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FACULTY OF SCIENCE

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Tailored & Sustainable Redevelopment
towards Zero Brownfields on Managing Urban Land
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Tool-assisted design and comparative evaluation of sustainable land use alternatives for brownfield redevelopment

Michael Finkel, Sebastian Schädler, Maximilian Morio

University of Tübingen, Department of Geosciences, Hölderlinstr. 12, 72074 Tübingen, Germany

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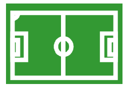
Land consumption („Land take“) vs. Brownfields

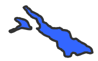
Some numbers …

- Land take in Germany 1992 - 2010:

  ~115 ha/day

   / ~9 minutes

  ~420 km²/year

  → size of Munich or nearly 

- Land take in Europe (2000 - 2006):

  > 1000 km²/year

- Area of available brownfields in Germany (2010): ~1,500 km²

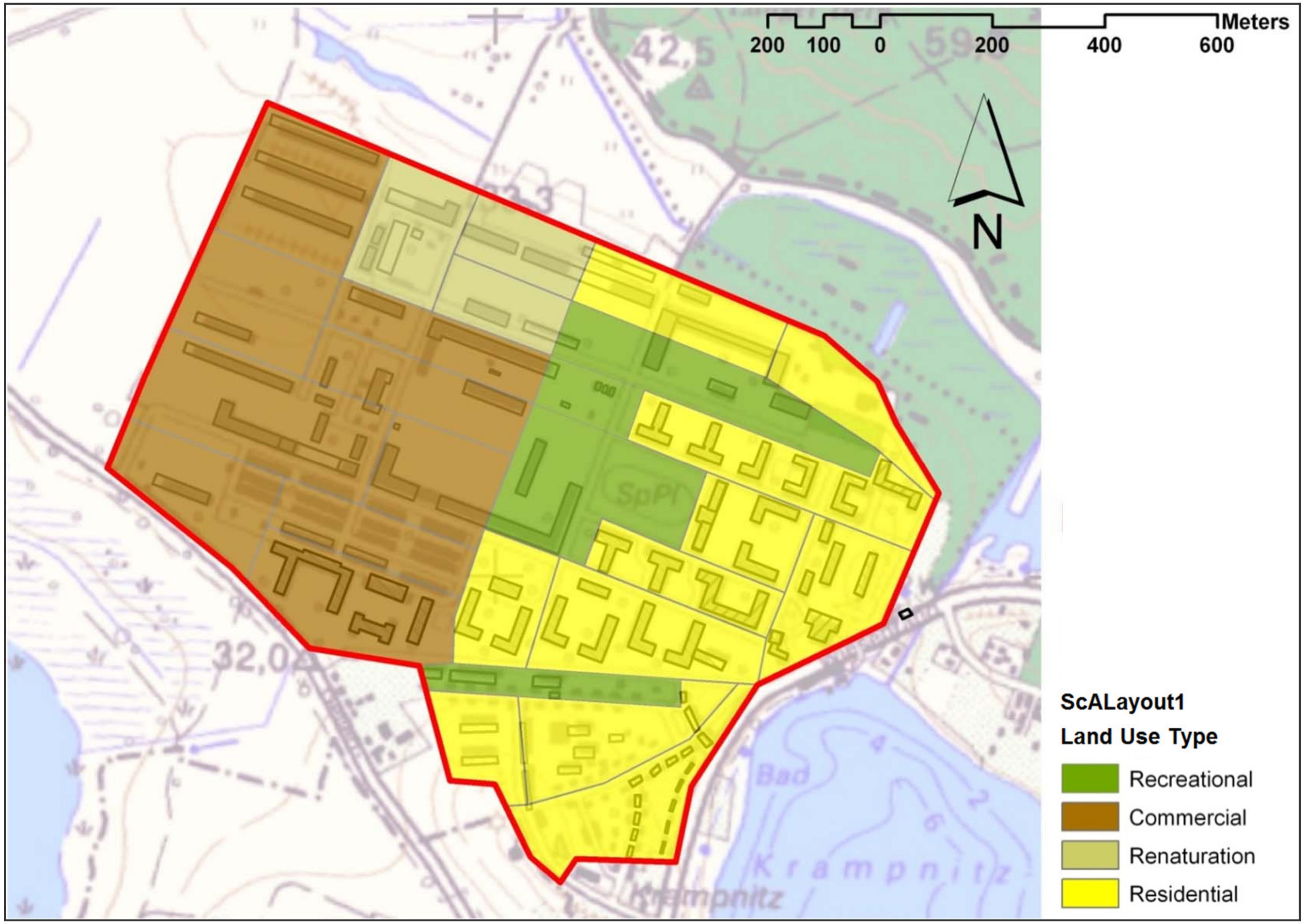
Challenges

- Brownfield Revitalization (BR) often hampered by a lack of knowledge about site characteristics and related opportunities and risks.
- BR involves diverse stakeholders with differing expertise and potentially conflicting interests.
- Appropriate means of communication and harmonization (standardized and transparent procedures) are missing.
- BR involves a multitude of aspects that need to be considered.
- Lack of spatial Decision Support Systems (sDSS) that appropriately address the relevant aspects.

Scope of research:
Early-stage planning of sustainable re-use of brownfields

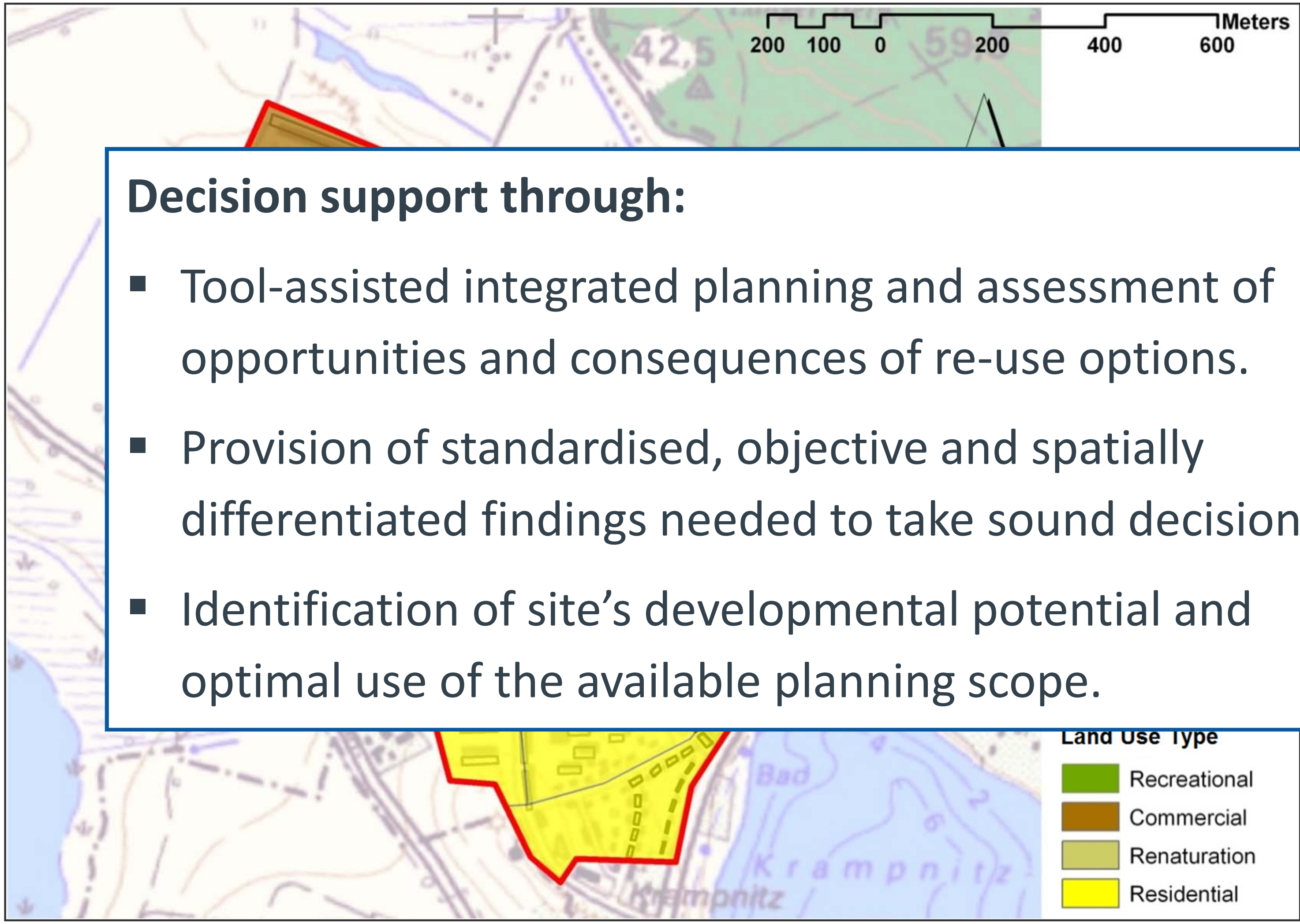
- Provision of GIS-based software tool as decision support tool for sustainable brownfield redevelopment
- Enabling integrated evaluation of planning options
  - to date decision are most often driven by economic reasons
  - sustainability issues should also be accounted for
- Integrated assessment of brownfield-specific aspects
  - Subsurface remediation and site preparation costs
  - Market-oriented economic evaluation of revitalized site
  - Evaluation of sustainable development
- Facilitating information and participation of people/institutions involved in revitalization efforts

Main Goal: Finding the appropriate re-use options for a particular site



Shared redevelopment vision is crucial for successful initiation of BR process

What is the most appropriate re-use of the site?



