Sustainable Urbanizing Landscape Development (SULD) decision support tool: report on other Aqua Cases

Aqua-Add Technical Report nº.04, prepared by:

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Executive summary

This report has been developed in the context of the international co-operation project Aqua-Add (Deploying the added value of water in local and regional development), aiming at the sharing of knowledge and experience between project partners as to better deploy the potential of 'water' (economically, socially and environmentally) in urbanised landscapes and to improve the implementation of water measures in local and regional spatial development. Aqua-Add not only collects, analyses, disseminates and promotes the specific functions, services and values of green/blue spaces, but also develops and applies a Decision Support Tool (DST) that: i) demonstrates the (potential) social, environmental and economic impacts of different water management scenarios, and ii) facilitates the planning process and better informed decision making across stakeholders.

The objective of this report is twofold. First, the importance of stakeholder meetings in the development and application of the Sustainable Urbanizing Landscape Development (SULD; Roebeling et al., 2007, 2014) decision support tool is assessed. In particular, the extent to which these meetings facilitated the identification, assessment and communication of different views and interests and, in turn, encouraged the effective engagement of stakeholders in the participative design of (peri-) urban development plans. Second, the application of SULD to the other Aqua Cases (Bremerhaven DE; Copenhagen DK; Debrecen HU; Imperia IT; Lyon FR; Sofia BU) is presented and discussed, to assess the impact of location-specific green/blue space and infrastructure projects on the location of residential development, housing quantity, residential development density, population density, population composition, household living space and real estate values.

The importance of the stakeholder meetings has been assessed through a questionnaire provided to participating partners using a web-survey, developed along three main axes of concern: learning, facilitating and projecting. In terms of **learning**, over 85% of respondents indicated to have learned “Somewhat” to “A lot” through the stakeholder meetings – in particular regarding concerns and interests of other stakeholders as well as in relation to the participants’ way of thinking, learning or working. In terms of **facilitating**, over 90% of respondents indicated to have gained new information or professional contacts through the stakeholder meetings. Also, respondents indicated to be “Satisfied” to “Completely satisfied” about the exposition and perception of points of view (over 85%), the discussion on project options (76%) and consensus formation (53%). In terms of **projecting**, respondents considered the stakeholder meetings “Somewhat” to “Very” useful for them (91%), the neighbourhood (86%) and the city (86%). Participants, hence, indicated they would (43%) or likely (57%) attend/organize another stakeholder meeting. The stakeholder meetings were considered an ideal place to discuss problems with other planning professionals and stakeholders, especially when held regularly and as early as possible in the project. In addition, they welcomed the use of a visually appealing and user friendly decision support tool to stimulate discussion.

Based on the results from all Aqua Cases (Aveiro PT; Eindhoven NL; Bremerhaven DE; Copenhagen DK; Debrecen HU; Imperia IT; Lyon FR; Sofia BU), the following four major tendencies regarding the establishment, re-introduction or re-qualification of green and blue spaces can be derived:

1. First, cities become more compact as people are willing to accept smaller housing when living closer to an attractive area;
2. Second, population density increases as green and blue spaces attract more people;
3. Third, there is an appreciation in real estate values as people are willing to pay more when living closer to an attractive area;
4. Finally, changes in demographic distribution patterns will occur as higher income households are attracted to these more attractive areas.

Note, however, that the value-added of green and blue space depends on: one, the quality and size of the intervention; two, the location of the intervention relative to existing residential areas, urban centres and environmental amenities; and three, the social classes attracted to the intervention area.

The SULD decision support tool and, in particular, the SULD web-based application (http://suld.web.ua.pt/), is not an aim in itself but the starting point of a process. It facilitates participatory planning and scenario development, creating confidence in and familiarity with the model and its outputs. Also, it enriches public discussion and adds transparency to the urban planning and decision-making processes. Consequently, it encourages stakeholders to reflect about their reality and future possibilities – effectively engaging them in the design of urban development plans where the value of water and green spaces may assume a forefront position.

Acknowledgements

This report has been developed in the context of Aqua-Add (Deploying the added value of water in local and regional development), a 3-year co-operation project of 11 partners from 8 EU regions. The project aims to share knowledge and experience between the project partners, to better deploy the potential of 'water' (economically, socially and environmentally) in urbanised landscapes and to improve the implementation of water measures in local and regional spatial development. The project is co-financed by the European Regional Development Fund (ERDF) along with each of the 11 partners and made possible by the INTERREG IVC programme. The Interregional Cooperation Programme INTERREG IVC helps Regions of Europe work together to share experience and good practice in the areas of innovation, the knowledge economy, the environment and risk prevention.

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1. Introduction

European regions and cities face important water challenges, including water storage and discharge after rainfall events, water quality and the impact of summer droughts on water supply. This sense of urgency is getting larger in the face of climate change. To address these challenges, it is evident that 'water' must become an integrated part of spatial policy development and implementation. Water management issues are, however, often secondary. While dealing with water may not seem urgent in the short term, implementing measures in the medium term is necessary to prevent problems in the long term.

There are, however, many obstacles to achieving medium-long term water management goals. First, water issues compete with other public concerns, resulting in insufficient public and political support. Second, stakeholders in the public domain are often not aware of the added value that effective water management can bring to spatial development. Finally, efficient water management will avoid high costs in the long term and, in turn, result in higher housing/real estate values.

The objective of the Aqua-Add project is to "better deploy the potential of 'water' (economically, socially and environmentally) in urbanised landscapes and to improve the implementation of water measures in local and regional spatial development". To this end Aqua-Add builds on exchange of experiences and good practices, including soft testing on:

1. Stakeholder involvement;
2. The added value of green/blue space in urbanised landscapes;
3. Practical and successful business models for 'water-projects'.

Knowledge on the functions, services and values of green/blue spaces is incomplete and not easily accessible for policymakers, spatial planners, developers, entrepreneurs and other stakeholders – especially when it comes to economic and social values. Aqua-Add not only collects, analyses, disseminates and promotes the specific functions, services and values of green/blue spaces, but also develops and applies a decision support tool that: i) demonstrates the (potential) social, environmental and economic impacts of different water management scenarios, and ii) facilitates the planning process and better informed decision making across stakeholders. The Sustainable Urbanizing Landscape Development (SULD; Roebeling et al., 2007, 2014) decision support tool is developed and applied to eight Aqua Case studies (two frontrunner Aqua Cases[1] and six other Aqua Cases[2]), with input from partners that are knowledge institutions and based on the needs of the partners that are regional/local authorities.

The objective of this report is twofold. First, the importance of stakeholder meetings in the development and application of SULD is assessed. In particular, the extent to which these meetings facilitated the identification, assessment and communication of different views and interests and, in turn, encouraged the effective engagement of stakeholders in the participative design of (peri-) urban development plans. Second, the application of SULD to the other Aqua Cases is presented and discussed. Case studies are presented for the six other Aqua Cases (Bremerhaven DE; Copenhagen DK; Debrecen HU; Imperia IT; Lyon FR; Sofia BU), to assess the impact of location-specific green/blue space and socio-economic

[1] Frontrunner Aqua Cases include Aveiro (Portugal; PT) and Eindhoven (Netherlands; NL).

[2] Other Aqua Cases include Bremerhaven (Germany; DE), Copenhagen (Denmark; DK), Debrecen (Hungary; HU), Imperia (Italy; IT), Lyon (France; FR) and Sofia (Bulgaria; BU).

scenarios on the location of residential development, housing quantity, residential development density, population density, population composition, household living space and real estate values.

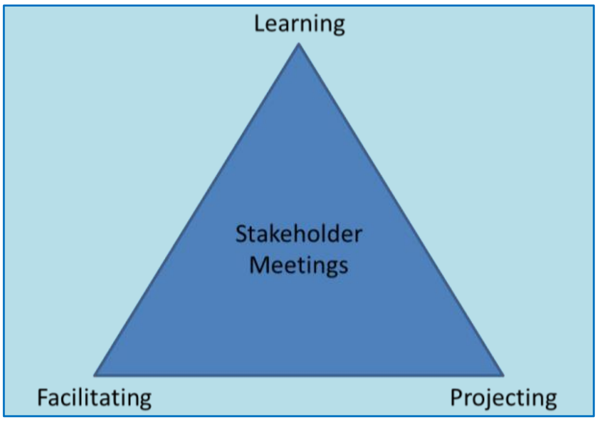
The structure of the report is as follows. In the next chapter the partner feedback on the stakeholder meetings is presented and discussed. In Chapter 3 a summary overview of the modelling approach underlying the SULD decision support tool is presented. Chapter 4 provides a short description of the Bremerhaven, Copenhagen, Debrecen, Imperia, Lyon and Sofia other Aqua Cases and, in turn, respective results for various green/blue space and infrastructure projects are presented in Chapter 5. Finally, Chapter 6 provides conclusions and recommendations.

2. Stakeholder meetings: partner feedback

Stakeholders are involved in the development and application of SULD, providing input on the information to be produced and, hence, building confidence in and familiarity with the model and its outputs. In this participatory process, social, environmental and economic impacts of green/blue scenarios are determined and illustrated through publications, the SULD web-based application (http://suld.web.ua.pt/) and stakeholder meetings. These meetings aim to facilitate the identification, assessment and communication of different views and interests and, thus, encourage effective engagement of stakeholders in the participative design of (peri-) urban development plans.

The importance of the Aqua-Add stakeholder meetings has been assessed through a questionnaire provided to the participating partners using a web-survey (using Google Surveys). This survey comprised 11 questions, developed along three main axes of concern. In particular, the extent to which: i) participants have **learned** from the stakeholder meetings, ii) the stakeholder meetings **facilitated** participants' networking, knowledge sharing and debate on relevant issues, and iii) the stakeholder meetings contributed to **projected** outputs and outcomes of their work and for their city (see Figure 1). Possible answers for qualitative questions followed a 5-point Likert Scale (e.g. 'Nothing at all', 'A little', 'Somewhat', 'A lot' and 'A great deal').

Figure 1 The Aqua-Add stakeholder meeting triangle

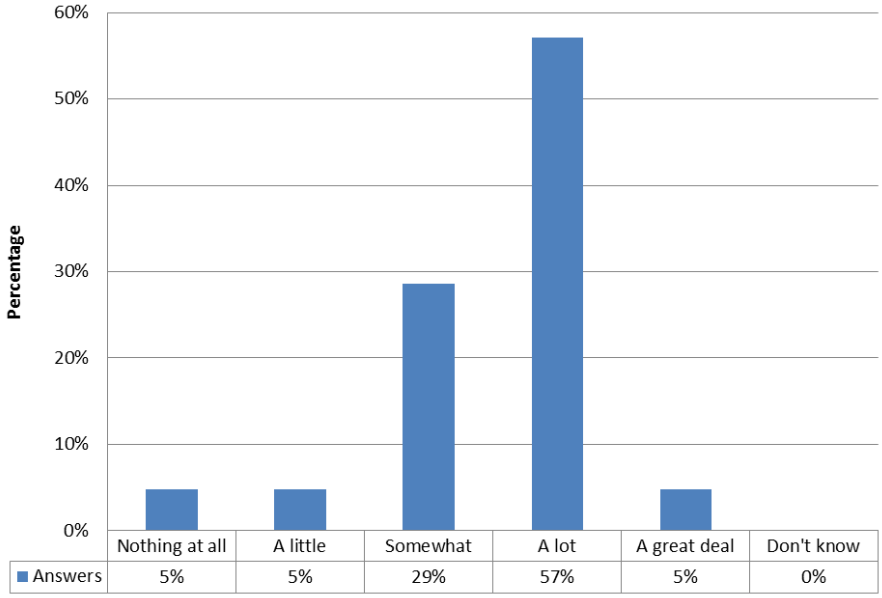


The survey had a total of 21 valid responses, with over 90% of respondents being either researchers in the Academia or Municipal Officials (43% and 48% of respondents, respectively). The next three sections provide a description of the results along the abovementioned three main axes of concern.

2.1. Learning

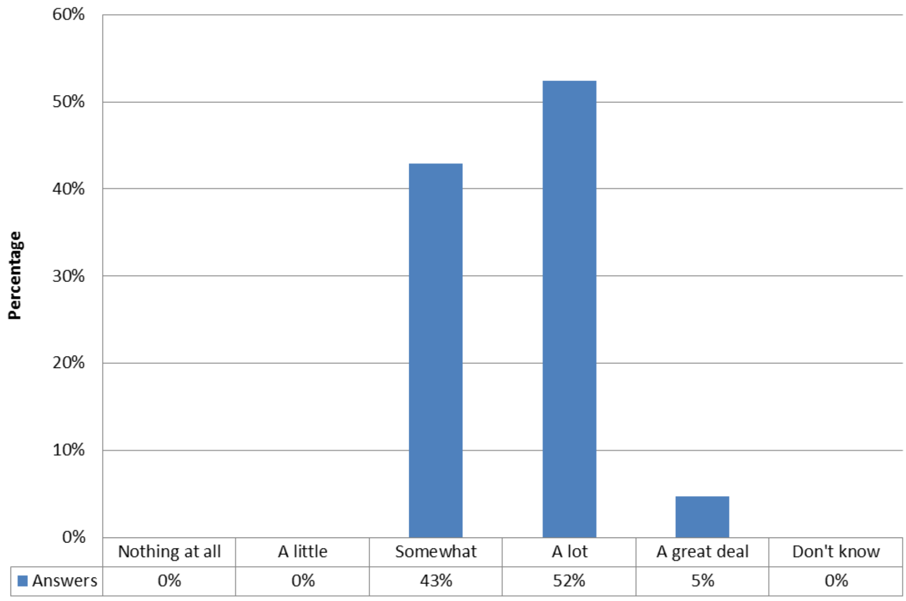
Overall, participants indicated to have learned considerably through the stakeholder meetings. First they were asked, in a general sense, if they had "learned anything new" from the stakeholder meetings. Almost two thirds of respondents answered 'A lot' or more, while the majority of the remaining third indicated to have learned 'Somewhat' from the stakeholder meetings (see Figure 2).

Figure 2 Answers to Question 3: Overall, did you learn anything new from the stakeholder meetings?



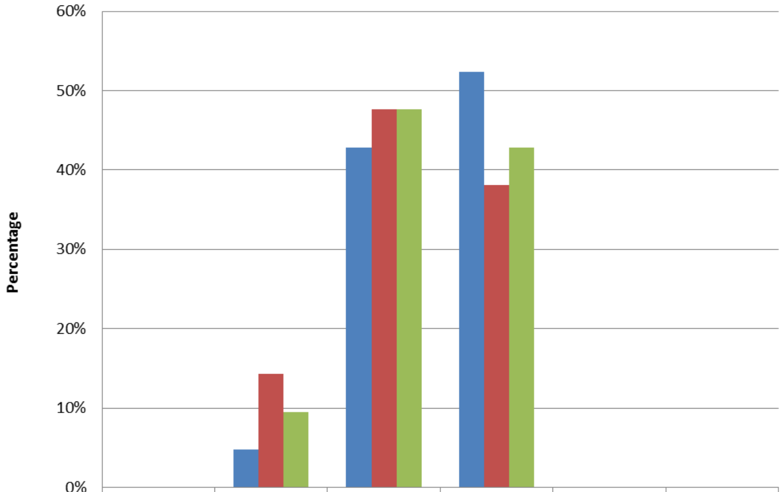
Stakeholders indicated to have learned "Somewhat" or "A lot" (95% of responses) about the concerns and interests of other stakeholders, which attests to the importance of these meetings as a place for sharing knowledge, discussing ideas and gaining insights in points of view from others (Figure 3). It is also worthy to note that nobody answered 'Nothing at al' or 'A little'.

Figure 3 Answers to Question 6: Did you learn anything new about other stakeholders' interests or concerns (related to green/blue space in urban landscapes)?



Finally, stakeholders were asked if their way of thinking, learning or working had changed because of the stakeholder meetings (Figure 4).

Figure 4 Answers to Question 8: Did the stakeholder meetings bring changes to your professional life, regarding your way of thinking, learning and working?



	None	A little	Some	A lot	A great deal	Don't know
Your way of thinking	0%	5%	43%	52%	0%	0%
Your way of learning	0%	14%	48%	38%	0%	0%
Your way of working / doing things	0%	10%	48%	43%	0%	0%

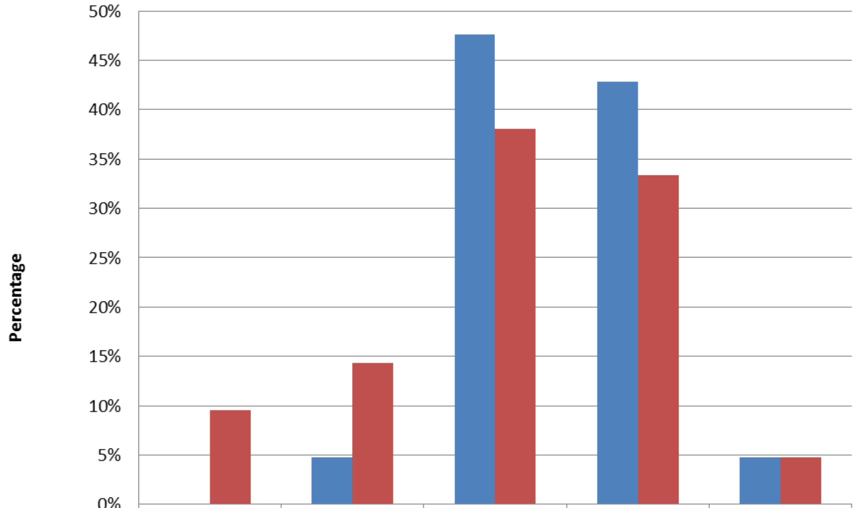
Over 85% of respondents answered "Some" or "A lot" to these three questions. The way of thinking was the one that was most stimulated by the stakeholder meetings, with over 50% of respondents answering "A lot". On the other hand, the way of learning was the least affected, with 15% of respondents answering "A little". The positive impact on the way of working/doing things is to be commended.

2.2. Facilitating

One of the purposes of conducting the stakeholder meetings was to facilitate communication between stakeholders – i.e. to create an environment where ideas could be exchanged freely between participants. From there, the goal was to discuss green/blue space intervention projects and, ideally, arrive at a consensus that provides the best solution for the concerned study areas.

When asked if participants had gained new information through the stakeholder meetings, respondents reacted positively – with 90% of participants responding 'Some' or 'Considerable' (Figure 5). When asked if participants had gained new professional contacts, over one third of respondents said 'Some' and another third said 'Considerable'. Yet it is noticeable that about 25% of respondents gained 'None' or 'Few' contacts. This may be because some meetings had a small variety of stakeholders or, alternatively, these were regular participants of these types of meetings who, obviously, already know each other.

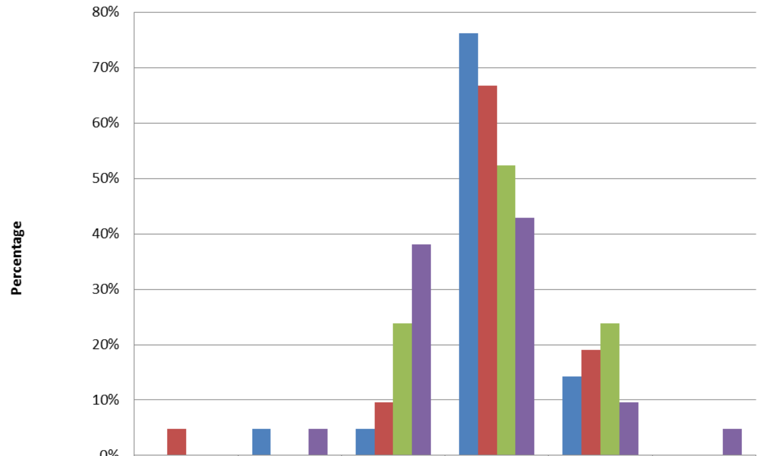
Figure 5 Answers to Question 4: Did you gain, through the stakeholder meetings, new information and professional contacts?



	None	Few	Some	Considerable	A lot
Information	0%	5%	48%	43%	5%
Professional contacts	10%	14%	38%	33%	5%

With respect to the degree of satisfaction regarding the outcomes of the meeting in terms of the discussion and the formation of consensus, these answers are the most positive of the entire survey. This reflects the success of the stakeholder meetings and, hence, that one of the key objectives of these meetings have been met.

Figure 6 Answers to Question 5: How satisfied are you with the outcomes of the stakeholder meetings, regarding the exposition and perception of points of view, the discussion and the consensus formation?



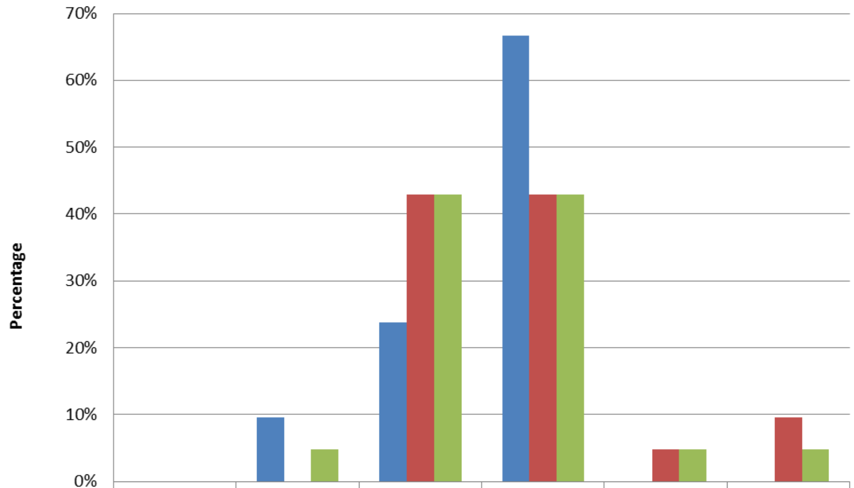
	Completely dissatisfied	Dissatisfied	Neutral	Satisfied	Completely satisfied	Don't know
Exposition of stakeholder viewpoints/opinions	0%	5%	5%	76%	14%	0%
Perception of stakeholder viewpoints/opinions	5%	0%	10%	67%	19%	0%
Discussion on green/blue space project options	0%	0%	24%	52%	24%	0%
Consensus formation across stakeholders	0%	5%	38%	43%	10%	5%

The exposition of stakeholder viewpoints was considered effective, with 76% of respondents 'Satisfied' (Figure 6). Regarding the perception of viewpoints of others and the discussion on green/blue space projects, the degree of satisfaction is split between 'Completely Satisfied', 'Satisfied' and 'Neutral'. For the perception of the viewpoint of others the tendency is towards 'Completely Satisfied', whereas regarding the discussion on green/blue space projects half of the respondents answer 'Completely Satisfied' or 'Neutral' (in equal shares). Hence, 75% of respondents are 'Satisfied' or 'Completely satisfied' with the discussions that took place. On the other hand, stakeholders are divided as to the formation of a consensus – almost 40% of respondents remain neutral in answering if a consensus was formed though another 40% of respondents have been 'Satisfied' with consensus formation. The degrees of dissatisfaction are consistently low across all questions.

2.3. Projecting

Finally, a set of questions was provided to evaluate the extent to which the outputs and outcomes of the stakeholder meetings have made an impact on the participants, the urban areas they represent and the lessons they have learned. Participants were also given two open questions, allowing to provide comments and suggestions about the meetings and the major impacts these have had on them.

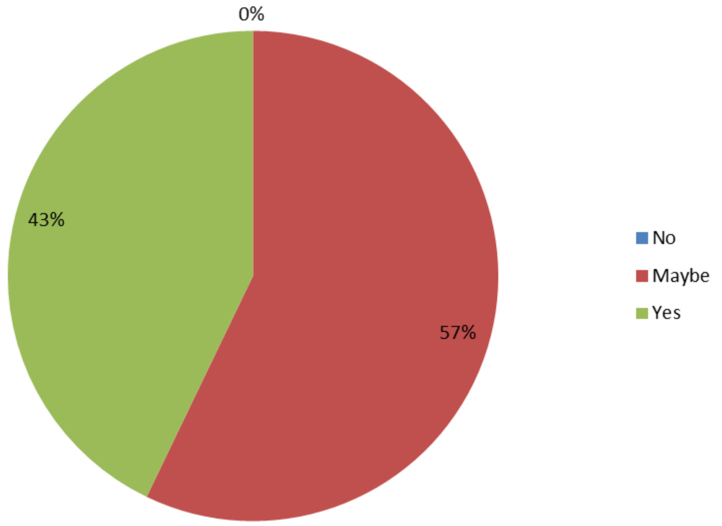
Figure 7 Answers to Question 7: Do you feel the stakeholder meetings were useful for you, the neighbourhood and the city?



