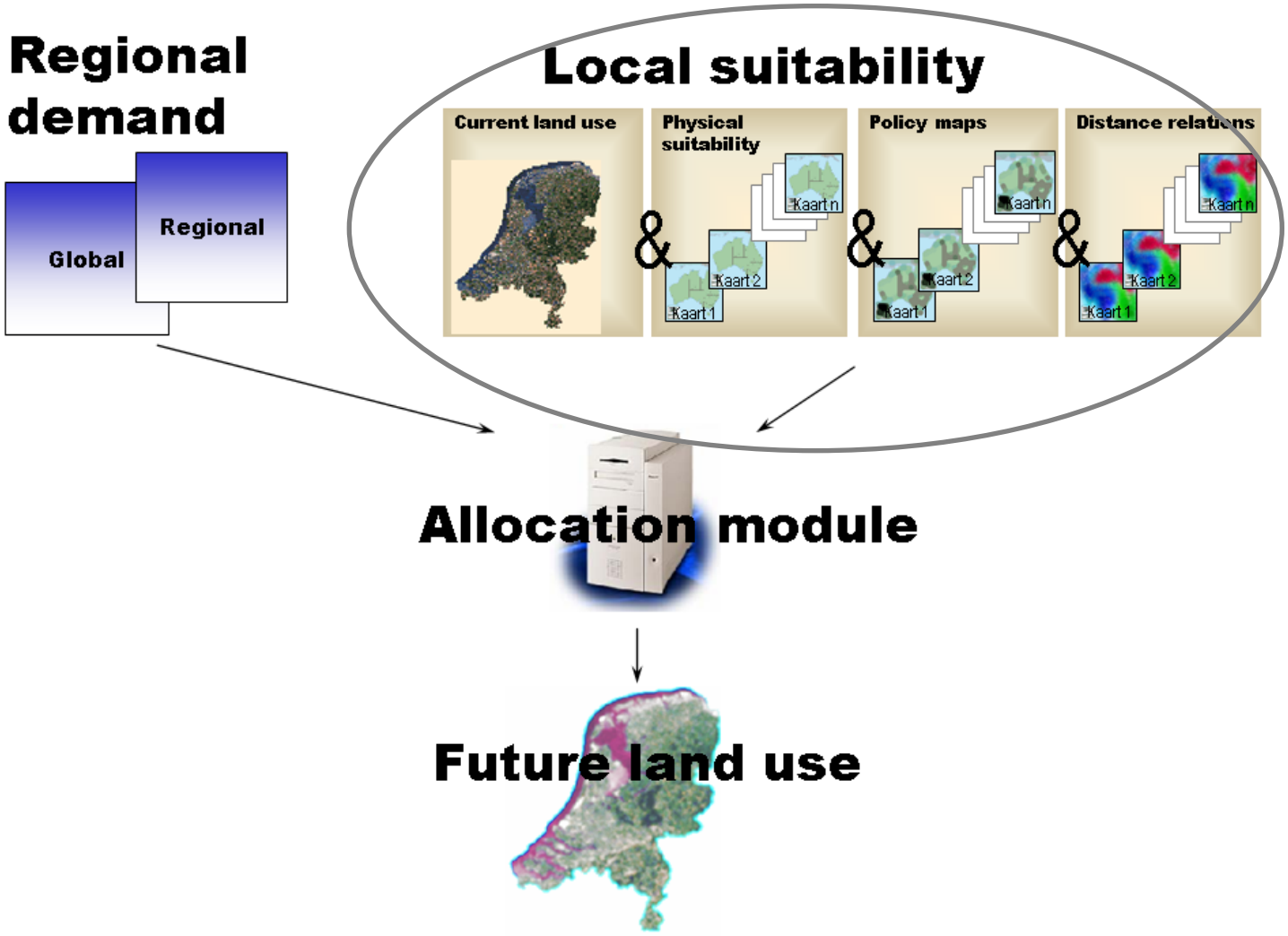
Well documented in, for example,

Hilferink & Rietveld (1999); Dekkers & Koomen (2007); Borsboom-van Beurden et al. (2007); Koomen et al. (2010) see: www.feweb.vu.nl/gis

Model characteristics

- GIS based (**100m** or 500m grid)
- integrated (all types of land use)
- exhaustive (full country)
- satellite structure (external claims)
- cross-sectional (static approach)
- policy oriented (applied science)
- two different versions (**continuous** and discrete land-use description per cell)
- two approaches (**logit** and optimization)

Model layout



Allocation - continuous model

The continuous model uses a logit-type approach to allocate future land use, providing an economic analogy.

