

Sophie Schetke

Socio-environmental impacts of
settlement growth under conditions
of fostered infill development

A methodological framework for a
multicriteria assessment

Sophie Schetke • **Socio-environmental impacts
of settlement growth**

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Abstract

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The background of this study is characterized by three major issues of current land use planning:

First, in Germany, around 100 hectare of greenfield sites are used for settlement and traffic purposes every day. The trend of land-consumption is rarely unbroken and the loss of natural resources increases. *Second*, simultaneously, a paradox settlement growth can be found in lots of German agglomerations: Whilst planners and communes are under continuous suburban development pressure, considerable amounts of brownfields and open spaces are emerging in inner urban areas due to the declining population, housing estates not being marketable anymore and structural change. *Third*, the German Council of Sustainability promotes quantitative and qualitative targets of future land management such as the reduction of land consumption to 30 hectare per day by the year 2020 and a promotion of infill development versus greenfield development at a ratio of 3:1. Facing these political targets aiming an intensified infill development gives both planners and scientists reasons for serious concern when focusing on quality of life and ecological conditions. Moreover, residents do not aspire to the compact city and see their quality of life endangered.

Against these notions, the major objective of this study is to analyze socio-environmental conditions under which a sustainable and resource-preserving settlement development can be promoted and to assess respective impacts of greenfield and infill development. By doing so, an essential part of this study is dedicated to the development of an innovative theoretical and methodological concept of a two-stepped Multicriteria Assessment scheme (MCA) for a demography-driven and scenario-based assessment of land use change.

The first step of this concept is characterized by the assessment of socio-environmental prerequisites of future housing sites of a city and their contribution to a sustainable settlement development defined by the term Quality of Place (QoP). It results from a close collaboration between planners and scientists within a research-project on sustainable settlement-development. Test-runs and discussions with planners have been conducted throughout a period of three years to discuss the necessity of the socio-ecological indicators and to identify individual weights. The second step is formed by an on-site-assessment of socio-environmental impacts on the target concepts Quality of Life (QoL) and Urban Ecosystem Services (UES) due to the housing-development of varying densities within housing scenarios. A prototype of a Decision Support System (DSS) integrates both steps of assessment and is presented within this work.

Using the results from the case study of this work - the German City of Essen - this study shows that a strategy of fostered infill development cannot be rejected nor accepted unbiased. The socio-environmental prerequisites of infill development show an overall promising picture and can support the political targets of the German government. In terms of socio-environmental impacts and related concerns as expressed by scientists, a more heterogeneous picture is formed. This study states that socio-environmental impacts are dependent on three aspects: site-characteristics, surroundings and housing densities. And as a matter of fact, infill development needs to be considered as an alternative to greenfield development and is to be fostered in current urban planning.

Zusammenfassung

Socio-environmental impacts of settlement growth under conditions of fostered infill development: a methodological framework for a multicriteria assessment

Der Hintergrund dieser Arbeit ist durch drei aktuelle Hauptdiskussionsfelder charakterisiert: *Erstens*, heute werden noch jeden Tag nahezu 100 Hektar Boden für Siedlungs- und Verkehrszwecke in Anspruch genommen. Der Trend der Flächeninanspruchnahme ist ungebremst und der Verlust natürlicher Ressourcen auf dem Vormarsch. *Zweitens*, ist gleichzeitig ein Paradoxon der Siedlungsentwicklung in zahlreichen Deutschen Agglomerationsräumen feststellbar: Während Planer und Gemeinden unter anhaltend hohem Entwicklungsdruck stehen, der meist innerhalb der Außenentwicklung umgesetzt wird, entstehen in den Innenbereichen immer mehr Brachflächen. Sie resultieren aus sinkenden Bevölkerungszahlen, nicht marktfähigen Wohnbaubeständen sowie dem wirtschaftsstrukturellen Wandel. *Drittens*, der Deutsche Nachhaltigkeitsrat proklamiert Flächensparziele, die die Flächeninanspruchnahme auf 30 ha/d im Jahr 2020 reduzieren sollen. Es gilt die Innenentwicklung zu stärken und in einem Verhältnis von 3:1 gegenüber der Außenentwicklung zu realisieren. Dennoch fürchten Planer und Wissenschaftler eine Verschlechterung der Lebensqualität und der ökologischen Rahmenbedingungen in der Stadt. Auch durch die Bürger werden die Bestrebungen einer kompakten Siedlungsentwicklung äußerst kritisch bewertet, wähen sie doch ihre Lebensqualität in Gefahr. Vor diesem Hintergrund ist das Hauptziel dieser Arbeit, die sozio-ökologischen Bedingungen, unter denen eine nachhaltige und ressourcenschonende Siedlungsentwicklung realisierbar ist, zu analysieren und die entsprechenden Folgewirkungen von Außen- und Innenentwicklung zu bewerten. Hauptbestandteil der Arbeit ist somit die Entwicklung eines theoretisch und methodisch innovativen Konzepts einer zweistufigen Multikriterienanalyse für eine demographie-orientierte und szenariobasierte Bewertung des Landnutzungswandels im Rahmen der Siedlungsentwicklung. Der erste Schritt dieses Konzepts besteht aus der Bewertung der ökologischen und sozialen Rahmenbedingungen und Standortqualitäten („Quality of Place“) von Wohnbaulandpotenzialen und ihren Beitrag zu einer nachhaltigen Siedlungsentwicklung. Er basiert auf einer engen dreijährigen Zusammenarbeit zwischen Planern und Wissenschaftlern im Rahmen eines Forschungsprojekts zur nachhaltigen Siedlungsentwicklung, in der im Rahmen von Testläufen des Bewertungsmodells und Diskussionen planungs- und entscheidungsrelevante Indikatoren extrahiert und entsprechend ihrer Bedeutung gewichtet wurden. Der zweite Schritt des Konzepts ist die Vorortbewertung potentieller Wohnbauflächen gemäß sozio-ökologischer Folgewirkungen in verschiedenen Bebauungsdichten hinsichtlich der Konzepte Lebensqualität („QoL“) und urbane Ökosystemdienstleistungen (UES). Der Prototyp eines Entscheidungsunterstützungswerkzeugs (DSS) wird in dieser Arbeit vorgestellt. Aufbauend auf den Ergebnissen aus der Fallstudie der Stadt Essen zeigt die Arbeit, dass eine Strategie forcierter Innenentwicklung differenziert zu betrachten ist. Die sozio-ökologischen Standortvoraussetzungen zeigen ein klares positives Bild der Innenentwicklungspotenziale und unterstützen die Strategie der Bundesregierung. Hinsichtlich der Folgewirkungen und den erwähnten Bedenken muss jedoch ein wesentlich heterogeneres Bild dargestellt werden. Die Arbeit konstatiert in diesem Zusammenhang, dass sozio-ökologische Folgewirkungen von drei wesentlichen Faktoren abhängen: Charakteristik der Wohnbaufläche, Umgebung und Siedlungsdichte. Die Arbeit macht deutlich, dass Innenentwicklung als reale Alternative zu Außenentwicklung wahrgenommen und in der aktuellen Planung gestärkt werden muss.

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Annotation

During the preparation period of this thesis several scientific papers were prepared and partially published. The following publications are integrated into the thesis and cited within the text:

- Schetke, S. 2008: Quantification of land use changes, modelling of processes and impacts of shrinkage and the question of scale. In: Sánchez-Marrè, M., J. Béjar, J. Comas, A. E. Rizzoli, and G. Guariso (eds.) 2008. Proceedings of the iEMSs Fourth Biennial Meeting: International Congress on Environmental Modelling and Software (iEMSs 2008). pp. 2083-2084
- Schetke, S., and D. Haase 2008: Multi-criteria assessment of socio-environmental aspects in shrinking cities. Experiences from eastern Germany. In: Environmental Impact Assessment Review, Jg. 28, H. 7, S. 483–503.
- Schetke S, T. Kötter, B. Frielinghaus, and D. Weigt. 2009a. Assessment of sustainable land use in Germany – the project FIN.30. In: Urbanistica, H. 138, S. 103–106, 117.
- Schetke S., T. Kötter, and D. Haase. 2009b. Socio-environmental impacts of new housing estates in a shrinking city: fostered infill-development versus urban sprawl - the example Essen. Breuste, J.; Kozová, M. and M. Finka (eds.). European IALE Conference 2009 - 70 years of Landscape Ecology. Bratislava.
- Schetke, S., D. Haase, and J. Breuste. (*): Green space functionality under conditions of uneven urban land use development. Revised for: Special Issue “Assessing the impacts of land use change on transforming regions”. Forthcoming in Land Use Science (2nd issue 2010)
- Schetke, S., T. Kötter, and D. Haase. (**): Socio-environmental impacts of new housing estates under conditions of infill- and suburban development – methodological design for a multicriteria impact assessment. Selected for: PIRO, R., and R. GANSER (ads.) “Urban fringe and rural development patterns of growth and decline - Challenges for Spatial Planning and Sustainable Development” (working title). UPE-book series. Ashgate (London)
- Schetke, S., D. Haase, and T. Kötter. (in preparation): Innovative urban land development – a new methodological design for implementing ecological targets into strategic planning of the City of Essen, Germany. To be submitted in `Landscape Ecology`
- Kötter T., S. Schetke, and B. Frielinghaus 2008. Assessment of Sustainable Land Use within the town planning process. In: Proceedings of the FIG working week Stockholm, 14.-19.06.2008.
- Kötter, T., B. Frielinghaus, S. Schetke, and D. Weigt. 2009a. Intelligente Flächennutzung - Erfassung und Bewertung von Wohnbaulandpotentialen in der Flächennutzungsplanung. In: Flächenmanagement und Bodenordnung, Vol. 71, issue 1/2009: 39–45.
- Kötter, T., D. Weigt, B. Frielinghaus, and S. Schetke 2009b. Nachhaltige Siedlungs- und Flächenentwicklung. Inhaltliche und methodische Aspekte der Erfassung und Bewertung. In: Hepperle, Lenk (Hg.) 2009 – Land Development Strategies: Patterns, Risks, and Responsibilities, pp. 61–83, vdf Hochschulverlag AG, Zurich.

Kötter, T., S. Schetke, B. Frielinghaus, and D. Weigt. accepted. Nachhaltige Wohnbaulandentwicklung - ein Bewertungsrahmen für die Flächennutzungsplanung. In: Lieber, M., and S. Frerichs (eds). DIFU/ BKR Aachen. (Beiträge aus der REFINA-Forschung, 2).

Kötter, T., S. Schetke, B. Frielinghaus, and D. Weigt. accepted. Flächen intelligent nutzen – ein Bewertungsrahmen für ein nachhaltiges Flächenmanagement. In: Libbe, J., and S. Bock (eds.) „Handbuch nachhaltiges Flächenmanagement in Kommunen und Regionen“ (working title). DIFU, Projektübergreifende Begleitung REFINA

Kötter, T., D. Weigt, B. Frielinghaus, and S. Schetke. forthcoming. FIN30 - Flächen intelligent nutzen. Documentation of the BMBF-research project. University of Bonn.

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“All action results from thought, so it is thoughts that matter.” Sai Baba

1. Introduction and Motivation

In Germany, around 100 hectare of greenfield-sites are used for settlement and traffic purposes every day. The trend of land-consumption is unbroken and the loss of natural resources- such as the unrecoverable resource “soil” is still on the rise. As cities and settlements expand, residents need to cope with longer travel distances causing increased nuisance, air pollution and a diminished amount of recreational areas, in return¹.

Despite these trends, we state a *paradox of settlement growth* in many German agglomerations. Whilst planners and communes are under a continuous suburban development pressure, considerable amounts of brownfields and open spaces are emerging in inner urban areas due to a declining population, housing estates not being marketable anymore and due to structural change².

In order to adjust settlement-development - and especially housing-development as a major driver of land-consumption - to a more sustainable, resource-preserving direction and to strengthen the use of existing potentials and capacities, the German Council for Sustainability (2004) promoted a double-track strategy³. On the one hand, it aspires to a quantitative reduction of daily land-consumption of 30 hectare per day in the year 2020. On the other, it fosters an infill development which is considered to be the most suitable mean to actively reduce land-consumption. It strives for a ratio of 3:1 of infill- compared to greenfield development.

Facing these *political targets* which aim at an intensified infill development, both planners and scientists have reasons for serious concern in the course of its socio-environmental effects. On the one hand, ecologists state negative additional ecological effects, as cities are already perceived “as an aggression against the environment”⁴ and suffer from environmental stress. Urbanization processes are significantly altering ecosystem functions and fragment, isolate, and degrade natural habitats.⁵ Comprehensive studies on their ecological impacts are needed⁶. According to WITTIG ET AL. (2008)⁷ “cities consume natural resources”.