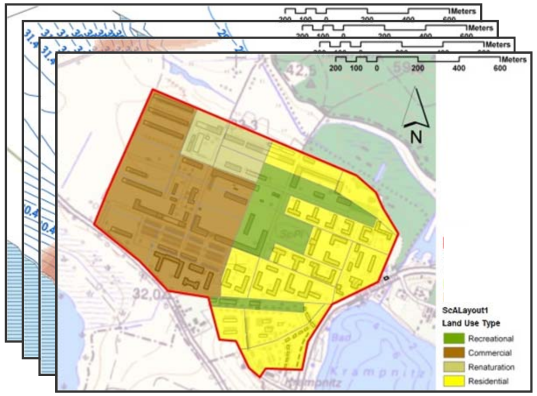
Decision support through:

- Tool-assisted integrated planning and assessment of opportunities and consequences of re-use options.
- Provision of standardised, objective and spatially differentiated findings needed to take sound decisions.
- Identification of site's developmental potential and optimal use of the available planning scope.

Integrated Assessment

Bioenergy potential

Sustainability
Is a certain re-use suitable with respect to sustainable urban development?



Risk mitigation and related costs
What are the costs for remediation and site preparation?

Market Value
What will be the value of the site - prepared for a certain re-use?

Human health risks

Enabling/Facilitating Participation

- Interactive Land Use Map Creator: Module to allow quick and intuitive design of possible options for redeveloping a site
- Tool-assistance: More or less automatic evaluation of re-use options (after proper preparation of required data)
- Facilitation in two ways:
  - Support of discussion meetings and round tables via „live assessment“ of re-use alternatives (desktop tool)
  - Involvement of non-experts, e.g. interested stakeholders via web-based tool

Tool-Assistance: Desktop Tool – MMT & Others

Preparation
- Data Inquiry, Site Investigation
- GIS-Based Data Management
- Land Uses and Further Input Data

↓

Visions and Plans for Future Use

↓

Conflict Analysis/ Required Remediation

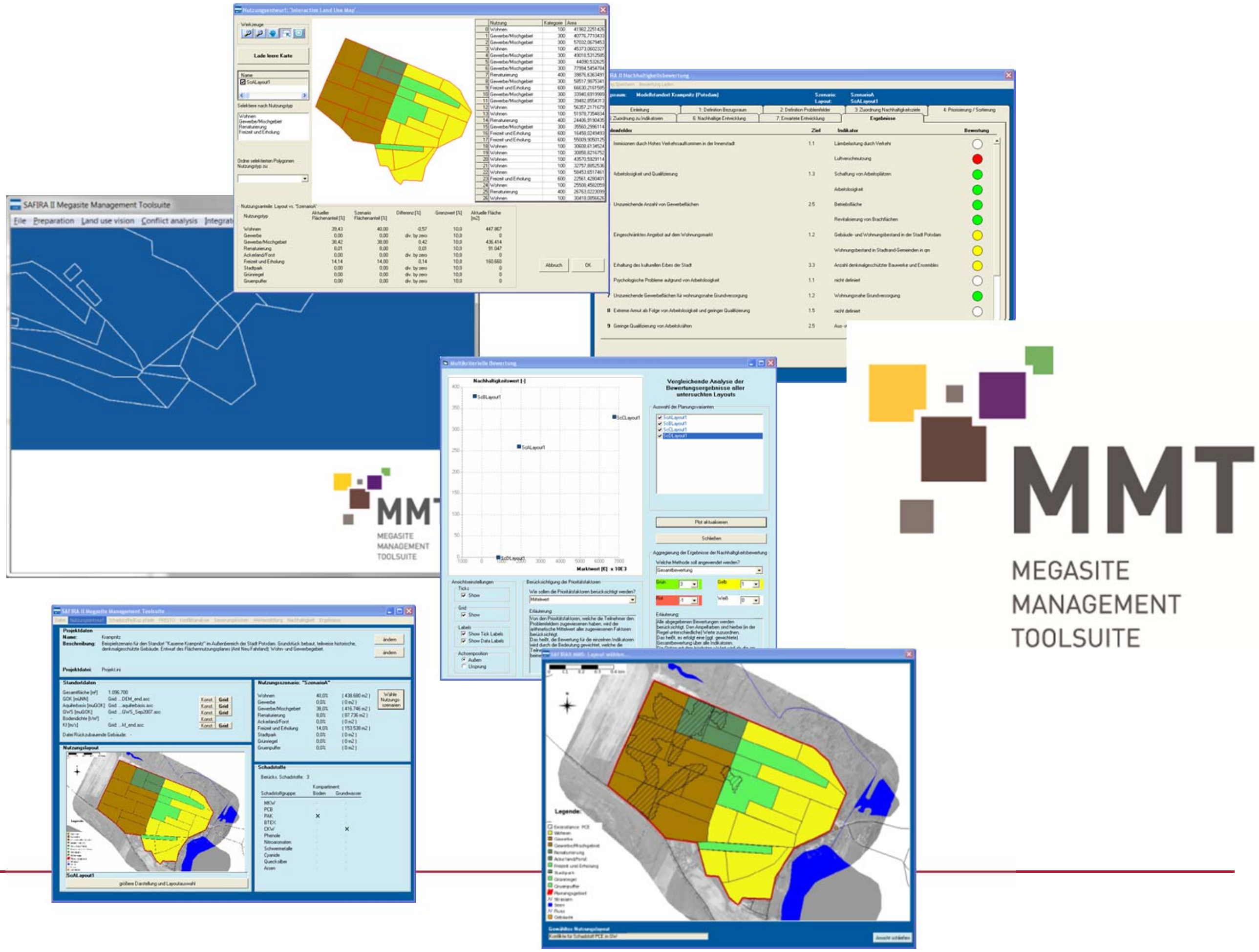
↓

Holistic (Integrated) Assessment

↓

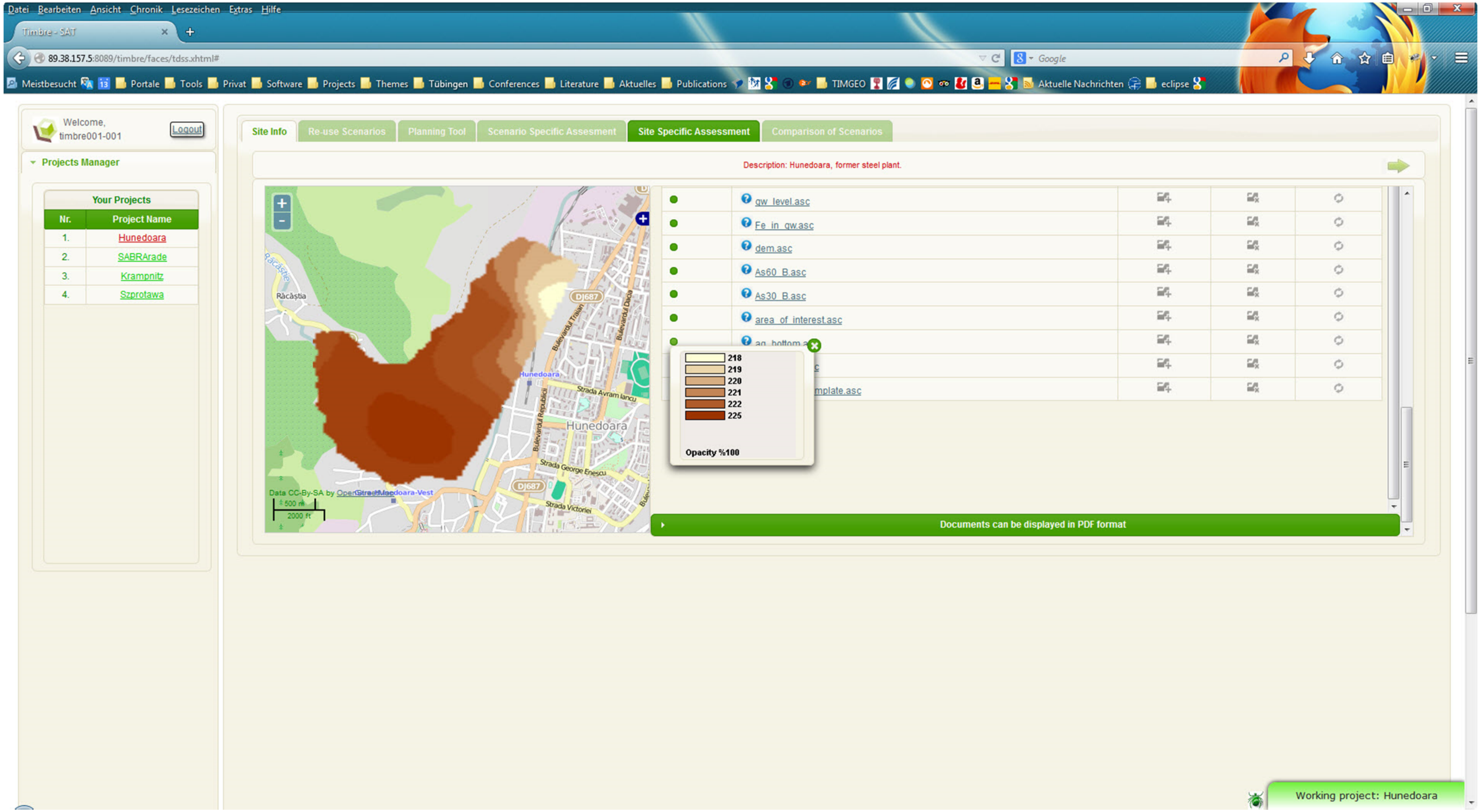
Visualization and Export of Results

… to organize relevant data, to specify the assessment parameters and to evaluate re-use options in detail