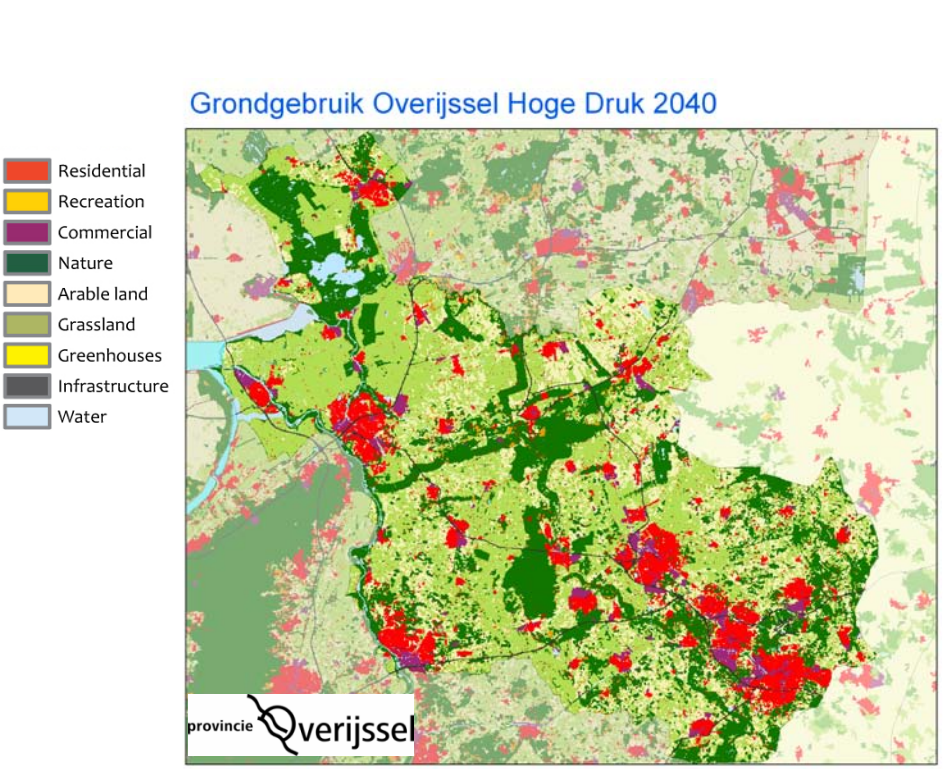
Doubly constrained logit model:

$$M_{cj} = a_j \cdot b_c \cdot e^{(\beta \cdot s_{cj})}$$

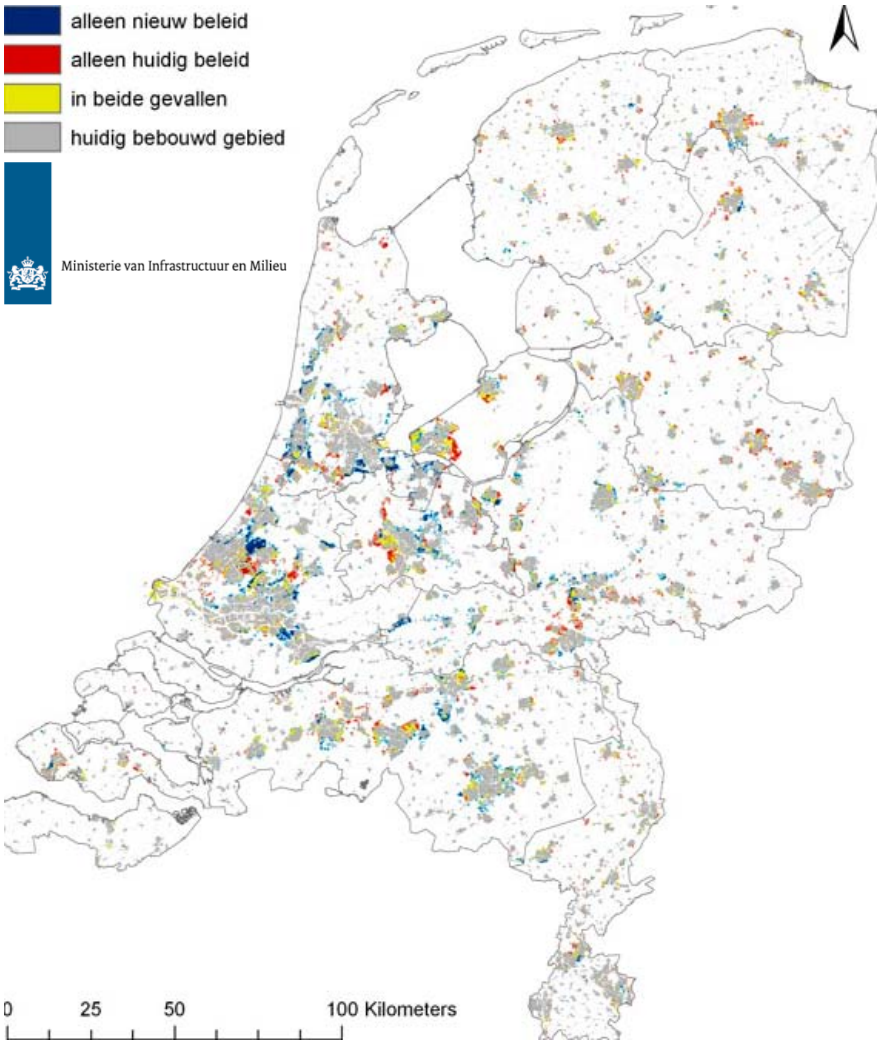
Allocation balances demand and supply

Competing claims start a bidding process

Future land use supports planning



Koomen et al. (2010)



Elings et al. (2011)

Evaluate suitability specifications

1. Statistically explain observed (1996) land use
   a) Multinomial Logit (MNL)
   b) Binomial Logit (BNL)
   c) Binomial Logit (BNL) –> rescaled to avg. land prices
2. Add alternative, utility-based approaches for
   a) Urban area land price (linear regression) and/or
   b) Arable farming and/or Grassland land price (Net Present Value)
   c) Combinations of 2a) and 2b)
3. Simulate 1996 land use (11 LU types: 7 endo, 4 exo)
4. Validate result with observed 1996 land use

1) Logistic regression

- Form of regression analysis when the dependent is any of a number of possible states
  - two states (0/1): binomial
  - multiple states (0..n): multinomial
- Continuous and/or categorical independents can be used
- Returns probability of occurence of each state (event) as value between 0 and 1