On the other hand, residents “aspire to the very opposite of a compact city” and see their quality of life endangered as housing density rises⁸. WILLIAMS (2004a)⁹ states a gap in attitudes to urban living between local planners and residents and critically discusses the demand for an urban renaissance exemplifying England. Moreover, arbitrarily fixed political targets do not provide with tools and strategies to promote sustainable settlement development and do not reveal distinct impacts of

¹ BOCK ET AL. IN DIFU 2008

² KOLL-SCHRETZENMAYR 1999; FRITSCHKE ET AL. IN LANGNER & ENDLICHER (EDS) 2007; SCHETKE & HAASE 2008

³ a.o. DOSCH 2001a

⁴ PRIEGO ET AL. 2008, p.2; DOUGLAS 1983

⁵ Referring to expressions of ALBERTI 2005, p. 169; Note also the very critical review of ecological impacts due to urbanization by PICKETT ET AL. 2001 reflecting on the severe threats but also chances of urbanization processes on the ecosystem

⁶ MC DONNELL ET AL. IN MARZLUFF ET AL. 2008

⁷ p. 691 in MARZLUFF ET AL. 2008

⁸ BREHENEY 1997 cit. In COUCH & KARECHA 2006, p.357

⁹ In RICHARDSON 2004

housing development¹⁰. Moreover, not only the means of infill development, the types of inner urban decongestions and the affected settlement-patterns but also the residential groups who are affected, vary throughout a city and need to be taken into consideration¹¹.

Major target of this study is therefore, to analyze socio-environmental framework-conditions, under which a sustainable and resource-preserving settlement development can be promoted. It is the task of this study to analyze and discuss the most suitable locations for additional housing-development according to socio-environmental framework conditions and to assess the socio-environmental impacts of both infill- and greenfield development according to different housing-densities.

An integral part of this study is dedicated to the theoretical and methodological conception of a Multicriteria Assessment scheme (MCA) which covers both targets: *i*) the analysis of socio-environmental framework-conditions of future housing sites¹² within a city and their contribution to a sustainable settlement-development and *ii*) the execution of an on-site-assessment of direct socio-environmental impacts due to housing-development within different housing densities. The MCA is applied to future housing-sites displayed at the strategic level of a land use plan. To enable a simultaneous assessment of both framework-conditions and impacts, a prototype of a Decision-Support-System (DSS) executed within a Visual-Basic-Interface is presented.

1.1. State of the Art

Three major domains of current urban planning, which form the background of this study and its deriving research-questions, are introduced in the following paragraphs.

Paradox of settlement growth

Traditionally, the ideal of a sparsely built and green city structure in suburbs is highly preferred in terms of favorable living conditions promoting quality of life¹³. Moreover, increasing personal and social wealth and mobility are amongst others driving factors for that^{14,15}. In 2004, the daily land consumption in Germany demanded 115 hectares per day¹⁶. And in the last years, this figure could only be reduced due to economic deficiency and reduced construction of new roads, but not due to significant reduction of land consumption. In spite of a decreasing population in Germany (see fig. 1), no apparent slowing in this trend is visible.

¹⁰ See the critical review on trends of settlement growth of SCHULTZ & DOSCH (2005) reflecting on political strategies and steering instruments in Germany.

¹¹ See also the publications of JENKS ET AL. (1996) and of JENKS & BURGESS (2000) for an exhaustive discussion about the compact city and issues of sustainability.

¹² Within this work the term housing site is described by the German term "Wohnbaufläche" and describes an area of gross building land for housing development displayed in a land use plan.

¹³ see a.o. TYRVÄINEN ET AL. 2007; SCHWEPPE-KRAFT ET AL. 2008; SIEDENTOP 2005

¹⁴ SIEVERTS 2007; CHESHIRE 1995; DOSCH 2001a; EEA 2006

¹⁵ An expansive outline of all driving factors of suburbanization will not be executed. The author refers to current and recent literature on this topic cites within this chapter.

¹⁶ FEDERAL STATISTICAL OFFICE 2005

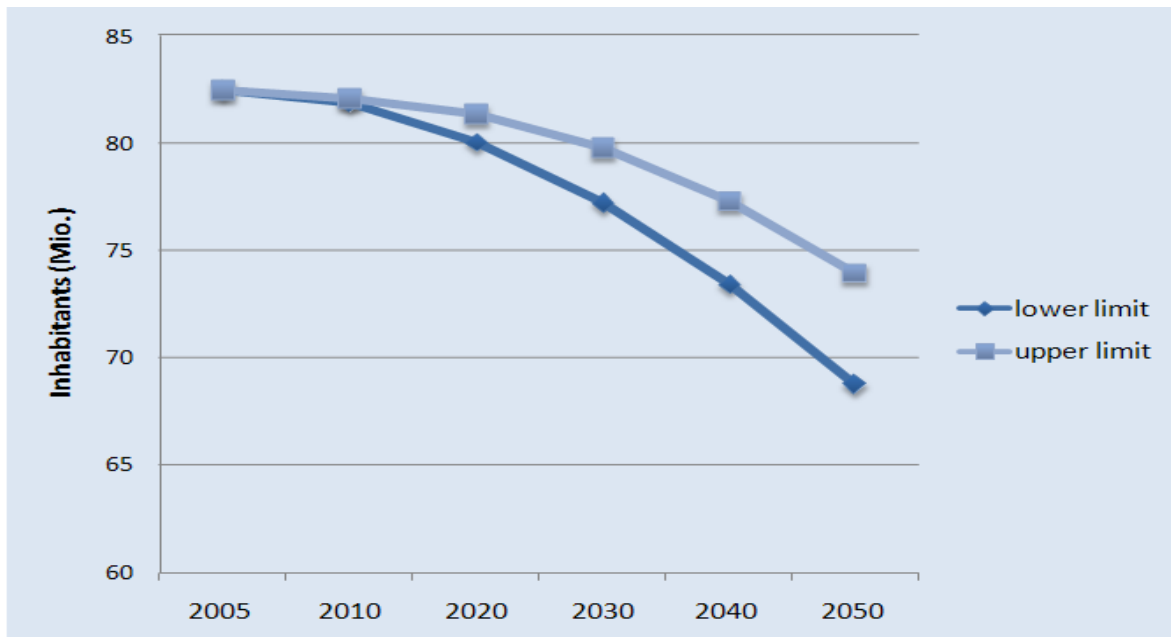


Figure 1 Demographic development in Germany until 2050 illustrates minimum and maximum development-paths (Source: Federal Statistical Office 2006, Layout: author)

Instead, suburban settlement development and urban expansion are still on the rise regardless of the demographic and economic dynamics of the respective core city.

Studies on the dynamics of European cities, discussed in that context, highlight terms such as urban sprawl or urban dispersion¹⁷. TUROK & MYKHENKO (2007, p. 166 discussing VAN DEN BERG ET AL. 1982) highlight three characteristic stages of change and dynamics of settlement development that is “urbanisation (spatial concentration of activity) followed by 'suburbanisation' (decentralisation and decline in the core) and ultimately 'desurbanisation' (dispersal of activity to satellite towns I...I).”¹⁸

Besides spatial dynamics of cities, current demographic trends are imposing significant pressure on planning strategies, not only in Germany. Setting findings of urban growth in a “context of stable or decreasing I...I population”¹⁹ numbers, a simultaneously decreasing compactness in many European cities evokes more and more *paradoxical dynamics of current settlement development*. The EEA (2006, p.8f.) also states that “urban sprawl²⁰ is I...I no longer tied to population growth.” Following HAASE ET AL. (2008, p. 2062) “cities are at the same time sprawling and shrinking, here from arise spatially uneven patterns of development within the borders of an urban region”. Also the BMVBS

¹⁷ KASANKO ET AL. 2006; HAASE & NUISSL 2007

¹⁸ See also studies of CHESHIRE ET AL. 1986 & CHESHIRE 1995 regarding European patterns of growth and decline

¹⁹ KASANKO ET AL. 2006, p. 111

²⁰ “The European Environment Agency (EEA) has described sprawl as the physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas. Sprawl is the leading edge of urban growth and implies little planning control of land subdivision. Development is patchy, scattered and strung out, with a tendency for discontinuity. It leap-frogs over areas, leaving agricultural enclaves. Sprawling cities are the opposite of compact cities — full of empty spaces that indicate the inefficiencies in development and highlight the consequences of uncontrolled growth.” (EEA Report No 10/2006, p. 6).

and BBR (Federal Ministry of Transport, Building and Urban Development and the Federal Office for Building and Regional Planning, 2008) stress the fact that cities and urban development are per se characterized by simultaneous shrinkage and growth.

KÜHN (1998) assumes that the development of cities and regions is apparently determined by contrariness and simultaneity of different and also opposing spatial trends. In many cities and regions, suburban expansion is detached from demographic and economic decline²¹. KASANKO ET AL. (2006) discuss different European trends of population development and the growth of built-up areas “which are not always parallel to each other”²². Advantages of location of the city have been put into perspective facing an economy and companies being independent from locally adjusted knowledge and infrastructure and which move to suburban areas. Especially these dynamics have resulted in a simultaneous shrinkage of urban cores and growth of semi-urban areas tending to merge into each other²³. Also HUTTER (2003); BANZHAF & HÖFER (2008); NUISSL ET AL. (2009) or HAASE ET AL. (2007b) citing HEILIG 2002 state that traditionally many cities and agglomerations in Europe and North America witness simultaneous effects of urban growth and decline.

Asking which one of the processes –shrinkage or growth– is the current problem of urban development in Germany, HESSE & KALTENBRUNNER (2005) suggest an integrated discussion. Both issues are mutually dependent and part of the same medal (p.21 citing JESSEN 1998). Discussed in a context of simultaneous shrinkage and growth, BANZHAF & HÖFER (2008, p.1) state that, inner cities in Germany and other European countries with a compact urban form “are suffering from declining population numbers [see fig.2], residential vacancy and derelict industrial land”²⁴. Consequently “such shrinking cities with expanding spatial land consumption have developed an urban form that is far from being sustainable”²⁵. In this context TUROK & MYKHENKO (2007, p. 166 reflecting on studies of VAN DEN BERG ET AL. 1982) highlight the term “deconcentration” describing “dispersal of activities to satellite towns and rural areas” resulting from suburbanization and a decline in the core²⁶. And HAASE ET AL. (2008, p. 2062) present a concept of shrinkage comprising “features of non-growth, on-going sprawl and upcoming reurbanisation alike”.

But still, a critical reflection of ongoing land consumption with simultaneously decreasing population numbers remains elusive²⁷. A discussion “of urban sprawl in declining contexts [...] has widely remained marginal”²⁸. According to SANDER (2006, p. 3) “the long-standing debate among experts on whether the European city is sustainable at all in view of the spatial dispersion of use structures gains a new aspect in the light of current urban shrinkage.” NUISSL & RINK (2005, p.124) highlight examples

²¹ BBR 2004a; JERING ET AL. 2003 highlighting the development in the new 'Länder' in Germany

²² KASANKO ET AL 2006, p. 128

²³ a.o. KÜHN 1998, p. 497 referring to the German expression 'Siedlungsbrei' (urban pudding); VAILLANT & VONDERSTEIN 2005; FISHMAN in BÖLLING & SIEVERTS 2004

²⁴ see also BMVBS, BBR 2007b; HAASE ET AL. 2007a

²⁵ BANZHAF ET AL. 2009, p. 1676

²⁶ In that context CHESHIRE ET AL (1986, p. 134) speak of decentralization processes of population distribution “with the core losing faster than the hinterland”

²⁷ SIEDENTOP 2004. Here future economic deficits of communes to sustain existing and new infrastructure are meant (see also KOZIOL 2002).

²⁸ COUCH ET AL. 2005, p. 118

from Eastern Germany being especially “instructive as to how urban sprawl can be contained in a context of decline—an issue that will become increasingly relevant in other parts of Europe”. Here, urban sprawl in declining areas is less determined by market forces than by local policies. COUCH ET AL. (2005) speak of “a zero-sum-game in which new areas are developed at the expense of existing urban quarters”²⁹ as another specific characteristic of those areas. SIEDENTOP & FINA (2008) introduce the term “excessive sprawl” with decreasing annual population numbers and remaining growth of urbanized areas (p. 4). They distinguish it from the known process of sprawl under conditions of urban growth (“growth sprawl”, see fig. 2).

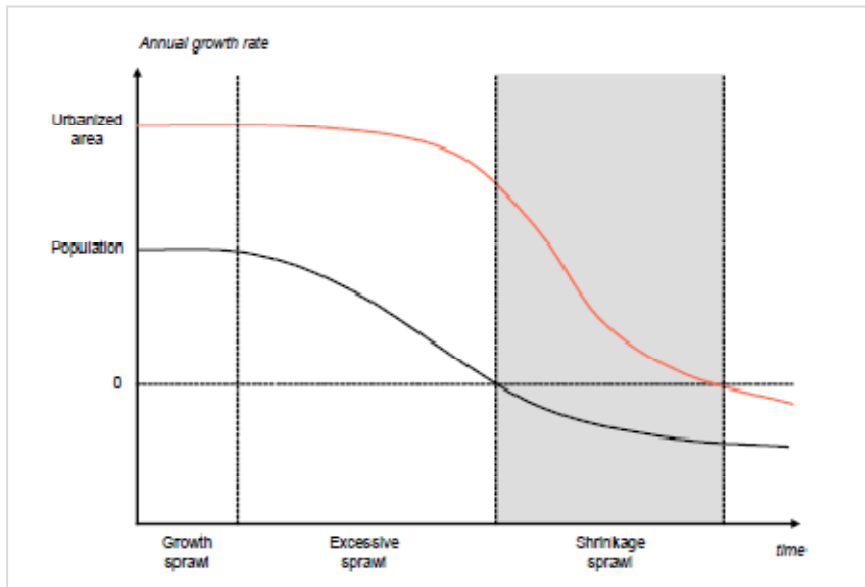


Figure 2 Patterns of urban sprawl (Siedentop & Fina 2008, p. 5)

Looking into the future, MÜLLER & SIEDENTOP (2004, p. 19) state that “growth and shrinkage will also be experienced side by side within agglomerations”. They critically reflect on a possible slowing trend of suburbanization and dispersion compared to the mid 1990ies under conditions of demographic decline leading to the more extreme pattern of “shrinkage sprawl” (see fig. 2 and 3). Also HAASE ET AL. (2007a, p. 335) mention “remaining trends in sprawling land (use) development such as land consumption around cities” in the context of “demographic change, individualization and related changes in housing preferences combined with a simultaneous rise in the disproportion of existing supply of urban housing”³⁰.