Tool-Assistance: Web-based Tool

… to share information about the site and possible re-use options



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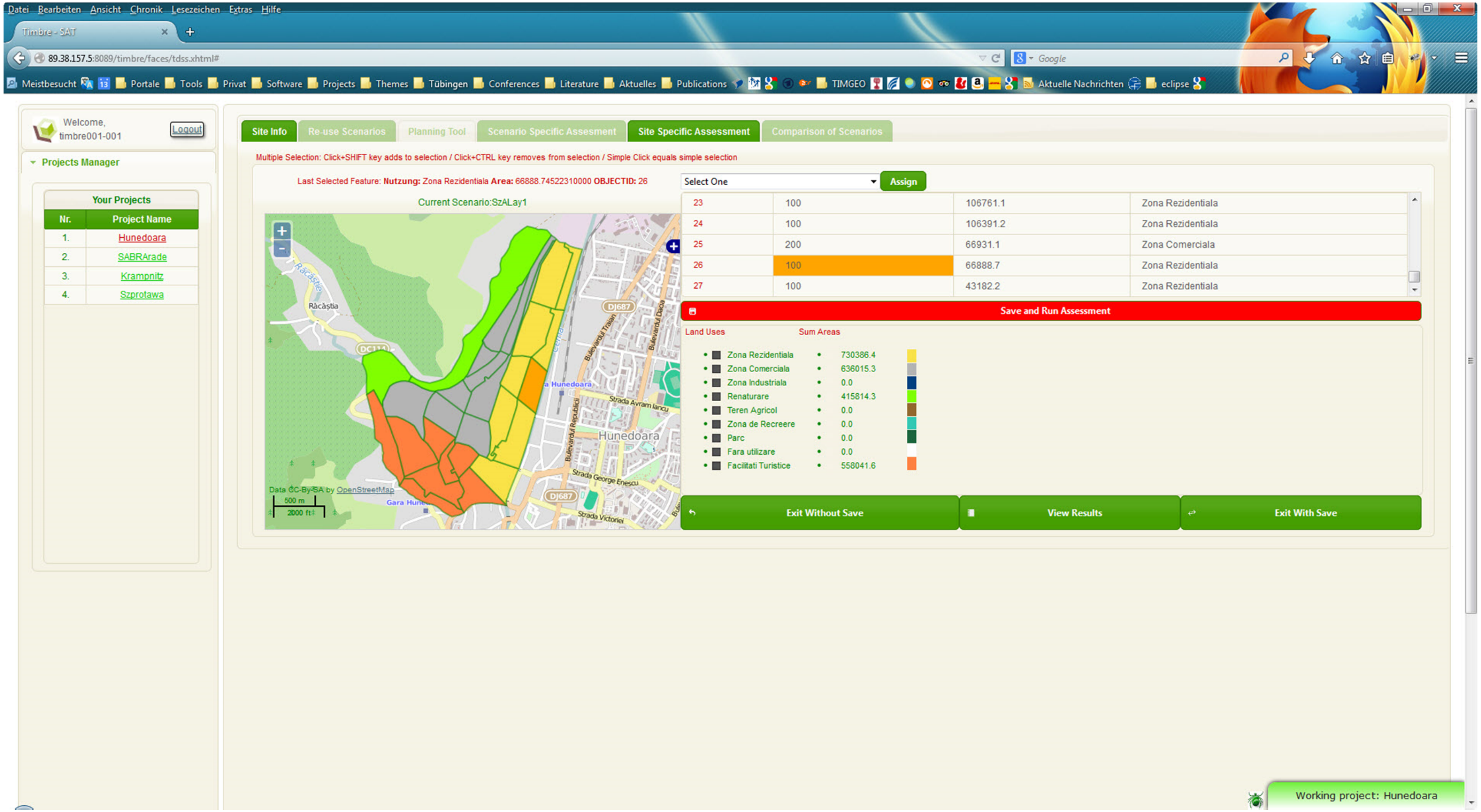
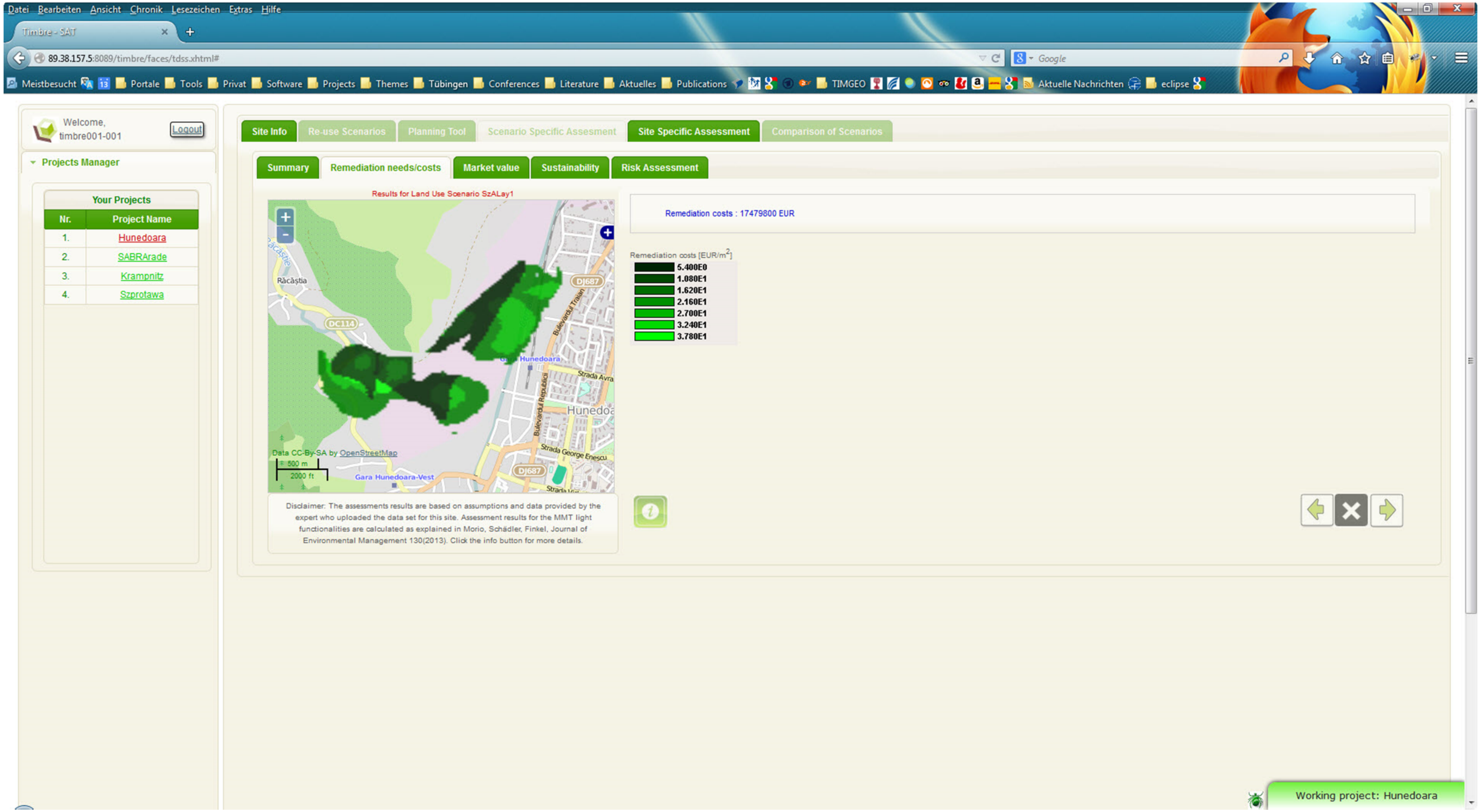
Tool-Assistance: Web-based Tool

… to design re-use options and automatically assess them



Tool-Assistance: Web-based Tool

… to quantify the consequences of particular re-use options



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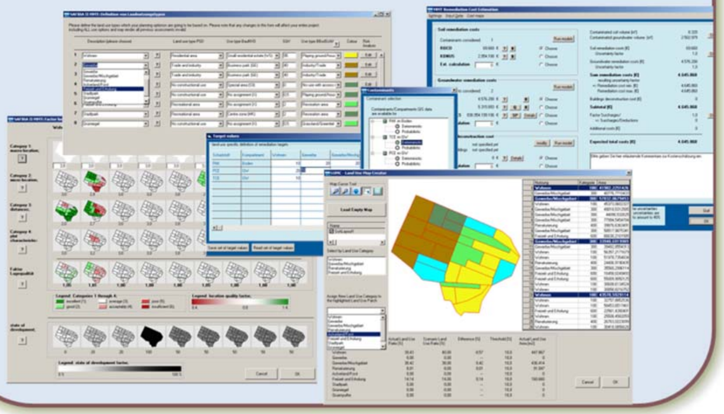
Tool-Assistance: Expert vs. Non-expert Tool