	Not at all	A little	Somewhat	Very	Extremely	Don't know
You	0%	10%	24%	67%	0%	0%
The neighborhood	0%	0%	43%	43%	5%	10%
The city	0%	5%	43%	43%	5%	5%

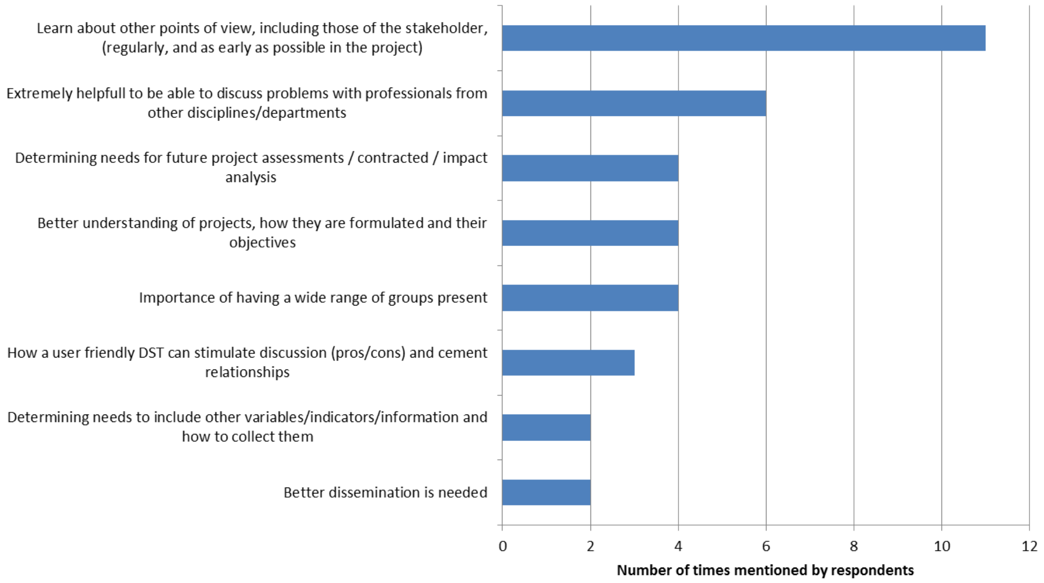
Overall, the stakeholder meetings are considered to have been extremely useful (Figure 7). Most notably, two thirds of the participants answered 'Very' useful while none of the participants considered the stakeholder meetings 'Not at all' or 'Extremely' useful. Respondents rated the usefulness of the stakeholder meetings for the neighbourhood and city somewhat lower, with respondents answering 'Somewhat' and 'Very' useful on both accounts (43%). Note that none of the respondents considered the stakeholder meetings less than 'Somewhat' useful for the neighbourhood, while only 5% of the respondents considered the stakeholder meetings only 'A little' useful for the city.

Figure 8 Answers to Question 11: Would you attend/organize another stakeholder meeting?



As a consequence it seems logical that none of the respondents indicated that they would definitely not attend/organize another stakeholder meeting again. Over 40% of respondents indicated they would attend/organize another stakeholder meeting again, while almost 60% of respondents are inclined to attend/organize another stakeholder meeting (Figure 8).

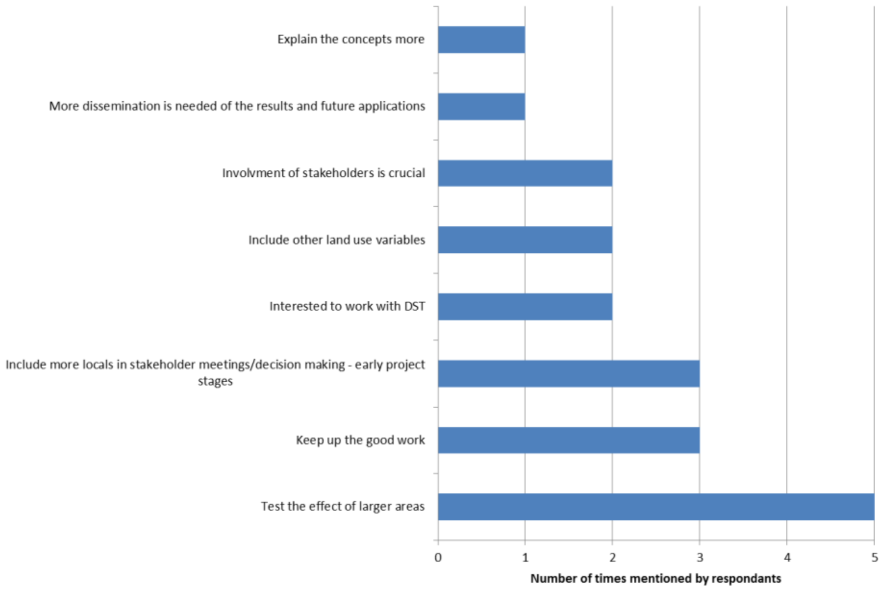
Figure 9 Answers to Question 9: What kind of changes [after Question 8]. Please indicate here:



The two open questions provide additional insight in this respect. Respondents were asked, after Question 8 (see Figure 4), to describe what they felt to have learned in the stakeholder meetings and how that could affect them in the future. Similar responses were grouped, while singular responses were excluded from Figure 9.

As can be observed the major concern of participants is the inclusion of a diversified group of stakeholders in the meetings, and that the stakeholder meetings should be held regularly and as early as possible in the project. They consider the stakeholder meetings an ideal place to discuss problems with other planning professionals and the public, and welcomed the use of a visually appealing and user friendly decision support tool to stimulate discussion. Yet, respondents also show concern for the dissemination of the project results, would like to have a better understanding of the green/blue space projects (how they are formulated and their objectives), and would like to see included and discussed other variables of interest.

Figure 10 Answers to Question 10: Do you have any comments or suggestions for the project?



Finally, respondents were asked to provide any comments or suggestions for the project and for future stakeholder meetings (Figure 10). Similar concerns were expressed. Respondents would like to see included a more diversified group of local stakeholders in the meetings at an early stage of the project. Also, they would like to see other variables included in the discussions, they feel that some concepts may require more explanation, and that more dissemination is needed. Overall, respondents are happy with the good work performed and showed interest in working with the DST. As a main suggestion for the future, respondents would like to see the DST applied to a larger area – suggesting a minimum area of analysis so that the effects demonstrated by the DST become better perceptible.

3. Methodology: the SULD modelling approach

The Sustainable Urbanizing Landscape Development decision support tool (SULD; Roebeling et al., 2007, 2014) is a GIS-based optimization model, that builds on hedonic pricing theory and that is based on a classic urban-economic model with environmental amenities (see Mills, 1981, O'Sullivan, 2000, Wu and Plantinga, 2003). In essence SULD determines the value of housing given its location relative to urban centres and environmental amenities – i.e. the equilibrium price for which demand for and supply of housing are equal (Roebeling et al., 2007, 2014). For detailed information on the SULD approach, the reader is referred to Roebeling et al. (2014).

The **demand side** (Equation 1) is represented by households, characterized by their preferences for a certain set of goods and services: residential space *S*, other goods and services *Z*, and environmental amenities *e*. The utility obtained by households in each location is a function of their preferences, distance to environmental amenities and income. Households maximize their utility *U* at location *i* subject to the budget constraint *y*, which is spent on housing *S*, other goods and services *Z*, and transportation between the residential area and the urban centre ($p_X x$):

$$\underset{S_i,Z_i}{Max}\, U_i(S_i, Z_i) = S_i^{\mu} Z_i^{(1-\mu)} e_i^{\varepsilon}$$

$$\text{subject to } y = p_i^h S_i + Z_i + p_x x_i \qquad (1)$$

U_i = household utility
S_i = residential space
Z_i = other goods and services
e_i = environmental amenity value
y = household income
p_i^h = rental price housing
p_x = commuting costs
x_i = distance to urban centre

The environmental amenity value e_i that the household experiences at location *i* is decreasing with distance from the amenity source, and is determined by:

$$e_i = 1 + a \cdot \exp^{-\eta z_i} \qquad (2)$$

where *a* is the environmental amenity, *η* is the amenity distribution factor, and where z_i is the distance from location *i* to the environmental amenity *a*. The household's bid-rent price at a given location can now be derived (see Roebeling et al., 2007, 2014) and gives the household's maximum willingness to pay for housing (p_i^{h*}) at location *i*. Considering that households face a given rental price (they are "price-takers"), they can select the faced rental price and obtained utility/welfare from the environmental amenities and other goods by choosing the residential location *i*.

The **supply side** (Equation 3) is represented by developers, who maximize their profit by trading off returns from housing development density net of associated development costs, subject to households' willingness to pay for housing. Developers aim to maximize their profit π at location *i*, which is given by the revenue of construction (p^hD) net of incurred development costs ($l+c_0+D^\eta$):

$$\underset{D_i}{Max}\,\pi_i(D_i) = p_i^h D_i - (l_i + c_0 + D_i^\eta)$$

with $D_i = n_i S_i$

π_i = developer's profit
D_i = development density
p_i^h = rental price housing
l_i = opportunity cost land (3)
$c_0+D_i^\eta$ = construction costs
n_i = household density
S_i = residential space

The developers bid-price for land can then be derived (see Roebeling et al., 2007, 2014), and they will develop when residential land rents ($p_i^hD_i$) are larger than the opportunity cost of development ($l_i + c_0 + D_i^\eta$) – which is equal to the forgone land rents (l_i ; e.g. revenues from agriculture or payments from ecosystem services) and the costs of converting land ($c_0 + D_i^\eta$).

Finally, **equilibrium** occurs where supply for housing equals demand for housing. The equilibrium land rent price at a given location *i* can then be derived (see Roebeling et al., 2007, 2014), and development patterns for a certain population size are determined given the location of urban centres and environmental amenities.

The SULD decision support tool builds on a numerical application of the above described model (Roebeling et al., 2007, 2014), using the General Algebraic Modelling System (GAMS 21.3; (Brooke et al., 1998). The objective function maximizes, for a given household population Q_t, benefits *B* from residential land uses L_i^{res} and non-residential land uses L_i^{nres} net of development costs ($l_i+c_0+D_i^\eta$) over all locations *i*, so that:

$$\underset{L_i}{Max}\,B(L_i) = \sum_i \left(l_i L_i^{nres} + (r_i - l_i - c_0 - D_i^\eta) L_i^{res} \right) \quad (4)$$

subject to $Q_t = \sum_i n_i$ and $L_i^{res} + L_i^{nres} = a_i$, and where l_i is the opportunity cost of land, r_i is the land rent price, and a_i is the grid-cell area at location *i*. Note that land use conversion can take place between residential and user-defined non-residential land uses – the remaining land uses are fixed.

Thus SULD calculates the equilibrium price for housing as a function of demand and supply, determining the location of residential development, residential development density, population density, housing quantity, living space and real estate value. In turn, impacts of location-specific green/blue space, infrastructure and socio-economic scenarios can be assessed.

4. Aqua Case study descriptions

The SULD decision support tool is developed and applied to eight Aqua Case studies, including two frontrunner Aqua Cases (Aveiro PT; Eindhoven NL) and six other Aqua Cases (Bremerhaven DE; Copenhagen DK; Debrecen HU; Imperia IT; Lyon FR; Sofia BU). This chapter provides a short description of the Bremerhaven (Section 4.1), Copenhagen (Section 4.2), Debrecen (Section 4.3), Imperia (Section 4.4), Lyon (Section 4.5) and Sofia (Section 4.6) Aqua Cases. For a more detailed description of all the Aqua Cases, please refer to Roebeling et al. (2012).

4.1. Bremerhaven (DE)

The city of Bremerhaven (112,895 inhabitants and 1,200 inhabitants/km^2) is addressing problems related to ecosystem services, namely recreation in the district of Geestemünde. The district is surrounded by water, but it is not easy to access or experience as there are many barriers – both physically and in people's minds. The area is characterised by abandoned port facilities and high vacancy rates due to outward migration. Hence, the city of Bremerhaven intends to use the potential of the river and harbour basins in order to make the district more attractive, to contribute to quality of life as well as to encourage small and medium enterprises (SMEs) and shop owners to stay inside and/or move into the Geestemünde district.

4.1.1. Problem setting and objective

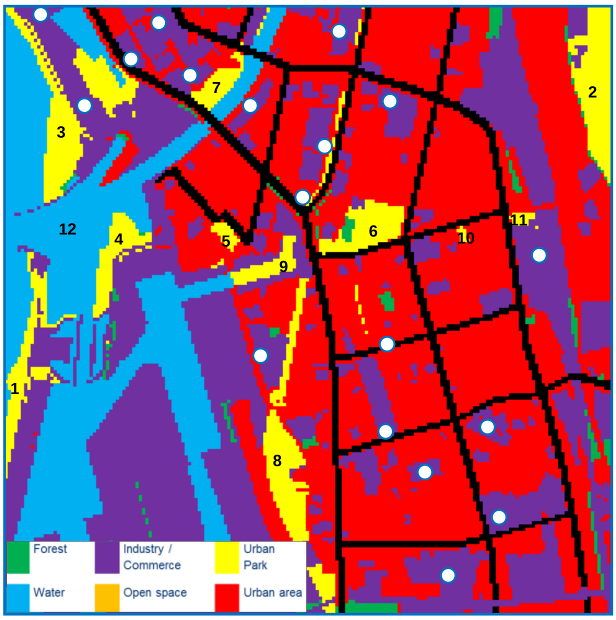
The objective is to initiate and support testing strategies to improve the integration of water in spatial development processes – i.e. to make water-places visible and accessible in order to enhance the living conditions and the quality of housing and working in the district. This will allow the city to attain the following core objectives for the district: i) stabilisation of population figures, ii) stabilisation of the social structure, iii) increase in property values in the neighbourhood, iv) preservation of purchasing power in the district, and v) promotion of non-motorised transport. The proposed solutions to this problem are defined in the Master Plan for the waterside in Geestemünde, and include:

- The development of urban green/blue space (establishment of natural riparian zones in the urban context).
- The development of an area for housing, shopping and leisure functions (creation of footpaths and public spaces).
- The construction of road and infrastructure connections (improvement of infrastructure connections from the district centre to the waterfront; creation of paths along the water; crossing facilities; relocation of car parking spaces).

4.1.2. Bio-physical characteristics

The Bremerhaven case study focusses on the Geestemünde district, which comprises an area of 3.4 km^2 and is located on the South side of the city. The district is serviced by one highway (A27/E234), one provincial road (L135) and a railway station (on the West side of Geestemünde).

Figure 11 Land use in and around the Geestemünde district (based on BSO, 2014)



Geestemünde has twelve environmental amenities, including three urban parks (Seedeich (#1), Bürgerpark (#2) and Weser-Strandbad (#3)), four neighbourhood parks (Geestevorhafen (#4), Berliner Platz (#5), Holzhafen (#6) and Wencke-Dock (#7)), four local parks (Elhornstrasse (#8), Handelshafen (#9), Walter-Rathenau-Platz (#10) and Bismarckplatz (#11)) and water (#12). There are eighteen urban centres, including six shopping centres/areas, five schools, two museums, the Alfred Wegener Institute, the University of Applied Sciences and the railway station (see white dots in Figure 11).

4.1.3. Socio-economic characteristics

For the Bremerhaven case study, the definition of household socio-economic characteristics was obtained using available statistics on population, household size, expendable income and expenditure distribution (Table 1). The total population living in the study area is 35,754 and the total number of households equals 20,548 (SLB, 2012), resulting in an average household size of 1.74 persons/household

Table 1 Household characteristics for the Bremerhaven case study area (based on SLB, 2012)

	Unit	Household type 1	Household type 2	Household type 3	Total
Demographics					
Population	#	16,053	14,281	5,420	35,754
Household size	#/household	1.74	1.74	1.74	1.74
Households (Q)	#	9,226	8,207	3,115	20,548
Household budget					
Expendable income (y)	€/yr	11,618	26,391	43,200	$458.4*10^6$
Housing expenditures (μ)	%	29.5%	28.5%	27.5%	28.4%

Based on income data for the Bremerhaven region in Germany (SLB, 2012), we distinguish three income groups: low, middle and high income households. The low income household type (HHtype1) corresponds with the 1st and 2nd decile of income, the middle income household type (HHtype2) corresponds with the 3rd to 7th decile of income, and the high income household type (HHtype3) corresponds with the 8th to 10th decile of income. The number of households per type is calculated using data about the percentage of households per decile of income. Consequently, HHtype1 corresponds to 45% of the population that earns 20% of total income, HHtype2 corresponds to 40% of the population that earns 50% of total income, and HHtype3 corresponds to 15% of the population that earns 30% of total income.

Finally, housing expenditures are obtained for the identified household types based on household expenditure data for the Bremerhaven region in Germany (SLB, 2012). Households spend on average 28.4% of their income on housing, with low income households spending relatively more (29.5%) and high income households relatively less (27.5%) than average.

4.2. Copenhagen (DK)

The city of Copenhagen (569,557 inhabitants and 6,600 inhabitants/km^2) is addressing a problem of flooding in "Sct Kjelds Kvarter", an old and densely populated urban area located in the North-Eastern part of the city. The area is located close to one of the most popular parks in Copenhagen (Faelledparken), though neither has accessible green space nor recognizably culture, café life or tourist attractions. In June 2011 the area experienced the most intense flooding during an extreme rain event and is, therefore, one of the areas identified in the Copenhagen Climate Adaption Plan (CAP) in risk of flooding due to increasing rainfall events and rising sea levels. In order to solve this problem, the city of Copenhagen initiated a pilot project in the area in 2012.

4.2.1. Problem setting and objective

The main objective of the case study is to develop and implement best practices on how to innovate and integrate climate adaption in an existing urban area – with special attention on how to handle and manage increasing rainfall events while respecting the structure, history and architecture of the area. The City of Copenhagen, the Department for City Design and the Department of Parks and Nature, aim to increase the popularity of the Sct Kjelds Kvarter area and to motivate citizens to stay and take part in urban life. The area has an unused square area with potential for initializing urban life and private housing, which demands more green/blue space. To prevent future flooding of the Sct Kjelds Kvarter area, the municipality of Copenhagen aims to implement a wide range of measures to address the focal issues of the city's CAP, to reduce the risk of flooding and damages as well as to test and document potential benefits from new ways and methods in water management. Proposed solutions include:

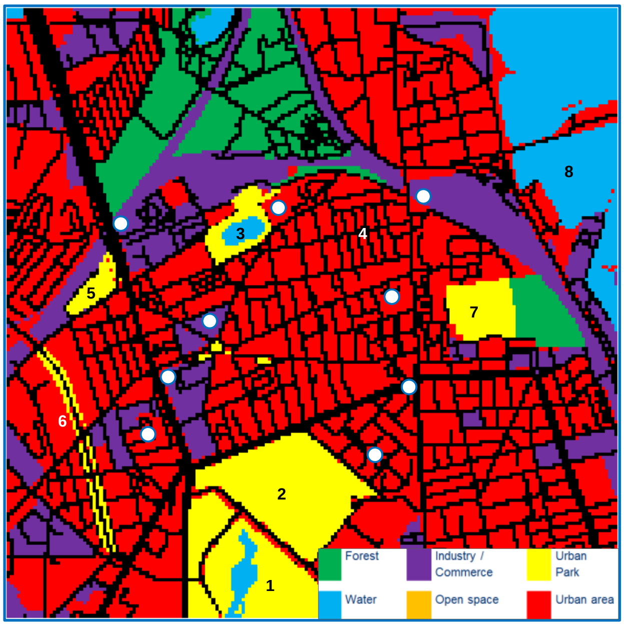
- Decoupling surface rainwater from the sewer system and reconstruction of roads in combination with development of green/blue space.
- Creation of a sustainable drainage system (SUDS).
- Development of urban green/blue space for recreation, leisure and cultural activities.

To involve the stakeholders in this process from a grey city to a green climate neighbourhood, a public office of the Department for City Design and the Department of Parks and Nature has been established in the centre of the study area, which coordinates stakeholder involvement and gives room for cultural and art events.

4.2.2. Bio-physical characteristics

The Copenhagen case study focusses on the St. Kjeld's neighbourhood in Østerbro, which comprises an area of 5.8 km^2 and is located on the North-Eastern part of the city. The neighbourhood is serviced by one large highway (Lyngbyvej/19), two major roads (Østerbrogade and Kalkbraenderihavnsgade) as well as several railway stations.

Figure 12 Land use in and around the Sct Kjelds Kvarter neighbourhood (based on Bydata, 2013)



St. Kjeld's has eight environmental amenities, including one urban park (Faelledparken (#1)), three neighbourhood parks (Klosterfaelled (#2), Kildevaeldsparken (#3) and Kildevaeldsgade (#4)), three local parks (Beauvaisgrunden (#5), Lersoe Parkalle (#6) and Gasvaerksgrunden (#7)), and the harbour (#8). There are nine urban centres, including two railway stations, four shopping centres, a school, a city centre and a business centre (white dots Figure 12).

4.2.3. Socio-economic characteristics

For the Copenhagen case study, the definition of household socio-economic characteristics was obtained using available statistics on population, household size, expendable income and expenditure distribution (Table 2). The total population living in the study area is 49,238 and the total number of households equals 27,443 (Bydata, 2013), resulting in an average household size of 1.79 persons/household.

Table 2 Household characteristics for the Copenhagen case study area (based on Bydata, 2013)

	Unit	Household type 1	Household type 2	Household type 3	Total
Demographics					
Population	#	33,123	13,853	2,263	49,238
Household size	#/household	1.65	2.10	2.93	1.79
Households (*Q*)	#	20,074	6,596	772	27,443
Household budget					
Expendable income (*y*)	€/yr	49,941	76,091	148,963	$1{,}620*10^6$
Housing expenditures (μ)	%	31.5%	31.0%	30.0%	31.2%

Based on income data for the Copenhagen region in Denmark (Bydata, 2013), we distinguish three income groups: low, middle and high income households. The low income household type (HHtype1) corresponds with the 1st to 6th decile of income, the middle income household type (HHtype2) corresponds with the 7th to 9th decile of income, and the high income household type (HHtype3) corresponds with the 10th decile of income. The number of households per type is calculated using data about the percentage of households per decile of income. Consequently, HHtype1 corresponds to 67% of the population that earns 60% of total income, HHtype2 corresponds to 28% of the population that earns 30% of total income, and HHtype3 corresponds to 5% of the population that earns 10% of total income.

Finally, housing expenditures are obtained for the identified household types based on household expenditure data for the Copenhagen region in Denmark (Bydata, 2013). Households spend on average 31.2% of their income on housing, with low income households spending relatively more (31.5%) and high income households relatively less (30.0%) than average.

4.3. Debrecen (HU)

The city of Debrecen (204,333 inhabitants and 443 inhabitants/km^2) is addressing a problem related to ecosystem services, namely recreation along the Tócó creek on the West side of the city. The city is facing continuous urban growth, and the growth towards the West has reached the creek flow area. In addition, both the city and its flat surrounding areas are poor in watercourses and, hence, an overall plan for the Tócó creek's future status is necessary.

4.3.1. Problem setting and objective

The main objective is the preparation of a Tócó basin development plan that focuses on the inner belt section of the creek (managed by the City), but not neglecting the upper and lower sections (managed by the Water Inspectorate), so that a new and valuable green/blue space will come into existence. In particular, the plan may address water flow, water quality, rainfall and wastewater partition, recreational use, stakeholder involvement and different solutions for creek sections. Possible solutions envisaged in this plan include:

- Development of urban green/blue space (with the rehabilitation of Tócó creek surroundings in the inner belt section).
- Development of an area for housing, shopping and leisure functions (so that the city can better accommodate current and expected urban growth).

4.3.2. Bio-physical characteristics

The Debrecen case study focusses on the soon to be developed area around the Tócó creek, which comprises an area of 3.0 km^2 and is located on the Western part of the city. This area (Tócóskert) is surrounded by a major highway to the West (M35/E79), two regional roads to (the 33 to the North and the 4/E573 to the South), and contains one railway station.

The Tócóskert area has three environmental amenities, including two neighbourhood parks (Park Tócóskert (#1) and Park Margit (#2)) and water (Tócó creek (#3)). There are eight urban centres, including one school, three shopping areas and four bus stops (see white dots in Figure 13).