1) Logistic regression

1a) MNL

$$P_{cj} = e^{a+\beta * X_{cj}} \Big/ \sum_k e^{a+\beta * X_{ck}}$$

1b) BNL

$$P_{cj} = e^{a+\beta * X_{cj}} \Big/ \left(1+e^{a+\beta * X_{cj}}\right)$$

1c) BNL – rescaled

$$P_{resc\,cj} = \min\left\{B_j * P_{cj}, B_j\right\}$$

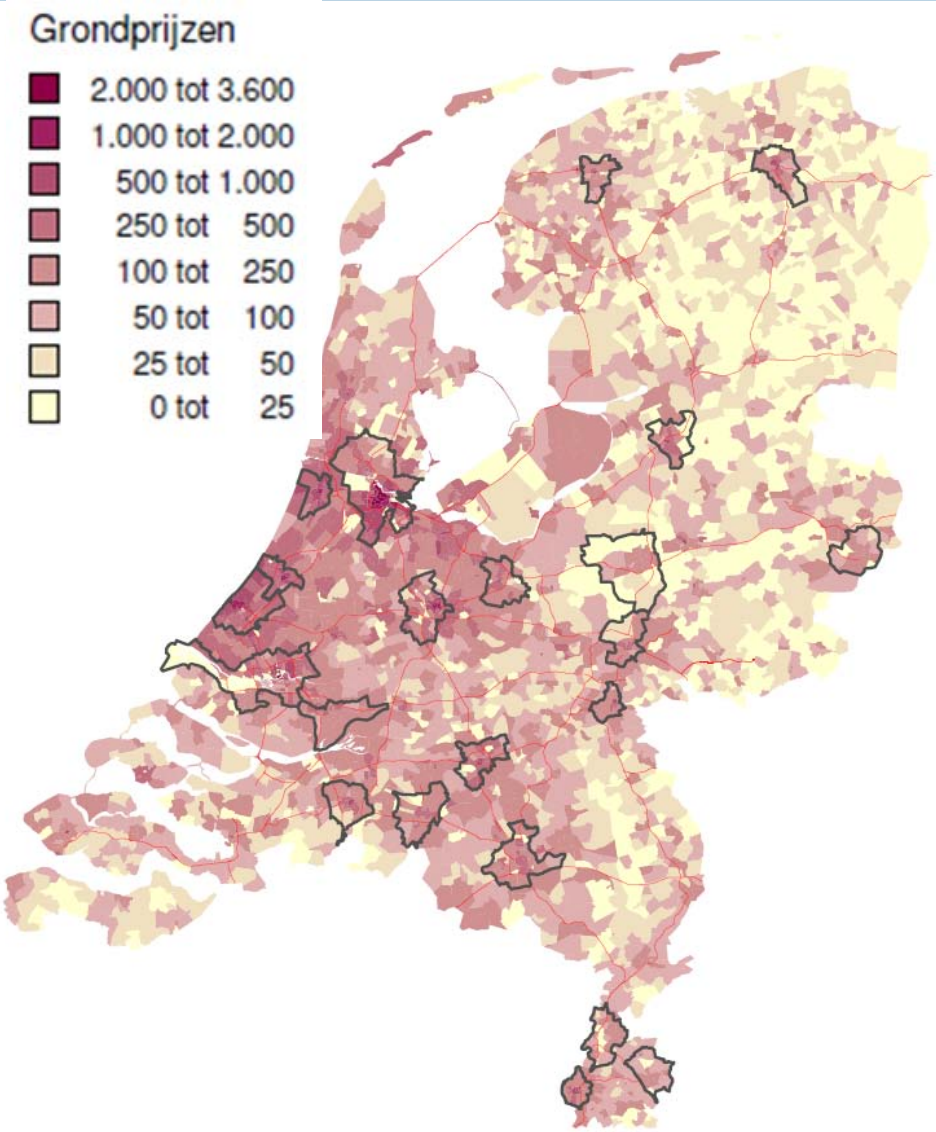
In which:

- X_{cj} is a set of location factors (explan. var.) for cell *c* for land-use type *j*
- X_{ck} is a set of location factors for cell *c* for all (*k*) land-use types
- B_j is the maximum bid price for land-use type *j*

Alternative suitability map specifications

BNL – Utility UrbanArea

- Linear regression of location value (€/m2)
- Location value per pc4 deducted from house prices (NVM)