²⁹ COUCH ET AL. 2005, p. 118

³⁰ HAASE ET AL. 2007a, p. 334

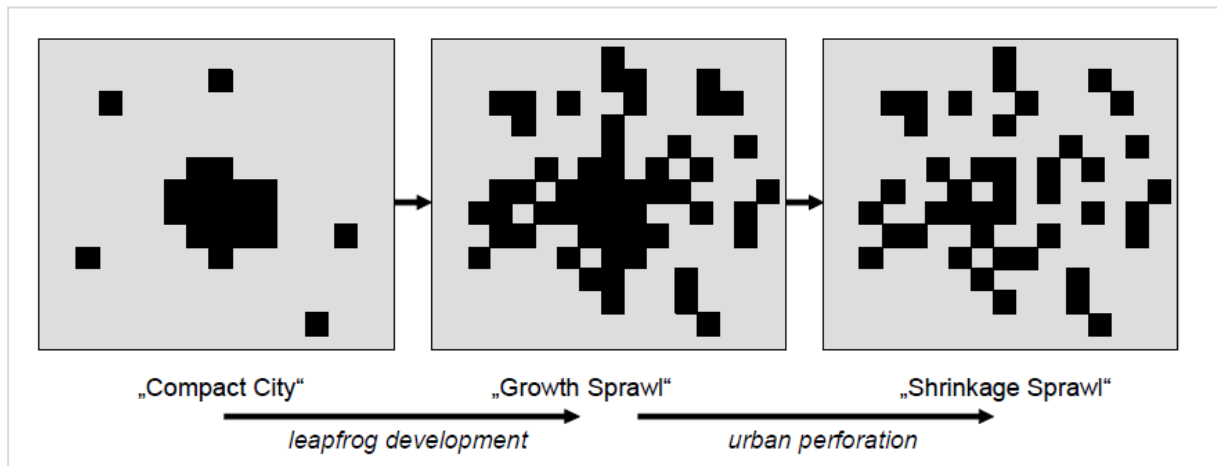


Figure 3 Patterns of urban sprawl 2 (SIEDENTOP & FINA 2008, p. 5).

Political targets to steer settlement growth

The preceding paragraphs doubtlessly highlighted not only the severity of current settlement development. But also the independency of urban dispersion and settlement growth with processes of growth and shrinkage of the respective core city was discussed. We have also learnt that these processes do not only affect German cities.

As a matter of fact, decreasing population numbers, low birth rates, longer life expectancy, changing family structures and forms of living together “are leading to an ever more differentiated demand for land and residential, commercial and industrial buildings”³¹. This trend is criticised and limiting measures are needed, because of the major impacts that are “evident in increased energy, land and soil consumption”³². To realize significant changes in German settlement development towards the principles of sustainability³³, two targets fostering reduced land consumption and a resource-preserving settlement development were elaborated by the German Council of Sustainability³⁴. A *quantitative target* aiming at a reduction of current demand of land for settlement purposes of 106 hectare per day (year 2006) towards 30 hectare per day in 2020 (see fig. 4).

But not only can an effective reduction of land consumption lead to a sustainable settlement development. Also means of land-recycling such as brownfield redevelopment³⁵ and high-quality densification of housing are on top of the agenda of the Federal Government’s Sustainability Policy.

³¹ BOCK ET AL. in DIFU 2008, p. 7

³² EEA 2006, p. 5

³³ See a.o. HAASE 2009 presenting an overview about recent studies on social and ecological impacts of ongoing urban sprawl.

³⁴ See publications of the German Government and the associated research initiative REFINA of the German Ministry for Education and Research at www.difu.de; <http://www.refina-info.de>, <http://www.fona.de/de/7039> (Ministry of Research and Education); www.bbr.bund.de and also associated authors (a.o.) discussing the 30-ha –goal from various perspectives: HESSE & KALTENBRUNNER 2005; HAASE & NUISSL 2007; NUISSL ET AL. 2009; DOSCH 2001b; SIEDENTOP 2001; BRANDTL ET AL. 2009; KÖTTER ET AL. 2009a, JERING ET AL. 2003; BACHMANN 2005; SIEGEL 2005.

³⁵ See e.g. THOMAS 2002 highlighting brownfield redevelopment as core strategy for a sustainable land use in Michigan, USA.

Retention of open spaces and recreation areas as well as renovation of existing housing stocks, land recycling and reduction of commuter travel are major issues dealt with in achieving the above mentioned targets³⁶.

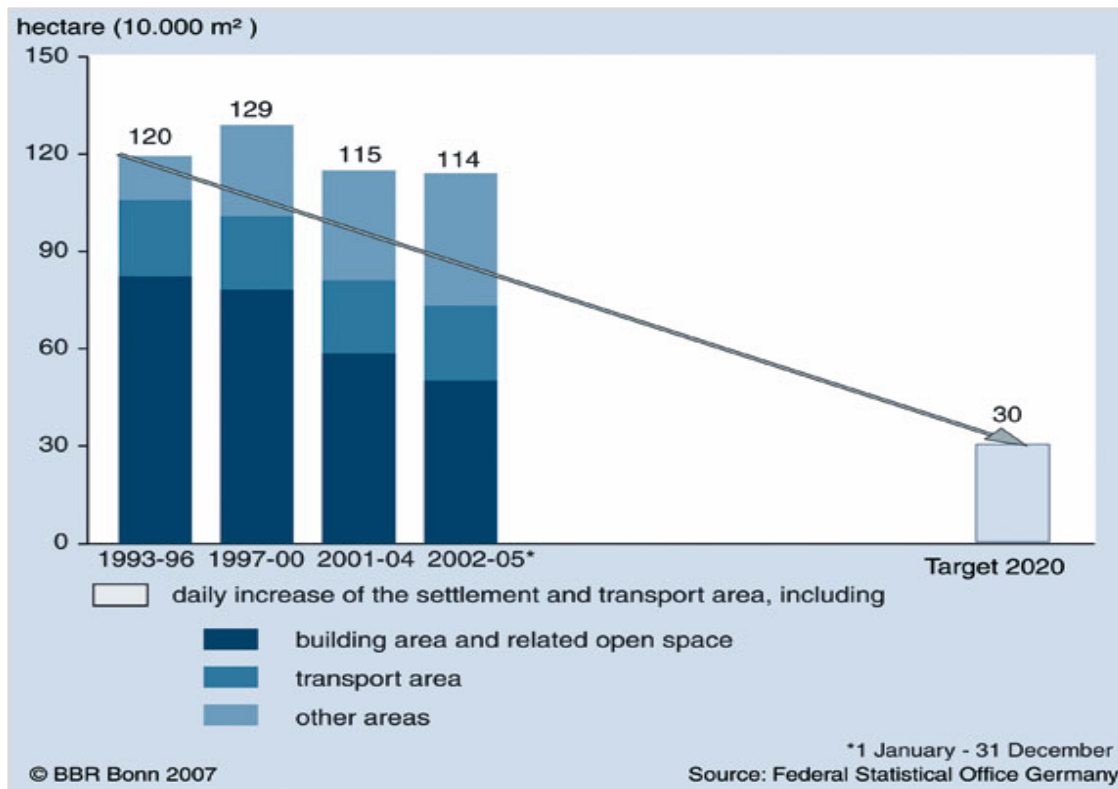


Figure 4 Trend of land consumption in Germany and a reduction to 30ha/d in 2020 (www.refina-info.de/en)

Here a *quality target* fostering infill versus suburban greenfield development at the rate of 3:1³⁷ was developed to achieve efficiency and quality of land use³⁸.

³⁶ BOCK ET AL. in DIFU 2008

³⁷ GERMAN COUNCIL FOR SUSTAINABLE DEVELOPMENT 2004; BUNDESREGIERUNG/ FEDERAL GERMAN GOVERNMENT 2008

³⁸ a.o. Progress Report of current German National Sustainability Strategy of the BUNDESREGIERUNG/ FEDERAL GERMAN GOVERNMENT 2008; SIEDENTOP 2004, JERING ET AL. 2002; SCHWEPPE-KRAFT ET AL. 2008; KRAMPULZ 2005

Concerns

Both the *paradox of current settlement growth* and *political ambitions* to smooth this extreme spatial development of urban sprawl and land consumption not only evoke chances and paths to finally achieve this somewhat blurry state of urban planning called “sustainability”. Despite a broad consensus about the negative social and ecological implications of ongoing urban sprawl on the one side, more reserved tendencies facing a fostered infill development as a means to promote a sustainable and resource-protecting settlement development also need to be taken into account. Political ambitions to strengthen infill development such as the 3:1 ratio of infill and greenfield development are without doubt a reasonable direction to adjust settlement development. But still, its executive measures and effects have to be assessed critically against ecological and social concerns. These concerns will be outlined within the next paragraphs.³⁹

Ecological concerns: PRIEGO ET AL. (2008, p. 2) state that “cities have traditionally been perceived as an aggression against the environment”⁴⁰ and that urban growth “has profoundly transformed the landscapes in recent decades”. In doing so, profound negative impacts on surrounding ecosystems cannot be excluded. According to these notions, cities are suffering from an increasing deficit of green spaces and habitats. Green spaces and recreational areas are a precious good within the urbanised world and a resource to preserve and enlarge, if possible⁴¹. According to DE RIDDER ET AL (2004), cities are suffering from environmental stress. “...Further densification...[is]...already I...I associated with a range of problems ... [such as]...lack of public and green space and environmental degradation.”^{42, 43}

Following these statements, also PAULEIT ET AL. (2005) critically reflect on both infill development and suburban growth taking into account ecological impacts. The sprawl of low-density settlements is leading to environmentally inefficient settlement patterns and to “negative impacts on the surrounding countryside”⁴⁴. In most cases, infill development is the only way for communes to reduce their land consumption⁴⁵. But despite the fact that “the compaction of existing settlements has therefore been suggested as a strategy to counter these trends”⁴⁶, negative ecological impacts of a fostered infill development are suspected⁴⁷. “However, this may lead to the loss of informal open

³⁹ Significant insights into a critical and international discussion of multidimensional concerns on urban compaction are given by JENKS ET AL. (1996), JENKS & BURGESS (2000) and WILLIAMS ET AL. (2001). See also a.o. WESTPHAL (2008) for a concise insight and BREHENY (1997) stressing the assessment of urban compaction against three types of test covering both the ecological and social dimension: “veracity, feasibility and acceptability” (p. 209).

⁴⁰ Here, PRIEGO ET AL. 2008 also refer to the work of DOUGLAS 1983

⁴¹ SCHETKE ET AL. *

⁴² BURGESS in JENKS & BURGESS, 2000,p.15 referring to HARDOY ET AL. 1990; see also HOWLEY 2009

⁴³ Note also SIEDENTOP (2001, 2005 citing KOWARIK 1992) mentioning a positive ecological connotation of infill development on the side of urban planners and positive scientific connotations of urban settlements providing more ecological diversity than monostructural farmlands (SIEDENTOP 2005 citing KOWARIK 1992). He also discusses heterogeneous social effects due to measurements of the infill and stresses the point that infill development can overcome deficits in the urban structure and mean a clear benefit for living surroundings and QoL.

⁴⁴ PAULEIT ET AL. 2005, p. 295; ANTROP 2000

⁴⁵ BANZHAF & HÖFER 2008

⁴⁶ PAULEIT ET AL. 2005, p. 295

⁴⁷ a.o. MC KINNEY 2002; WHITFORD ET AL. 2001; BREHENY IN JENKS ET AL. 1996

space within cities which can not only be a valuable resource for recreation but also provide important habitats for wildlife and enhance environmental services, for instance the infiltration of rainwater⁴⁸. Moreover, environmental consequences such as a modified hydrological regime of “increased surface runoff and pollutant emissions into the atmosphere, water and soil”⁴⁹, the loss of open spaces and negative outcomes for local climate are feared⁵⁰. Following TROY (in JENKS ET AL. 1996), ongoing compaction can also lead to an unsustainable urban development and negative ecological effects in terms of air pollution, reduced green spaces or a decrease of habitats for birds and other native fauna.⁵¹

Still, concrete outcomes of settlement growth remain elusive and “...studies that value multiple ecosystem functions simultaneously and that capture the “before and after” states during environmental change are rare”⁵². This study aims at filling this gap with a GIS-based and scenario steered approach of socio-environmental impacts due to settlement growth using cadastral data for the calculated alteration of land use and its consequences.

Social concerns: An extension of the urban fabric following a strategy of fostered infill development is often seen in accordance with a decrease of residents’ QoL and a serious impact on existing living surroundings comes along⁵³.