Figure 13 Land use in and around the Tócóskert neighbourhood (based on CEMP, 2013)

4.3.3. Socio-economic characteristics

For the Debrecen case study, the definition of household socio-economic characteristics was obtained using available statistics on population, household size, expendable income and expenditure distribution (Table 3). The total population living in the study area is 13,385 and the total number of households equals 4,615 (CEMP, 2013), resulting in an average household size of 2.90 persons/household.

Table 3 Household characteristics for the Debrecen case study area (based on CEMP, 2013)

	Unit	Household type 1	Household type 2	Household type 3	Total
Demographics					
Population	#	3,614	8,834	937	13,385
Household size	#/household	2.90	2.90	2.90	2.90
Households (*Q*)	#	1,246	3,046	323	4,615
Household budget					
Expendable income (*y*)	€/yr	10,313	12,582	21,451	$58.2*10^6$
Housing expenditures (μ)	%	23.0%	22.5%	22.0%	22.6%

Based on income data for the Debrecen region in Hungary (CEMP, 2013), we distinguish three income groups: low, middle and high income households. The low income household type (HHtype1) corresponds with the 1st and 2nd decile of income, the middle income household type (HHtype2) corresponds with the 3rd to 9th decile of income, and the high income household type (HHtype3) corresponds with the 10th decile of income. The number of households per type is calculated using data about the percentage of households per decile of income. Consequently, HHtype1 corresponds to 27% of the population that earns 20% of total income, HHtype2 corresponds to 66% of the population that earns 70% of total income, and HHtype3 corresponds to 7% of the population that earns 10% of total income.

Finally, housing expenditures are obtained for the identified household types based on household expenditure data for the Debrecen region in Hungary (CEMP, 2013). Households spend on average 22.6% of their income on housing, with low income households spending relatively more (23.0%) and high income households relatively less (22.0%) than average.

4.4. Imperia (IT)

The city of Imperia (42,243 inhabitants and 920 inhabitants/km^2) is addressing a problem of flooding in the districts of Oneglia and Castelvecchio di Santa Maria Maggiore – in particular in a critical area that can be considered as a five sided polygon bounded on the North by the Collette stream basin, on the West by the Impero river, on the East by the Santa Lucia stream and on the South by the harbour. The insufficient capacity of the urban drainage system combined with the transformations of the streams into culverts, cause problems for water quantity and quality. During heavy rainfall events, floods are frequent and combined sewer systems discharge into coastal bathing waters. After the inundations in 1998 and 2000, the Municipality carried out a plan to change the sewer from combined to separate and to restore the flow rate of the streams/culverts. The general conditions have improved, but during heavy rainfalls events large parts of the town are still subject to flooding.

4.4.1. Problem setting and objective

The main objectives of the proposed project are to, one, adopt most adequate technical solutions that allow for effective flooding control in the area and, two, enhance urban liveability in the Oneglia district.

In the oldest part of the city centre rainwater mixes with waste water. Separating these two systems could take a long time and, in addition, implies high costs. The considerable variations in flow during rainfall events causes, however, flooding in large parts of the city centre. It is proposed to disconnect the storm water discharges from the main drainage system and, at the same time, to split the flow in different directions to receiving bodies in order to protect the flat coastal area from flooding risks. Hence, less stress is put on existing conduits fed by rainwater runoff.

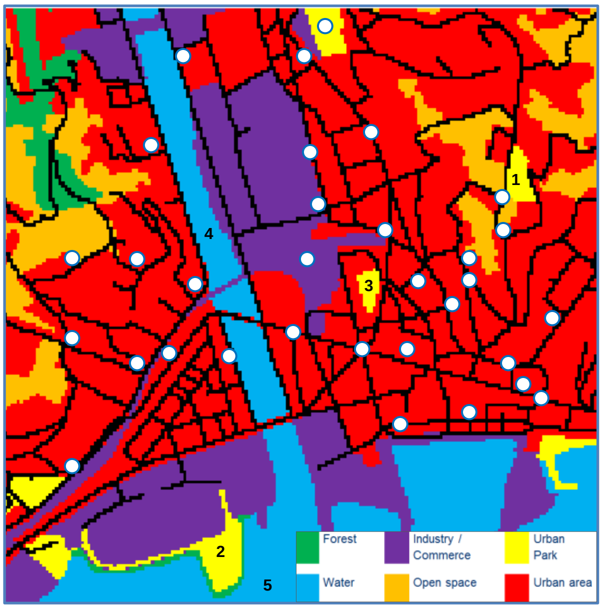
In addition, the project entails the renovation of the Oneglia railway area. In particular, a new blue corridor has been designed in the area actually corresponding to the railway track that will be dismissed before 2017. In this plan, water is intended as a key element of urban design, such that water issues can be turned into a potential resource.

The Oneglia railway project area is designed as a multifunctional space, including recreational activities and environmental amenities marked off by water paths. Note that the new railway station is planned in the Northeast of Imperia city.

4.4.2. Bio-physical characteristics

The Imperia case study focusses on the area East and West of the Impero river, and comprises an area of 2.6 km^2. The city is serviced by one major highway (A10), two provincial roads (Via Nazionale) and one railway station.

Figure 14 Land use in and around the city of Imperia (Citta D'Imperia, 1998)



Imperia has five environmental amenities, including one urban park (Villa Grock (#1)), one neighbourhood park (San Leonardo Park (#2)) and one local park (Arturo Toscanini garden (#3)) and two water (Imperio river (#4) and Mediterranean Sea (#5)). There are seven urban centres, including a shopping district, a stadium, a library, the railway station, a museum and several schools, as well as numerous bus stops (see white dots in Figure 14).

4.4.3. Socio-economic characteristics

For the Imperia case study, the definition of household socio-economic characteristics was carried out using available statistics on population, household size, expendable income and expenditure distribution (Table 4). The total population living in the study area is 61,405 and the total number of households equals 29,240 (SISTAN, 2012)), resulting in an average household size of 2.10 persons/household.

Table 4 Household characteristics for the Imperia case study (based on Comuni Italiani, 2010; SISTAN, 2012)

	Unit	Household type 1	Household type 2	Household type 3	Total
Demographics					
Population	#	17,973	39,446	3,987	61,405
Household size	#/household	2.10	2.10	2.10	2.10
Households (*Q*)	#	8,558	18,784	1,898	29,240
Household budget					
Expendable income (*y*)	€/yr	9,599	24,432	85,140	$702.7*10^6$
Housing expenditures (μ)	%	30.0%	29.0%	28.0%	28.9%

Based on income data for the Imperia region in Italy (Comuni Italiani, 2010), we distinguish three income groups: low, middle and high income households. The low income household type (HHtype1) corresponds with the 1st decile of income, the middle income household type (HHtype2) corresponds with the 2nd to 8th decile of income, and the high income household type (HHtype3) corresponds with the 9th to 10th decile of income. The number of households per type is calculated using data about the percentage of households per decile of income. Consequently, HHtype1 corresponds to 29% of the population that earns 10% of total income, HHtype2 corresponds to 64% of the population that earns 70% of total income, and HHtype3 corresponds to 6% of the population that earns 20% of total income.

Finally, housing expenditures are obtained for the identified household types based on household expenditure data for the Imperia region in Italy (Comuni Italiani, 2010; SISTAN, 2012). Households spend on average 28.9% of their income on housing, with low income households spending relatively more (30.0%) and high income households relatively less (28.0%) than average.

4.5. Lyon (FR)

The city of Lyon (491,268 inhabitants and 10,245 inhabitants/km^2) is currently addressing an urban renewal challenge in an area located in the Perrache Peninsula – the "Lyon Confluence" project. This area has had problems related to water management and flood control, namely maintenance difficulties caused by silting pipes or inadequately sized infrastructures; pollution of the receiving bodies during storm events due to overflow devices; and improper conditions for river side residents caused by the presence of rats, odour pollution and flood risk. In addition, this area has long been restricted to industry and transport facilities, and therefore had the risk of becoming a brownfield. Furthermore, the A7 highway is a man-made barrier between the Confluence and the Rhone river.

4.5.1. Problem setting and objective

The "Lyon Confluence" project aims to transform this area of approximately 2.5 km^2 into a new downtown district, increasing its number of inhabitants from around 17.000 to 25.000 by 2030, creating 14.000 new jobs, open to the water and with improved natural areas that provide new ecosystem services (recreational and cultural). The latter by developing urban green/blue spaces and by integrating storm water management in the cityscape. Proposed solutions for the area include:

- The development of urban green/blue space as well as areas for housing, shopping and leisure functions.
- Reducing investment and operation costs of technical solutions by implementing those options that best fit sustainability criteria among the 13 imagined possibilities for the rehabilitation/requalification of the sewer system.
- Enhancing the receiving bodies' water quality, protecting the water resources and reducing flood risks by rehabilitating the sewer networks.
- The construction of swales for flood control and green/blue spaces for storm water management.

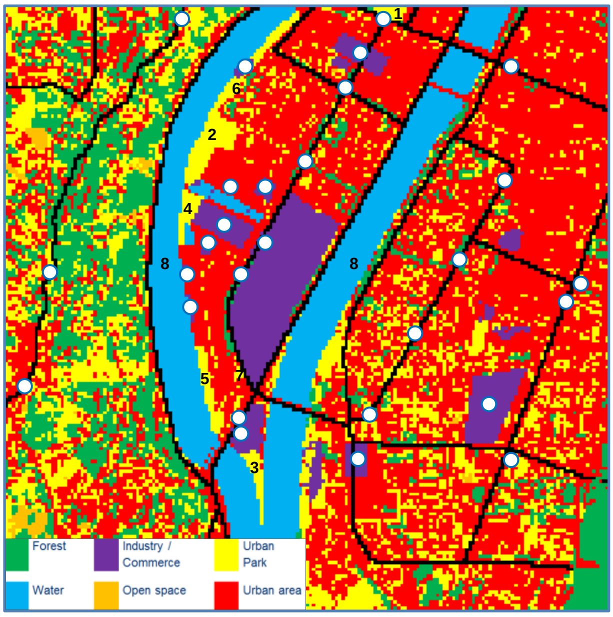
4.5.2. Bio-physical characteristics

The Lyon case study focusses on the Confluence area, which comprises an area of 5.8 km^2 and is located on the Southern part of the city. The area is crossed by a major highway (A7/E15), is serviced by several important road connections (Av. Leclerc, Av. Berthelot, Route de Vienne and Quai Jean-Jacques Rosseau) and contains one intercity railway station.

The Confluence area has eight environmental amenities, including three urban parks (Place des Archives (#1), Jardin Aquatique Ouagadougou and stadium Sony Anderson (#2) and Parc du Musée Confluence (#3)) two neighbourhood parks (Jardin aquatique Jean Couty (#4), Jardin Gabriel Rosset (#5)), two local parks (Square Général Delfosse (#6) and #7) and water

(#8). There are twelve urban centres, including a shopping district, an entertainment area, a museum, an exhibition/concert hall, a stadium, a university, a public building and several transport hubs (including an intercity railway station, several tramway stations and numerous bus stops (see white dots in Figure 15).

Figure 15 Land use in and around the Confluence area (based on EVA, 2009)



4.5.3. Socio-economic characteristics

For the Lyon case study, the definition of household socio-economic characteristics was obtained using available statistics on population, household size, expendable income and expenditure distribution (Table 5). The total population living in the study area is 60,418 and the total number of households equals 30,209 (INSEE, 2011), resulting in an average household size of 2.00 persons/household.

Table 5 Household characteristics for the Lyon case study area (based on INSEE, 2011)

	Unit	Household type 1	Household type 2	Household type 3	Total
Demographics					
Population	#	30,209	22,657	7,552	60,418
Household size	#/household	2.00	2.00	2.00	2.00
Households (*Q*)	#	15,105	11,328	3,776	30,209
Household budget					
Expendable income (*y*)	€/yr	18,050	43,861	69,312	$262.2*10^6$
Housing expenditures (μ)	%	29.0%	28.5%	27.5%	28.4%

Based on income data for the Lyon region in France (INSEE, 2011), we distinguish three income groups: low, middle and high income households. The low income household type (HHtype1) corresponds with the 1st quartile of income, the middle income household type (HHtype2) corresponds with the 2nd and 3rd quartile of income, and the high income household type (HHtype3) corresponds with the 4th quartile of income. The number of households per type is calculated using data about the percentage of households per quartile of income. Consequently, HHtype1 corresponds to 50% of the population that earns 25% of total income, HHtype2 corresponds to 38% of the population that earns 50% of total income, and HHtype3 corresponds to 13% of the population that earns 25% of total income.

Finally, housing expenditures are obtained for the identified household types based on household expenditure data for the Lyon region in France (INSEE, 2011). Households spend on average 28.4% of their income on housing, with low income households spending relatively more (29.0%) and high income households relatively less (27.5%) than average.

4.6. Sofia (BU)

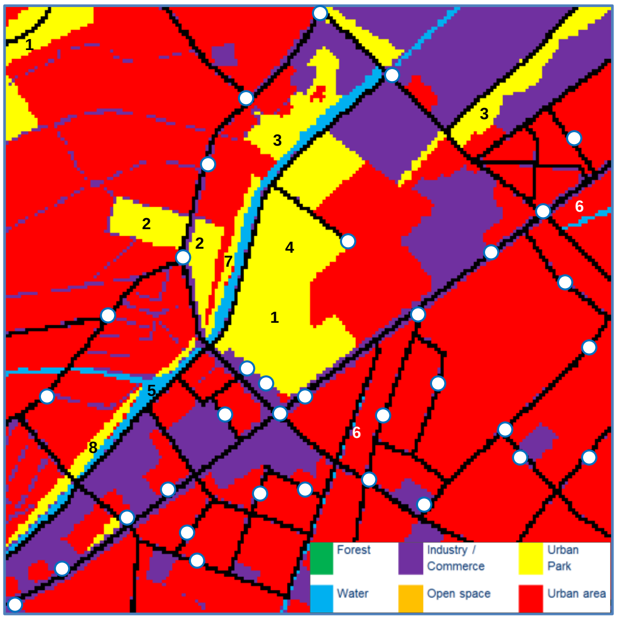
The city of Sofia (1,288,658 inhabitants and 1,060 inhabitants/km^2) is addressing problems related to flood control and ecosystem services – in particular regarding recreation along the Vladaiska river (the longest open water course running through Sofia). The Vladaiska riverbed is sectioned into earth levees, realigned riverbeds and natural river courses. For each section construction and non-construction works will be necessary to conciliate flood control, ecosystem services and quality of life.

4.6.1. Problem setting and objective

The objective of the "Vladaiska Riverbed Realignment" project is, on the one hand, to consolidate the river banks (improving water flow and reducing floods) and, on the other, to modernize the city and improve quality of life of people living in the areas along the river through landscaping and the creation of new amenities. The Sofia Municipality continually carries out project preparation works for the construction of non-realigned sections of the Vladaiska riverbed, through land acquisition procedures and assignment of design works. The prepared projects are further included in the yearly investment programme. The Vladaiska Riverbed Realignment project aims to achieve:

- The consolidation of river banks (including dikes and levees).
- The development of urban green/blue space alongside the river (including recreational facilities and bike lanes).
- Construction of roads and rehabilitation of bridges to reduce traffic in the city.

Figure 16 Land use in and around the Vladaiska river (based on SM, 2012)



4.6.2. Bio-physical characteristics

The Sofia case study focusses on the area surrounding the Vladaiska riverbed, which comprises an area of 5.3 km^2 and is located on the South-West of the city. The area is accessible, to the Southwest, by three major boulevards (Bulevard Tsar B. III, Bulevard Akad. Ivan Evtatiev Geshov and Bulevard Balgariya) and to the East by Bulevard Nikola Musharov.

The area has eight environmental amenities, including urban parks (#1), neighbourhood gardens (#2), local parks (#3), one sports facility (#4), the Vladaiska riverbed (#5) and other water channels (#6). Two green links (#7 and #8) will be rehabilitated – the proposed project interventions. There are four types of urban centres, namely schools, bus/tram stops, the intercity bus station and the shopping centre (see white dots in Figure 16).

4.6.3. Socio-economic characteristics

For the Sofia case study, the definition of household socio-economic characteristics was carried out using available statistics on population, household size, expendable income and expenditure distribution (Table 6). The total population living in the study area is 51,866 and the total number of households equals 20,829 (NSI, 2012), resulting in an average household size of 2.49 persons/household.

Table 6 Household characteristics for the Sofia case study area (based on NSI, 2012)

	Unit	Household type 1	Household type 2	Household type 3	Total
Demographics					
Population	#	44,086	2,593	5,187	51,866
Household size	#/household	2.49	2.49	2.49	2.49
Households (Q)	#	17,705	1,041	2,083	20,829
Household budget					
Expendable income (y)	€/yr	4,117	11,651	17,497	$121.5*10^6$
Housing expenditures (μ)	%	18.0%	17.5%	16.8%	17.6%

Based on income data for the Sofia region in Bulgaria (NSI, 2012), we distinguish three income groups: low, middle and high income households. The low income household type (HHtype1) corresponds with the 1st to 6th decile of income, the middle income household type (HHtype2) corresponds with the 7th decile of income, and the high income household type (HHtype3) corresponds with the 8th to 10th decile of income. The number of households per type is calculated using data about the percentage of households per decile of income. Consequently, HHtype1 corresponds to 85% of the population that earns 60% of total income, HHtype2 corresponds to 5% of the population that earns 10% of total income, and HHtype3 corresponds to 10% of the population that earns 30% of total income.

Finally, housing expenditures are obtained for the identified household types based on household expenditure data for the Sofia region in Bulgaria (NSI, 2012). Households spend on average 17.6% of their income on housing, with low income households spending relatively more (18.0%) and high income households relatively less (16.8%) than average.

5. Aqua Case study results

The SULD decision support tool can be used to assess the socio-economic impacts of location-specific green/blue space projects, road/railway infrastructure developments and socio-economic scenarios. This chapter presents the results for the Bremerhaven (Section 5.1), Copenhagen (Section 5.2), Debrecen (Section 5.3), Imperia (Section 5.4), Lyon (Section 5.5) and Sofia (Section 5.6), Aqua Cases, assessing various green/blue space projects, infrastructure developments and socio-economic scenarios.

5.1. Bremerhaven (DE)

The numerical application of SULD to the Bremerhaven case study is based on a population comprising three household types (low, middle and high income households), differentiated by number of households (Q), levels of expendable income (y) and shares of housing expenditures (μ; see Table 1 in Section 4.1.3) as well as levels of utility (u=2,600 for HHtype1, u=5,906 for HHtype2 and u=9,668 for HHtype3). All household types share the same appreciation for environmental amenities (ε=0.08; a=12.50/8.75/5.00; η =1.0), annual commuting costs (p_x=375 €/km), opportunity cost of land (l_i=1,000 €/yr) and development costs (c_0=0 and η=1.64). The study area encompasses an area of 1.85km by 1.85km (=3.43km^2), covered by a grid layer of 185 by 185 (=34,225) cells of 10m by 10m. It includes twelve environmental amenities (three urban parks, four neighbourhood parks and water with varying amenity value; a=12.50/8.75/5.00) and eighteen urban centres (see Figure 11 in Section 4.1.2), with distances to environmental amenities and urban centres based on straight-line and road-network distances, respectively.

This section presents the results for the base run (Section 5.1.1) and scenario simulation (Section 5.1.2) results, with numerical results presented in Table 7 and cartographic results presented in Figure 17 to 20. Results are based on available data for 2010, and assessed scenario simulations include (see also http://suld.web.ua.pt/): i) Project 1 (Elbinger Platz I), 2 (Elbinger Platz II), 3 (Handelshafen) and 4 (Kaistrasse), ii) the previous projects as well as Project 5 (An der Geeste), 6 (Alter Geestevorhafen) and 12 (Klussmannstrasse), and iii) all previous projects as well as Project 7 (Ulmenstrasse), 8 (Ellhornstrasse) and 9 (Hamburger Strasse).

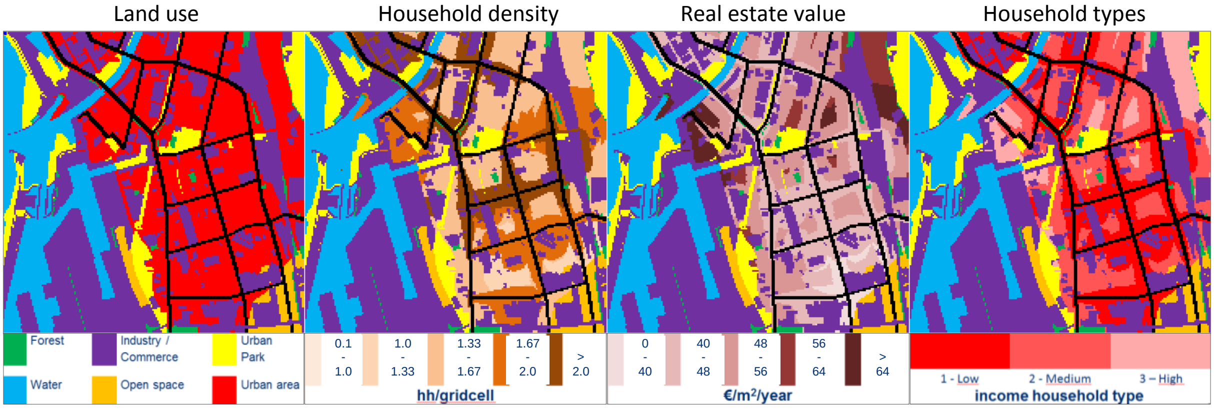
5.1.1. Base run results

The Bremerhaven study area is composed by almost equal shares of urban residential (118 ha) and industry/commerce (113 ha) land-uses. To the west, this urban area faces the water (51 ha) and there is also a considerable amount of green spaces (25 ha of urban parks and 4 ha of forest area; see Table 7).

The total population of 35.754 inhabitants comprises 45% low income, 40% middle income and 15% high income households. Low income households tend to live closer to the urban centres and, most notably, along the main roads. High income households, on the other hand, tend to live closer to the waterfront and/or urban parks (e.g. Burger park) and farther away from the main roads.

The total built area (housing quantity) equals ~1.5*10^{6}m^2, distributed over low (24%), middle (53%) and high (23%) income households. The total floor space (development density) covers a larger area (~2.4*10^{6}m^2), distributed similarly over low (29%), middle (48%) and

Figure 17 Base run simulation results for the Bremerhaven case study



high (23%) income households. Consequently, household density is highest in low income areas (up to over 2.0 households per grid cell), lower in attractive high income areas (up to 1.7 households per grid cell) and lowest in middle income areas farther away from both major roads and environmental amenities (up to 1.5 households per grid cell). Available living space equals, on average, around 122m^2 per household, while noting large differences between household types: about 80m^2, 145m^2 and 185m^2 for low, middle and high income households, respectively.

Table 7 Base run and scenario simulation results for the Bremerhaven case study

	Unit	Base	Scenario 14		Scenario 15		Scenario 16	
Land use								
- Forest	ha	4	4	0.0%	4	0.0%	4	0.0%
- Water	ha	51	51	0.0%	51	0.0%	51	0.0%
- Open space	ha	8	8	3.3%	10	25.5%	18	117.0%
- Industry / Commerce	ha	113	111	-1.9%	109	-3.4%	107	-5.0%
- Park_urban	ha	25	28	8.6%	29	15.0%	31	22.2%
- Roads	ha	23	23	0.0%	23	0.0%	23	0.0%
- Urban	ha	118	118	-0.2%	116	-1.7%	108	-8.0%
Total	ha	342	342	0.0%	342	0.0%	342	0.0%
Population								
- HHType1	#	16052	16052	0.0%	16052	0.0%	16052	0.0%
- HHType2	#	14281	14281	0.0%	14281	0.0%	14281	0.0%
- HHType3	#	5421	5421	0.0%	5421	0.0%	5421	0.0%
Total	#	35754	35754	0.0%	35754	0.0%	35754	0.0%
Housing quantity								
- HHType1	1000 m^2	358.6	357.4	-0.3%	352.3	-1.8%	311.1	-13.3%
- HHType2	1000 m^2	786.6	784.1	-0.3%	767.3	-2.5%	702.3	-10.7%
- HHType3	1000 m^2	347.8	347.0	-0.2%	334.5	-3.8%	323.4	-7.0%
Total	1000 m^2	1493.1	1488.5	-0.3%	1454.1	-2.6%	1336.8	-10.5%
Living space								
- HHType1	m^2/hh	79.5	79.4	-0.1%	79.1	-0.5%	76.5	-3.7%
- HHType2	m^2/hh	144.6	144.5	-0.1%	143.6	-0.7%	140.2	-3.0%
- HHType3	m^2/hh	184.7	184.6	-0.1%	182.6	-1.1%	180.9	-2.1%
Average	m^2/hh	121.5	121.4	-0.1%	120.6	-0.7%	117.8	-3.0%
Real estate value								
- HHType1	€/m^2/yr	42.8	42.8	0.1%	43.0	0.5%	44.5	4.1%
- HHType2	€/m^2/yr	51.6	51.6	0.1%	52.0	0.7%	53.3	3.3%
- HHType3	€/m^2/yr	63.9	64.0	0.1%	64.6	1.1%	65.2	2.1%
Average	€/m^2/yr	50.2	50.2	0.1%	50.5	0.6%	52.0	3.5%
Total	m€/yr	129.4	129.4	0.0%	129.4	0.0%	129.5	0.1%

Real estate (rental) values equal, on average, about 50€/m^2/yr, varying between 42.8€/m^2/yr for low, 51.6€/m^2/yr for middle and 63.9€/m^2/yr for high income households.