Expert Tools



... to assist core group of stakeholders and experts

Web Tool

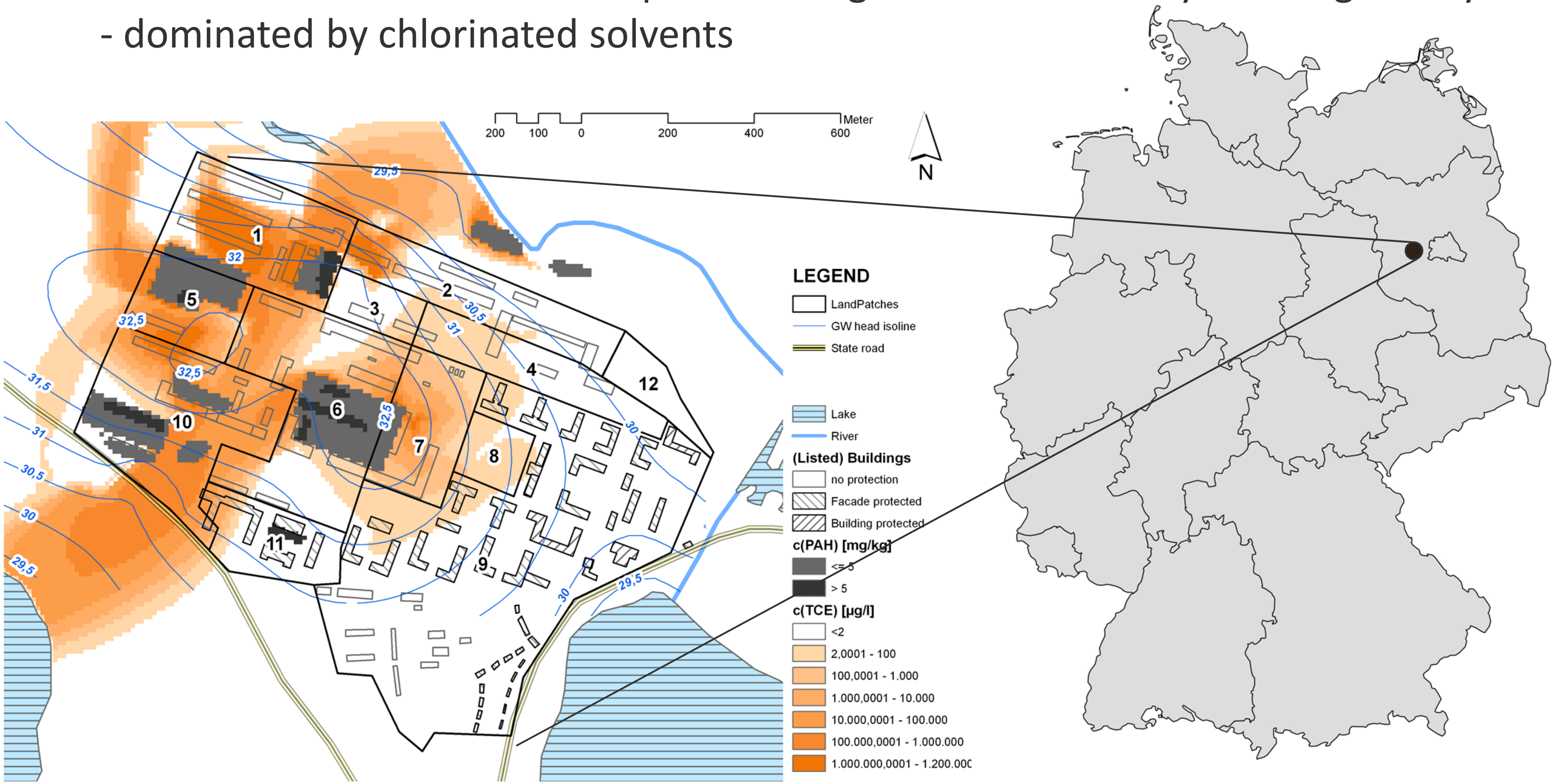
→ User can change only a subset of input data, i.e. those parameters that can be reasonably specified by non-experts.

→ Focus on
- mapping own re-use visions
- communicating results

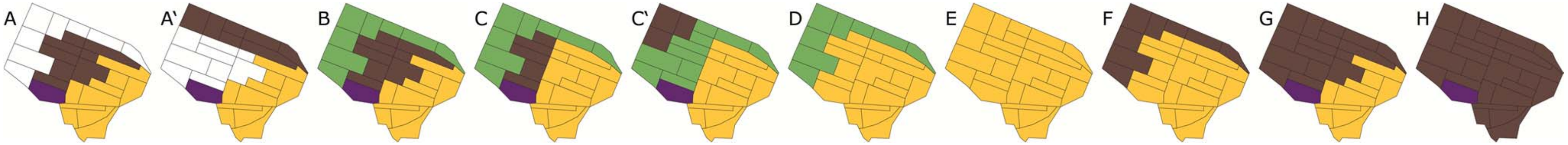
... to communicate results and to allow participation of further stakeholders

APPLICATION: KRAMPNITZ CASE STUDIES

- former military site in the outskirts of the city of Potsdam near Berlin
- 113 ha used by German and Russian armed forces until 1945 and 1991
- vast GW contamination from operation of gas stations and dry cleaning facility - dominated by chlorinated solvents



(1) Comparative evaluation of redevelopment options



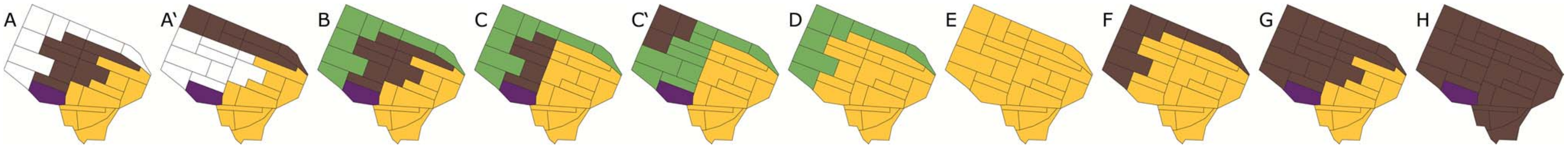
- Initial option based on stakeholder discussions
- „Trial and error“ iterative re-planning guided by evaluation results (maps)
- Seeking improvement by
  - minimizing remediation expenditures
  - maximizing site value
  - increasing sustainability

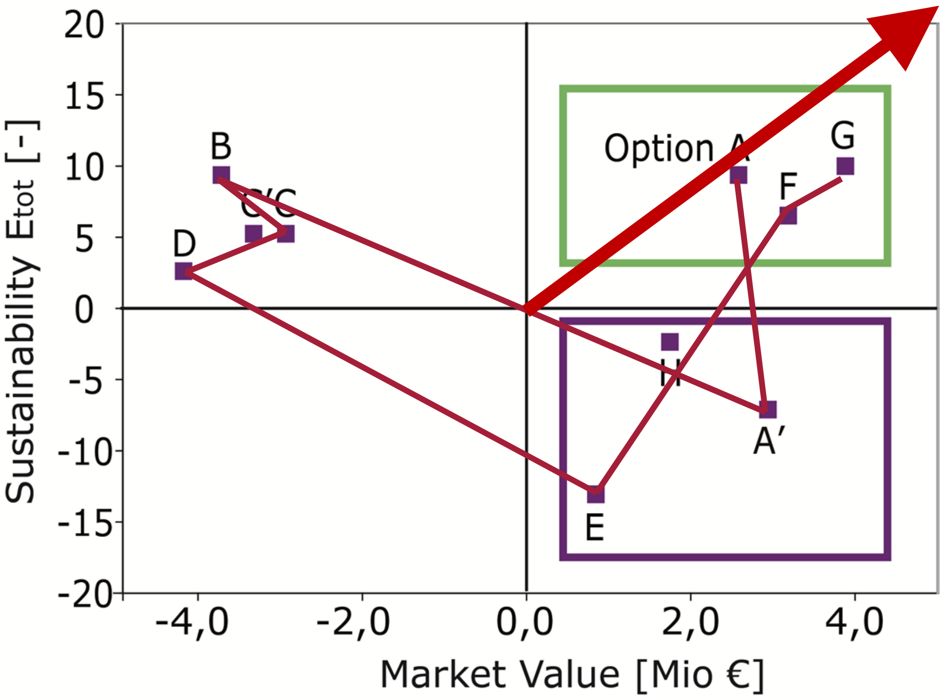
Schädler et al. (2011) J. Environmental Management, 92 , 827 – 837.