Alternative suitability map specifications

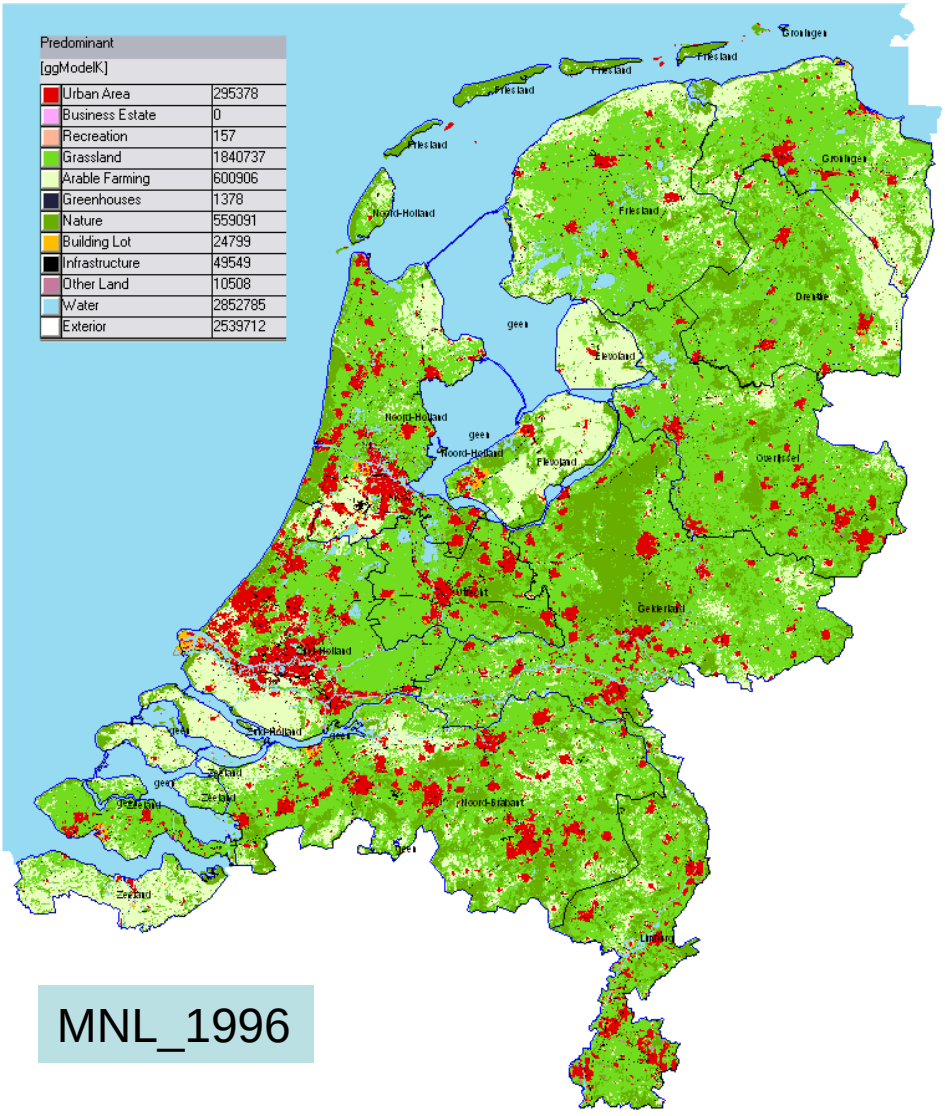
BNL – Utility ArableFarming (Net Present Value)

Consists of:

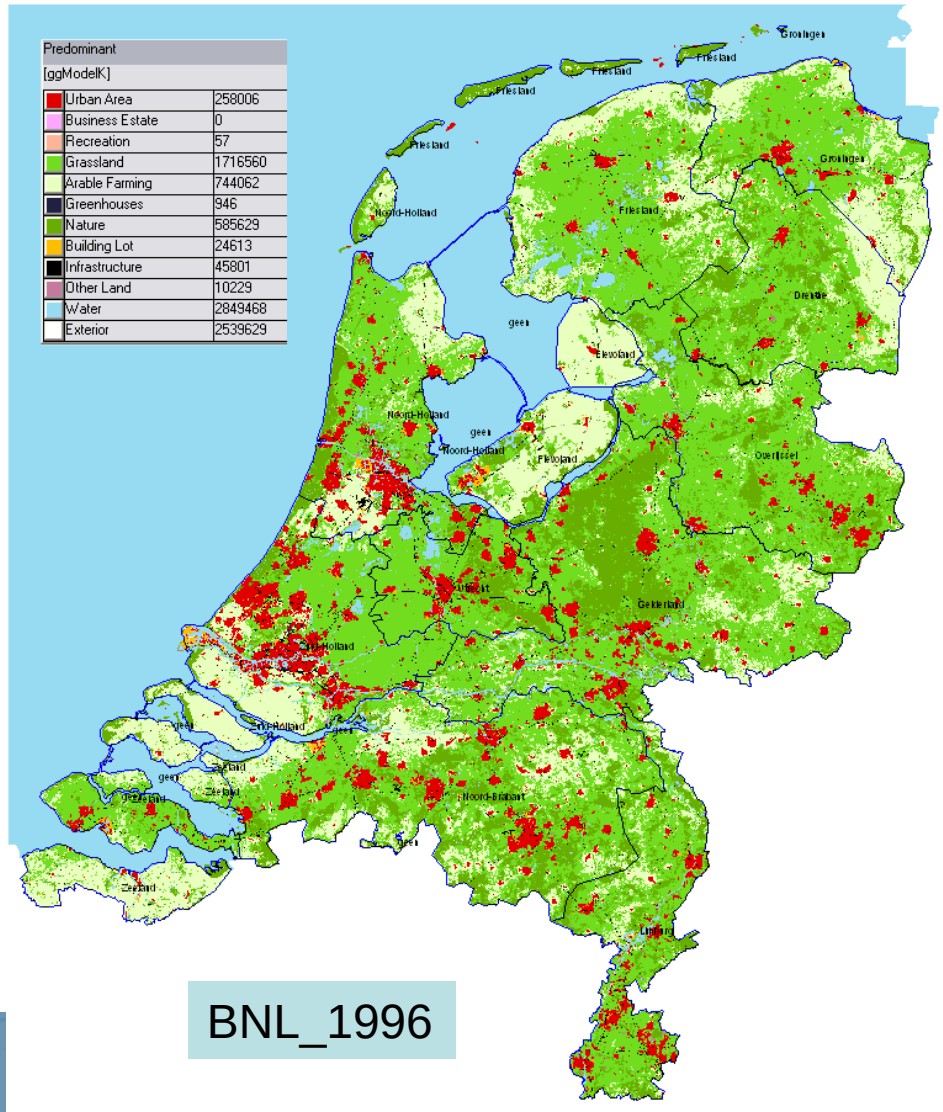
- yield losses per soil type (clay or sand);
- annual equal cash flows;
- interest (5,5%), and
- a timespan of 20 yrs. for ROI.