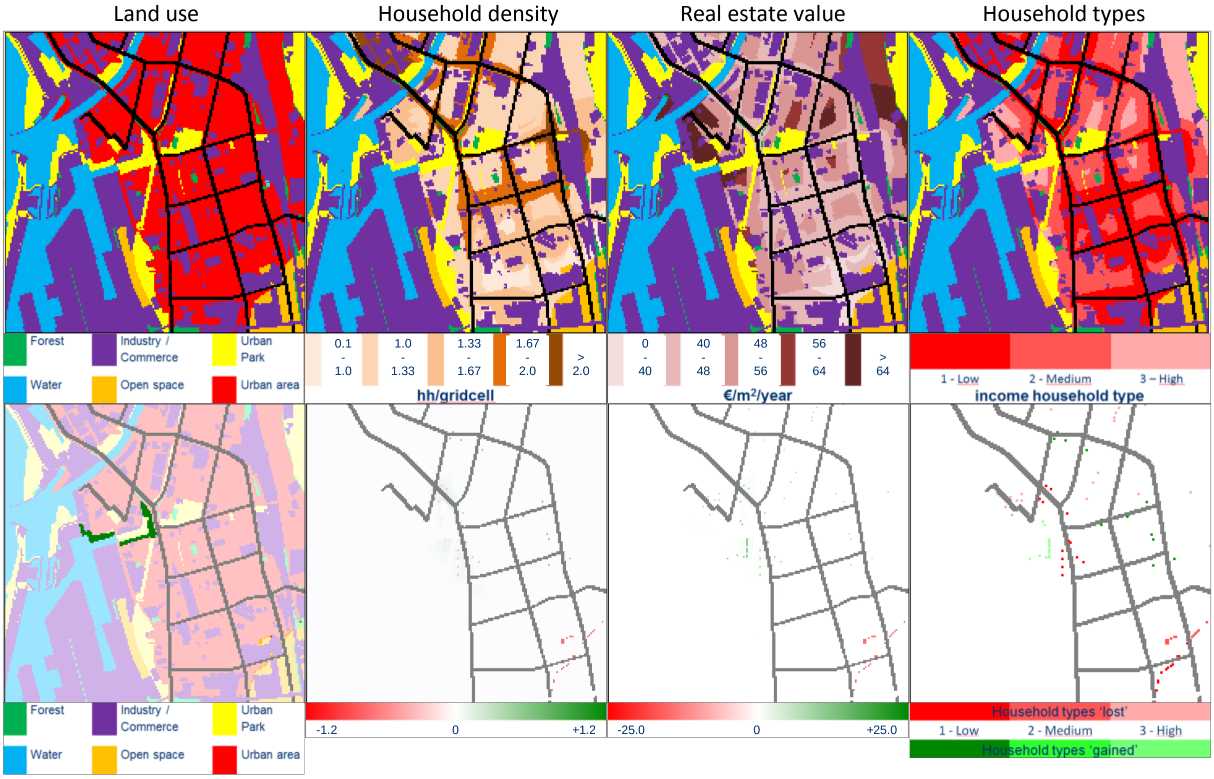
Largest values can be observed in attractive high income areas (up to well over 66€/m²/yr) and lowest values can be observed in low income areas, particularly in the South of the study area around major roads and industrial areas (up to 39€/m²/yr). The total real estate (rental) value for the study area in Bremerhaven equals 129.4 million Euros per year.

5.1.2. Scenario simulation results

Scenario 14

Scenario 14 involves the implementation of Project 1 (Elbinger Platz I), 2 (Elbinger Platz II), 3 (Handelshafen) and 4 (Kaistrasse) in the study area. These new/requalified green spaces replace prior industrial and/or paved infrastructure areas. Project 1 (Elbinger Platz I) is intended to be a local park given it is an extension of the existing Holzhafen park, while Project 2 (Elbinger Platz II), Project 3 (Handelshafen) and Project 4 (Kaistrasse) assume greater importance as green/blue connections surrounding the water. Projects 3 and 4 include a promenade along the water axis.

Figure 18 Scenario 14 simulation results for the Bremerhaven case study



The simultaneous establishment of these four project interventions results in a 8.6% increase in green-spaces, and a slight contraction in overall urban residential area (-0.2%). Few middle and high income households are attracted to the area surrounding the Handelshafen, leading to a small (local) increase in population density.

Overall across the entire study area, the total built area (housing quantity), floor space (development density) and living-space decrease marginally, with -0.3%, -0.1% and -0.1%, respectively. Locally, however, we observe a small increase in household densities in the area surrounding the Handelshafen, in particular to the South where higher quality urban parks are currently absent. To the North household densities increase to a lesser extent given the proximity to the Berliner Platz and the Geeste river.

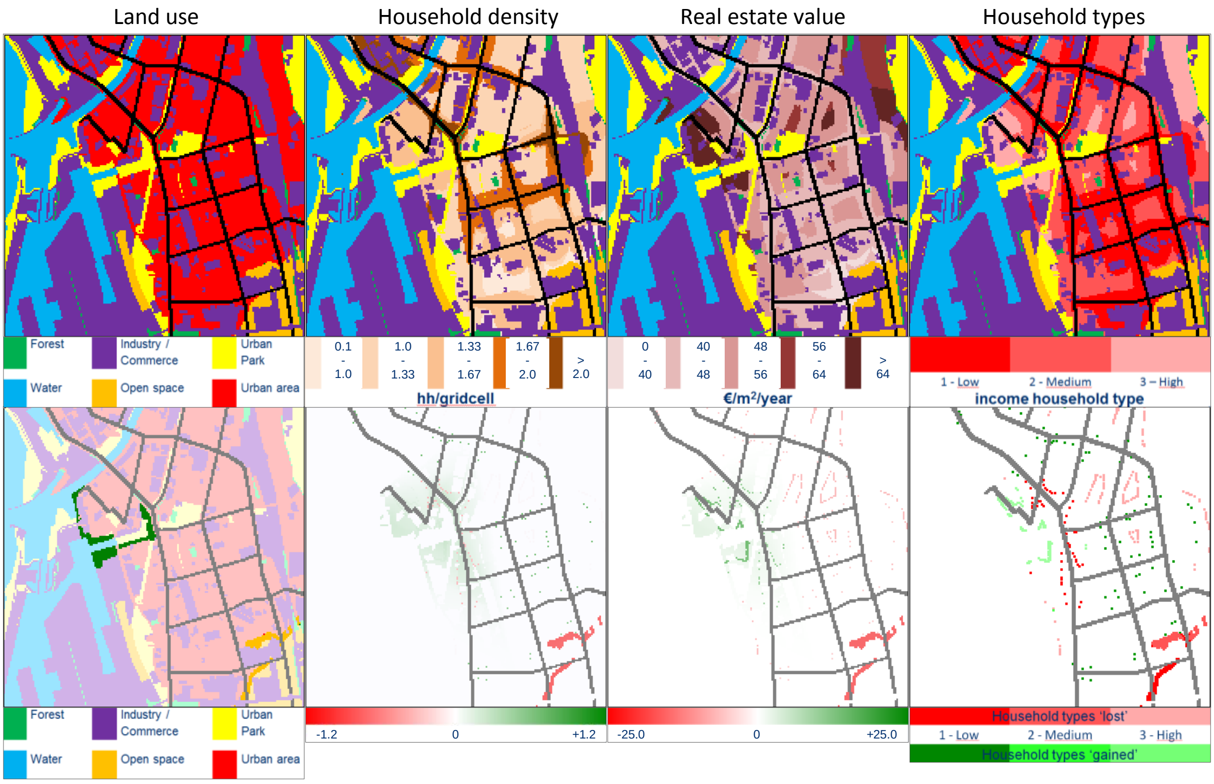
Increases in real estate values are negligible across the entire study area (+0.1%), though significantly positive in the area surrounding the Handelshafen – in particular to the South and somewhat less to the North of the Handelshafen. A small increase in real estate (rental) values can be observed (+0.1%), while the total real estate (rental) value for the Bremerhaven case study area remains at 129.4 million Euros per year.

Summarizing, the establishment of this combination of four urban parks represents a minor overall though locally small added value and attraction, leading to a small local increase in population density and real estate (rental) values. Few middle and high income households are willing to accept a somewhat smaller living space when able to live in the vicinity of these four projects surrounding the Handelshafen.

Scenario 15

Scenario 15 represents the inclusion of three additional projects to the above presented Scenario 14, in particular Project 5 (An der Geeste), 6 (Alter Geestevorhafen) and 12 (Klussmannstrasse). Project 5 (An der Geeste) is a green strip along the river meant to serve a new residential area and to form a connection with Project 6. Project 6 (Alter Geestevorhafen) is designed as a new green space in the harbour area, which is currently used as an informal connection for pedestrians along the water axis. Project 12 (Klussmannstrasse) replaces a previous industrial/commercial area and forms a connection along the water-side with Project 4.

Figure 19 Scenario 15 simulation results for the Bremerhaven case study



The simultaneous establishment of these 7 project interventions results in a 15.0% increase in green-spaces and a small reduction in urban residential area (-1.8%). Some middle and high income households are attracted to the area surrounding these project interventions (particularly to the South and North-East of the Handelshafen), leading to a moderate (local) increase in population density.

Overall, across the entire study area, total built area (housing quantity) and floor space (development density) decrease with -2.6% and -0.7%, respectively. In particular, the built area (housing quantity) decreases with between -1.8% for low income households and -3.8% for high income households, while floor space (development density) as well as living space decrease with between -0.5% for low income households and -1.1% for high income households. Locally, household densities increase in the areas surrounding the Handelshafen – in particular to the North and South. Some middle and high income households are attracted to the areas near these parks and water, while low income households settle in more affordable areas further away from these parks and water.

Across the entire study area, increases in real estate values are minor (+0.6%). Locally, however, significant increases in real estate values are observed – particularly to the North and South of the Handelshafen. Real estate (rental) values increase with between +0.5% for low income households and +1.1% for high income households. The total real estate (rental) value for the Bremerhaven case study area remains at 129.4 million Euros per year.

Summarizing, the establishment of this combination of seven urban parks leads, overall, to a somewhat condensed city with slightly higher real estate (rental) values. Locally, in the area North and South of the Handelshafen, small increases in population density and real estate (rental) values are observed. Middle and high income households are attracted to the area surrounding these project interventions, while low income households settle in more affordable areas further away from these project interventions.

Scenario 16

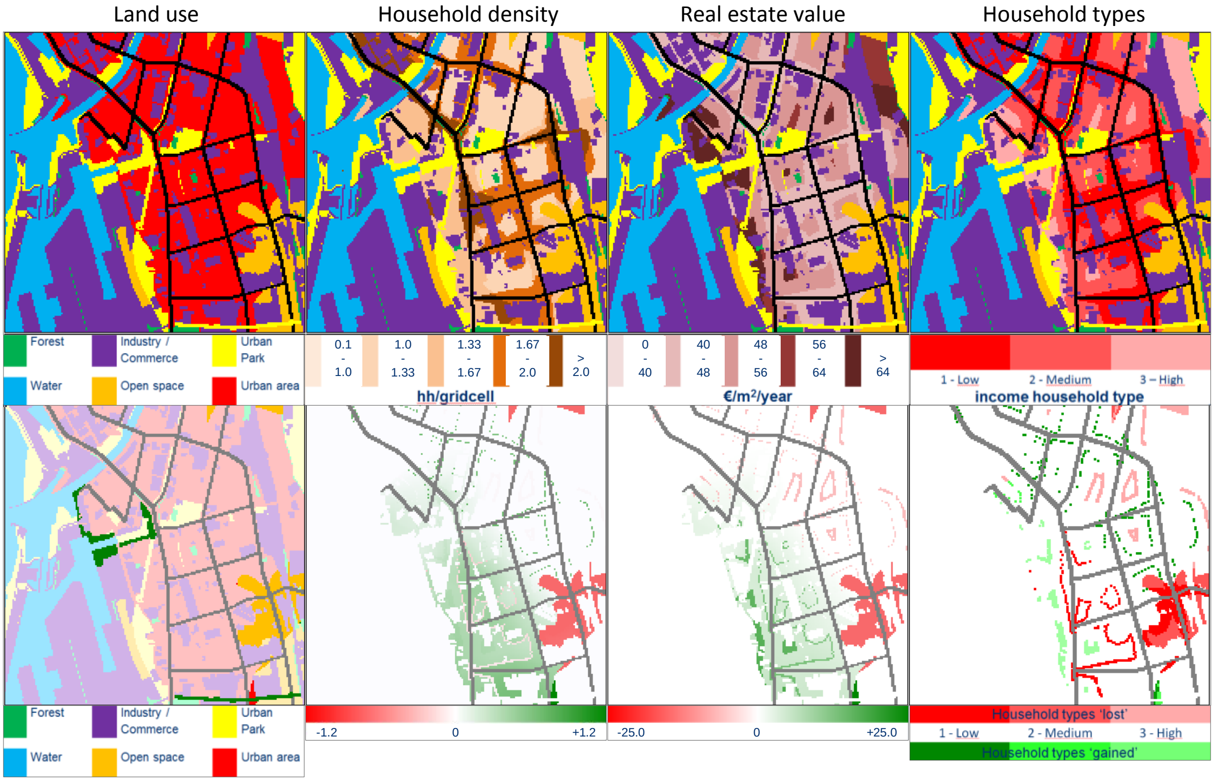
Scenario 16 represents the inclusion of another three additional projects to the above presented Scenario 15, in particular Project 7 (Ulmenstrasse), 8 (Ellhornstrasse) and 9 (Hamburger Strasse). Project 7 (Ulmenstrasse) and 9 (Hamburger Strasse) represent green-corridors along street axis, functioning as important connections for pedestrians and cyclists. Project 8 (Ellhornstrasse) is a wasteland which is foreseen to become an important neighbourhood park and nature area for children.

The simultaneous establishment of these 10 project interventions results in an increase of 22.2% in green-spaces and a significant decrease in urban residential area (-8.0%). Many middle and high income households are attracted to the areas surrounding these project interventions – in particular to the South of the Handelshafen and to the East of the Ellhornstrasse park. The green-corridors (Projects 7 and 9) attract additional households from same income groups.

Over the entire study area, total built area (housing quantity) and floor space (development density) decrease with -10.5% and -3.0%, respectively. In particular, the built area (housing quantity) decreases with between -13.3% for low income households and -7.0% for high income households, while floor space (development density) and living space decrease with between -3.7% for low income households and -2.0% for high income households. Locally, household densities increase in the areas North and South of the Handelshafen as well as North and East of the Ellhornstrasse park. Many middle and high income households are attracted to the areas near these parks and water, thereby crowding-out low income households that settle in less expensive areas away from these parks and water.

Overall increases in real estate values are small (+3.5%), while locally increases in real estate values are large (up to about +15%) – particularly South of the Handelshafen as well as North and East of the Ellhornstrasse park. Real estate (rental) values increase with between +4.1% for low income households and +2.1% for high income households. The total real estate (rental) value for the Bremerhaven case study increases with 0.1 million Euros per year (+0.1%) to 129.5 million Euros per year.

Figure 20 Scenario 16 scenario simulation results for the Bremerhaven case study



In sum, the establishment of this combination of ten urban parks leads to a more condensed city, higher real estate (rental) values and a small net increase in total real estate value. Middle and high income households are attracted to the areas North and South of the Handelshafen as well as North and East of the Ellhornstrasse park, willing to accept smaller living spaces and higher real estate (rental) values when able to live in the vicinity of these parks. Low income households are crowded-out to less expensive areas further away from these parks, though also benefitting from their proximity.

5.2. Copenhagen (DK)

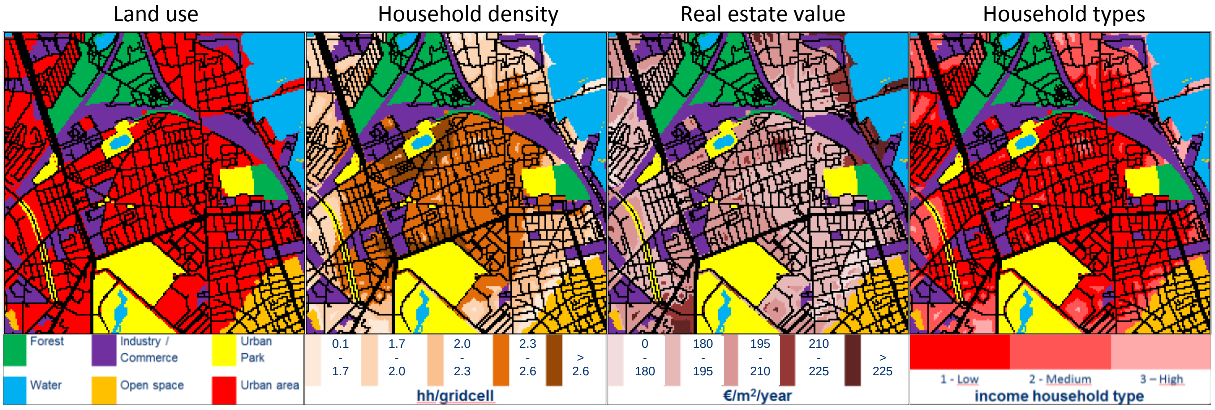
The numerical application of SULD to the Copenhagen case study is based on a population comprising three household types (low, middle and high income households), differentiated by number of households (Q), levels of expendable income (y) and shares of housing expenditures (μ; see Table 2 in Section 4.2.3) as well as levels of utility (u=6,435 for HHtype1, u=9,781 for HHtype2 and u=19,176 for HHtype3). All household types share the same appreciation for environmental amenities (ε=0.08; a=12.50/8.75/5.00; η =1.0), annual commuting costs (p_x=382.5 €/km), opportunity cost of land (l_i=1,000 €/yr) and development costs (c_0=0 and η=1.875). The study area encompasses an area of 2.4km by 2.4km (=5.8km^2), covered by a grid layer of 185 by 185 (=34,225) cells of 13m by 13m. It includes eight environmental amenities (one urban park, three neighbourhood parks, three local parks and water with varying amenity value; a=12.50/8.75/5.00) and nine urban centres (see Figure 12 in Section 4.2.2), with distances to environmental amenities and urban centres based on straight-line and road-network distances, respectively.

This section presents the results for the base run (Section 5.2.1) and scenario simulation (Section 5.2.2) results, with numerical results presented in Table 8 and cartographic results presented in Figure 21 to 24. Results are based on available data for 2013, and assessed scenario simulations include (see also http://suld.web.ua.pt/): i) Project 1 (greening of the Bryggervangen and Sct Kjeld´s square), ii) Project 2 (greening of the Tåsingegade), and iii) Project 4 (requalification of the Tåsinge square).

5.2.1. Base run results

The Copenhagen case study area comprises the St. Kjeld's neighbourhood, a mainly urban residential (209 ha) and industry/commerce (67 ha) area, with some urban parks (47 ha) and forest areas (22 ha). On the Northeast the area borders the Øresund strait between Copenhagen and Malmö.

Figure 21 Base run simulation results for the Copenhagen case study



The total population of 49.238 inhabitants comprises 67% low income, 28% middle income and only 5% high income households. Middle and high income households locate mainly near the water, in the Northeast of the study area, as well as close to the Faelledparken urban park, in the South. With the exception of particular neighbourhoods, like the Kildevældsgade, the core of the study area is comprised of low income households.

The total built area (housing quantity) equals ~$1.2*10^6m^2$, distributed over low (58%), middle (35%) and high (7%) income households. Household density is highest in low income areas near urban centres (up to over 2.8 households per grid cell) and lower in attractive high income areas closer to environmental amenities (up to 1.5 households per grid cell). Available living space equals, on average, around 92m^2 per household, while noting large differences between household types: about 82m^2, 115m^2 and 172m^2 for low, middle and high income households, respectively.

Real estate (rental) values equal, on average, about 197€/m^2/yr, varying between 191€/m^2/yr for low, 204€/m^2/yr for middle and 258€/m^2/yr for high income households. Larger values can be observed in attractive high income areas (up to 269€/m^2/yr), particularly around the Faelledparken urban park and in the Northeast, and lowest values can be observed in low income areas (up to 174€/m^2/yr), mainly in the East and Southeast of the study area. The total real estate (rental) value for the study area in Copenhagen equals about 503 million Euros per year.

Table 8 Base run and scenario simulation results for the Copenhagen case study

	Unit	Base	Scenario 1		Scenario 2		Scenario 4	
Land use								
- Forest	ha	33	33	0.0%	33	0.0%	33	0.0%
- Water	ha	41	41	0.0%	41	0.0%	41	0.0%
- Open space	ha	17	17	0.8%	19	8.9%	18	2.4%
- Industry / Commerce	ha	67	67	0.0%	67	0.0%	67	0.0%
- Park_urban	ha	47	47	0.0%	47	0.0%	47	0.0%
- Roads	ha	164	164	0.0%	164	0.0%	164	0.0%
- Urban	ha	209	209	-0.1%	208	-0.7%	209	-0.2%
Total	ha	578	578	0.0%	578	0.0%	578	0.0%
Population								
- HHType1	#	33123	33123	0.0%	33123	0.0%	33123	0.0%
- HHType2	#	13853	13853	0.0%	13853	0.0%	13853	0.0%
- HHType3	#	2263	2263	0.0%	2263	0.0%	2263	0.0%
Total	#	49238	49238	0.0%	49238	0.0%	49238	0.0%
Housing quantity								
- HHType1	1000 m^2	686.3	685.5	-0.1%	678.1	-1.2%	683.8	-0.4%
- HHType2	1000 m^2	406.8	406.5	-0.1%	403.5	-0.8%	406.1	-0.2%
- HHType3	1000 m^2	82.3	82.3	0.0%	82.2	-0.1%	82.3	0.0%
Total	1000 m^2	1175.3	1174.3	-0.1%	1163.8	-1.0%	1172.2	-0.3%
Living space								
- HHType1	m^2/hh	82.0	82.0	0.0%	81.7	-0.4%	81.9	-0.1%
- HHType2	m^2/hh	114.5	114.5	0.0%	114.2	-0.3%	114.4	0.0%
- HHType3	m^2/hh	172.2	172.1	0.0%	172.1	0.0%	172.2	0.0%
Average	m^2/hh	91.6	91.6	0.0%	91.3	-0.3%	91.5	-0.1%
Real estate value								
- HHType1	€/m^2/yr	190.9	190.9	0.0%	191.6	0.4%	191.1	0.1%
- HHType2	€/m^2/yr	204.3	204.4	0.0%	204.9	0.3%	204.4	0.1%
- HHType3	€/m^2/yr	258.3	258.3	0.0%	258.4	0.0%	258.3	0.0%
Average	€/m^2/yr	197.3	197.4	0.0%	198.0	0.3%	197.5	0.1%
Total	m€/yr	502.8	502.7	0.0%	502.7	0.0%	502.8	0.0%

5.2.2. Scenario simulation results

Scenario 1

Project 1 involves the greening of the Bryggervangen and Sct Kjeld´s square, including a redesigned Bryggervangen-Landskronagade intersection, the creation of corridors for traffic and pedestrians, the relocation of parking spaces and the introduction of a green corridor. The latter aims to create a green stream through the neighbourhood, making the Bryggervangen lush and allowing to channel rainwater to the harbor during cloudbursts.