The acceptance of infill development is critically discussed among planners and scientists, as in most cases, local residents strongly disapprove of the infill of the current city structure and higher densities. This highlights the gap in values between local residents’ preferences and urban policies⁵⁴. Residents fear negative changes of their own quality of life (“QoL”) and a loss of their familiar living surroundings⁵⁵. Here, very subjective aspects of QoL and personal well-being come to pass and influence the acceptance of infill development. Factors such as landscape perception and ideals of living surroundings are essential parts of QoL-studies. Already SEIK (2001, p.1) stated in an issue of “Cities” exclusively dedicated to QoL in urban areas that “it is inevitable that as cities move forward in to the 21st century, urban QoL-studies will increasingly become important tools for planning and managing liveable, viable and sustainable cities.”

⁴⁸ PAULEIT ET AL. 2005, p. 295

⁴⁹ PAULEIT ET AL. 2005 p. 296; see also various authors on this topics in MARZLUFF ET AL. 2008 and the studies of ALBERTI 2005, 2009

⁵⁰ see also KÜHN 1998

⁵¹ See also ARLT ET AL. 2005

⁵² GRÉT-REGAMEY ET AL. 2008, p. 198

⁵³ a.o. BANZHAF & HÖFER 2008; PRIEGO ET AL. 2008; SIEDENTOP 2005, TYRVÄINEN ET AL. 2007, BREHENY IN JENKS ET AL. 1996

The author refers also to the dissertation of WESTPAHL (2008) which gives a concise insight into the multidimensional discussion about increasing densities in inner urban areas. In this context HUTTER ET AL. (2002) stress the issue of an adequate built density.

⁵⁴ Still, awareness about the positive impacts of e.g. brownfield redevelopment is on the rise amongst planners by holding “enormous potential for “greening” city environments, through the implementation of parks, playgrounds, trails, greenways, and other open spaces” (DE SOUSA 2003, p.181). ZERBE ET AL. (2003, p. 139) discuss “a new type of environment with species compositions and habitats peculiar to urban-industrial areas”. Also MCKINNEY (2002) discusses a necessary and evident distinction between species composition along a urban-rural gradient various challenges of urban growth and harms on native ecosystems.

⁵⁵ See studies of eg. SCHWEPPE-KRAFT ET AL. (2008) highlighting necessary ecological and aesthetical up valuation measures in accordance to infill development in order to sustain QoL. Also compare HOWLEY ET AL. (2009).

Aside of the control of urban sprawl being one of the key issues urban planners have to deal with in many countries, doubts have been raised about the feasibility and acceptance of an urban compaction⁵⁶. According to BREHENY (1997)⁵⁷ “people aspire to the very opposite of the compact city...there is a clear clash between the high-density aspirations of the compactionists and the desires of local communities to protect their quality of life”. Also Williams et al. (1996) highlight the issue of “local acceptability”⁵⁸ as a major concern to be taken into account for e.g. UK strategies for sustainability going hand in hand with urban intensification.

TYRVÄINEN ET AL. (2007, p. 9) highlight terms such as “peace and quiet”, “freedom and space”, or possibilities for recreation determining residents’ QoL and the livability of a city⁵⁹. “Residents appreciated relatively sparsely built and green city structure in suburbs, and infilling the existing housing areas was strongly disapproved. The infill of the current city structure is most strongly opposed [...]”⁶⁰ by selected residential groups. According to MAAS ET AL. (2006, p. 587), increasing urbanization and a planning “policy of densification [cause that], more people face the prospect of living in residential environments with fewer green resources.”

This short outline shows that urban compaction such as infill development not only holds significant ecological impacts, but also implies social impacts depending on urban density.

1.2. Deriving Research-Questions

The previous paragraphs have shown that the paradox of settlement growth and the demand to reduce land-consumption are major challenges of current planning policy. But still, beside arbitrarily fixed political targets, concrete planning strategies and means to adjust settlement development according to the goals of sustainability remain elusive⁶¹. Here, quantitative benchmarks alone cannot help to reduce land-consumption. Moreover, communal land use planning needs tools to analyze its procedural methods assessing the contributions of new building land as to whether the goals of sustainability are met. In this context, the essential hypothesis of this study can be formulated:

“The success of a strategy of fostered infill development cannot be generalized. Both the suitability of a site for housing purposes and its socio-environmental impacts at local level – due to either infill or greenfield development – are significantly determined by individual prerequisites and framework-conditions.”

⁵⁶ COUCH & KARECHA 2006, WILLIAMS 2004b, HARDOY ET AL. cited in JENKS & BURGESS (eds) 2000, p.15

⁵⁷ cit. in COUCH & KARECHA 2006, p. 357

⁵⁸ WILLIAMS ET AL., p. 85 IN JENKS ET AL. 1996

⁵⁹ See also TUROK & MYKHENKO 2007 highlighting household preferences as drivers of deconcentration of population for more spacious lifestyles

⁶⁰ TYRVÄINEN ET AL. 2007, p. 9

⁶¹ Research-programs, such as the Refina-Program of the German Ministry for Education and Research with a budget of more than 20 Mio. € holding 45 single research-projects elaborating management and planning strategies to implement political targets to foster sustainable settlement-growth, speak a clear language of the necessity to translate political targets into planning strategies and actions.

Following that, two research-questions will be posed in order to launch the methodological approach of a multicriteria-assessment (MCA) analyzing the benefits, threats and socio-environmental impacts of settlement-growth in both the urban fringe and core:

1. Which socio-environmental prerequisites exist in inner-urban and suburban areas determining the suitability of site (“QoP”) for housing purposes against the demand for sustainable and resource-preserving settlement-development? How can Quality of Place (QoP) be operationalized by indicators applicable and understandable for both planners and scientists?

Previous research on socio-environmental impacts of housing demolition has shown in reverse that a reduction of the urban fabric does not *per se* mean an improvement of both urban ecological conditions and residents’ QoL⁶². The ecological performance of cities is highly dependent on existing structures and means of settlement growth⁶³. We have to carefully focus on prerequisites, preconditions and socio-environmental circumstances accompanying each change – both reduction and expansion – of the urban fabric. The compaction of existing urban cores is frequently seen as *the* means to reduce land consumption and to provide sustainable settlement development, on the one side. But it also implies significant negative socio-environmental impacts and concerns, on the other. Therefore this study poses the question:

2. What socio-environmental impacts can be stated due to infill-and greenfield development? And can we *per se* state positive or negative effects on Quality of Life (“QoL”) and Urban Ecosystem Services (“UES”) of a strategy of fostered infill development or do we need to consider additional external effects?

1.3. Methods and Structure of the Study

To answer the research-questions, an integral innovative part of this study is dedicated to the theoretical and methodological conception of a Multicriteria Assessment –scheme (MCA) which covers two targets: *i)* the analysis of socio-environmental framework-conditions of future housing sites of a city displayed in a land use plan and their contribution to a sustainable settlement development and *ii)* the assessment of direct socio-environmental impacts due to housing-development at those sites. Figure 5 outlines the major components of the approach and sketches the prerequisites for sustainable urban planning and housing development (QoP) and the socio-environmental impacts of the same due to modifications of green land uses and structures on QoL and UES.

⁶² SCHETKE & HAASE 2008

⁶³ a.o. DE SOUSA 2003, ZERBE ET AL. 2003; MCKINNEY 2002; WHITFORD ET AL. 2001

Firstly, the concept of “Quality of Place”⁶⁴ (QoP) is used to assess the socio-environmental prerequisites of future housing sites with an emphasis on reduced use of natural resources and promotion of equitable access to facilities of social infrastructure. The operationalization of the concept of QoP and its translation into a set of indicators is an innovative approach of this study. It helps to translate arbitrarily fixed political targets to reduce land consumption (as presented above) into concrete and comprehensive ways and to implement the vision of sustainable settlement development into planning strategies. To join the multifarious definitions of QoP with the somewhat blurry term “sustainability” recent findings from the author’s current research embedded into the project FIN.30⁶⁵ at the University of Bonn⁶⁶ were adopted for operationalization⁶⁷. The indicator-set was consensually elaborated and tested during stakeholder workshops with urban planners of three partner cities in North Rhine-Westphalia⁶⁸. Its complexity, structure and comprehensibility are adjusted to the demands of communal planners.

Secondly, the concepts of Quality of Life⁶⁹ (QoL) and Urban Ecosystem Services (UES) are used as target-systems to assess the socio-environmental impacts of settlement-growth. Answers on frequently expressed socio-environmental concerns on both infill- and greenfield development will be given. This impact-assessment is executed within different housing-scenarios with varying urban structure types and different housing-densities. The concepts of QoL and the broad concept of Ecosystem Services (ESS)⁷⁰ are discussed in scientific literature beside each other. Despite a common-sense of their interrelations and mutual dependencies⁷¹ valuable theoretical approaches and indicator-sets to link the two concepts remain elusive. This study strives for filling the gap of missing linkage. Therefore, a major innovative contribution of this study is to provide with a sound theoretical approach elaborating the prominent role of urban green spaces as binding elements of both concepts. An indicator-set, which integratively depicts both concepts and enables a quantifiable scenario-steered impact-assessment⁷² will be developed.

In this context, this study introduces the term “Urban Ecosystem Services” (UES). UES only refer to the urban ecosystem and the services that are provided by mainly urban green⁷³ and are regarded as a subset of the broad range of the above mentioned ESS. In doing so, a novel classification of UES uniquely related to the urban environment with a close relationship to residents’ QoL will be

⁶⁴ According to JIRON & FADDA 2000; FLORIDA 2000; with modified operationalization following KÖTTER ET AL. 2009a & SCHETKE ET AL. 2009a

⁶⁵ The project FIN.30 is adjusted to the research initiative REFINA (see www.refina-info.de/en) and funded by the German Ministry of Education and Research (BMBF). Major target of FIN.30 is the conception of a MCA-scheme promoting analysis, decision-making and monitoring of land use as the central part in coping with sustainable spatial development.

⁶⁶ Institute of Geodesy and Geoinformation, Department of Urban Planning and Real Estate Management

⁶⁷ SCHETKE ET AL. 2009a; KÖTTER ET AL. 2009a

⁶⁸ Essen, Euskirchen and Erftstadt

⁶⁹ As defined by FADDA & JIRON 1999 or SANTOS & MARTINS 2007

⁷⁰ As defined according to concepts of COSTANZA ET AL 1997 referring to ESS, the author introduces the term “Urban Ecosystem Services” to which this study will refer to. Get closer insights from a recent publication of SCHETKE ET AL*.

⁷¹ a.o. BOLUND & HUNHAMMAR 1999

⁷² SCHETKE ET AL.*

⁷³ See also first studies on ecosystem services in urban areas from BOLUND & HUNHAMMAR (1999) individually exemplified in the area of Stockholm.

elaborated. A new approach of linking QoL and UES using urban green as a center of attention resulting from this classification will be presented.

The conceptual approach of the MCA will be applied using the City of Essen located in the German Ruhr Area as a pilot case-study. Essen with its past as a city of heavy industry has been shrinking during the last years. However, it still provides an enormous amount of industrial brownfields and has to cope with a very challenging greenfield development, as cities in the Ruhr Area tend to merge into each other. As housing-development is a major driver of land consumption, future housing sites displayed in a draft of a new regional land use plan (status 2008) of the City of Essen will be subject to both assessment of socio-environmental prerequisites and scenario-based impact-assessment.

To adjust the formulated research-questions to a sound theoretical basis, the following paragraphs will give an insight into the major target concepts of this work and their meaning for the conceptualization of a MCA assessing both the framework-conditions (step 1) and impacts (step 2) for and of settlement development. Chapter 3 presents the methodological design of the study.

Chapter 4 is dedicated to the presentation of the results of both potential-analysis following the concept of QoP and scenario-steered impact-assessment against the target-systems QoL and UES. All results will be discussed in chapter 5 and a typology of future housing-sites according to socio-environmental prerequisites and impacts will be presented. Major conclusions from this work are presented in chapter 6. Chapter 7 is then dedicated to an outlook presenting suggestions for and demands of further research.

2. Theory

Despite a decreasing population in many German agglomerations, urban expansion and spatial development pressure are the “driving forces of an enormous consumption of land, the usage of natural resources and the loss of ecosystem services I...I”⁷⁴. Politicians and urban planners have to focus on infill and more compact settlement development in order to realize the enormous target of a sustainable settlement development and a reduction of land consumption. This has to include re-densification of built-up areas and brownfield (re-)development⁷⁵. Besides, practical strategies to implement arbitrarily fixed political goals to reduce land consumption remain elusive. On top of this, criteria determining a Quality of Place (QoP) of new housing sites to enhance a resource-protecting and sustainable settlement growth are needed and “the debate on spatial models for sustainable urban development [is] often little substantiated by facts”⁷⁶. Despite obvious socio-environmental negative effects of suburban settlement growth, positive socio-environmental impacts of infill development are still doubted⁷⁷. Its impacts on residents’ Quality of Life (QoL) and on Urban Ecosystem Services (UES) are uncharted terrain.

The major part of this chapter presents the prominent theoretical concepts of this study (chapter 2.1-2.4). They are used to *first*, innovatively provide an assessment of future housing-sites against the targets of sustainable and resource-preserving settlement development (QoP) and *second* to enable a scenario-steered socio-environmental impact assessment. For this second step, the focus will lie on the concepts of QoL and UES to operationalize a socio-environmental impact assessment. Moreover, bridging the gap between those two complementary concepts is one of the central innovative parts of this study and will be outlined in chapter 2.5.