(1) Comparative evaluation of redevelopment options

Economic Evaluation [Mio €]	A	A'	B	C	C'	D	E	F	G	H
$V_{L,theor}$	8.7	8.7	8.9	9.8	9.8	11.5	16.7	14.1	11.4	8.8
BDC	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
GW remediation costs	0.0	0.0	0.8	0.8	0.8	0.9	0.9	0.9	0.7	0.7
Soil remediation costs	0.9	0.6	7.2	7.8	8.2	10.6	10.6	5.2	1.8	1.8
Costs: GW flux site boundary	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Preliminary land value	3.1	3.6	-3.2	-2.9	-3.3	-4.2	1.0	3.9	4.7	2.1
MVR	0.6	0.6	0	0	0	0	0.2	0.7	0.9	0.4
Market value	**2.6**	**2.9**	**(-3.2)**	**(-2.9)**	**(-3.3)**	**(-4.2)**	**0.8**	**3.2**	**3.9**	**1.7**
Sustainability Evaluation [%]										
Housing Area	17	17	17	4	4	4	-13	7	11	-
Trade/Industry	8	-35	8	8	8	-	-	2	8	-4
High Tech Industry	30	30	30	30	30	-	-	30	30	30
Recreational	-	-	0	0	0	0	-	-	-	-
Sustainability Rating E_{tot}	**9.4**	**-7.1**	**9.4**	**5.3**	**5.3**	**2.7**	**-13**	**6.6**	**10.1**	**-2.3**
Sustainability Ranking	2	9	2	5	5	7	10	4	1	8

(1) Comparative evaluation of redevelopment options





„Trial and error“ !!

How to get to a more effective i.e. targeted design of redevelopment options?

(2) Targeted design of sustainable redevelopment options

→ Integration of spatial data & evaluation tools for automatic targeted derivation of promising re-use options

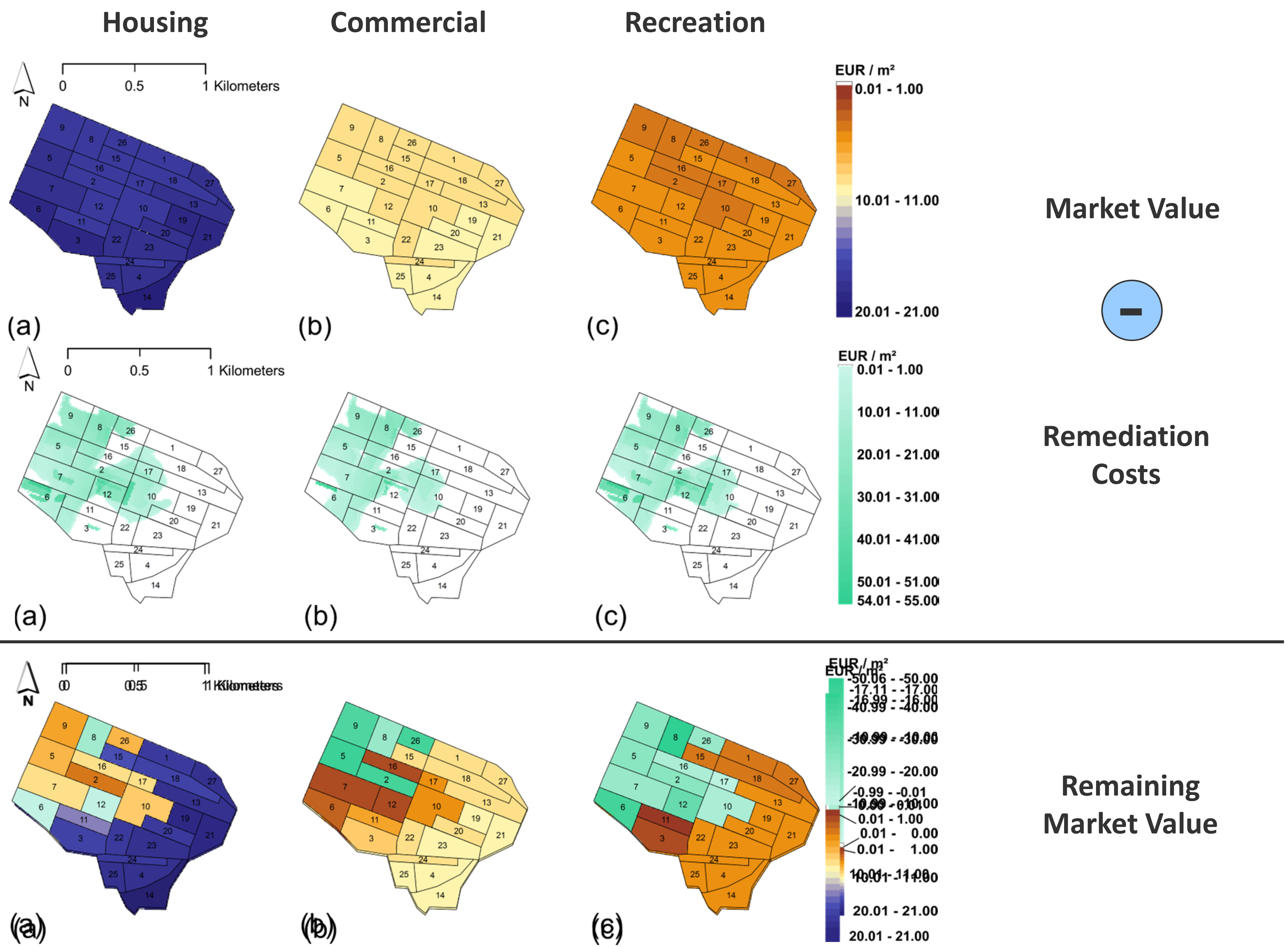
→ Splitting the search for promising re-use options

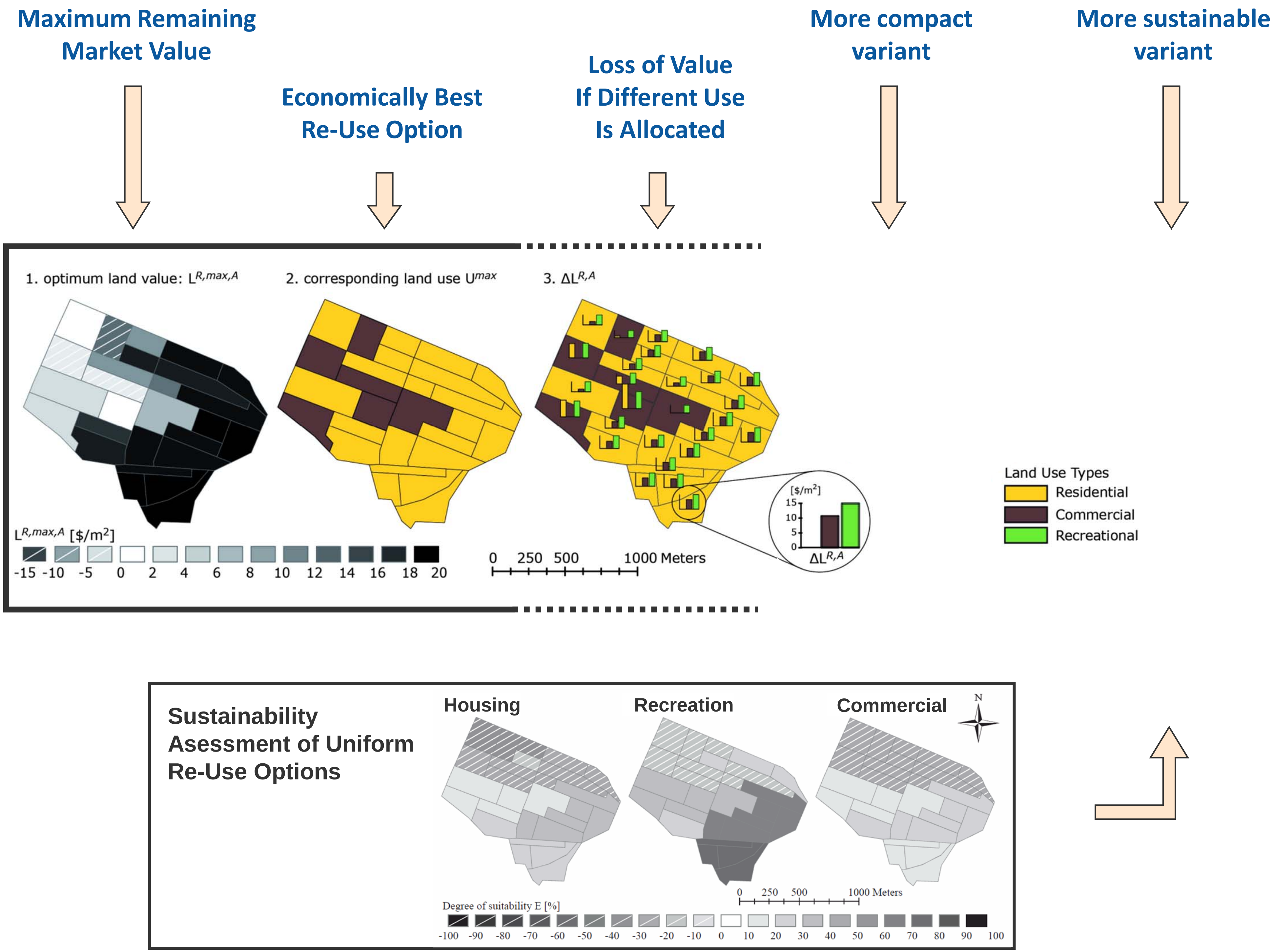
1. Determination of option representing the economic optimum
2. Targeted enhancement of option with respect to sustainability

→ Guidance for iterative re-planning

Schädler et al. (2013) J. Contaminant Hydrology, doi:10.1016/j.jconhyd.2011.03.003