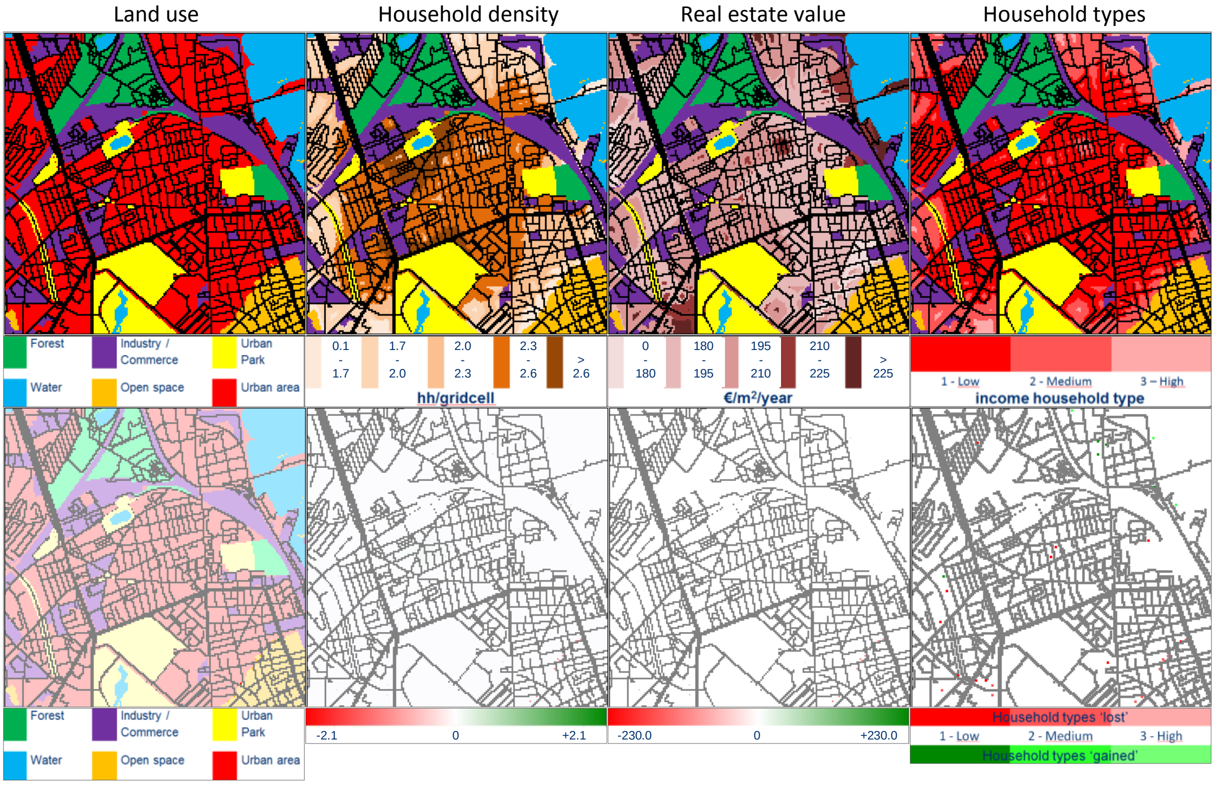
The establishment of this project results in insignificant changes in land use, including a slight contraction in urban residential area (-0.1%). Few additional low and middle income households are attracted by this intervention, leading to a small (local) increase in population density.

Overall across the study area, decreases in total built area (housing quantity) and living space are negligible. Locally, however, we observe a small increase in household densities in the immediate area surrounding the project interventions – in particular to the East of the Bryggervangen. The intervention favours the current resident population, though is not attractive enough to draw higher income households to the area.

Across the entire study area, increases in real estate values are negligible. Locally small increases in real estate values can be observed, up to +1.5% for properties located on the

Bryggervangen. The total real estate (rental) value for the Copenhagen case study area remains at about 503 million Euros per year.

Figure 22 Scenario 1 simulation results for the Copenhagen case study



Summarizing, the establishment of Project 1 represents a minor overall and locally small added value and attraction, leading to a small local increase in population density and real estate (rental) values. It affects only a small strip of mostly low and middle income households in the immediate surroundings of the project intervention.

Scenario 2

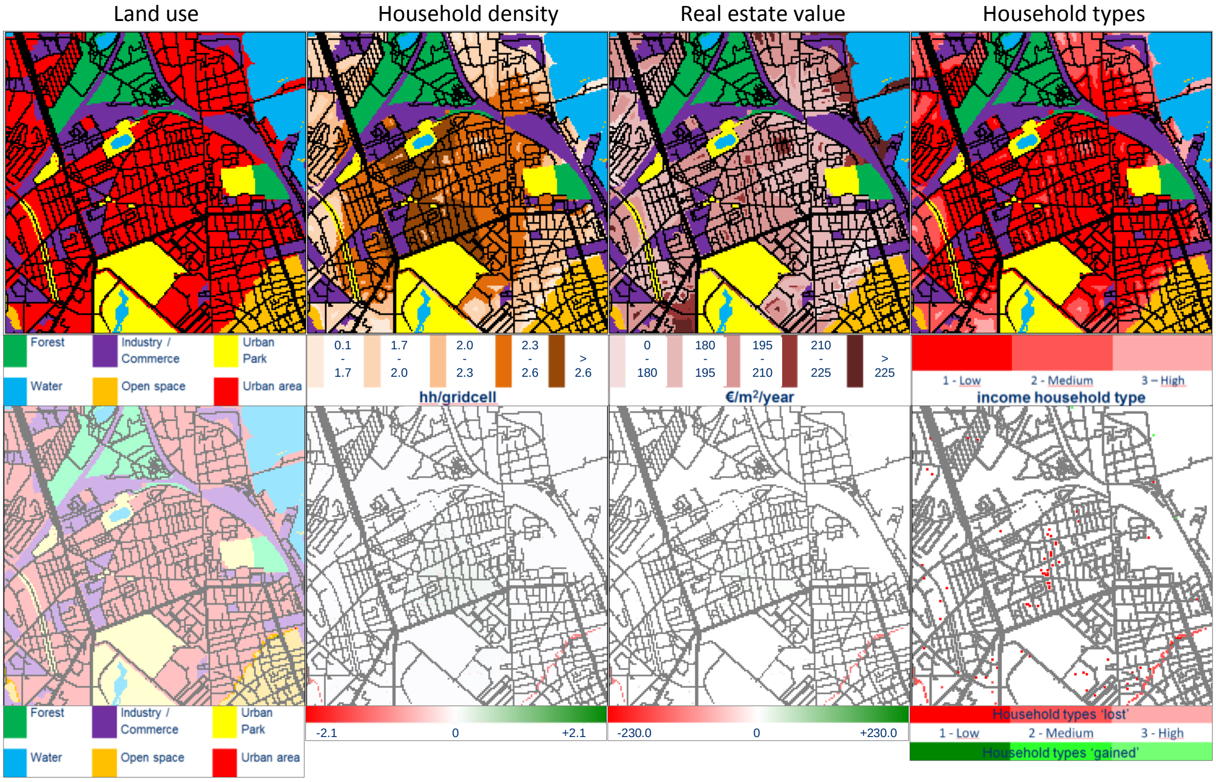
Project 2 involves the greening of the Tåsingegade, a private road that is of great importance for cloudburst management in the area and connects Copenhagen's first climate-space (Taasinge Space) with other planned cloudburst solutions on the way to the harbour.

The establishment of this project results in small changes in land use, including a minor contraction in urban residential area (-0.7%). Some additional low income and few middle income households are attracted by this intervention, leading to a small (local) increase in population density.

Overall across the study area, total built area (housing quantity) and living space decrease with -1.0% and -0.3%, respectively. Locally, moderate increases in household densities can be observed to the North and South of the project area. The intervention favours the current low income population in the area, though is not sufficiently attractive to draw high income households to the area.

Across the study area, increases in real estate values are minor (+0.3%). Locally, however, small increases in real estate values can be observed – up to +2.7% for properties located on the Tåsingegade. The total real estate (rental) value for the Copenhagen case study area remains at about 503 million Euros per year.

Figure 23 Scenario 2 simulation results for the Copenhagen case study



Summarizing, the establishment of Project 2 leads to minor overall though locally small value added – in particular for low income households to the North and South of the Tåsingegade. This results in moderate increases in population densities and small increases in real estate (rental) values in the immediate surroundings of the project intervention.

Scenario 4

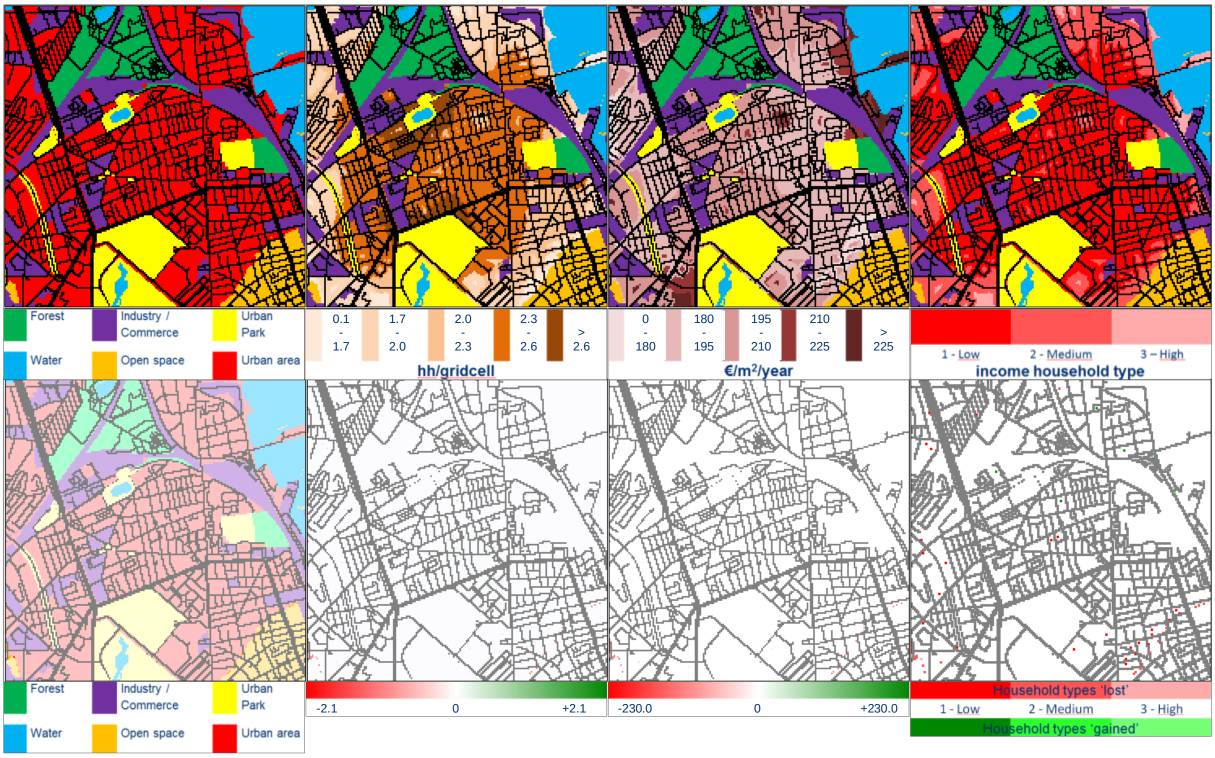
Project 4 entails the requalification of the Tåsinge square, including a redesigned traffic flow, the establishment of new sidewalks and the creation of a new green space. The square is expected to become a vibrant and attractive place to meet – an urban space with ample room for dog walkers, city gardens, benches and children.

The establishment of this project results in minor changes in land use, including a slight contraction in urban residential area (-0.2%). Few additional low and middle income households are attracted by this intervention, leading to a small (local) increase in population density.

Overall, decreases in total built area (housing quantity) and living space are minor. Locally, small increases in household densities can be observed in the area surrounding the project intervention – in particular to the East of the Tåsinge square. Again, the intervention favours the current low and middle income population in the area but is not sufficiently emblematic to attract higher income households to the area.

Increases in real estate values are, overall, negligible. Locally, however, minor increases in real estate values can be observed for properties located on the Tåsinge square (up to +0.7%). The total real estate (rental) value for the Copenhagen case study area remains at about 503 million Euros per year.

Figure 24 Scenario 4 simulation results for the Copenhagen case study



In sum, the establishment of Project 4 represents a negligible overall and locally small added value and attraction – leading to a minor local increase in population density and small increases in real estate (rental) values. It is mainly the current low and middle income resident population around Tåsinge square that benefits from this intervention.

5.3. Debrecen (HU)

The numerical application of SULD to the Debrecen case study is based on a population comprising three household types (low, middle and high income households), differentiated by number of households (*Q*), levels of expendable income (*y*) and shares of housing expenditures (μ; see Table 3 in Section 4.3.3) as well as levels of utility (u=3,250 for HHtype1, u=3,965 for HHtype2 and u=6,760 for HHtype3). All household types share the same appreciation for environmental amenities (ε=0.08; a=9.0/7.5/5.0; η =1.0), annual commuting costs (p_x=150 €/km), opportunity cost of land (l_i=1,000 €/yr) and development costs (c_0=0 and η=1.65). The study area encompasses an area of 1.73km by 1.73km (=2.99km^2), covered by a grid layer of 185 by 185 (=34,225) cells of 9.35m by 9.35m. It includes three environmental amenities (two neighbourhood parks and water with varying amenity value; a=9.0/7.5/5.0) and eight urban centres (see Figure 13 in Section 4.3.2), with distances to environmental amenities and urban centres based on straight-line and road-network distances, respectively.

This section presents the results for the base run (Section 5.3.1) and scenario simulation (Section 5.3.2) results, with numerical results presented in Table 9 and cartographic results presented in Figure 25 to 27. Results are based on available data for 2013, and assessed scenario simulations include (see also http://suld.web.ua.pt/): i) development of a new residential area with green space and one small lake (Scenario 1), and ii) development of a new residential area with green space and two lakes (Scenario 2).

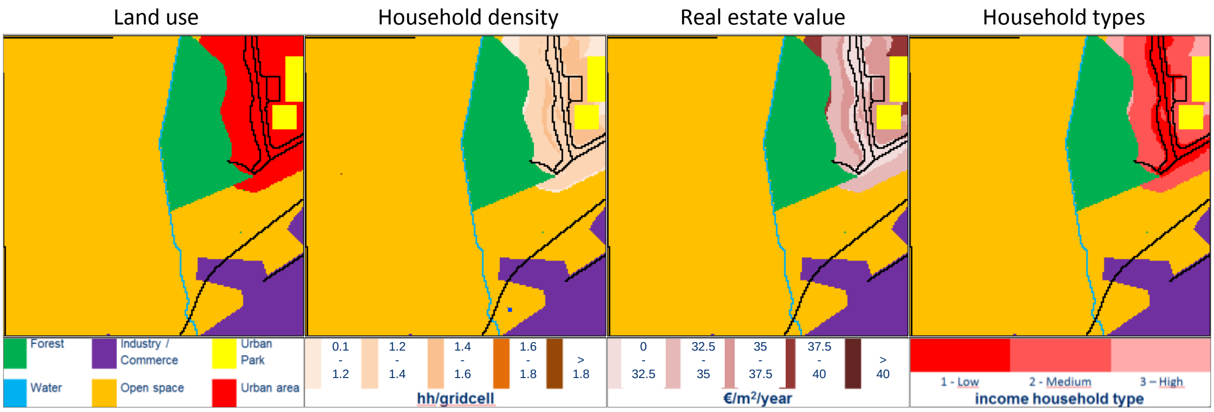
Table 9 Base run and scenario simulation results for the Debrecen case study

	Unit	Base	Scenario 1		Scenario 2	
Land use						
- Forest	ha	31	5	-85.0%	7	-77.4%
- Water	ha	2	3	47.5%	6	183.9%
- Open space	ha	203	200	-1.4%	198	-2.6%
- Industry / Commerce	ha	21	21	0.0%	21	0.2%
- Park_urban	ha	5	20	323.8%	17	258.5%
- Roads	ha	7	10	33.6%	10	34.2%
- Urban	ha	30	41	34.5%	41	35.5%
Total	ha	299	299	0.0%	299	0.0%
Population						
- HHType1	#	3614	6505	80.0%	6505	80.0%
- HHType2	#	8834	15901	80.0%	15901	80.0%
- HHType3	#	937	1687	80.0%	1687	80.0%
Total	#	13385	24093	80.0%	24093	80.0%
Housing quantity						
- HHType1	1000 m^2	69.9	82.2	17.7%	82.2	17.6%
- HHType2	1000 m^2	180.0	216.2	20.2%	218.5	21.4%
- HHType3	1000 m^2	36.5	45.3	23.9%	47.1	28.8%
Total	1000 m^2	286.3	343.7	20.0%	347.7	21.4%
Living space						
- HHType1	m^2/hh	73.5	65.2	-11.3%	65.2	-11.4%
- HHType2	m^2/hh	80.4	71.7	-10.9%	71.8	-10.7%
- HHType3	m^2/hh	120.6	108.4	-10.1%	109.6	-9.1%
Average	m^2/hh	81.4	72.5	-10.9%	72.7	-10.7%
Real estate value						
- HHType1	€/m^2/yr	32.2	36.3	12.7%	36.3	12.7%
- HHType2	€/m^2/yr	34.9	39.1	11.9%	39.0	11.6%
- HHType3	€/m^2/yr	38.8	43.1	11.0%	42.6	9.8%
Average	€/m^2/yr	34.5	38.7	12.1%	38.6	11.8%
Total	m€/yr	13.0	23.4	79.6%	23.4	79.6%

5.3.1. Base run results

The Debrecen study area is dominated by open space/agricultural (203 ha) areas, followed by forest (31 ha), urban residential (30 ha) and industry/commerce (21 ha) areas. Urban parks, in the North-East corner, account for less than 2% (5 ha) of the study area; the Tócó creek is somewhat distanciated towards the West side of the urban residential area.

Figure 25 Base run simulation results for the Debrecen case study



The total population of 13.385 inhabitants comprises of 27% low income, 66% middle income and only 7% high income households. High income and, to a minor extent, middle income households are located close to the neighbourhood parks (in the North-East) and the creek/forest-front areas (to the West), while low income households live close to the main roads and urban centres.

The total built area (housing quantity) equals ~$0.29*10^6 m^2$, distributed over low (24%), middle (63%) and high (13%) income households. Household density is lowest in high income areas (up to 1.0 households per grid cell) and highest in low and middle income areas close to urban centres and neighbourhood parks (up to 1.5 households per grid cell). Available living space equals, on average, around $81m^2$ per household, while noting large differences between household types: about $74m^2$, $80m^2$ and $121m^2$ for low, middle and high income households, respectively.

Real estate (rental) values equal, on average, about 35€/m^2/yr, varying between 32.2€/m^2/yr for low, 34.9€/m^2/yr for middle and 38.8€/m^2/yr for high income households. Larger values can be observed in attractive high income areas (up to 40€/m^2/yr), and lowest values can be observed in the low income areas, along the main roads (where values can reach 31€/m^2/yr). The total real estate (rental) value for the study area in Debrecen equals 13.0 million Euros per year.

5.3.2. Scenario simulation results

Scenario 1

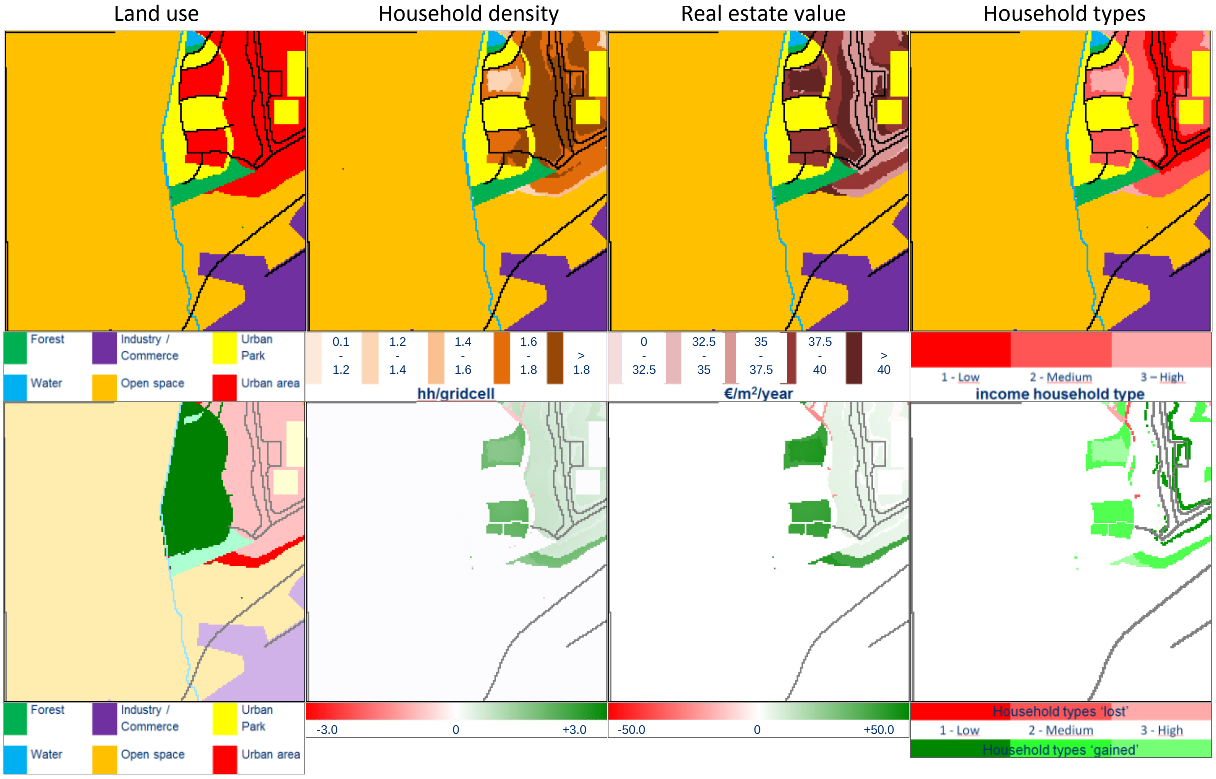
Scenario 1 entails the development of a new residential area between the existing urban residential area and Tócó creek. This project is designed such that part of the forest area is converted into a new urban park, with two urban residential areas within and a small lake in the North. The project aims to attract additional residents to the area – in this case we consider a 80% increase in population.

The establishment of this project intervention results in a 324% increase in green-space, a 48% increase in water area, a 35% increase in urban residential area, and a -85% decrease in forest area. Middle and high income households are attracted to the new urban residential areas, while additional low and middle income households are attracted to the existing low and middle income urban residential areas.

Overall across the entire study area, the total built area (housing quantity) increases with +20% while living space decreases with -11%. Locally, it can be observed that the project intervention substantially increases the attractiveness of the area, attracting middle income (Southern area) and high income (Northern area) households. Low income households remain concentrated around the main roads and away from environmental amenities. Household densities increase, particularly, in existing urban residential areas bordering the new urban parks as well as around the existing neighbourhood parks.

Increases in real estate values are large across the entire study area (+12.1%), in particular in the abovementioned existing urban residential areas bordering the new urban parks (up to +17%) and the existing neighbourhood parks (up to +13%). Highest real estate (rental) values can be observed in the new Northern urban residential area (up to 45€/m^2/yr) as well as to the East of the project area. The total real estate (rental) value for the Debrecen case study area increases with almost 80%, to 23.4 million Euros per year.

Figure 26 Scenario 1 simulation results for the Debrecen case study



Summarizing, Scenario 1 leads to a more urbanized area with larger housing quantity and increased household densities but, also, larger areas of high quality parks. Middle and high income households are attracted to the new urban residential areas as well as to the East of the project area. These households accept smaller living spaces and higher real estate (rental) values when able to live in or around this attractive area with ample urban parks.