2.1. Quality of Place (QoP)

The term “Quality of Place (QOP) is introduced in this study to support an assessment of socio-environmental framework-conditions and prerequisites. It answers research-question 1 and assesses the contribution of future housing sites to a sustainable and resource-preserving settlement development. The introduced political targets of the German Council for Sustainable Development to reduce land consumption evoke the impression of being fixed arbitrarily. These targets lack any approaches of a practical realization within land use planning. Therefore an operationalization of reduced land consumption is inevitable to develop strategies and methods to assess future housing sites within a city and to develop adequate planning strategies.

QoP has been discussed in recent literature in many different ways and under varying premises. It appears as an umbrella-term covering aspects such as RICHARD FLORIDA’s (2000) quality of a place as

⁷⁴ SCHETKE ET AL. 2009a, p. 103

⁷⁵ KÖTTER & WEIGT 2006

⁷⁶ PAULEIT ET AL. 2005, p. 295f.

⁷⁷ TYRVÄINEN ET AL. 2007. Note also the books “The compact city” of JENKS, BURTON & WILLIAMS 1996 and “Compact Cities” of JENKS & BURGESS 2000 providing a sound compilation of critical research on the sustainability of compact urban development focusing on both the social and ecological dimension.

places, cities, regions being attractive to live and work in due to job opportunities, economic factors or lifestyle amenities within the new economy. “Quality-of-place - particularly natural, recreational and lifestyle amenities – is absolutely vital in attracting knowledge workers and in supporting leading-edge high technology firms and industries. Knowledge workers essentially balance economic opportunity and lifestyle in selecting a place to live and work”⁷⁸. He considers QoP-strategies as essential elements of regional economic development strategies to provide attractiveness by enhancing economical, social and ecological amenities providing a certain QoL.

JÍRON & FADDA (2000) follow this concept and define QoP as “the physical environment and surroundings [that] play a deterministic role in one’s QoL” (p.3). They not only highlight closer connections to the term QoL, but also define the ecological, social and economic side of QoP. In their sense, QoP-studies are based on aggregated governmental statistics and are used “to measure the conditions of places, rank them and infer that the highly rated cities offer high QoL” (p.3).

In this study, the term QoP is used according to these definitions and narrows the view by providing an operationalization of the terms “sustainable and resource-protecting settlement development”. It focuses innovatively on socio-environmental prerequisites that a housing site has to provide in order to enable the defined development pathways of settlement development. The elaborated operationalization of QoP and translation into suitable indicators within this study provides innovative planning- and assessment-approaches for a resource-preserving settlement development and intelligent land use.⁷⁹ Sites, that provide the preservation of natural resources and a suitable provision of social and infrastructural amenities, score high in providing QoP. These sites promote a sustainable settlement development.⁸⁰

Detailed ecological determinants of QoP are determined as the preservation of existing natural resources and landscape functions as well as environmental risk factors (e.g. flood risk), which influence QoP and the suitability of a place for living.⁸¹ The assessment in terms of social suitability of future housing sites focuses on the technical and nature-oriented quality of living surroundings and human well-being. Availability and accessibility of adequate recreational facilities as well as social and technical infrastructure, are of central interest. A second focus is put on the attractiveness of living surroundings in terms of noise exposure and accessibility of recreational areas⁸².

The associated indicators used for QoP-assessment will be presented in chapter 3.

2.1.1. Settlement-development and Obstacles for Sustainability

If we want to learn about the possibilities to steer and assess sustainable settlement development, becoming aware of its obstacles and the major socio-environmental impacts of land use planning

⁷⁸ FLORIDA 2000, p. 5

⁷⁹ SCHETKE ET AL. 2009a; SCHETKE ET AL. (in prep.); KÖTTER ET AL. 2009a,b

⁸⁰ KÖTTER ET AL. 2009a; SCHETKE ET AL. 2009a

⁸¹ SCHETKE ET AL. (in prep.)

⁸² KÖTTER ET AL. 2009a; SCHETKE ET AL. 2009a

(see tab.1) and specifically of urban sprawl and land consumption⁸³ is inevitable. They are bridging factors for translating sustainability-issues into suitable indicators and assessment-procedures. Moreover, the ultimate scale for analysis has to be chosen to adjust land use planning to the goals of sustainability.

Table 1: Socio-environmental impacts of urban sprawl (Modified according to KRAMPULZ 2005; PAULEIT ET AL 2005, GAINSBOROUGH 2002; HAASE 2009; EPA 2001, ALBERTI 2005, 2009, MARZLUFF ET AL. 2008^{84,85})

Ecological Consequences	Social Consequences
Limitation of soil functions: - Seeping and flood-protection - Buffer-function - Increased surface runoff	Social Segregation due to suburbanization - Segregation of unprivileged groups - Danger of inner-urban desolation
Loss of connected open spaces: - Destruction of habitats und limitation of biodiversity - Reduction of recreational function - Disturbance of natural scenery	Reduced financial power of core-cities - Reduction of local quality of life due to loss of central facilities and cultural infrastructure
Implication of additional individual traffic: - Additional emissions of CO ₂ and noise - Increasing pollutant emissions into the water, soil and atmosphere	Deficient provision of daily needs for an aging society in suburban areas - Long distances - Insufficient infrastructure
Loss of fertile soils	

As mentioned in chapter 2.1 current political targets to reduce land consumption only provide arbitrarily fixed benchmarks. But concrete planning strategies remain elusive. Moreover, scientists criticize that a quantitative benchmark alone such as the 30-ha-goal suggests the minimization of long-term threats and downplays obvious ecological concerns. These concerns focus on the fragmentation of landscape elements, a reduction of biodiversity and also socio-economical nuisances such as rising investive and follow-up costs for existing and additional infrastructure.⁸⁶

Here, the level of preparatory land use planning (“Vorbereitende Bauleitplanung”) and the land use plan as its tool, offers a suitable opportunity and a strategic level to adjust future settlement development to a sustainable development and foster qualitative approaches for assessment. With around 38 % of total daily land consumption⁸⁷, the development of new residential land is a major driver of these effects. Socio-environmental prerequisites contributing to the QoP of future housing sites displayed in a land use plan can be assessed at an early stage.

⁸³ Here, HAASE (2009) recently delivered a compilation of major social and ecological concerns related to urban sprawl as expressed within recent studies. See also UNITED STATES ENVIRONMENTAL PROTECTION AGENCY 2001 “Our built and natural environments.”

⁸⁴ ALBERTI (2005, 2009) and MARZLUFF ET AL. (2008) impressively highlight the interconnections between landscape pattern, ecological processes and the impacts of urbanization. In doing so, they use the term “urbanization processes” and the modification of natural habitats in general. Here, urban sprawl needs to be regarded as the a major driver of these patterns.

⁸⁵ See also HAASE & NUISSL (2007) or NUISSL ET AL. (2009) for a concise literature- overview of socio-environmental effects of urban sprawl and compare also the multidimensional impacts summarized by SIEDENTOP (2005)

⁸⁶ SIEDENTOP 2002; KÖTTER ET AL. 2009a

⁸⁷ JERING ET AL. 2003, p. 3

Sites which enhance an efficient and resource-preserving settlement growth counting for both natural and social resources will achieve best scores in QoP. Whilst natural resources are to be sustained and preserved, resources of social infrastructure are to be used to capacity. In doing so settlement growth should focus on the use of already existing infrastructures, enhancing compact settlement growth, avoiding longer distances as well as increased individual traffic and limiting parallel infrastructures and rising costs.

Accordingly, the following system is suggested: Sites promoting a valuable contribution to sustainable settlement development within the assessment are suggested to be bequeathed to binding land use planning (“Verbindliche Bauleitplanung”) and shall be covered with residential houses. Sites failing to provide a suitable QoP are not suggested to proceed to binding land use planning, as they counteract a sustainable settlement development. Figure 6 below outlines an insight into the system of land use planning and the possibilities to strategically influence its adjustment towards sustainable settlement development.

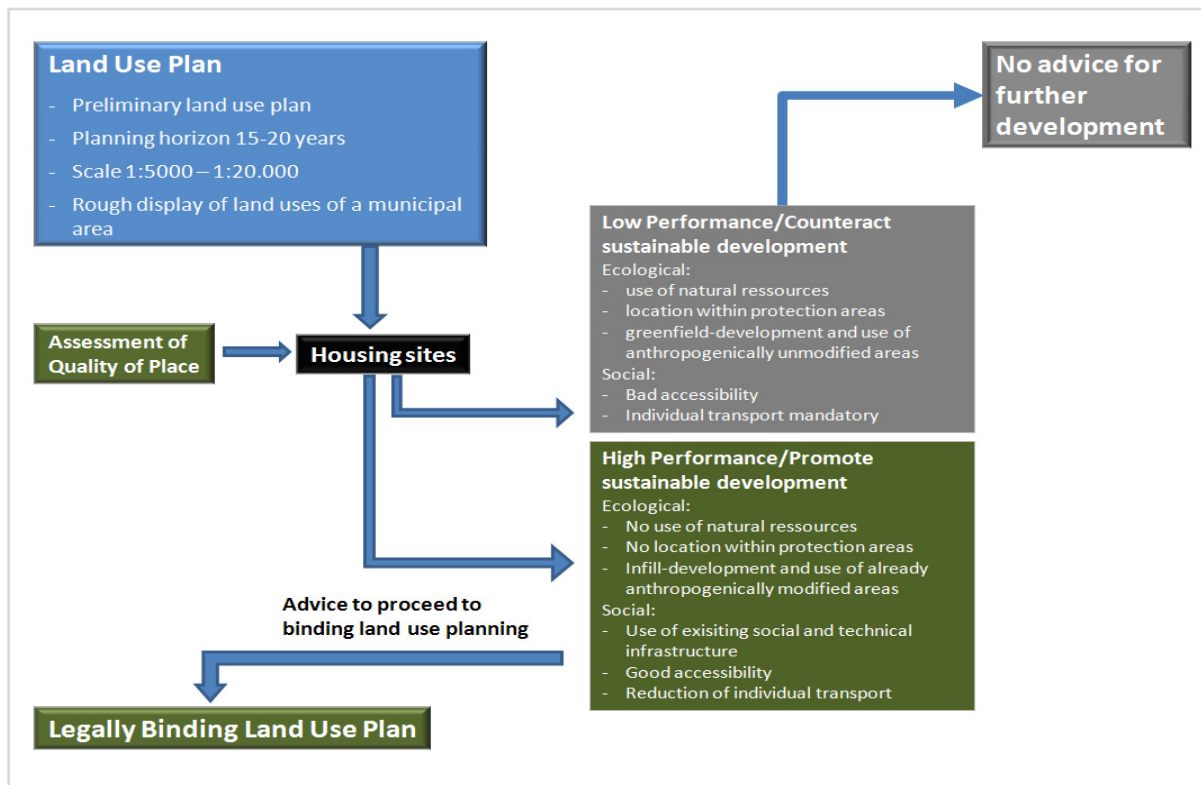


Figure 6 Principle of land use planning whilst integrating QoP-assessment (author’s draft)

The concept of QoP was introduced to provide an analysis of overall socio-environmental framework-conditions within a city and the contribution of potential housing sites displayed in a land use plan due to their respective location. The following impact-assessment as conducted within this study as the second step of the MCA is dedicated to the special role of urban green spaces to its target-systems QoL and UES. According to current literature, urban green spaces have significant impacts on both and act as a linking element.

2.2. Quality of Life (QoL)

In answering research question 2, the term “Quality of Life” (QoL) will be introduced with respect to terminology, origin and application within this study. TYRVÄINEN ET AL. (2007) see residents’ QoL as significantly affected by measures of urban planning, such as infill development and settlement growth itself. The following paragraphs give a short insight into the characteristics of the concept of QoL and its multidisciplinary peculiarity. Regarding current literature⁸⁸, QoL appears as an encounter holding not only social determinants, but also taking into account ecological as well as economical factors. In that context, it goes without question that *urban green structures* and *environmental quality/ environmental conditions* are essential determinants of QoL being sensitive to each change of the built environment⁸⁹. Its modifications due to settlement development are seen as valuable means to assess socio-environmental impacts of housing development. A broad consensus exists as to the positive influences of urban green on residents’ QoL⁹⁰.

According to SEIK (2001) urban QoL studies will become an important tool for planning and managing liveable, viable and sustainable cities providing an evaluation of planning policies, rating of places and the formulation of planning strategies. Facing the fact that citizens’ QoL is central to planning and policy decisions and processes, related studies have proved invaluable for planners and decision makers⁹¹. Actions such as the Urban Audit Project “Assessing the Quality of Life of Europe’s Cities”⁹² promoted by the European Union or the Millennium Ecosystem Assessment (MEA 2003) prove evidence of QoL’s prime importance for a sustainable urban development. There is a growing demand for an assessment of the quality of life in cities. Also e.g. PACIONE (2003, p. 28) points out the central importance of QoL-research for scientists and policy makers. He relates it to the “monitoring [of] the effects of policies on the ground”. Hence, a close relationship to political targets, such as fostered infill development, reduced land consumption and its socio-environmental impacts as presented before, is seen within this study.

Also COSTANZA ET AL. (2007) state that the concept of QoL is a major driver for planning policy and an essential component of a sustainable settlement development. As one essential contribution to this study, the concept of QoL is valued as an indispensable target system to assess socio-environmental impacts of settlement-growth. Due to its multidimensional character, the evaluation and monitoring of QoL “which are seen as important support to urban planning and management”⁹³ takes a central position in this study.