Comparing results

Predominant LU: difficult to see differences



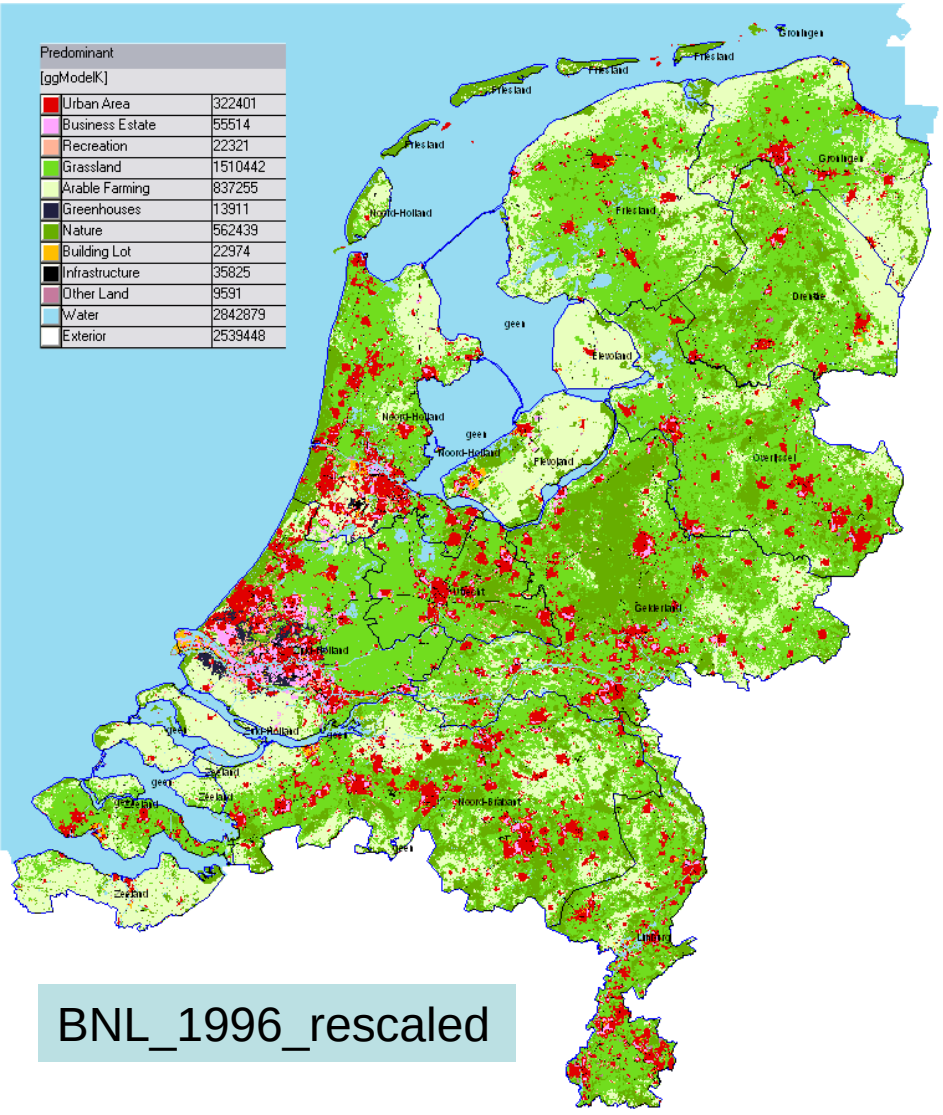
MNL_1996



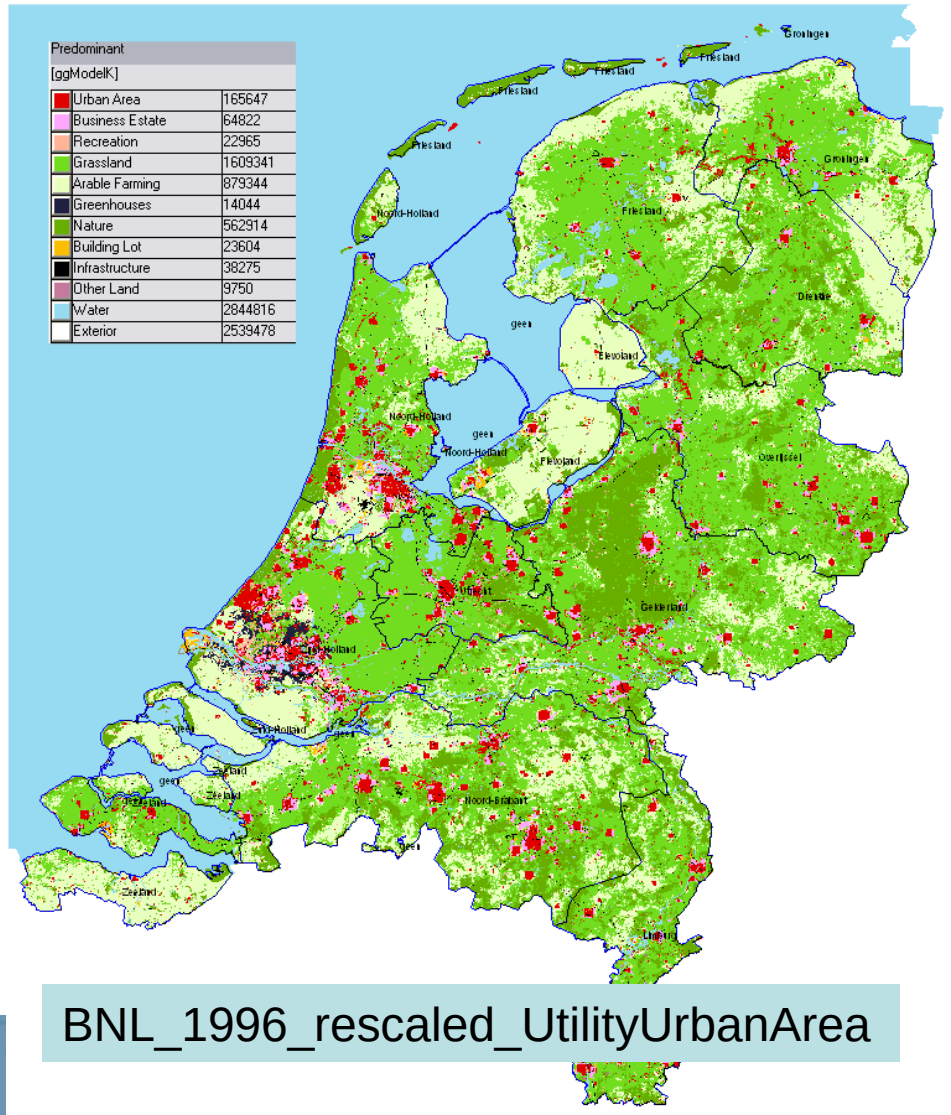
BNL_1996

Comparing results

Predominant LU: difficult to see differences



BNL_1996_rescaled



BNL_1996_rescaled_UtilityUrbanArea

Comparing results

- Degree of Correspondence (0-100%):

$$C_j = 100 - 100\left(\frac{\sum_c |M_{cj} - O_{cj}|/2}{\sum_c O_{cj}}\right)$$

where:

C_j is the degree of correspondence for land-use type j expressed as percentage;
M_{cj} is the **simulated** amount of land in cell c for land-use type j;
O_{cj} is the **observed** amount of land in cell c for land-use type j.

Loonen and Koomen (2009)

Results & Conclusions

Degree of Correspondence (simulated and observed 1996 land use)	UrbanArea	BusinessEstate	Recreation	Grassland	ArableFarming	Greenhouses	Nature	Weighted average DoC
1a) MNL	52.4	16.9	2.9	64.1	49.2	11.8	67.6	**57.9**
1b) BNL	54.4	11.0	2.7	65.4	50.6	10.0	70.9	**59.4**
1c) BNL_rescaled	60.6	22.2	6.8	67.1	53.2	13.1	72.0	**61.9**
2a) BNL_utility_urban area (Lin. Regr.)	***37.1***	22.1	6.6	66.5	52.3	17.2	72.9	**59.2**
2b) BNL_utility_arable farming (NPV)	60.6	21.9	6.8	67.9	***50.5***	11.3	73.8	**61.7**
BNL_utility_grassland (NPV)	60.4	21.9	7.1	***65.7***	51.6	12.3	73.1	**60.9**
2c) BNL_utility_urban area & arable farming	***19.2***	22.5	6.7	67.3	***44.8***	17.1	73.5	**56.0**
BNL_utility_urban area & arable & grassl	***11.4***	22.5	7.0	***58.6***	***43.3***	16.7	73.0	**50.9**

- Rescaling BNL to bid prices: works well
- Utility functions: room for improvement
  - Make functions spatially more explicit
  - More or other explanatory variables
  - NPV is one factor in the decision-making process of actors…

Future work

- Improve spatial explanation of land price
- Add utility-based frameworks for other land-use types (e.g., office rents for commercial land)
- Focus on explaining and simulating land-use *change* (transition analysis, conversion costs)
- Incorporate (urban) land-use density and multi-functionality

Further reading available from:

- www.feweb.vu.nl/gis