Scenario 2

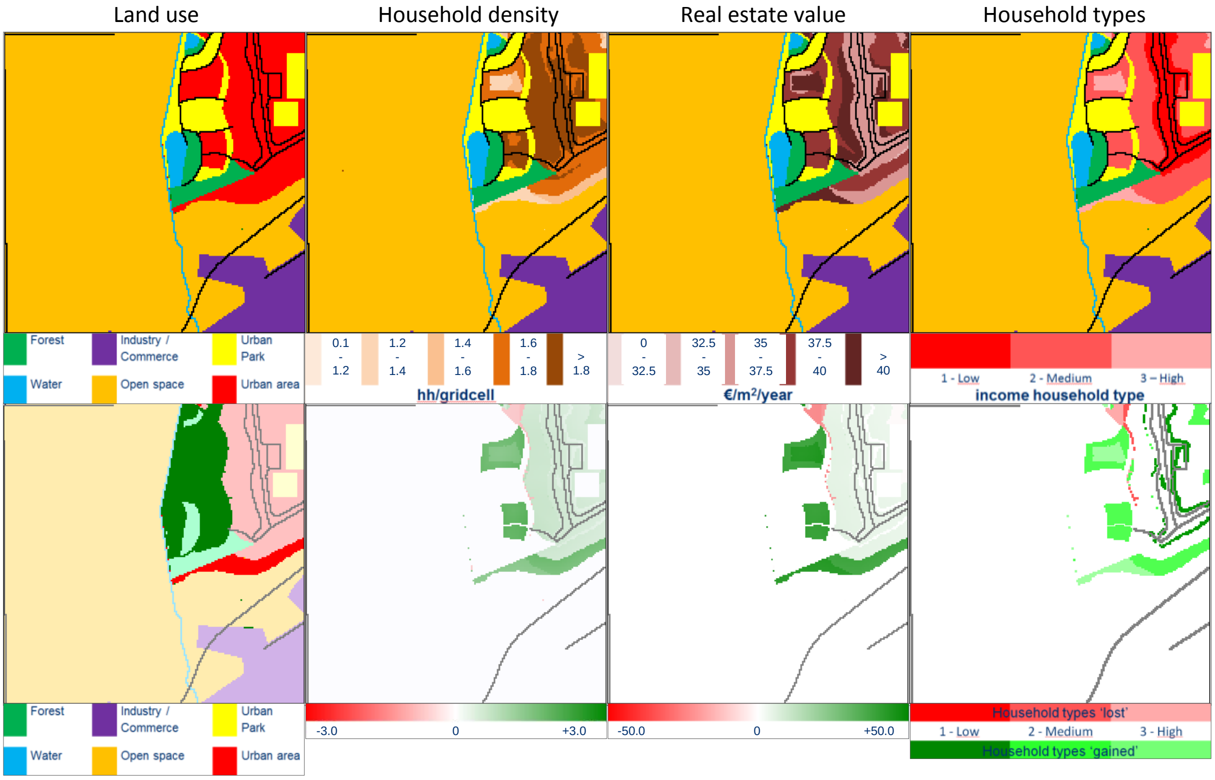
Scenario 2 entails, like Scenario 1, the development of a new residential area between the existing urban residential area and Tócó creek. Again, part of the forest area is converted into a new urban park, with two urban residential areas within, one small lake in the North and one larger lake in the South. The project aims to attract additional residents to the area – again, a 80% increase in population is considered.

The establishment of this project results in a 259% increase in green-space, a 184% increase in water area, a 36% increase in urban residential area, and a -77% decrease in forest area. Middle and high income households are attracted to the new urban residential areas as well as to the South of the project area, while additional low and middle income households are attracted to the existing low and middle income urban residential areas.

Overall and similar to Scenario 1, the total built area (housing quantity) increases with +21% while living space decreases with -11%. Locally the project intervention substantially increases the attractiveness of the area, attracting middle income (Southern area) and high income (Northern area) households. Note that the larger lake in the South attracts additional high income households to the area South of the project area. Low income households stick to the main roads and away from environmental amenities. Again, household densities increase in existing urban residential areas bordering new and existing parks.

Increases in real estate values are large across the study area (+11.8%), particularly in abovementioned existing urban residential areas bordering the new urban parks (up to +17%) and around existing neighbourhood parks (up to +14%). Highest real estate (rental) values are observed in the new Northern urban residential area (up to 44€/m^2/yr) as well as to the East and South of the project area. Like in Scenario 1, the total real estate (rental) value increases with almost 80% to 23.4 million Euros per year.

Figure 27 Scenario 2 simulation results for the Debrecen case study



In sum, Scenario 2 leads to similar results as those obtained for Scenario 1. The area becomes more urbanized, with larger housing quantity, increased household densities and larger areas of high quality parks and water. Middle and high income households are attracted to the new urban residential areas as well as the East and South of the project area – accepting smaller living spaces and higher real estate (rental) values when able to live in or around this attractive area with ample urban parks and lakes.

5.4. Imperia (IT)

The numerical application of SULD to the Imperia case study is based on a population comprising three household types (low, middle and high income households), differentiated by number of households (Q), levels of expendable income (y) and shares of housing expenditures (μ; see Table 4 in Section 4.4.3) as well as levels of utility (u=2,000 for HHtype1, u=5,000 for HHtype2 and u=17,800 for HHtype3). All household types share the same appreciation for environmental amenities (ε=0.08; a=10.0/7.5/5.0; η =1.0), annual commuting costs (p_x=250 €/km), opportunity cost of land (l_i=1,000 €/yr) and development costs (c_0=0 and η=1.65). The study area encompasses an area of 1.60km by 1.60km (=2.56km^2), covered by a grid layer of 185 by 185 (=34,225) cells of 8.65m by 8.65m. It includes five environmental amenities (one urban park, one neighbourhood park, one local park and two water with varying amenity value; a=10.0/7.5/5.0) and seven urban centres (see Figure 14 in Section 4.4.2), with distances to environmental amenities and urban centres based on straight-line and road-network distances, respectively.

This section presents the results for the base run (Section 5.4.1) and scenario simulation (Section 5.4.2) results, with numerical results presented in Table 10 and cartographic results presented in Figure 28 to 31. Results are based on available data for 2010, and assessed scenario simulations include (see also http://suld.web.ua.pt/): i) Project 1 (requalification of the Oneglia railway area), ii) Project 1 and Project 2 (redevelopment of the Porta di Mare area), and iii) Project 1 and Project 3 (redevelopment of the Italcementi area).

Table 10 Base run and scenario simulation results for the Imperia case study

	Unit	Base	Scenario 1		Scenario 2		Scenario 3	
Land use								
- Forest	ha	5.5	5.5	-1.1%	5.5	-1.1%	5.5	-1.1%
- Water	ha	44.1	43.6	-1.1%	43.6	-1.1%	43.6	-1.1%
- Open space	ha	23.7	28.6	20.7%	30.9	30.3%	31.5	32.9%
- Industry / Commerce	ha	42.9	39.2	-8.6%	37.4	-12.9%	36.7	-14.4%
- Park_urban	ha	7.0	8.5	22.5%	8.5	22.5%	8.5	22.5%
- Roads	ha	33.3	33.0	-0.9%	33.0	-0.9%	33.0	-0.9%
- Urban	ha	99.5	94.7	-4.8%	94.3	-5.2%	94.3	-5.2%
Total	ha	256.0	253.1	-1.1%	253.1	-1.1%	253.1	-1.1%
Population								
- HHType1	#	17973	17973	0.0%	17973	0.0%	17973	0.0%
- HHType2	#	39446	39446	0.0%	39446	0.0%	39446	0.0%
- HHType3	#	3987	3987	0.0%	3987	0.0%	3987	0.0%
Total	#	61405	61405	0.0%	61405	0.0%	61405	0.0%
Housing quantity								
- HHType1	1000 m^2	143.1	137.4	-3.9%	136.9	-4.3%	136.9	-4.3%
- HHType2	1000 m^2	1027.2	972.3	-5.3%	966.9	-5.9%	967.1	-5.9%
- HHType3	1000 m^2	670.9	631.3	-5.9%	622.6	-7.2%	622.9	-7.1%
Total	1000 m^2	1841.1	1741.0	-5.4%	1726.4	-6.2%	1726.9	-6.2%
Living space								
- HHType1	m^2/hh	56.8	56.1	-1.1%	56.1	-1.2%	56.1	-1.2%
- HHType2	m^2/hh	116.5	114.7	-1.5%	114.5	-1.7%	114.5	-1.7%
- HHType3	m^2/hh	337.9	332.1	-1.7%	330.7	-2.1%	330.9	-2.1%
Average	m^2/hh	113.4	111.7	-1.5%	111.4	-1.7%	111.5	-1.7%
Real estate value								
- HHType1	€/m^2/yr	50.5	51.1	1.1%	51.1	1.2%	51.1	1.2%
- HHType2	€/m^2/yr	59.5	60.4	1.6%	60.5	1.7%	60.5	1.7%
- HHType3	€/m^2/yr	70.6	71.8	1.7%	72.1	2.1%	72.1	2.1%
Average	€/m^2/yr	59.4	60.3	1.5%	60.4	1.7%	60.4	1.7%
Total	m€/yr	199.9	199.9	0.0%	199.9	0.0%	199.9	0.0%

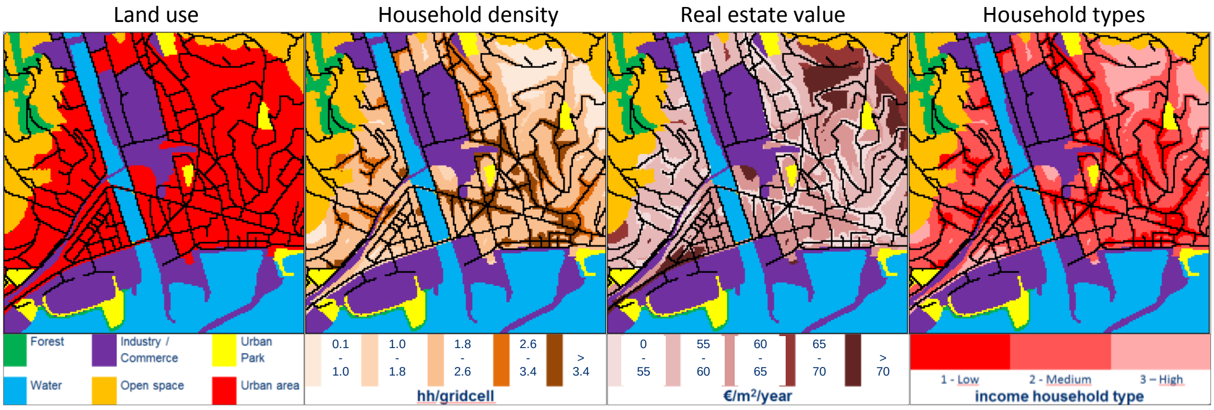
5.4.1. Base run results

The Imperia study area comprises the entire city of Imperia, which covers an urban residential (99.5ha) and industry/commerce (42.9ha) area of about 142ha. The city contains few urban parks (7.0ha) and forest (5.5ha) areas, though is surrounded by open-space/agricultural and the Mediterranean Sea as well as crossed by the Impero river (see Table 10).

The total population of 61,405 inhabitants comprises 29% low income, 64% middle income and only 6% high income households. High income households are mainly located in the Northeast of the study area, away from urban centres and main roads, and to a minor extent in small strips near the sea. Low income households are located near the road network and urban centres. The bulk of the study area is occupied by middle income households.

The total built area (housing quantity) equals ~$1.8*10^6$ m^2, distributed over low (8%), middle (56%) and high (36%) income households. Hence, household density is highest in low income areas (up to over 3.7 households per grid cell) and lower in attractive high income areas (as low as 0.9 households per grid cell). Available living space equals, on average, around 113m^2 per household, while noting large differences between household types: about 57m^2, 117m^2 and 338m^2 for low, middle and high income households, respectively.

Figure 28 Base run simulation results for the Imperia case study



Real estate (rental) values equal, on average, about 59€/m^2/yr, varying between 51€/m^2/yr for low, 60€/m^2/yr for middle and 71€/m^2/yr for high income households. Larger values can be observed in attractive high income areas (up to 73€/m^2/yr), particularly in the Northeast near Villa Grock, and lowest values can be observed in low income areas (up to 47€/m^2/yr), particularly along major roads. The total real estate (rental) value for the study area in Imperia equals 200 million Euros per year.

5.4.2. Scenario simulation results

Scenario 1

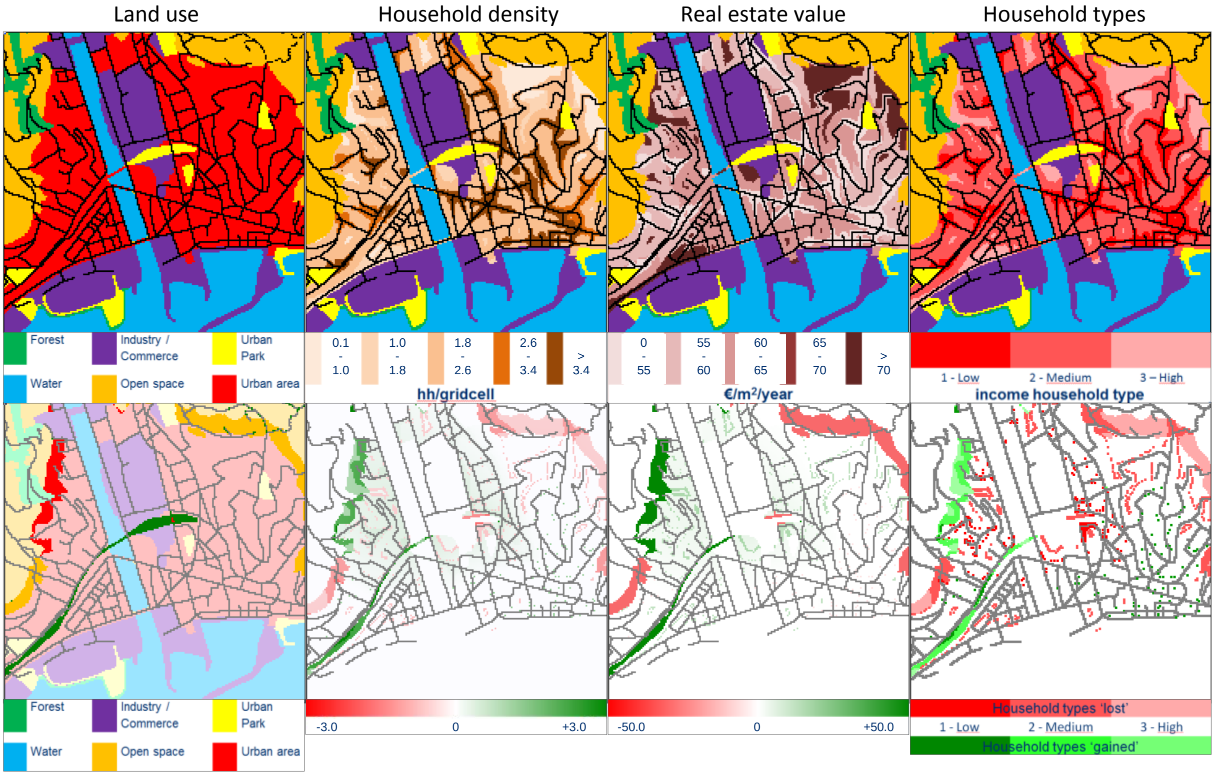
Project 1 involves the conversion of the Oneglia railway area into a central urban park (Oneglia park), the requalification of the (to be ceased) old railway track/bridge into a bus and bicycle lane, and the relocation of the railway station to the Northeast of the city along the (to be opened) new railway track.

The simultaneous establishment of these project interventions results in a 23% increase in green spaces, and an almost 5% reduction in urban residential area – mainly in the Northeast and Southwest of the city. Middle income households are attracted to the area near the new railway station, leaving attractive residential space in the Northeast (i.e. close to the Oneglia park) for high income households.

Across the entire study area, total built area (housing quantity) and living-space decrease with -5.4% and -1.5%, respectively. Locally, however, moderate to large increases in household densities can be observed in the area between Oneglia park and the new railway station (up to +15%) as well as North and South of Oneglia park (up to +12%). To the South household densities increase to a lesser extent given the proximity to the sea.

Increases in real estate values are minor across the entire study area (+1.5%), varying between +1.1% for low income households and +1.7% for high income households. Locally, small increases in real estate values can be observed between Oneglia park and the new railway station (up to +6%) and around Oneglia park (up to +5%). The total real estate (rental) value for the Imperia case study area remains at about 200 million Euros per year.

Figure 29 Scenario 1 simulation results for the Imperia case study



Summarizing, the establishment of Project 1 leads to a more condensed city with higher real estate values. Middle income households are willing accept smaller living spaces and higher real estate (rental) values when able to live in between the new railway station and Oneglia park. High income households are, as a result, able to live closer to the city and Oneglia park while driving-up real estate (rental) values in this area.

Scenario 2 (BS1)

Scenario 2 represents the inclusion of Project 2 to the above presented Scenario 1. Project 2 involves the redevelopment of the Porta di Mare area, in the South of the city facing the Mediterranean Sea. The Porta di Mare project includes a new urban residential area as well as a shopping centre.

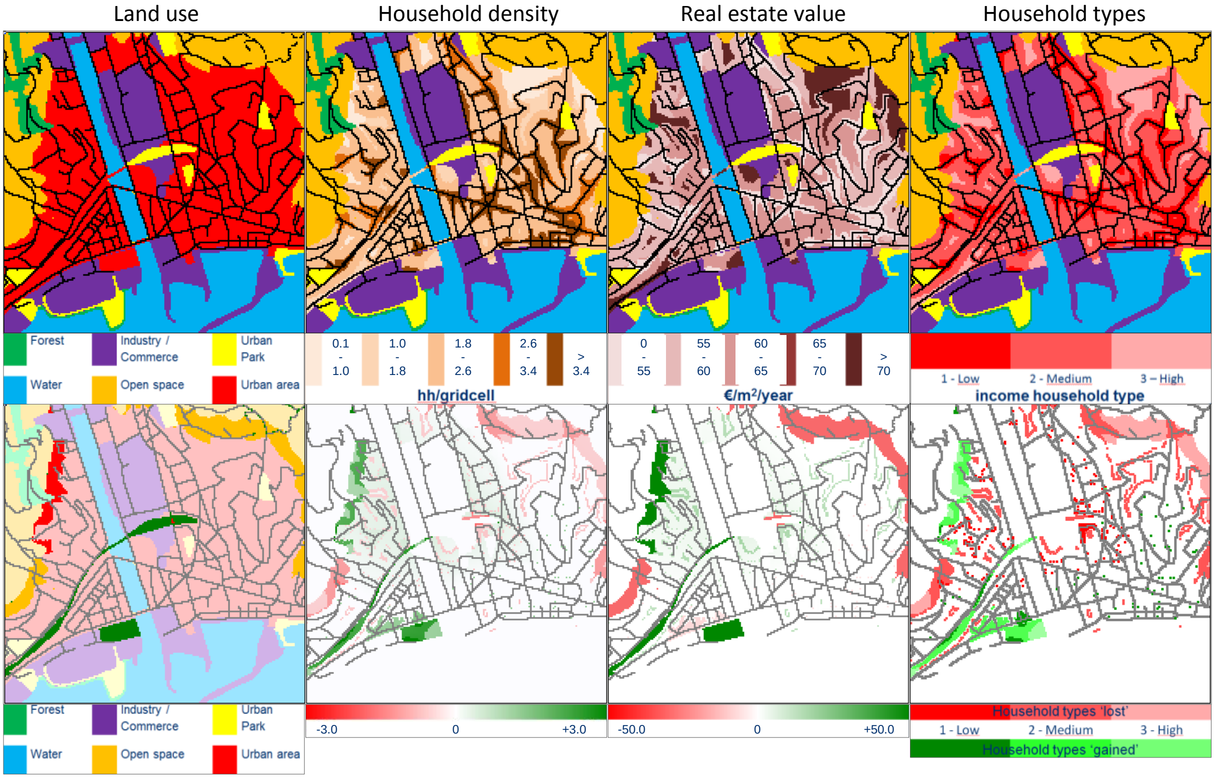
The establishment of the Porta di Mare intervention does not add to an increase in green space areas, though substitutes former industry/commerce areas (-13%) with an attractive, ocean-view, urban residential area (+1.8ha). This results in an overall decrease in urban-residential area of -5.2% in, mainly, the Northeast and Southwest of the city. Besides the dynamics observed in Scenario 1 (middle income households attracted to the area near the new railway station; high income households relocating in direction of Oneglia park and the city), the Porta di Mare project attracts middle and high income households.

Overall across the study area, total built area (housing quantity) and living-space decrease with -6.2% and -1.7%, respectively. Locally, and compared to Scenario 1, we see an additional increase in middle and high income population density on the West-side of the city – in between the new railway station (up to +16%) and the Porta di Mare (up to +115%).

Immediately around the Porta di Mare area, high income households are crowded-out by middle income households.

Increases in real estate values are minor (though somewhat larger compared to Scenario 1) across the entire study area (+1.7%), varying between +1.2% for low income households and +2.1% for high income households. Locally, compared to Scenario 1, we see that real estate values decrease immediately around the Porta di Mare area (up to -17%) as high income households are crowded-out by middle income households. In turn, however, high income households move to the Northwest – driving-up real estate values around the new railway station (up to +28%). The total real estate (rental) value for Imperia remains at about 200 million Euros per year.

Figure 30 Scenario 2 simulation results for the Imperia case study



Summarizing, compared to Scenario 1 the additional establishment of Project 2 leads to a further concentration of the city as well as further increases in real estate values. Middle and high income households are attracted to the Porta di Mare project area, while middle income households are also attracted to the area surrounding Porta di Mare – in both cases willing accept smaller living spaces and willing to pay higher real estate (rental) values.

Scenario 3 (BS2)

Scenario 3 represents the inclusion of Project 3 to the above presented Scenario 1. Project 3 involves the redevelopment of the Italcementi area, on the upstream East bank of the Impero river. This area will include a new urban residential area, a shopping centre and a University precinct.

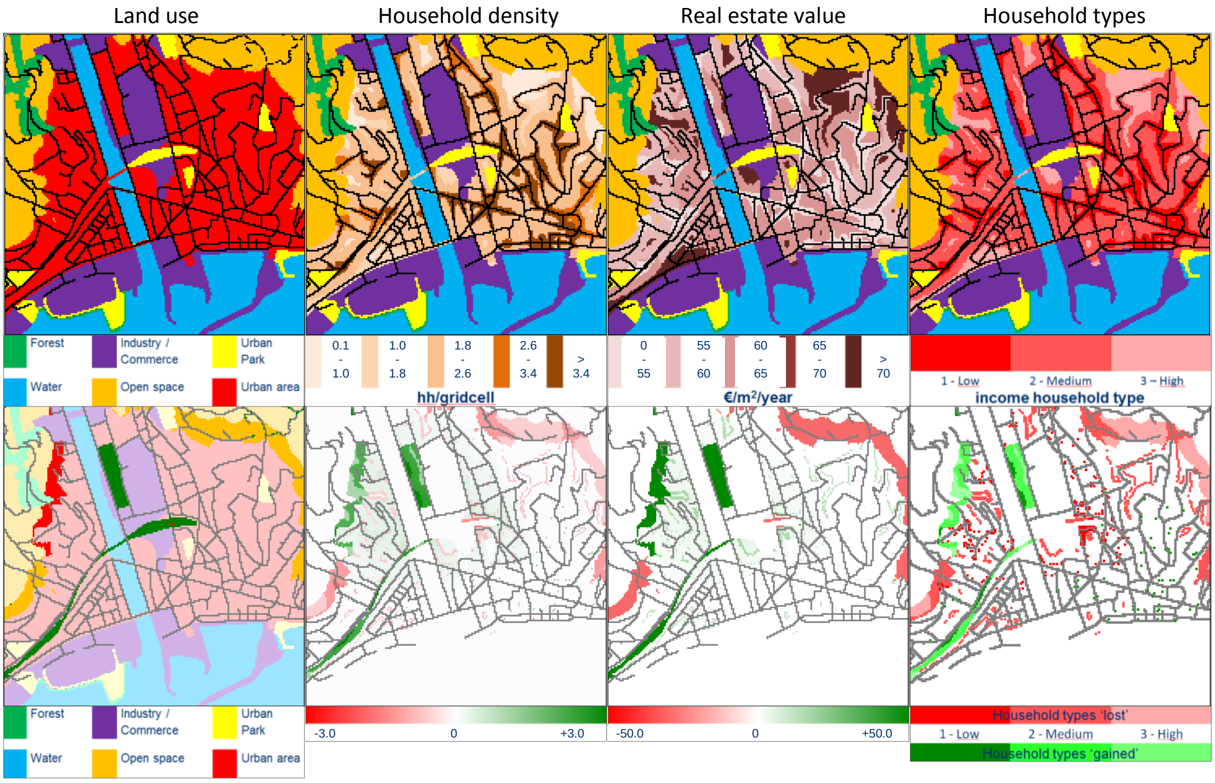
Similar to Scenario 2, the establishment of the Italcementi intervention does not add to an increase in green space areas, though substitutes former industry/commerce areas (-14%) with an attractive, river-view, urban residential area (+2.5ha). Again, we see an overall decrease in urban-residential area of -5.2% – mainly in the Northeast and Southwest of

Imperia. Besides the dynamics observed in Scenario 1 (middle income households attracted to the new railway station; high income households relocating towards Oneglia park and the city), the Italcementi project attracts mainly middle and low income households.