⁸⁸ a.o. PACIONE 2003; SANTOS & MARTINS 2007; FADDA ET AL. 2000a; FADDA ET AL. 2000b; FADDA & JIRÓN 1999

⁸⁹ a.o. ARLT ET AL. 2005; BAUMGART ET AL. 2004; PACIONE 2003

⁹⁰ a.o. TZOULAS ET AL. 2007; COMBER ET AL. 2008, p. 104; MITCHELL & POPHAM 2008; DE RIDDER ET AL. 2004; DE RIDDER 2004; VAN KAMP ET AL. 2003; SANTOS & MARTINS 2007; PRIEGO ET AL. 2008

⁹¹ SEIK 2001, p. 1

⁹² REGIONAL POLICY-INFOREGIO of the European Community

⁹³ SANTOS & MARTINS 2007, p. 411

Regarding the literature on QoL, a broad range of approaches and definitions emerges⁹⁴. The range of it comprises studies of varying “disciplines such as planning, geography, sociology, economics, psychology, political science, medicine, marketing and management”⁹⁵. Four major definitions will be highlighted in the next paragraphs:

Following FADDA & JIRÓN (1999), the concept of QoL is more “than the private “living standards” and refers to all the elements of the conditions in which people live, that is, all their needs”⁹⁶ for a.o. available and accessible social and public infrastructure or space for outdoor recreation. “It has long been accepted that material wellbeing, as measured by gross domestic product per person, cannot alone explain the broader quality of life in a country”⁹⁷.

COSTANZA ET AL. (2007) outline major influencing factors (“opportunities”) on QoL which itself is to be divided into human needs and subjective well-being (see figure 7). And FADDA ET AL. (2000b, p. 168) state the assessment of “QoL-factors relates both to the objective conditions and subjective perceptions.”

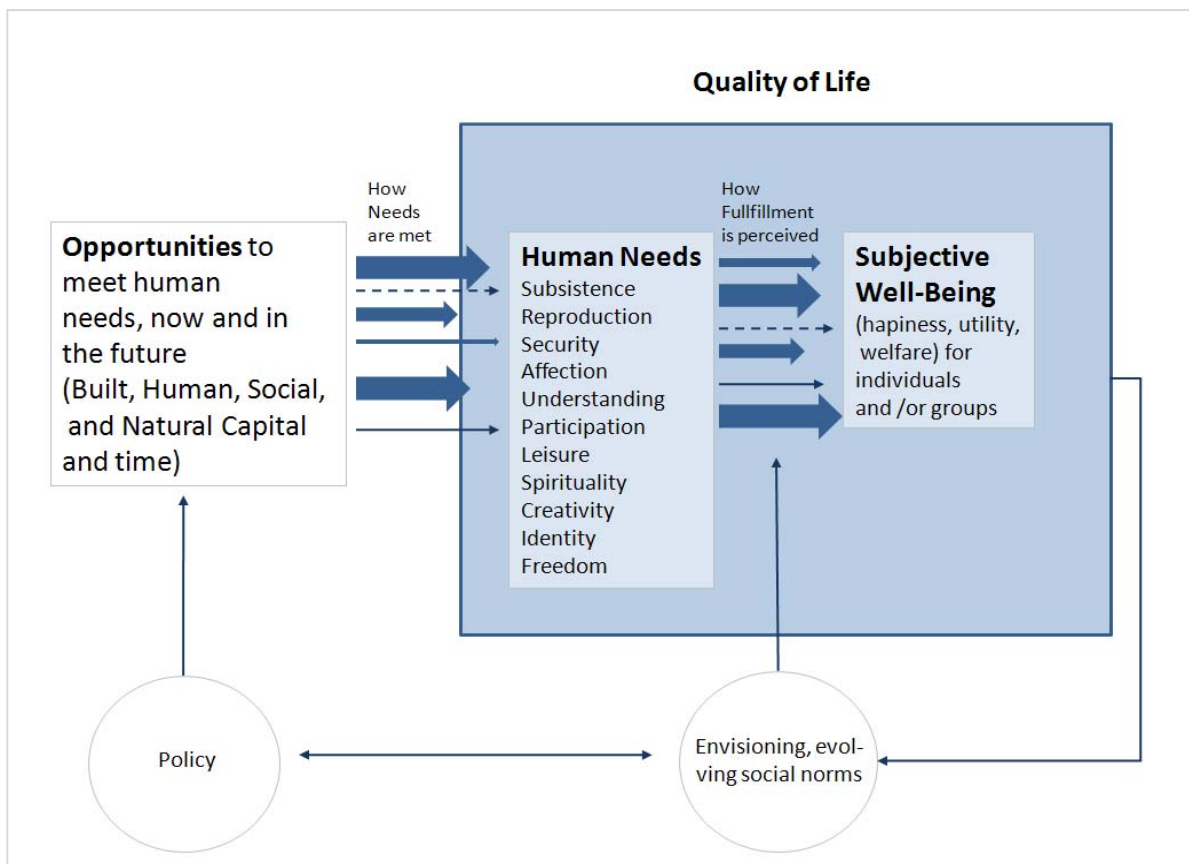


Figure 7 The concept of QoL integrating subjective needs and objective preconditions (modified according to COSTANZA ET AL. 2007, p. 269)

⁹⁴ see, among others, EUROPEAN FOUNDATION for the improvement of living and working conditions 2004; KAWKA & STURM 2006; BURGESS ET AL. 1988; SANTOS & MARTINS 2007; COSTANZA ET AL. 2007; FADDA & JIRON 1999 and their concise review of definitions on QoL.

⁹⁵ SEIK 2001, p. 1

⁹⁶ FADDA & JIRÓN 1999, p. 262

⁹⁷ *The World in 2005*, Economist.com (<http://www.economist.com/theworldin/>)

SANTOS & MARTINS (2007) define ecological, economical and collective material conditions and society itself as major contributors to QoL (see table 2⁹⁸). Here, *environmental conditions* refer to general “natural and physical aspects of the city (air, water, green spaces I...I)” (p. 414). *Economic conditions* refer to “the city as a centre of economic activity and the inherent issues I...I: income and consumption, labour market, housing, economic dynamism”⁹⁹. *Collective material goods* are determined by social, technical and cultural infrastructure and facilities as well as transport, welfare and others. *Societal conditions* as a fourth field of QoL, refer to all processes of interaction between citizens and their participation¹⁰⁰.

Table 2 Fields of QoL according to SANTOS & MARTINS 2007, p. 415

Environmental Conditions	Collective Material Conditions
Green spaces	Cultural facilities
Climate	Sports facilities
Noise	Educational facilities
Air quality	Social and health facilities
Bathing water quality	Heritage
Basic infrastructure	Mobility
	Retailing and services
Economic Conditions	Society
Income and consumption	Population
Labour market	Education
Housing market	Cultural dynamism
Economic dynamism	Civic participation
	Health
	Safety
	Social problems

The MILLENNIUM ECOSYSTEM ASSESSMENT both defines determinants of human well-being, which are often used complementary to the term QoL, and also highlights close relations to ESS on a global level (see figure 8 below).

⁹⁸ See also figure C1 in annex C showing the original conception of SANTOS & MARTINS 2007

⁹⁹ SANTOS & MARTINS 2007, p. 415

¹⁰⁰ Santos & Martins 2007, p. 414f.

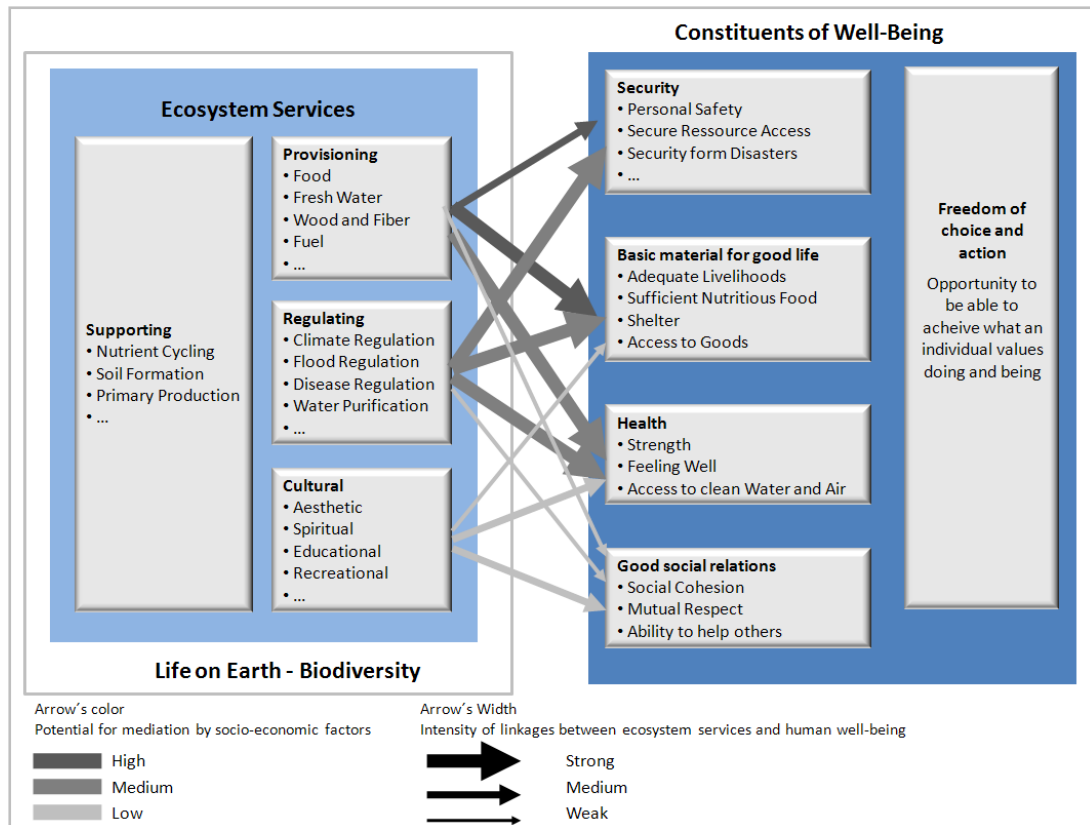


Figure 8 Concept of Ecosystem Services and relations to human well-being (modified according to MEA 2005)

Launching ten key messages in their report “Living Beyond Our Means: Natural Assets and Human Well-being” the MEA (2005a) points out the evident dependency of societies on nature and ecosystem services, their threatening by ongoing settlement growth and the rise and fall of human well-being associated to these processes.

As mentioned before, urban green spaces significantly contribute to QoL. Their part could be found in various terms in the presented concepts on QoL. TYRVÄINEN ET AL. (2007, p.5) present a valuable summary and stress the point that “green areas contribute to quality of life in cities. Their benefits are primarily determined by the quantity and quality of these areas as well as their accessibility. The social and aesthetic benefits of urban green areas are generally acknowledged as key functions of open space for local residents, including recreational opportunities, improvement of the home and work environment, impacts on physical and mental health as well as cultural and historic values.”

As one gets the impression that QoL is difficult “to apprehend, to define and [to] measure”¹⁰¹ leading to a somewhat blurry encounter, a black-box, this study narrows its view and clearly focuses on the evident relationship between QoL/human needs and ecological and natural assets according to current research¹⁰². The author’s focus will be on QoL and on the contribution of urban green spaces by providing UES (Urban Ecosystem Services). Especially the environmental and societal conditions

¹⁰¹ JIRÓN & FADDA 2000, p. 2

¹⁰² a.o. SANTOS & MARTINS 2007; PRIEGO ET AL. 2008; SCHETKE ET AL.*; MATSUOKA & KAPLAN 2008; DE RIDDER ET AL. 2004; MEA 2005

will be picked up by the new approach of this study linking the two concepts. It enables a socio-environmental impact-assessment of settlement-growth according to changing land-use patterns. In that context, QoL-analysis of this study firstly considers a *homo uniformus* and clearly focuses on the interrelations between QoL and UES¹⁰³. Later on, a comparison of socio-environmental impact assessment according to different social groups and their QoL, will be outlined in the excursus in chapter 5.2.

2.2.1. Subjective and Objective Drivers

Next to the multi-dimensional character of QoL as described by SEIK 2001 and others¹⁰⁴ the division between influencing objective and subjective factors is a second aspect frequently discussed. It also affects the conceptual design of this thesis' impact-assessment of QoL and UES. Additionally, PACIONE (2003, p. 19) states that "the meaning of the phrase quality of life differs a good deal as it is variously used but, in general, it is intended to refer to either the conditions of the environment in which people live [...] , or to some attribute of people themselves (such as health or educational achievement)." As this study focuses on an *objective* socio-environmental impact assessment due to settlement growth, a definition of objective determinants of QoL is crucial. This can be provided by two means:

Firstly, a clear focus on environmental determinants and contribution to QoL provided by urban green as discussed in this study sets clear limits for the elaboration of quantifiable and objective indicators. Following PRIEGO ET AL. (2008), residents are related to urban nature and have a "manifest need to have contact with and access to green areas [...] in order to achieve full personal development, mostly not depending on their social or cultural status"¹⁰⁵. A key element in urban landscapes is the provision of experiences of natural, liveable and attractive cityscapes, to improve satisfaction of residents¹⁰⁶. Such experiences contribute to peoples' local identity, as they are replete with personal and social meanings. "They provide a context for social interaction, they serve as tangible reminders of childhood and memories of community life, they offer 'gateways' or opportunities for people to escape for a while from [...] urban life"¹⁰⁷. This perception was also addressed by COSTA ET AL. (2008) within the research project "GreenKeys"¹⁰⁸.