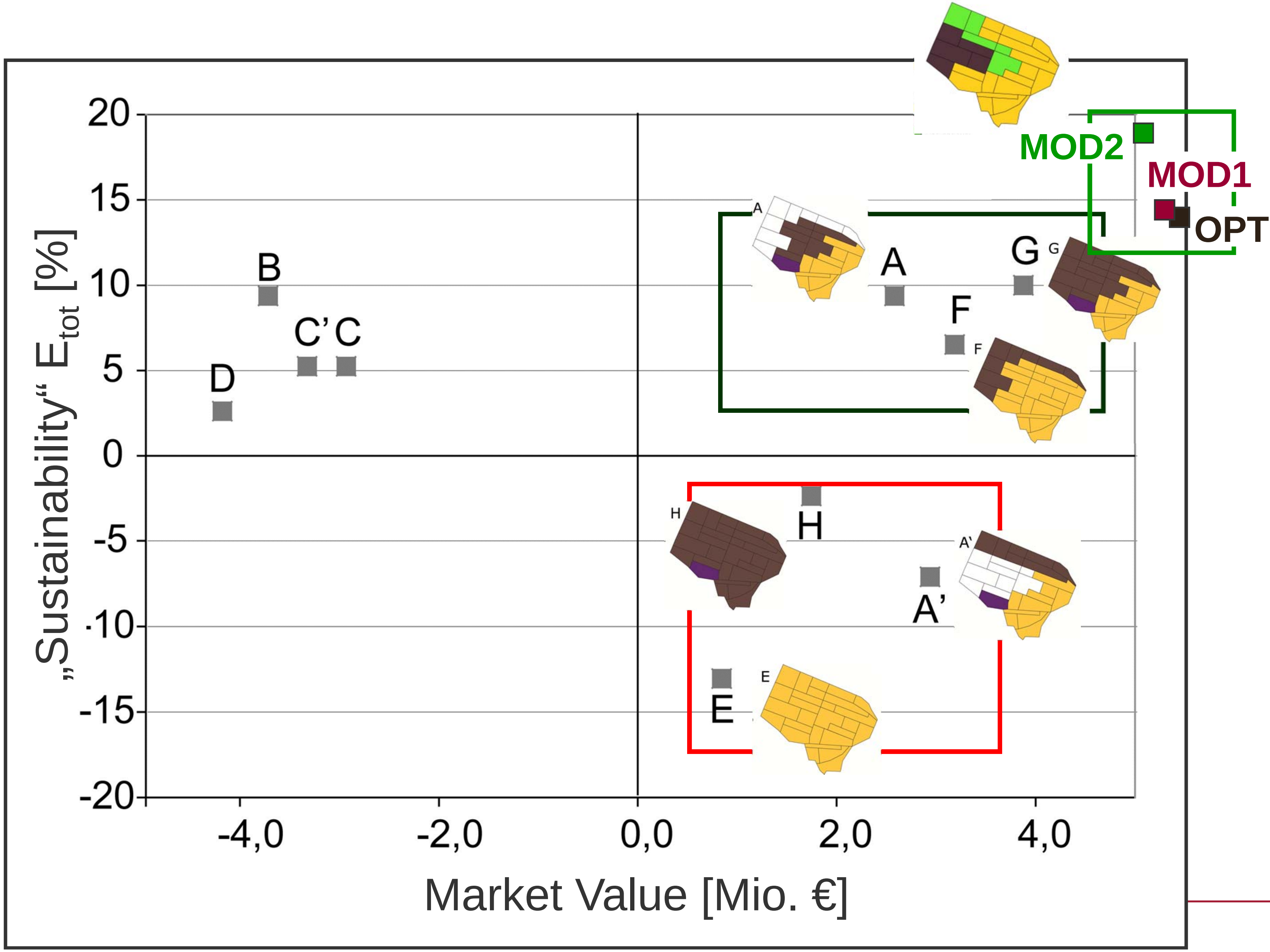
Uniform Use Options





Maximum Remaining Market Value
Economically Best Re-Use Option
Loss of Value If Different Use Is Allocated
More compact variant
More sustainable variant
1. optimum land value: $L^{R,max,A}$
2. corresponding land use U^{max}
3. $\Delta L^{R,A}$
$L^{R,max,A}$ [$/m²]
-15 -10 -5 0 2 4 6 8 10 12 14 16 18 20
0 250 500 1000 Meters
[$/m²]
15
10
5
0
$\Delta L^{R,A}$
Land Use Types
Residential
Commercial
Recreational
Sustainability Asessment of Uniform Re-Use Options
Housing
Recreation
Commercial
N
0 250 500 1000 Meters
Degree of suitability E [%]
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100

RESULTS



MOD2
MOD1
OPT
A
G
F
B
C' C
D
H
A'
E
20
15
10
5
0
-5
-10
-15
-20
-4,0
-2,0
0,0
2,0
4,0
„Sustainability" E_{tot} [%]
Market Value [Mio. €]

Interim Conclusion

- BR is not inherently sustainable
- Economically attractive + sustainable options exist!!
- Integrated comparative assessment framework supports
  - Quick reproducible comparison of planning options
  - Identification of (initial) favorable options

BUT…

- Only 13 out of 3^{27} (trillions!) options considered…
- Spatial sustainability evaluation not automated
- Spatial sustainability optimization impossible

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(3) Automated spatially explicit evaluation of sustainability

LIST OF 23 INDICATORS

	Weighting (%)	I. Residentital	II Local Services	III. Recreational	IV. Trade/ Industries	V. Emitting industries	VI. large-space business centres	VII. Monofunctional facilities w/ large open spaces
1. SUSTAINABLE LAND MANAGEMENT								
1.1: Realization of short distances by complementing land uses								
1.1.1 Residential Areas in the surrounding area	10	n	+1/-1	+1/0	+1/0	n	n	n
1.1.2 Green spaces in the surrounding area	10	+1/0	n	n	n	n	n	n
1.1.3 Local supplies within walking distance	10	+1/0	n	n	n	n	n	n
1.1.4 Neighbouring uses are strongly emitting	20	-1/0	n	-1/0	n	n	n	-1/0
1.2: Prevention from additional soil sealing								
1.2.1 Site contains <40% sealed soil	10	n	n	+1/-1	-1/0	-1/0	-1/0	+1/-1
1.3: Support for urban inner development								
1.3.1 Site location within urban area	40	+1/-1	+1/-1	n	+1/-1	n	n	n
2. PRESERVATION OF NATURE AND LANDSCAPE								
2.1: Preservation of sites important for urban ecology								
2.1.1 Site is part of a local habitat	40	-1/0	-1/0	n	-1/0	-1/0	-1/0	-1/0
2.1.2 High value tree or plant populations	20	n	n	n	n	-1/0	-1/0	n
2.2: Conservation of natural reserves								
2.2.1 Direct vicinity to nature reserve	40	-1/0	n	n	n	-1/0	-1/0	n
3. RESOURCE-CONSERVING & EMISSION-REDUCING MOBILITY MANAGEMENT								
3.1: Preventing overburdening of local road system								
3.1.1 Low capacity of access roads	30	n	n	n	-1/0	-1/0	-1/0	-1/0
3.2: Reduction of individual car use								
3.2.1 Good access to public transport	40	+1/-1	+1/-1	+1/0	+1/-1	n	+1/-1	+1/-1
3.3: Protection of residents from transport emissions								
3.3.1 Access to clearway	20	n	n	n	n	+1/-1	+1/-1	n
3.4: Support for non-motorized mobility								
3.4.1 Good accessibility for bikers	10	+1/-1	+1/-1	+1/-1	+1/-1	+1/0	+1/0	+1/0
4. HIGH QUALITY RESIDENTIAL ENVIRONMENT								
4.1: Good local supplies								
4.1.1 Local amenities in walking distance	10	+1/-1	n	n	+1/0	n	n	n
4.1.2 Primary school in walking distance	10	+1/-1	n	n	n	n	n	n
4.2: Preservation and development of local recreational space								
4.2.1 Great impact on recreational areas	20	-1/0	-1/0	n	-1/0	-1/0	-1/0	-1/0
4.3: Preservation and upscaling of historic cityscape								
4.3.1 Historically relevant buildings	10	+1/0	n	-1/0	+1/0	-1/0	-1/0	+1/0
4.3.2 Great influence on cityscape	10	n	n	+1/0	n	-1/0	-1/0	n
4.4: Minimizing land use conflicts								
4.4.1 Neighbouring uses sensitive to immissions	40	n	n	n	n	-1/0	-1/0	n
5. STRENGTHENING OF LOCAL ECONOMY								
5.1: Small burden for local budget by investment/follow-up costs related to local infrastructure								
5.1.1 Good supply and disposal infrastructure	20	+1/-1	+1/-1	n	+1/-1	+1/-1	+1/-1	+1/-1
5.2: Small burden for local budget related to site remediation								
5.2.1 Site strongly contaminated	30	-1/0	-1/0	-1/0	n	n	n	-1/0
5.3: Enhancement of local attractiveness by innovative businesses								
5.3.1 Site suitable for innovative industries	30	n	n	n	+1/0	n	n	n
5.4: Preservation of business location								
5.4.1 adjacent enterprises w/ precarious sense of security	20	-1/0	n	n	n	n	n	n
maximum positive score: $P_{+,max}$ = f(weights)		160	120	80	170	50	90	90
maximum negative score: $P_{-,max}$ = f(weights)		-300	-210	-80	-210	-260	-300	-210

FRAMEWORK FOR COMPLETE "TRANSLATION" OF THE INDICATOR SET INTO ALGORITHMS:

Examples

Indicator: number and description	Weight [%]	SD	Evaluation algorithm/result for PU *x*
1 Residential areas in the surrounding area	2	R	If $NND(\mathbf{A}_{res}; x) < thres_1$ then $k_{1,x}$ = TRUE Else $k_{1,x}$ = FALSE
2 Green spaces in the surrounding area	2	R	k_2 = TRUE
3 Commercial areas within walking distance	2	R	If $NND(\mathbf{A}_{comm}; x) < thres_3$ then $k_{3,x}$ = TRUE Else $k_{3,x}$ = FALSE
4 Neighboring uses strongly emitting	4	R	If PU TOUCHES $\mathbf{A}_{emitting}$ then k_4 = TRUE Else k_4 = FALSE

Schädler et al. (2013) Landscape & Urban Planning, 111, 34-45

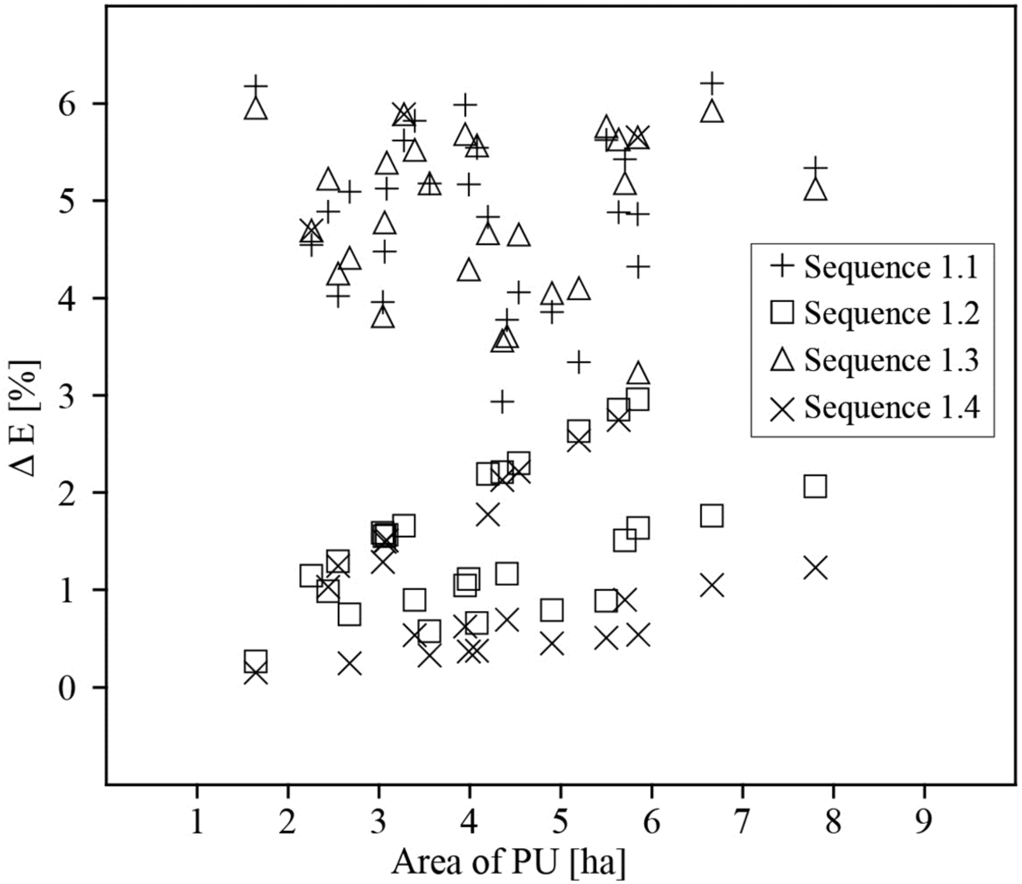
(3) Automated spatially explicit evaluation of sustainability

(i) Identify the most beneficial ALLOCATION of complementary land use

⇒ **Location of PU more important than its size!**

⇒ **Independent of the land use types, any addition of complementary use enhances sustainability!**

⇒ **Identified the most beneficial "allocation regions" for the different use types**



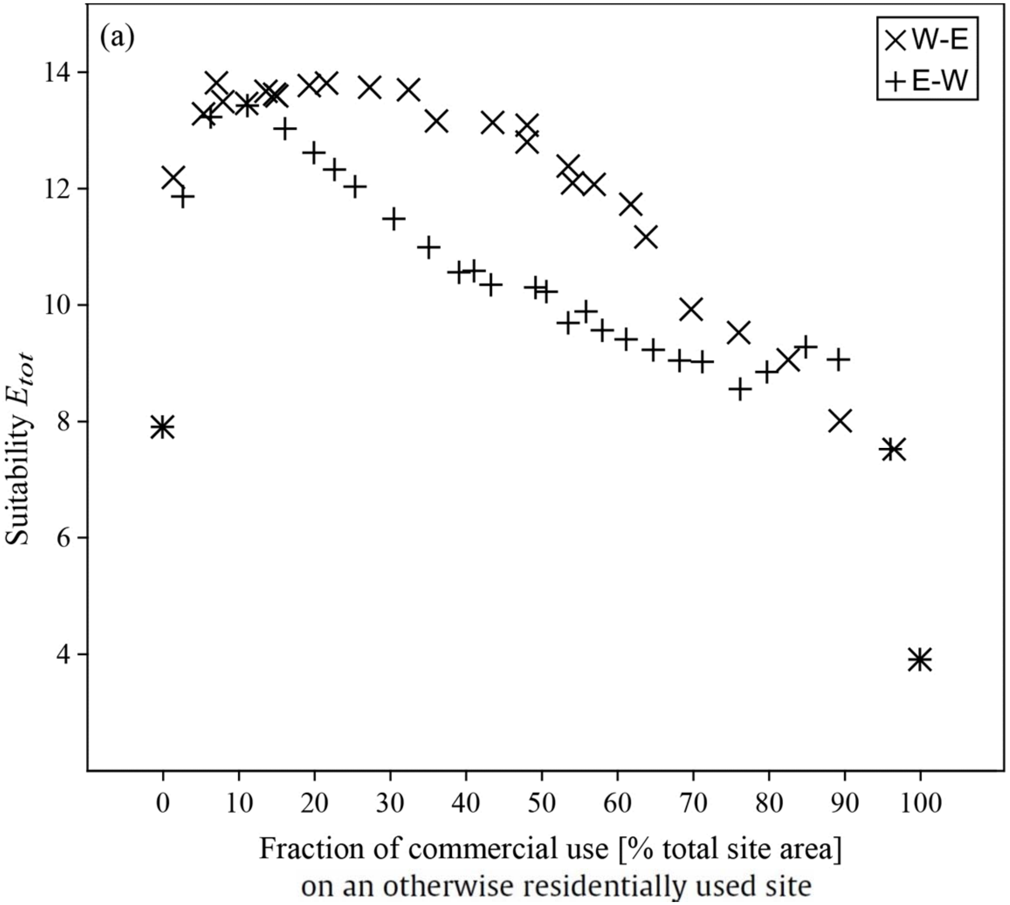
- Sequence 1.1: Residential use, one PU commercial use
- Sequence 1.2: Residential use, one PU recreational green space
- Sequence 1.3: Commercial use, one PU residential use
- Sequence 1.4: Commercial use, one PU recreational green space

(3) Automated spatially explicit evaluation of sustainability

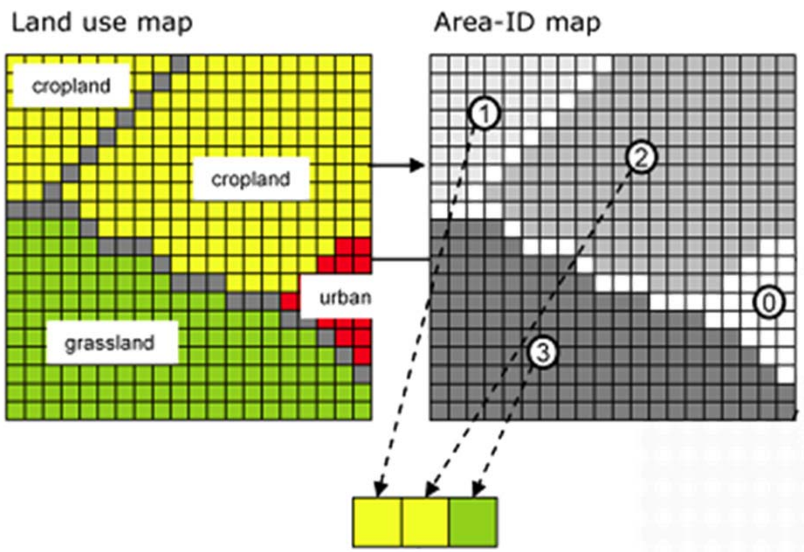
(ii) Identify the most beneficial AREAL FRACTION of complementary land use

⇒ **Location of PU more important than its size!**

⇒ **Importance of convenient spatial planning increases when areal fractions of both land use types get bigger/similar**