Across the entire study area, total built area (housing quantity) and living-space decrease with -6.2% and -1.7%, respectively. Compared to Scenario 1 we see, locally, an additional increase in middle and high income population density in the Northeast of the city – in particular around the Italcementi project area (up to +9%). Unlike Scenario 2, however, the seaside area will remain mostly unchanged.

Increases in real estate values are, again, minor across the entire study area (+1.7%), varying between +1.2% for low income households and +2.1% for high income households. Locally, compared to Scenario 1, we see that real estate values increase slightly in the area around Italcementi (up to 3.5%) due to the increase in same-household population density. The total real estate (rental) value for Imperia remains at ~200 million Euros per year.

Figure 31 Scenario 3 simulation results for the Imperia case study



In sum, compared to Scenario 1 the additional establishment of Project 3 leads to a further concentration of the city as well as further increases in real estate values. Middle and low income households are attracted to the Italcementi project area, while middle and high income households are also attracted to the area surrounding Italcementi. Again, these households are willing to accept smaller living spaces and higher real estate (rental) values.

5.5. Lyon (FR)

The numerical application of SULD to the Lyon case study is based on a population comprising three household types (low, middle and high income households), differentiated by number of households (Q), levels of expendable income (y) and shares of housing expenditures (μ; see Table 5 in Section 4.5.1) as well as levels of utility (u=3,300 for HHtype1,

u=8,019 for HHtype2 and u=12,672 for HHtype3). All household types share the same appreciation for environmental amenities (ε=0.08; a=10.0/7.5/5.0; η=1.0), annual commuting costs (p_x=375 €/km), opportunity cost of land (l_i=1,000 €/yr) and development costs (c_0=0 and η=1.75). The study area encompasses an area of 2.85km by 2.85km (=8.12km^2), covered by a grid layer of 185 by 185 (=34,225) cells of 15.4m by 15.4m. The area includes eight environmental amenities (three urban parks, two neighbourhood parks, two local parks and water, with varying amenity value; a=10.0/7.5/5.0) and twelve urban centres (see Figure 15 in Section 4.5.2), with distances to environmental amenities and urban centres based on straight-line and road-network distances, respectively.

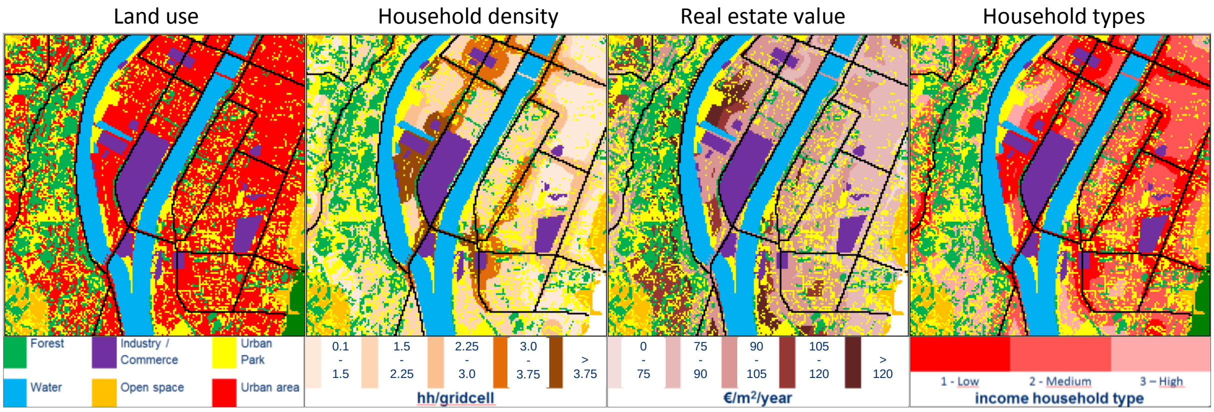
This section presents the results for the base run (Section 5.5.1) and scenario simulation (Section 5.5.2) results, with numerical results presented in Table 11 and cartographic results presented in Figure 32 to 35. Results are based on available data for 2011, and assessed scenario simulations include (see also http://suld.web.ua.pt/): i) industrial brownfield requalification into urban park and residential areas (Scenario 1), ii) the first scenario with requalification of the Rhone riverfront (Scenario 5), and iii) the first scenario with construction of two new bridges over the river Rhone (Scenario 7).

5.5.1. Base run results

The Lyon study area comprises mainly urban residential (339 ha) and green space (155 ha of urban parks and 102 ha of forest) areas. The Confluence intervention area is characterized by green space in the West, industrial brownfield in the East and residential in the North.

The total population of 60,418 inhabitants comprises 50% low income, 38% middle income and 13% high income households. In the Confluence area 70% of the population are low income households, which live close to the brownfield, urban centres and main roads. High income households live in more attractive areas, close to the waterfront and urban parks.

Figure 32 Base run simulation results for the Lyon case study



The total built area (housing quantity) equals ~1.6*10^{6}m^2, distributed over low (20%), middle (60%) and high (20%) income households. The total floor space (development density) covers almost double this area (~2.9*10^{6}m^2), while noting that low income households are located in the most densely populated areas (over 3.8 households per grid cell). In the Confluence area almost 50% of total floor space is occupied by low income households. Available living space equals, on average, 98m^2 per household, ranging between 59 m^2 for low income households and 158m^2 for high income households.

Table 11 Base run and scenario simulation results for the Lyon case study

	Unit	Base	Scenario 1		Scenario 5		Scenario 7	
Land use								
- Forest	ha	102	102	0.0%	102	0.0%	102	0.0%
- Water	ha	98	98	0.0%	98	0.0%	98	0.0%
- Open space	ha	30	58	93.2%	60	99.9%	58	94.4%
- Industry / Commerce	ha	43	22	-48.7%	22	-48.7%	22	-48.7%
- Park_urban	ha	155	160	3.5%	160	3.5%	160	3.5%
- Roads	ha	45	45	-0.1%	45	-0.1%	45	-0.1%
- Urban	ha	339	327	-3.5%	325	-4.1%	327	-3.6%
Total	ha	812	812	0.0%	812	0.0%	812	0.0%
Population								
- HHType1	#	30209	30209	0.0%	30209	0.0%	30209	0.0%
- HHType2	#	22657	22657	0.0%	22657	0.0%	22657	0.0%
- HHType3	#	7552	7552	0.0%	7552	0.0%	7552	0.0%
Total	#	60418	60418	0.0%	60418	0.0%	60418	0.0%
Housing quantity								
- HHType1	1000 m^2	287.5	279.0	-2.9%	278.0	-3.3%	276.6	-3.8%
- HHType2	1000 m^2	969.5	911.1	-6.0%	899.2	-7.3%	912.0	-5.9%
- HHType3	1000 m^2	347.0	323.5	-6.8%	321.9	-7.2%	325.6	-6.2%
Total	1000 m^2	1603.9	1513.7	-5.6%	1499.1	-6.5%	1514.2	-5.6%
Living space								
- HHType1	m^2/hh	58.8	58.3	-0.8%	58.2	-1.0%	58.2	-1.1%
- HHType2	m^2/hh	130.9	128.6	-1.7%	128.1	-2.1%	128.7	-1.7%
- HHType3	m^2/hh	158.1	155.1	-1.9%	154.9	-2.0%	155.4	-1.7%
Average	m^2/hh	98.2	96.8	-1.5%	96.5	-1.7%	96.8	-1.5%
Real estate value								
- HHType1	€/m^2/yr	87.5	88.3	0.9%	88.4	1.0%	88.6	1.2%
- HHType2	€/m^2/yr	93.9	95.8	1.9%	96.1	2.3%	95.7	1.9%
- HHType3	€/m^2/yr	118.3	120.9	2.2%	121.1	2.4%	120.7	2.0%
Average	€/m^2/yr	95.5	97.0	1.6%	97.3	1.9%	97.1	1.7%
Total	m€/yr	287.6	288.2	0.2%	288.2	0.2%	288.2	0.2%

Real estate (rental) values equal, on average, about 96€/m^2/yr, varying from 88€/m^2/yr for low income households to 118 €/m^2/yr for high income households. Largest values can be observed in attractive high income areas close to the river and green spaces (up to 200€/m^2/yr), while lowest values can be observed in low income areas close to main roads, urban centres and the railway station (up to 75€/m^2/yr). The total real estate (rental) value for the study area in Lyon equals 287.6 million Euros per year, and 75.0 million Euros per year for the Confluence area.

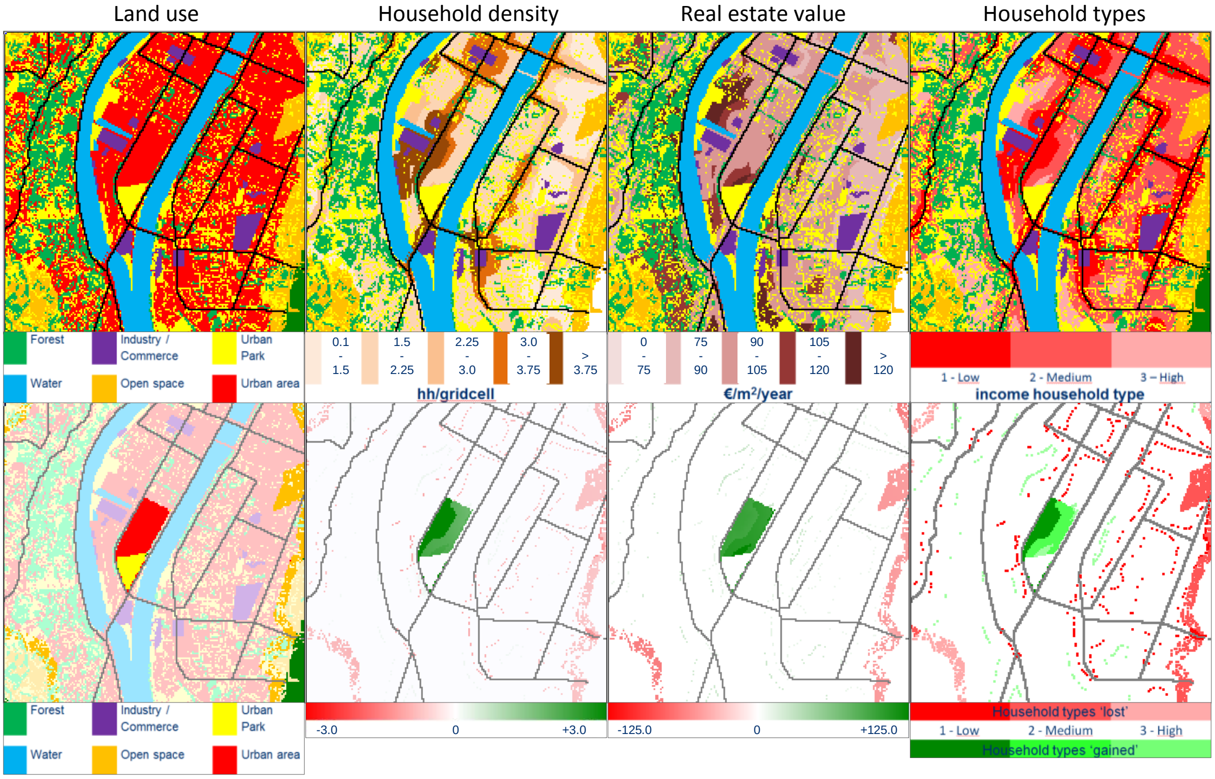
5.5.2. Scenario simulation results

Scenario 1

Scenario 1 entails the requalification of an industrial brownfield area in the South of Confluence, into an urban park (in the South) and residential area (in the North). It results in a 3.5% increase in green-spaces and 3.5% decrease in urban residential area. Numerous middle and high income households are attracted to this area in the South of Confluence.

Overall across the entire study area, the total built area (housing quantity) and living space decrease by, respectively, -5.6% and -1.5%. This decrease is largest for middle and high income households, implying that these households are attracted to this unlocked residential area with urban park while willing to accept a smaller living space. As a consequence, the number of middle and high income households in the Confluence area increases with 33% and the total built area (housing quantity) increases with 24% (each).

Figure 33 Scenario 1 simulation results for the Lyon case study



Overall increases in real estate values are small (+1.6%), while local real estate values in this newly developed Confluence area are high (up to about 200€/m^2/yr) – in particular to the North of the urban park. Real estate (rental) values increase with between +0.9% for low income households and +2.2% for high income households. The total real estate (rental) value for the Lyon case study increases with 0.6 million Euros per year (+0.2%) to 288.2 million Euros per year; the total real estate (rental) value for the Confluence area increases with +23% to 92.3 million Euros per year.

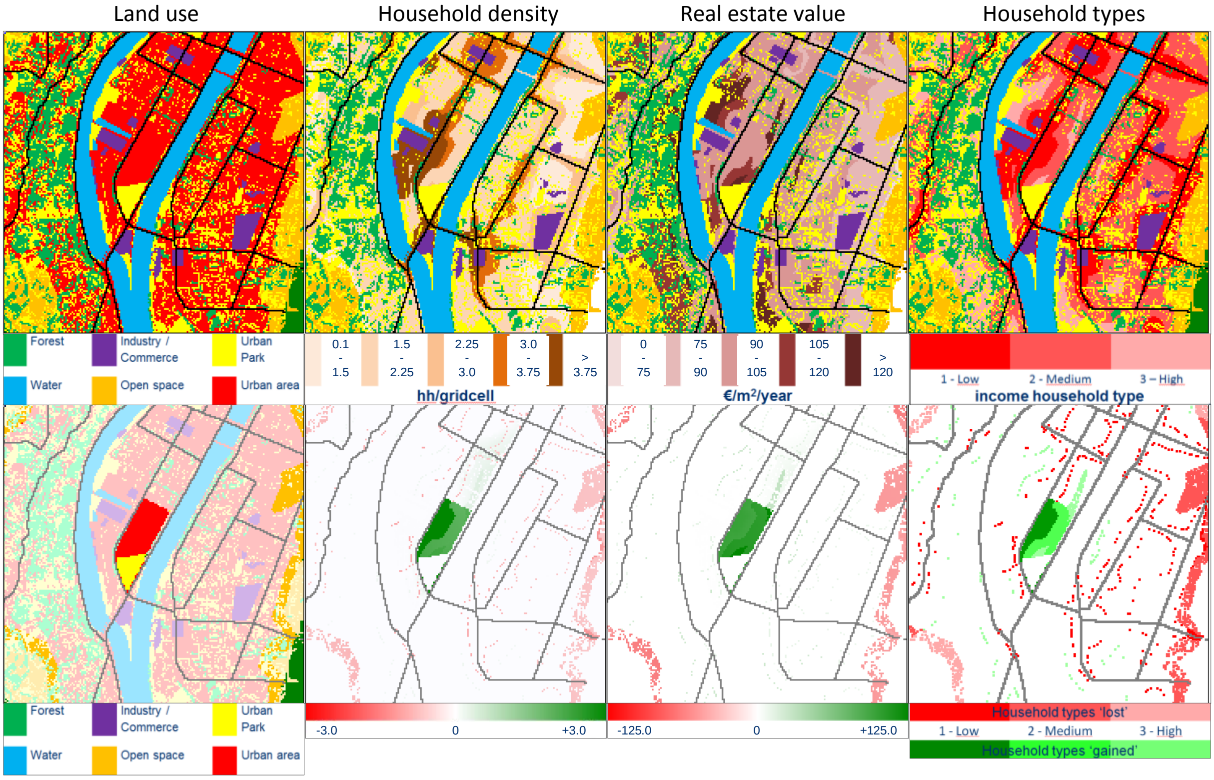
Summarizing, the redevelopment of the industrial brownfield in the Confluence area leads to a more condensed city, higher real estate (rental) values and a significant (local) net increase in total real estate value. Middle and high income households are attracted to this unlocked residential area with urban park, willing to accept smaller living spaces and higher real estate (rental) values.

Scenario 5

Scenario 5 adds to the requalification of the industrial brownfield in the South of Confluence (Scenario 1), the requalification of the Rhone riverfront such that the Highway A7 will be converted into a local road that allows greater interaction of Confluence households with the river Rhone. This results in a somewhat larger decrease in urban residential area (-4.1%), attracting additional middle and high income households to East Confluence.

Over the entire case study area, total built area (housing quantity) and living space decrease by -6.5% and -1.7%, respectively. This decrease is largest for middle and high income households (over -7% and -2%, respectively), that are attracted to this requalified area near the river front and willing to accept a smaller living space. Hence, the number of middle and high income households in the Confluence area increases with 33% and 49%, respectively, and the total built area (housing quantity) increases with 23% and 38%, respectively. Hence, middle and high income households and housing in the Confluence increase substantially.

Figure 34 Scenario 5 simulation results for the Lyon case study



While overall increases in real estate values are small (+1.9%), in the Confluence area increases in real estate values are large (up to almost +30%) – in particular to the North of the new urban park and along the Rhone riverfront. Real estate (rental) values increase with between +1.0% for low income households and +2.4% for high income households. The total real estate (rental) value for the Lyon case study increases with +0.2% to 288.2 million Euros per year; for the Confluence this value increases with +26% to 94.7 million Euros per year.

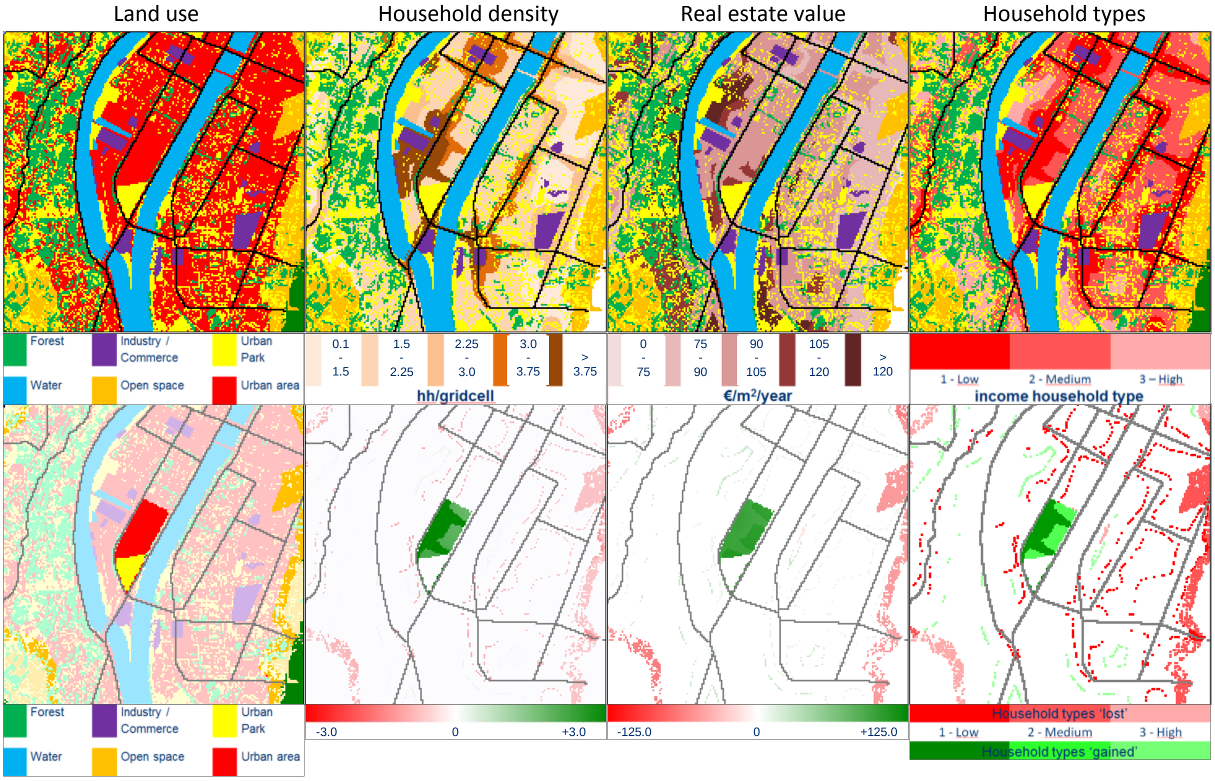
In sum, the additional requalification of the Rhone riverfront in the Confluence leads to an even more condensed city, higher real estate (rental) values and a significant (local) net increase in total real estate value. Additional middle and, in particular, high income households are attracted to this area, willing to accept smaller living spaces and higher real estate (rental) values when living in the vicinity of the requalified Rhone riverfront.

Scenario 7

Scenario 7 adds to the requalification of the industrial brownfield in South-Confluence (Scenario 1), the development of new road infrastructure that comprises the construction of two new bridges over the river Rhone – thus linking Confluence to East-Lyon. Compared to Scenario 1, this results in a similar decrease in urban residential area (-3.6%) though now attracting, in particular, low and middle income households.

Over the entire study area, the total built area (housing quantity) and living space decrease by, respectively, -5.6% and -1.5%. Compared to Scenario 1, this decrease is now larger for low income households and lower for high income households, implying that more low income households are attracted to Confluence as it is now more easily accessible. Consequently, the number of low, middle and high income households in Confluence increases with 18%, 30% and 19%, respectively; the total built area (housing quantity) increases with 14%, 22% and 12%, respectively.

Figure 35 Scenario 7 simulation results for the Lyon case study



Overall, increases in real estate values are small (+1.7%) while, locally, increases in real estate values are moderate (up to about +10%) – in particular to the West of the new urban park. Low and middle income households locate around the roads leading to the bridges, thereby noting that one of these roads borders to the North of the new urban park and, hence, this area ceases to be attractive for high income households. Real estate (rental) values increase with between +1.2% for low income households and +2.0% for high income households. The total real estate (rental) value for the Lyon case study increases with +0.2% to 288.2 million Euros per year; for the Confluence area this value increases with +22% to 91.4 million Euros per year.

Summarizing, the additional development of new road infrastructure in Confluence leads to a more condensed city, higher real estate (rental) values and a moderate (local) net increase in total real estate value. In particular low and middle income households are attracted by this intervention as accessibility is increased, though these households demonstrate less willingness to pay to live in the vicinity of the new urban park.

5.6. Sofia (BU)

The numerical application of SULD to the Sofia case study is based on a population comprising three household types (low, middle and high income households), differentiated by number of households (Q), levels of expendable income (y) and shares of housing expenditures (μ; see Table 6 in Section 4.6.3) as well as levels of utility (u=2,000 for HHtype1, u=5,660 for HHtype2 and u=8,500 for HHtype3). All household types share the same appreciation for environmental amenities (ε=0.08; α=12.50/8.75/5.00; η =1.0), annual commuting costs (p_x=250 €/km), opportunity cost of land (l_i=1,000 €/yr) and development costs (c_0=0 and η=1.505). The study area encompasses an area of 2.30km by 2.30km (=5.29km^2), covered by a grid layer of 185 by 185 (=34,225) cells of 12.4m by 12.4m. It includes eight environmental amenities (two urban parks, one sports area, one neighbourhood park, two local parks, the Vladaiska riverbed and other water channels with varying amenity value; a=12.50/8.75/5.00) and 33 urban centres / transport hubs (see Figure 16 in Section 4.6.2), with distances to environmental amenities and urban centres based on straight-line and road-network distances, respectively.

This section presents the results for the base run (Section 5.6.1) and scenario simulation (Section 5.6.2) results, with numerical results presented in Table 12 and cartographic results presented in Figure 36 to 39. Results are based on available data for 2012, and assessed scenario simulations include (see also http://suld.web.ua.pt/): i) Project 1 (requalification of the Vladaiska Northern riverbed), ii) Project 2 (requalification of the Vladaiska Southern riverbed), and iii) all previous projects (Project 1 and 2).