PRIEGO ET AL. (2008, p. 18) argue that the "socioeconomic status of urban dwellers plays a role in their general free-time behaviour, there are certain nature-related outdoor activities that are independent from this status". They also highlight the broad common basis of nature perception being independent from social conditions. Therefore the applied indicators of this second level of analysis reflect objective conditions and do not formally distinguish between different socio-economic groups. Moreover, "the only socio-economic difference in the utilization [*and therefore its*

¹⁰³ Which are regarded as a subset of ESS.

¹⁰⁴ Compare notions on QoL before.

¹⁰⁵ PRIEGO ET AL 2008, p. 16

¹⁰⁶ PRIEGO ET AL. 2008

¹⁰⁷ BURGESS ET AL. 1988, p. 459f.

¹⁰⁸ See www.greenkeys-project.net and the related publication of COSTA ET AL. 2008

benefits] consists of those nature parts in and outside cities which are not easy reachable and therefore connected with costs and time”¹⁰⁹.

A *second* way to determine objective components of QoL is to shed light on the related terminology. Facing current literature and QoL-indices as mentioned above, a relatively loose use of the term QoL appears being replaced by the term “human well-being”¹¹⁰, which – in most cases – assesses identical issues comprising of both objective and subjective issues. Contrarily, the figure by COSTANZA ET AL (2007, p. 269) shown above distinguishes between the term QoL and “subjective well-being”, which is only a component of the first extracting the clear subjective components and defines additional human needs. “Diverse objective and subjective indicators across a range of disciplines and scales, and recent work on subjective well-being surveys and the psychology of happiness have spurred interest”¹¹¹. Subjective indicators majorly refer to assessing the opportunities that individuals have to improve their well-being than QoL itself.

The term QoL must therefore not be mixed up with the term “subjective well-being”. In that context CHIESURA & DE GROOT (2003, p. 226) have discussed the evidence of natural ecosystems fulfilling “immaterial human needs”. The term “needs” is of central interest in this study in linking the concepts of QoL and UES and the contribution of urban green to both.

As the second target-system for the impact-assessment of settlement-growth the following paragraphs are dedicated to a short insight into the concept of ESS and the new term UES. *UES play an integral role in this thesis and are regarded as a subset of ESS*. Still, a first introduction into the general concept of ESS is essential.

2.3. Ecosystem Services (ESS)

In order to answer research question 2 the term “Ecosystem Services” (ESS) will be introduced regarding terminology, origin and its interrelation to the term QoL. The supply with urban green spaces and therefore the provision with ESS highly determine the impact-assessment (IA).

In the preceding chapters both terms, ESS and UES, have appeared. To clarify that, this chapter will be followed by a systematization of UES which was applied in this study.

As we learnt in chapter 2.1, the urban encounter itself holds many ecological conflicts and demands critical observation of socio-environmental impacts of measures of urban planning such as infill development and settlement-development itself. Figure 8, has highlighted the close interconnection between environmental conditions and human well-being in a more global and general context. Still, these connections within urban conditions need to be clarified and translated to a quantifiable indicator-framework for an impact assessment of settlement-growth.

ESS are defined according to COSTANZA ET AL. (1997) as consisting “... of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital

¹⁰⁹ PRIEGO ET AL. 2008, p. 18

¹¹⁰ e.g. MEA 2003, 2005

¹¹¹ COSTANZA ET AL. 2007, p. 267

services to produce human welfare”¹¹². Ecosystem Services (ESS) are “the benefits human populations derive, directly or indirectly, from ecosystem functions.” (Costanza et al. 1997, p. 253)

Ecosystem Functions (ESF) “refer variously to the habitat, biological or system properties or processes of ecosystems”¹¹³ (see fig. 9). The connection between ESS and ESF is varying and does not always show a one-to-one-correspondence. In some cases several ecosystem functions can contribute to one ESS and in other cases one ESF can also be regarded as an ESS directly. It is evident, that ESF and ESS cannot be regarded separated from each other.

According to de GROOT ET AL. (2002, p. 395), four major categories of ESF can be defined. Undoubtedly, these ESF together with associated ESS are essential contribution of urban green space structures on which the focus of this study is set.

Ecosystem Functions

- Regulation: This term incorporates a group of functions relating to the capacity of natural and also semi-natural ecosystems “to regulate essential ecological processes and life support systems through bio-geochemical cycles and other biospheric processes”¹¹⁴.
- Habitat: The habitat function essentially provides refuge and the possibility to reproduce flora and fauna while simultaneously enhancing biodiversity and evolutionary processes.
- Production: The production function incorporates all processes of conversion of energy, nutrients, water and carbohydrate structures to produce a large variety of biomass. This, in reverse, provides many ecosystem goods for human consumption, ranging from food and raw materials to energy resources and genetic material.
- Information: “Because most of human evolution took place within the context of undomesticated habitat, natural ecosystems provide an essential ‘reference function’ and contribute to the maintenance of human health by providing opportunities for reflection, spiritual enrichment, cognitive development, recreation and aesthetic experience”¹¹⁵.

¹¹² COSTANZA ET AL. 1997, p. 254

¹¹³ COSTANZA ET AL. 1997, p. 253

¹¹⁴ DE GROOT ET AL. 2002, p. 395

¹¹⁵ DE GROOT ET AL. 2002, p. 395

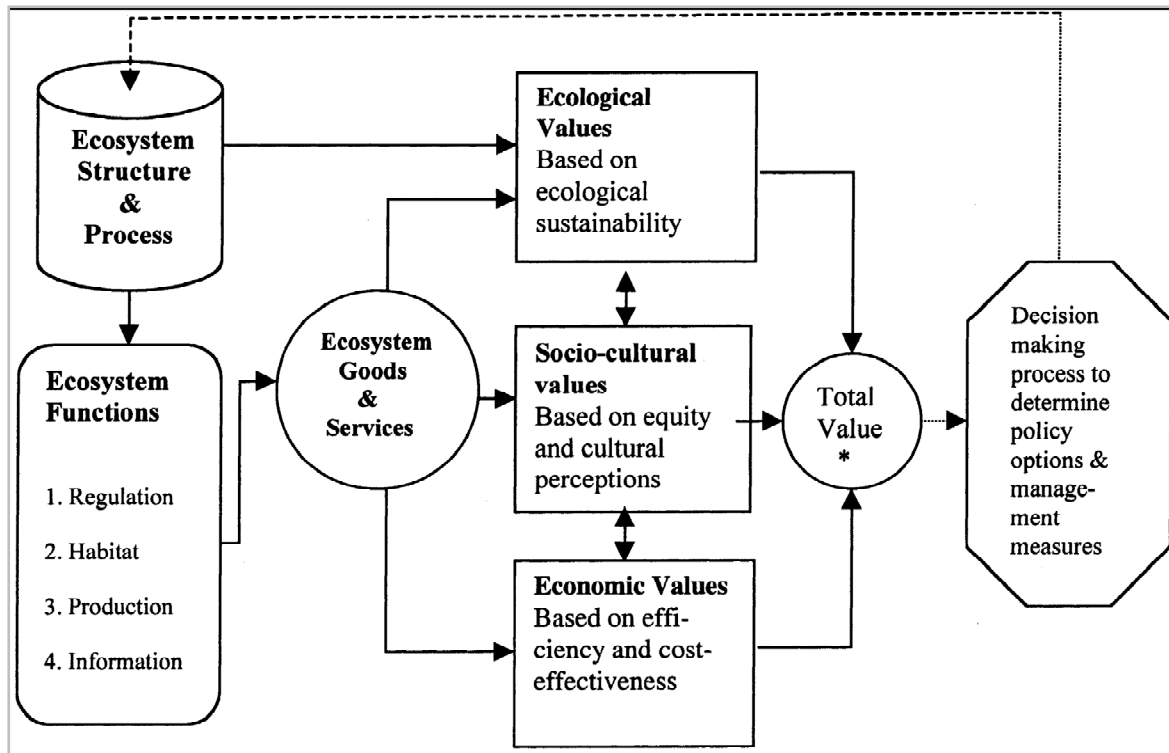


Figure 9 System of ecosystem services and ecosystem functions (source: DE GROOT ET AL. 2002)

The definition of four essential ESF shows high correspondence with those of COSTANZA ET AL. (1997) allowing a further derivation of associated and numerous ESS. They cover a broad field within the ecosystem and are of renewable and non-renewable character.

According to the MILLENNIUM ECOSYSTEM ASSESSMENT (2003) following COSTANZA ET AL. (1997) ESS can be distinguished between those of direct or indirect human use. "Moreover, unlike provisioning or regulating services, assessing the condition of cultural services heavily depends on either direct or indirect human use of the service. For example, the condition of a regulating service such as water quality might be high even if humans are not using the clean water produced, but an ecosystem service provides cultural services only if there are people who value the cultural heritage associated with it"¹¹⁶. The MEA provides a fourfold categorization of ESS (see also figure 8 above), which is an essential contribution to the linkage of QoL and UES:

- Regulating services
- Recreational services
- Cultural services
- Provisioning services

Beside the four major ESF as defined by DE GROOT ET AL. (2002) this classification of the MEA presents first theoretical links between the concepts of QoL¹¹⁷ and UES.

¹¹⁶ MEA 2003, p. 65f.

¹¹⁷ The MEA uses the term "well-being" instead.

2.4. Urban Ecosystem Services (UES)

In order to narrow the view on and to specify socio-environmental impacts of settlement growth, five major core-groups of UES can be extracted from the broad range of ESS as defined in current literature¹¹⁸ and have been adapted to these concepts. These five core-groups of UES will be substantiated and exemplified using the concepts of different authors in chapter 2.5 in order to highlight the connections between the concepts of QoL and UES.

This sub-chapter introduces the term “Urban Ecosystem Services”. They are regarded as a subset of ESS. As not all ESS as defined within literature, are relevant within urban areas or determine residents’ QoL, a specification of UES becomes inevitable. The concept of UES has been applied to evaluate the qualitative perception and the quantitative analysis of green areas and their quality, focusing on inventory and composition.

In contrast to other studies on ecosystem services, UES are exclusively related to urban green and the accordant determinants of QoL¹¹⁹.

Urban Ecosystem Services (UES)

- **Recreational services:** It goes without question that cities are stressful environments for citizens. “The overall speed and number of impressions cause hectic lifestyles with little room for rest and contemplation”¹²⁰; therefore, the provision of sufficient urban green spaces enhances their well-being and quality of life. The recreational function of urban green is one of the prominent ecosystem functions in cities, providing spaces for recreation and contemplation. In a closer sense, they compensate a lack of private green and enable residents to participate in leisure activities – to some extent – within their own neighbourhood and living surroundings. CHAN ET AL. (2006) perceive the recreational value of an area as a function of the amount of semi-natural and natural habitats. Additionally, he also values the accessibility of an area as measured by its “proximity to population centres and roads”¹²¹.
- **Regulation and environmental health:** Following the concept of DE GROOT ET AL. (2002) of ESS¹²², in our urban context also UES can be regarded as the capacity of natural processes and components to regulate essential ecological processes and life support systems. Major ecological functions are determined by regulative effects on water balance, noise, climate, and also pollution. According to SCHETKE ET AL.* “the resulting social amenities are provision of agreeable living conditions, and a feeling of naturalness, comfort and individual health.”

¹¹⁸ a.o. COSTANZA ET AL. 1997; BOLUND & HUNHAMMAR 1999; CHAN ET AL. 2006, DE GROOT ET AL. 2002. The paper of BOLUND & HUNHAMMAR (1999) exemplifying ESS in the urban area of Stockholm has been taken into account. But still concrete links to QoL and urban green remain elusive.

¹¹⁹ SCHETKE ET AL.*

¹²⁰ BOLUND AND HUNHAMMAR 1999, p. 298

¹²¹ CHAN ET AL. 2006, p. 2142

¹²² Here the definition of DE GROOT ET AL 2002 has been adopted for UES.

- Services of habitat provision: Ecosystems provide refuge and are habitats for “resident and transient populations”¹²³. Accordingly, they contribute to sustaining urban biodiversity¹²⁴. The author subsumes under their habitat function both quality and quantitative amount of the urban green land uses.
- Cultural Services: Provision of cultural services can be regarded in many respects. COSTANZA ET AL. (1997) describe the provision with opportunities for non-commercial use by urban green spaces. BOLUND & HUNHAMMAR (1999) refer to directly connected recreational with cultural functions of urban green space. Following this, ULRICH ET AL. (1991) state that green spaces and natural settings have a positive psychological influence for e.g. stress recovery. The MEA (2005) highlights aesthetic and recreational benefits with respect of cultural services. According to BURGESS ET AL. (1988, p. 459) urban green spaces and especially parks offer the possibility of contributing to residents’ sensitivity and evocation of memories, as they are “replete with historic and social meaning”¹²⁵. PRIEGO ET AL. (2008) mention an enhancement of community identity in relation to the meaning of nature.
- Services of Information/Meaning: Also the provision with information is to a great extent related to psychological and cultural services that can be derived from urban green space and green land uses. Associated ecosystem functions are seen in the context of an educational and scientific function and also in opportunities for interaction with nature¹²⁶. In a strict social sense, urban green spaces function as public domains¹²⁷. Especially focussing on spatial urban perforation they provide with social functions such as those mentioned above: recreation, aesthetic information, interaction of different social groups, compensation of the lacking private green spaces and spiritual enrichment as people get in touch with nature. Green spaces provide a broad range of diverse information and meaning to residents by saving memories and meanings of place.