(4) Optimization: Genetic Algorithms for identification of optimal reuse options



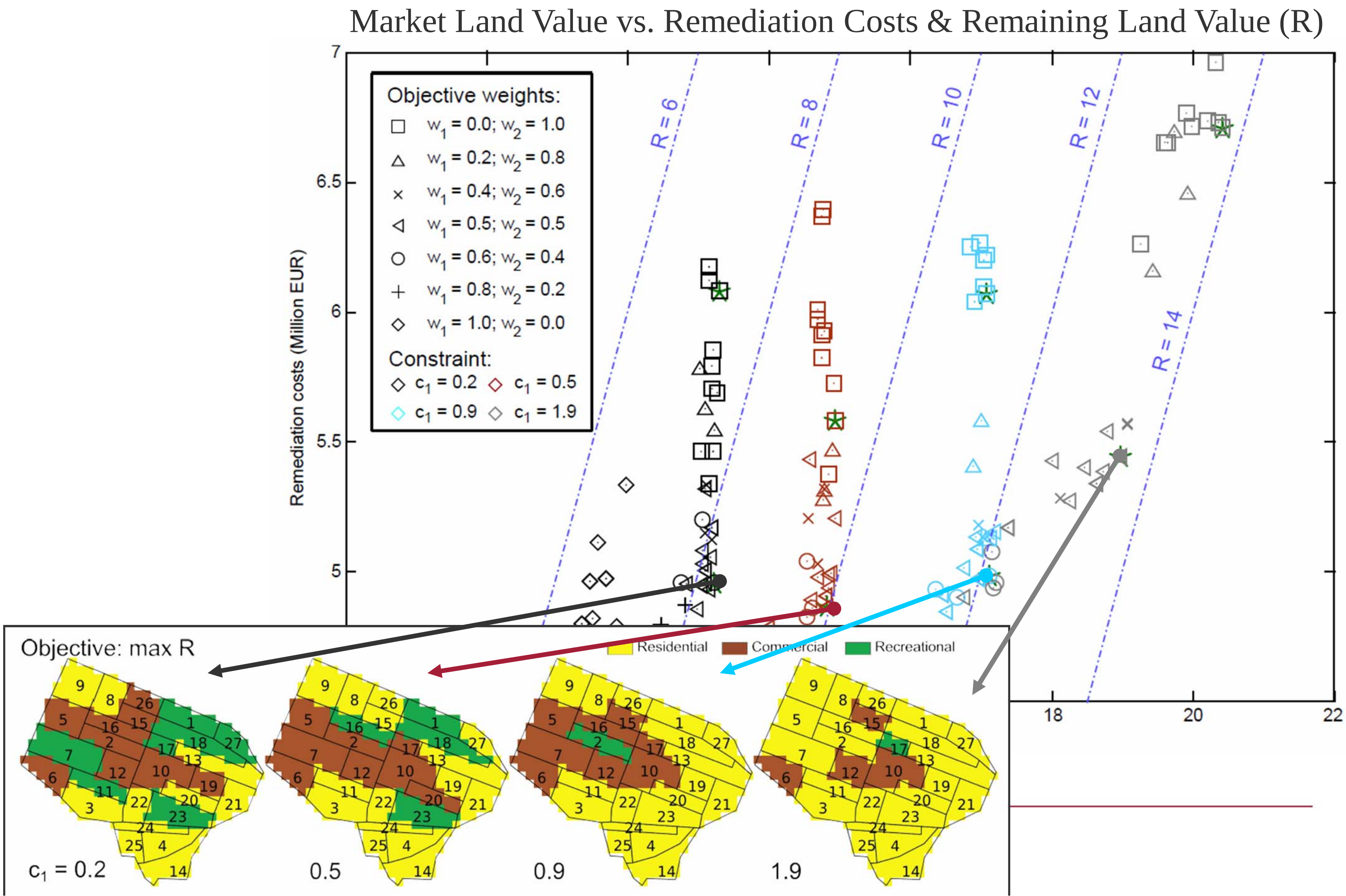
Adapted a multicriterial **genetic algorithm** (GA) approach to support generation and assessment of BR options.

➔ **Map represented by a genome (Holzkaemper et al., 2006).**

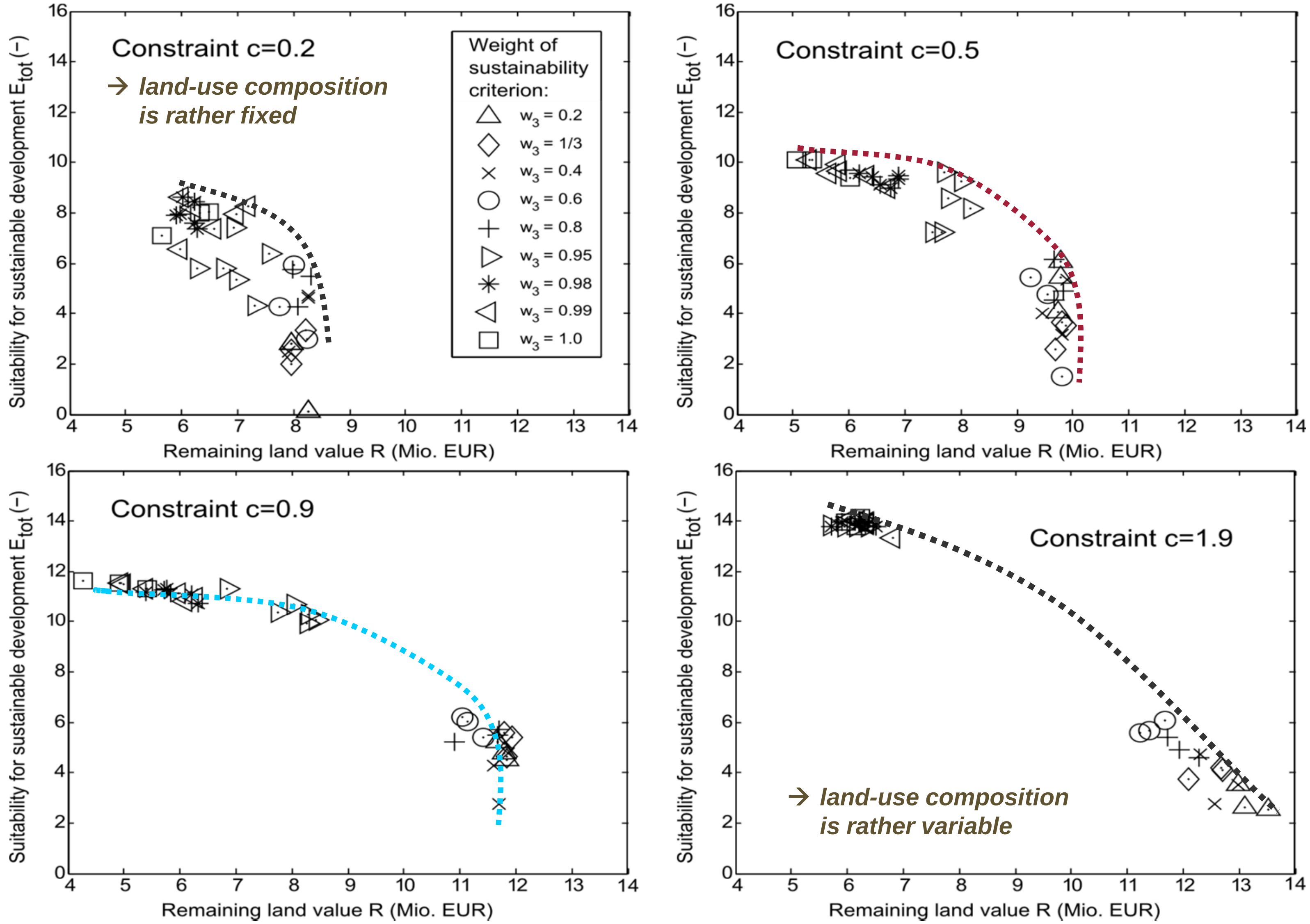
➔ **GA utilizes** stochasticity to create "populations" of individuals (i.e. maps)
- evaluation of individuals
- "better" individuals "mate" to build next generation
- crossover and mutation create new individuals
- evolution over generations until convergence

Morio et al. (2013), J. Env. Management, 130, 331–346

(4) Economically optimized allocation of 3 land-use types



(4) Multi-objective optimization: Pareto-curves



Publications

Morio, M., Finkel, M. & S. Schädler (2013): Applying a multi-criteria genetic algorithm framework for brownfield reuse optimization: Improving redevelopment options based on stakeholder preferences. Journal of Environmental Management, 130, 331–346.

Schädler, S., Finkel, M., Bleicher, A., Morio, M. & M. Gross (2013): Spatially explicit computation of sustainability indicator values for the automated assessment of land-use options. Landscape and Urban Planning, 111:34-45.

Schädler, S., Morio, M., Bartke, S. & M. Finkel (2012): Integrated planning and spatial evaluation of megasite remediation and reuse options. Journal of Contaminant Hydrology, 127(1-4), 88-100,

Schädler, S., Morio, M., Bartke, S., Rohr-Zänker, R. & M. Finkel (2011): Designing sustainable and economically attractive brownfield revitalization options using an integrated assessment model. Journal of Environmental Management, 92(3), 827-837.

Contributors and model sites

Development

Danish Technical University

STADTREGION
Büro für Raumanalysen und Beratung

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

JENA GEOS Consulting GmbH

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Technical University Bucharest

Model Sites

Stadt Brandenburg

Stadt Potsdam

Szprotawa (Poland)

Radeberg

Hunedoara (Romania)

GESA GESELLSCHAFT ZUR ENTWICKLUNG UND SANIERUNG VON ALTSTANDORTEN MBH

BRANDENBURGISCHE BODEN

University Ca' Foscari Venice

IETU - Institute for Ecology of Industrial Areas

Methods, Applications and Feedback

Thank you.

Contact:
michael.finkel@uni-tuebingen.de