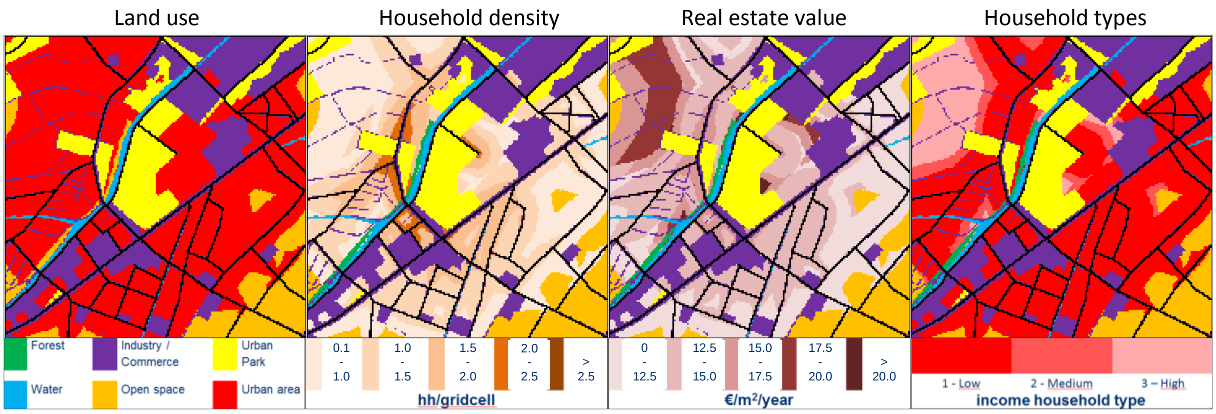
5.6.1. Base run results

The Sofia study area comprises mainly urban residential (281 ha) and industry/commerce (100 ha) land uses. Urban parks cover around 53 ha, with a large central urban park and additional green areas in the North. The Vladayska river runs through the centre of the study area and covers 9 ha (see Table 12).

The total population of 51.866 inhabitants comprises 85% low income, 5% middle income and 10% high income households. High income households are located mainly in the Northwest, in small strips near parks and water, and farther away from main roads. Middle income households practically occupy the same locations, though somewhat closer to main roads. The bulk of the study area is constituted by low income households, located along the main roads and around urban centres.

The total built area (housing quantity) equals ~1.4*10^{6}m^2, distributed over low (58%), middle (14%) and high (28%) income households. Household density is highest in low income areas (up to 2.6 households per grid cell) and lowest in middle and high income areas farther away from main roads and environmental amenities (up to 0.5 households per grid cell). Available living space equals, on average, around 69m^2 per household, while noting large differences between household types: about 55m^2, 130m^2 and 157m^2 for low, middle and high income households, respectively.

Figure 36 Base run simulation results for the Sofia case study



Real estate (rental) values equal, on average, about 14€/m^2/yr, varying between 13.0€/m^2/yr for low, 15.3€/m^2/yr for middle and 18.2€/m^2/yr for high income households. Larger values can be observed in attractive high income areas (up to 20€/m^2/yr), particularly in the Northwest of the study area, and lowest values can be observed in less attractive low income areas (10€/m^2/yr), mainly in the South and East of the study area. The total real estate (rental) value for the study area in Sofia equals 20.8 million Euros per year.

Table 12 Base run and scenario simulation results for the Sofia case study

	Unit	Base	Scenario 1		Scenario 2		Scenario 3	
Land use								
- Forest	ha	4	2	-41.4%	2	-58.6%	0	-100%
- Water	ha	9	9	-1.3%	9	-1.0%	9	-2.3%
- Open space	ha	40	57	42.6%	58	46.0%	69	72.9%
- Industry / Commerce	ha	100	100	-0.2%	99	-0.5%	99	-0.7%
- Park_urban	ha	53	55	3.8%	56	5.7%	58	9.5%
- Roads	ha	42	42	0.0%	42	0.0%	42	0.0%
- Urban	ha	281	264	-6.1%	263	-6.5%	252	-10.4%
Total	ha	529	529	0.0%	529	0.0%	529	0.0%
Population								
- HHType1	#	44086	44086	0.0%	44086	0.0%	44086	0.0%
- HHType2	#	2593	2593	0.0%	2593	0.0%	2593	0.0%
- HHType3	#	5187	5187	0.0%	5187	0.0%	5187	0.0%
Total	#	51866	51866	0.0%	51866	0.0%	51866	0.0%
Housing quantity								
- HHType1	1000 m^2	808.5	763.3	-5.6%	756.1	-6.5%	716.4	-11.4%
- HHType2	1000 m^2	187.6	165.8	-11.6%	165.3	-11.9%	158.9	-15.3%
- HHType3	1000 m^2	393.3	363.3	-7.6%	362.3	-7.9%	334.3	-15.0%
Total	1000 m^2	1389.4	1292.4	-7.0%	1283.6	-7.6%	1209.5	-12.9%
Living space								
- HHType1	m^2/hh	55.3	55.1	-0.3%	55.1	-0.5%	54.4	-1.7%
- HHType2	m^2/hh	129.8	127.7	-1.6%	127.7	-1.6%	126.4	-2.5%
- HHType3	m^2/hh	157.4	156.7	-0.5%	156.6	-0.5%	153.5	-2.5%
Average	m^2/hh	69.2	68.9	-0.5%	68.8	-0.6%	67.9	-1.9%
Real estate value								
- HHType1	€/m^2/yr	13.0	13.0	0.2%	13.1	0.5%	13.2	1.9%
- HHType2	€/m^2/yr	15.3	15.6	1.9%	15.7	2.0%	15.8	3.0%
- HHType3	€/m^2/yr	18.2	18.3	0.7%	18.4	0.8%	18.8	2.9%
Average	€/m^2/yr	13.9	13.9	0.3%	14.0	0.6%	14.2	2.0%
Total	m€/yr	20.8	20.8	0.0%	20.8	0.1%	20.8	0.3%

5.6.2. Scenario simulation results

Scenario 1

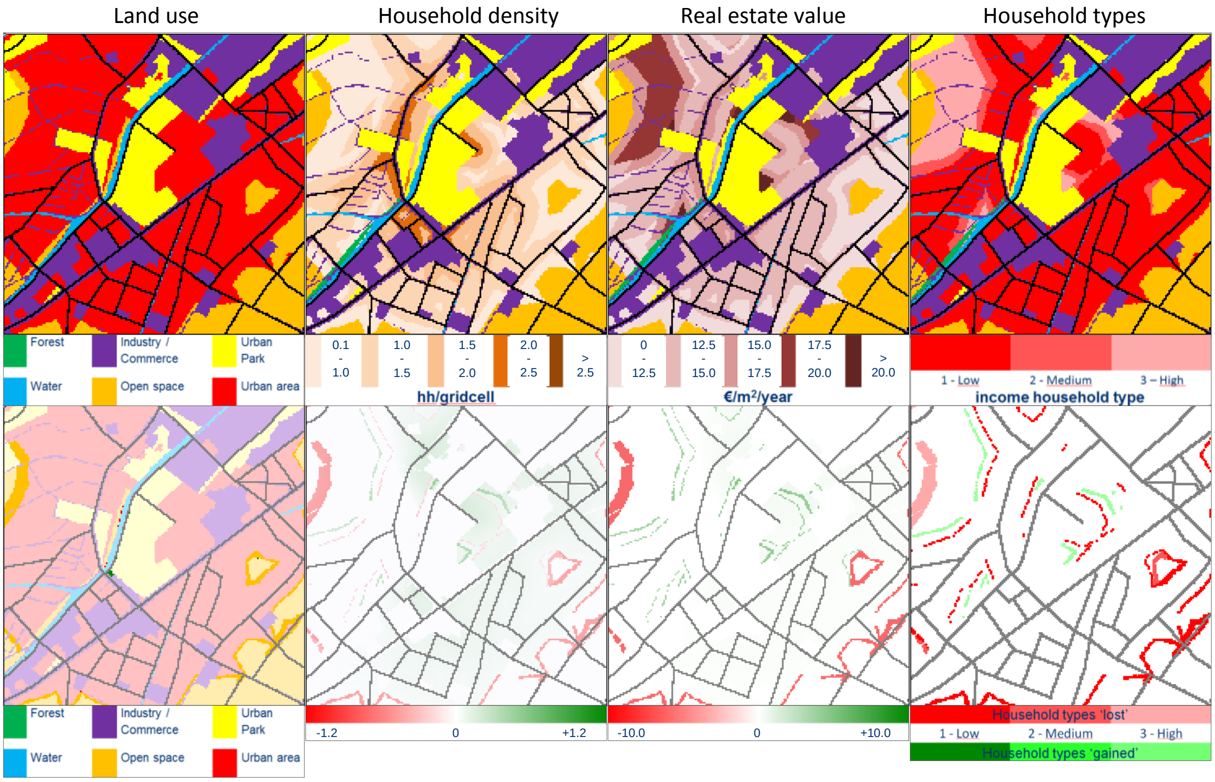
Project 1 entails the requalification of the Vladaiska Northern riverbed, including the conversion of open space areas into an extension of the nearby central urban park as well as the realignment/requalification of the riverbed. Hence, residents' access and relationship to the water is improved and stream flow potential increased.

The establishment of this project results in 3.8% increase in green-space and in a -6.1% decrease in urban residential area. Middle and, to a minor extent, high income households are attracted to the area surrounding the Northern riverbed, leading to a small (local) increase in population density.

Overall across the study area, the total built area (housing quantity) and living space decrease with -7.0% and -0.5%, respectively. Largest decreases in built area (housing quantity) and living space can be observed for middle and high income households, that are attracted by the project intervention. Hence, locally household densities increase in the areas surrounding the central urban park – particularly in those locations where middle and high income households live or are attracted to. Low income households concentrate along the main roads close to the project area.

Increases in real estate values are negligible across the entire study area (+0.3%), though significantly positive in the area surrounding the Vladaiska Northern riverbed – in particular to the North and East of the central urban park. Largest increases in real estate (rental) values can be observed for middle income households (locally up to +30%), while the total (rental) value for the Sofia case study area remains at 20.8 million Euros per year.

Figure 37 Scenario 1 simulation results for the Sofia case study



Summarizing, the establishment of Project 1 leads to a somewhat condensed city, and a local increase in population density and small increase in real estate (rental) values. Particularly middle and, to a lesser extent, high income households will be attracted to the area surrounding the Vladaiska Northern riverbed and the central urban park – willing to accept a smaller living space and willing to pay higher real estate (rental) values.

Scenario 2

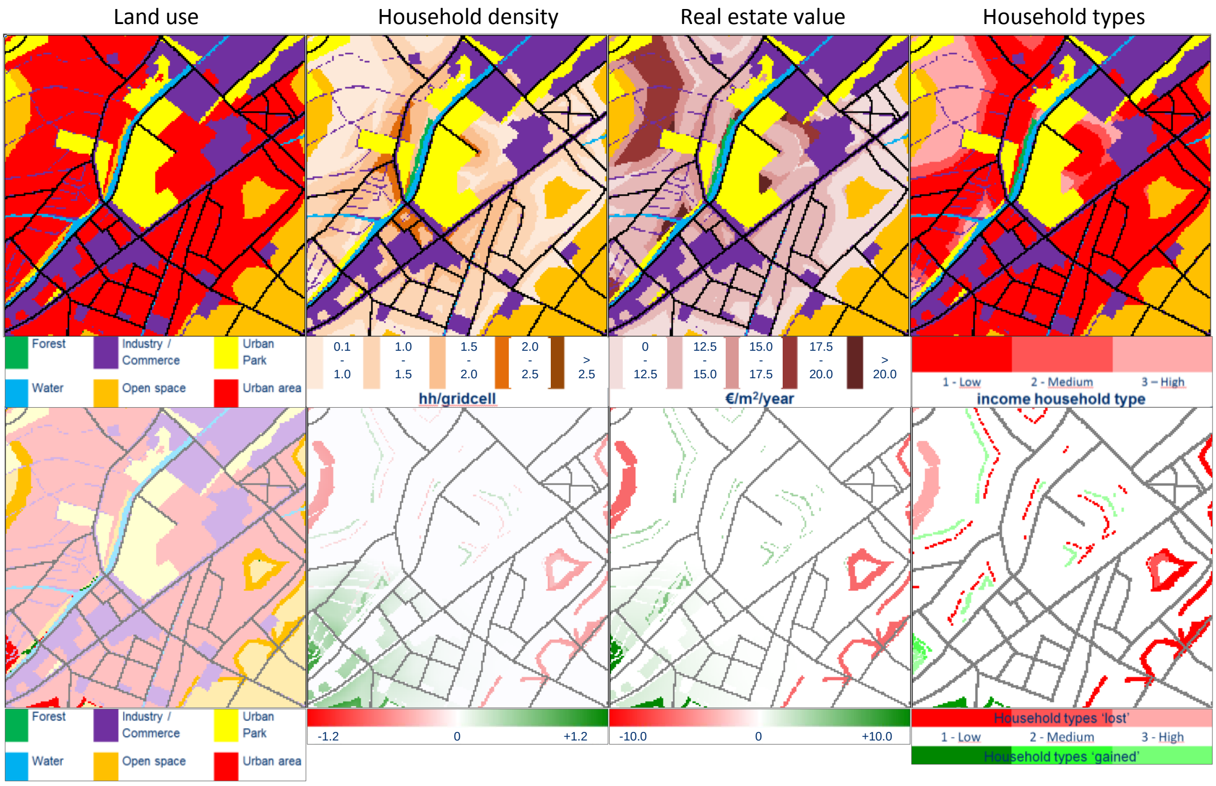
Project 2 entails the requalification of the Vladaiska Southern riverbed. Similar to Project 1, it includes the conversion of open space areas into an extension of a nearby urban park as well as the realignment/requalification of the riverbed. Besides recreational and hydrological functions, the project aims to attract real estate investments in the area.

Similar to Scenario 1, the establishment of this project results in a 5.7% increase in green-space and in a -6.5% decrease in urban residential area. Again, middle and, to a minor extent, high income households are attracted to the area surrounding the project intervention, leading to a small (local) increase in population density.

Over the entire study area, total built area (housing quantity) and living space decrease with -7.6% and -0.6%, respectively – again, largest decreases can be observed for middle and high income households that are particularly attracted by the project intervention. Low income households are crowded-out and move to affordable and accessible locations. Locally, household densities increase in the area surrounding the project intervention.

Compared to Scenario 1, increases in real estate values are minor across the entire study area (+0.6%), though significantly positive in the area surrounding the Vladaiska Southern riverbed – in particular to the North of the intervention area. Largest increases in real estate (rental) values can be observed for middle income households (locally up to +35%), while the total real estate (rental) value for the study area remains at 20.8 million Euros per year.

Figure 38 Scenario 2 simulation results for the Sofia case study



Summarizing, also the establishment of Project 2 leads to a more condensed city, and a local increase in population density and small increase in real estate (rental) values. Middle and, to a lesser extent, high income households are attracted to the area surrounding the Southern riverbed – accepting smaller living spaces and higher real estate (rental) values.

Scenario 3

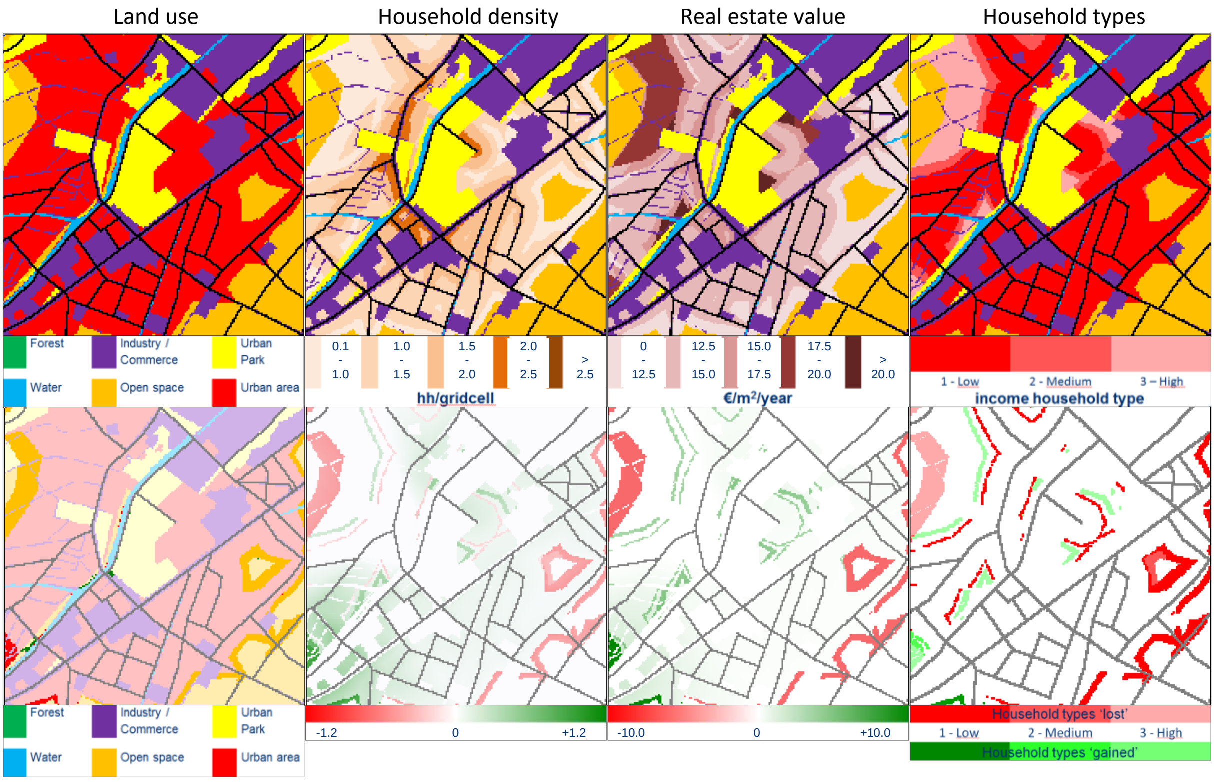
Scenario 3 entails the joint establishment of Project 1 and Project 2, thus creating a continuous green corridor along the Vladaiska river with multiple recreational and hydrological functions.

This scenario results in an increase of 9.5% in green-space and a -10.4% decrease in urban residential area. Whereas Project 1 and Project 2 in isolation lead to greater attraction of middle and, to a minor extent, high income households, the joint establishment of both Projects leads also to an equal attraction of middle and high income households. There is a moderate (local) increase in population density.

Overall, total built area (housing quantity) and living space decrease with -12.9% and -1.9%, respectively – particularly so for middle and high income households. Locally, household densities increase in the areas surrounding the central urban park (mainly North and East) and in the area surrounding Project 2 (mainly North and South). Low income households move out of these areas, towards low income areas along the main roads.

Across the entire study area, increases in real estate values are small (+2.0%) though significantly positive in the area surrounding the Vladaiska river (North and South) and in the areas surrounding the central urban park (North and East). Largest increases in real estate (rental) values can be observed for middle and high income households (locally up to +33%), while the total real estate (rental) value for the Sofia case study area remains at 20.8 million Euros per year (+0.3%).

Figure 39 Scenario 3 simulation results for the Sofia case study



Summarizing, the establishment of Projects 1 and 2 leads to a more condensed city with higher real estate values, resulting in a minor net increase in total real estate value. Both middle and high income households are attracted to the areas surrounding the Vladaiska river and the central urban park, accepting a smaller living space and willing to pay higher rents to be close to these environmental amenities. Low income families are crowded-out from these areas, moving towards more affordable low income areas along main roads.

6. Conclusions and recommendations

In this report we, not only, assessed the importance of stakeholder meetings in the development and application of the Sustainable Urbanizing Landscape Development (SULD) decision support tool (Roebeling et al., 2007, 2014), but also, presented the SULD model and application for the six other Aqua Cases (Bremerhaven DE; Copenhagen DK; Debrecen HU; Imperia IT; Lyon FR; Sofia BU). To this end, we analysed and discussed the results from a stakeholder-feedback web-survey that was applied across project partners participating in these stakeholder meetings. In turn, the other Aqua Cases were described, and results for green/blue space and infrastructure projects presented – with particular focus on the impact of these location-specific projects on the location of residential development, housing quantity, residential development density, population density, population composition, household living space and real estate values.

The importance of the Aqua-Add stakeholder meetings has been assessed through a questionnaire provided to participating partners using a web-survey, comprising 11 questions developed along three main axes of concern: learning, facilitating and projecting. In terms of **learning**, over 85% of respondents indicated to have learned “Somewhat” to “A lot” through the stakeholder meetings – in particular regarding concerns and interests of other stakeholders as well as in relation to the participants’ way of thinking, learning or working. In terms of **facilitating**, over 90% of respondents indicated to have gained new information or professional contacts through the stakeholder meetings. Also, respondents indicated to be “Satisfied” to “Completely satisfied” about the exposition and perception of points of view (over 85%), the discussion on project options (76%) and consensus formation (53%). In terms of **projecting**, respondents considered the stakeholder meetings “Somewhat” to “Very” useful for them (91%), the neighbourhood (86%) and the city (86%). Participants, hence, indicated they would (43%) or likely (57%) attend/organize another stakeholder meeting. The stakeholder meetings were considered an ideal place to discuss problems with other planning professionals and stakeholders, especially when held regularly and as early as possible in the project. In addition, they welcomed the use of a visually appealing and user friendly decision support tool to stimulate discussion.

For the Bremerhaven case study, the establishment of proposed urban parks leads to a more condensed city (decrease in urban residential area of up to -8%), higher real estate (rental) values and a small net increase in total real estate value (up to +0.1%). Middle and high income households are attracted to the intervention areas, willing to accept smaller living spaces and higher real estate (rental) values (up to +15%) when able to live in the vicinity of these parks. Low income households are crowded-out to less expensive areas further away from these parks, though also benefit from their proximity.

For the Copenhagen case study, the establishment of proposed green/blue projects leads to a minor overall though locally small value added. Urban contraction is minor (up to -0.7%) while projects favour, in particular, the current low income population. This results in moderate increases in population densities and small increases in real estate (rental) values (up to +3%) in the immediate surroundings of the project interventions.

For the Debrecen cases study, proposed combined residential development and urban park projects lead to a an increase in urban residential area (up to +36%), increased household densities, higher real estate (rental) values and a large net increase in total real estate value (up to +80%). Middle and high income households are attracted to the new urban residential areas, willing to accept smaller living spaces and higher real estate (rental) values (up to +17%) when able to live in or around these attractive areas with ample urban parks.

For the Imperia case study, the establishment of the Oneglia park project leads to a more condensed city (decrease in urban residential area of -4.8%) with higher real estate values. Middle income households are willing accept smaller living spaces and higher real estate (rental) values (up to +6%) when able to live in between the new railway station and Oneglia park; high income households will be able to live closer to the city. The Porta di Mare and Italcementi projects lead to a further reduction of the city (up to -5.2%) and increases in real estate values. Mainly middle income households are attracted to these areas, willing accept smaller living spaces and willing to pay higher real estate (rental) values (up to +3.5%).

For the Lyon case study, the redevelopment of the Confluence area leads to a more condensed city (-3.5%), higher real estate (rental) values and a significant (local) net increase in total real estate value (+23%). Middle and high income households are attracted to this redeveloped area with urban park. The additional requalification of the Rhone riverfront leads to an even more condensed city (-4.1%), higher real estate (rental) values and a significant (local) net increase in total real estate value (+26%). Middle and high income households are attracted by this intervention, willing to accept smaller living spaces and higher real estate (rental) values (up to +30%). The additional development of new road infrastructure leads to a more condensed city (-3.6%), higher real estate (rental) values and a moderate (local) net increase in total real estate value (+22%). Low and middle income households are attracted by this intervention, though these households demonstrate less willingness to pay higher real estate (rental) values (up to +10%).

Finally, for the Sofia case study the establishment of proposed green/blue projects leads to a more condensed city (up to -10%) with higher real estate values, resulting in a minor net increase in total real estate value (up to +0.3%). Middle and high income households are attracted to the areas surrounding the project interventions, accepting a smaller living space and willing to pay higher real estate (rental) values (up to +35%). Low income families move towards more affordable low income areas along main roads.

Based on the results from all Aqua Cases, the following four major tendencies regarding the establishment, re-introduction or re-qualification of green and blue spaces can be derived. First, cities become more compact as people are willing to accept smaller housing when closer to an attractive area. Second, population density increases as green and blue spaces attract more people. Third, there is an appreciation in real estate values as people are willing to pay more when living closer to an attractive area. Finally, changes in demographic distribution patterns will occur as higher income households are attracted to these more attractive areas. Note, however, that the value-added of green and blue space depends on: one, the quality and size of the intervention; two, the location of the intervention relative to existing residential areas, urban centres and environmental amenities; and three, the social classes attracted to the intervention area.

Consequently, the SULD decision support tool is not an aim in itself but the starting point of a process. It facilitates participatory planning and scenario development, creating confidence in and familiarity with the model and its outputs. It enriches public discussion and adds transparency to the urban planning processes. So, it encourages stakeholders to reflect about their reality and future possibilities – effectively engaging them in the design of urban development plans where the value of water and green spaces assume a forefront position.

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