2.5. Synthesis: An Approach of Linking QoL and UES

Since a variety of *urban green land uses* exist, this study innovatively focuses on examining their functionality in quantitative and qualitative terms using and linking the concepts of QoL and UES. In doing so, an integrative scheme that comprises components of both concepts, and further asks how they might be affected by settlement-growth was developed and translated into a quantitative impact-assessment and associated indicators. This forms an essential part for the second step of the MCA of this study. Regarding the composition of the final indicator set, it highlights interconnections between the concepts of QoL and UES providing a number of indicators being bi-functionally applied to the dimensions of both concepts¹²⁸.

¹²³ COSTANZA ET AL. 1997, p. 254

¹²⁴ COSTANZA ET AL. 1997

¹²⁵ See also SCHETKE ET AL.*

¹²⁶ DE GROOT ET AL. 2002

¹²⁷ HAJER & REINDORP 2001

¹²⁸ SCHETKE ET AL.*

Accordingly, this study shows *firstly*, that the concepts are partially complementary and dependent and use similar variables, but also enrich each other. *Secondly*, it becomes clear that settlement growth can have many obvious negative and critical implications, but still implies positive paths of spatial urban development, particularly urban green land use patterns and functionality. The author's approach described in SCHETKE ET AL.¹²⁹ will be adjusted towards an indicator-set, which promotes a quantitative and scenario-driven impact assessment of future housing sites.

The presented innovative conceptual approach is hierarchical in nature and starts with QoL (chapter 2.2) as an overall concept. As "natural and semi-natural ecosystems and landscapes provide benefits to human society, which are of great ecological, socio-cultural and economic value"¹³⁰ explicit benefits of urban green spaces¹³¹ and environmental conditions to the concept of QoL and provided by UES are identified and selected within a broad literature review. These benefits are addressed as human "needs", which are fulfilled by urban green and are regarded as dimensions of QoL. The next step comprises the selection of associated UES from the broad field of ESS as defined in the literature and outlined in chapters 2.3 and 2.4. In a last step quantifiable indicators of the three need-categories have been developed and will be presented in chapter 3.

According to JAMES ET AL. (2009, p. 65) "urban green space are seen as an integral part of cities providing a range of services to both people and the wildlife"¹³². This is confirmed by findings of the Greenkeys research project 2008¹³³. In addition, BOLUND & HUNHAMMAR (1999, p. 300) confirm a close interrelation of UES and QoL by highlighting "that urban ecosystem services contribute to the quality of urban life".

According to these notions, the three major human needs, which have been distilled from current literature¹³⁴, will be presented within the next paragraphs. They represent crucial determinants of QoL as provided by urban green¹³⁵ and are supported by associated UES. The contribution of UES to QoL comprises a direct and indirect link to nature. MATSOUKA & KAPLAN (2008, p. 9) define human needs and distinguish between nature needs, which are "more directly linked to with physical

¹²⁹ See also SCHETKE 2008

¹³⁰ DE GROOT 2006, p. 175

¹³¹ This study follows the definition of green spaces according to JAMES ET AL. (2009, p. 66) describing it as consisting of "predominantly unsealed, permeable, soft surfaces such as grass, soil, shrubs, trees I...!". Differing to JAMES ET AL (2009), the component "water" will not be taken into account. In German literature the term "Freifläche" (open space) predominates but is used synonymously in most cases. RICHTER (1981, p. 13) defines both "Grünflächenplanung" und Freiraumplanung (planning of green and of open spaces) and prefers the term "Freifläche" (open space). Additionally, he defines "Stadtgrün" (urban green) as the whole -but majorily green – amount of open spaces in a city (p. 14). In his book "Handbuch Stadtgrün" RICHTER presents a complex scheme of the contents and tasks of urban green (1981, p. 16).

¹³² See also SCHETKE (2008, p. 2084) stating that "urban green spaces are among the driving factors of quality of life and of that attractiveness of urban life planners are in charge to provide".

¹³³ See COSTA ET AL. 2008, p. 95 and compare findings of the GreenKeys research team at www.greenkeys-project.net

¹³⁴ a.o. MEA 2005; PRIEGO ET AL. 2008; BURGESS ET AL. 1988; SCHETKE & HAASE 2008; SCHETKE ET AL. *; SCHETKE ET AL. **; WERHEIT 2002, p. 93; DE RIDDER ET AL. 2004, p. 490; MITCHELL & POPHAM 2008; DE GROOT ET AL. 2002, DE GROOT ET AL. 2003; CHIESURA & DE GROOT 2003; DE GROOT 2006; RICHTER 1981; JAMES ET AL. 2009; THOMPSON 2002; MATSOUKA & KAPLAN 2008; SANTOS & MARTINS 2007. In this context tasks of urban green spaces are replete with various terms such as "human needs" nature fulfills (MATSOUKA & KAPLAN 2008); "landscape functions" (DE GROOT ET AL. 2006), "functions of natural capital" (DE GROOT ET AL. 2003) or "value of nature" (CHIESURA & DE GROOT 2003); "services" (JAMES ET AL. 2009)

¹³⁵ Several authors such as SANTOS & MARTINS (2007) use the term "environmental quality".

features of the environmental settings". Compared to that, human-interaction needs are indirectly linked to the environment. In addition, the classification of human needs by CHIESURA & DE GROOT (2003, p. 224) highlights basic personal, physiological and collective needs, which nature is able to provide. Valuable practical knowledge on the functionality of green spaces within an urban context and on the operationalization via indicators comes from the URGE-project¹³⁶ supported by the European Commission, DG Research, Key Action "City of Tomorrow and Cultural Heritage".

Within the presentation of the following human needs as determinants of QoL, the contributions of individual UES will become more concrete linking both concepts. They differ not only in meaning for QoL, but also in the types of associated UES.

Recreation

Following MATSUOKA & KAPLAN (2008) there is a clear pervasive need for recreational activities across the age-spectrum, diverse socio-economic groups and nationalities. Recreational benefits are essentially determined by natural prerequisites and composition¹³⁷ (e.g. diversity of habitats, amelioration of air pollution)¹³⁸ and such as feeling of the natural environment¹³⁹.

According to PRIEGO ET AL. (2008) the quality of nature is an essential driver for the optimal use of green spaces. Also SINGER (1995) states that urban green in inner urban areas needs to meet simultaneously the demands of urban design and quality of free time activities, recreational functions and quality of living surroundings. Here urban green is supposed to play a prominent role in the provision with these services. Apart from variety of subjective influencing factors, he states that the plurality of design of urban green spaces can be regarded as objective and general in nature to assess the recreational contribution¹⁴⁰.

Unless the fact that natural composition and biotope quality do not have the highest urban-ecological priority in urbanized areas¹⁴¹, these factors are considered fundamentally within the assessment. As e.g. biotopes are valued according to their anthropogenic modification, those land use classes¹⁴² with higher values and less modification have major influence on residents QoL. They provide less disturbed and modified living surroundings. Moreover, he states that also regulative functions are affecting human health and manifold processes within ecosystem¹⁴³. They also

¹³⁶ Duration:2001-2004 (www.urge-project.ufz.de)

¹³⁷ In that context JAMES ET AL. (2009, p. 68) speak of a "physicality" of urban green spaces.

¹³⁸ TZOULAS ET AL. 2007, p. 170; JAMES ET AL. 2009

¹³⁹ BURGESS ET AL. 1988

¹⁴⁰ Original German citation in SINGER (1995, p. 47)

¹⁴¹ SINGER 1995

¹⁴² Within this work the term land use class is bound to either cadastral land use classes as defined in layer 21 of the ALK (Automatisierte Liegenschaftskarte) providing actual land use or a land use mapping deriving from the Regional Association Ruhr (RVR 2005). Land use classes as defined in both data sets comprise both built and open spaces within a class. The land use mapping of the RVR is more general in nature and comprises 150 land use classes. It is based on the Deutsche Grundkarte 1: 5000 (German Planimetric Map).

¹⁴³ SINGER 1995

contribute essentially to environmental health and quality, which are of major importance for its active recreational use¹⁴⁴.

Table 3 shows major ESF and UES that determine the need “recreation” as one essential contribution of urban green to QoL as discussed in current literature. Here, MATSOUKA & KAPLAN (2008) especially highlight the contact with nature. Moreover, the provision with adequate living conditions as defined in SCHETKE ET AL.* and regulation at local level stated by BOLUND & HUNHAMMAR 1999 and DE GROOT ET AL. 2002 play an essential role for recreational benefits of urban green spaces. BURGESS ET AL. (1988) continue this argumentation as the feeling of the natural environment plays an important role of the recreational function of urban green. Therefore, it is an essential contributor to residents QoL.

To enable a socio-environmental impact assessment, associated UES adapted to concepts on ESS as discussed in the literature have been translated into selected quantifiable indicators as described chapter 3.3.2. A first conceptual approach derives from SCHETKE ET AL.* as presented in tab. a3 in the annex and presents possible indicators as discussed in current literature and science. Furthermore, indicators of this theoretical approach were adjusted to existing data-sets used for the impact assessment and substituted or slightly modified.

Table 3 Recreation: Ecosystem Functions, Social amenities and associated UES

Ecosystem Functions (ESF) & Social Amenities	Urban Ecosystem Services
<ul style="list-style-type: none"> • providing opportunities for recreational activities (MATSOUKA & KAPLAN 2008) • Provision of favorable living conditions (SCHETKE ET AL. *) • Contact with nature (MATSOUKA & KAPLAN 2008, PRIEGO ET AL. 2008) • Gas and climate regulation, habitat and refugium function (DE GROOT ET AL. 2002) • Regulation at local level (BOLUND & HUNHAMMAR 1999) • sense of naturalness, contact with nature (SINGER 1995, BURGESS ET AL. 1988; MATSOUKA & KAPLAN 2008) 	<ul style="list-style-type: none"> • Air filtering/ climate regulation (adapted to concepts of COSTANZA ET AL. 1997; BOLUND & HUNHAMMAR 1999, DE GROOT et al. 2002) • Recreation (adapted to concepts of COSTANZA ET AL. 1997; BOLUND & HUNHAMMAR 1999) • Noise reduction (adapted to concepts of BOLUND & HUNHAMMAR 1999) • Conservation (adapted to concepts of CHAN ET AL. 2006) • Refugia (adapted to concepts of COSTANZA ET AL. 1997)

Regulation and Environmental Health

According to the MILLENNIUM ECOSYSTEM ASSESSMENT, ecosystem services of direct and indirect human use can be defined. The previous category mainly focused on direct human use. Now, the merely indirect uses, which are independent from its users (residents) but significantly contributing to environmental health – being a critical environmental capital within the urban centers difficult to replace¹⁴⁵- and QoL are to be outlined. There is no doubt, that there exist many interlinkages between direct and indirect uses and the manifold benefits environmental health provides beside recreation¹⁴⁶.

¹⁴⁴ PRIEGO ET AL. 2008

¹⁴⁵ GILL ET AL. 2007

¹⁴⁶ BAUMGART ET AL. 2004; URGE-RESEARCH TEAM (2001-2004)

According to GILL ET AL. (2007) processes of settlement growth and urbanization replace vegetated land uses and diminish the provision with shadow, evaporative cooling, rainwater interception as well as storage and infiltration functions. Green spaces can provide areas within the built environment where those processes can take place and can moderate the effects of climate change. GILL ET AL. (2007¹⁴⁷) state, that ecosystem services within the built environment and provided by “urban green space are often overlooked and undervalued”. The analysis of local hydrological regimes, as modeled in GILL ET AL. (2007), highlight the special role of green spaces for the provision with regulative and deriving microclimatic processes¹⁴⁸.

Table 4 shows major ESF and UES that determine the need “regulation” as the second essential contribution of urban green to QoL as discussed in current literature. Whilst major ESF and social amenities are resulting from regulation of hydrological flows¹⁴⁹, also aspects such as gas regulation¹⁵⁰ as well as a repeated feeling of naturalness¹⁵¹ are essential ESF and are provided by urban green spaces.

Also these UES were adapted to concepts on ESS as discussed in the literature and translated into selected quantifiable indicators as described above. And a first conceptual approach derives from SCHETKE ET AL.* as presented in tab. a3 in the annex. It presents possible indicators as discussed in current literature and science. Furthermore, the indicators of this theoretical approach were adjusted to existing data-sets used for the impact assessment of this study and were substituted or slightly modified.

Table 4 Regulation: Ecosystem Functions, Social amenities and associated UES

Ecosystem Functions (ESF) & Social Amenities	Urban Ecosystem Services
<ul style="list-style-type: none"> regulation of hydrological flows (COSTANZA ET AL. 1997; BOLUND & HUNHAMMAR 1999) and climate regulation soil formation processes (COSTANZA ET AL. 1997) habitat function (DE GROOT ET AL. 2002) Regulation of atmospheric chemical composition, air filtering (COSTANZA ET AL. 1997; BOLUND & HUNHAMMAR 1999) 	<ul style="list-style-type: none"> Water regulation / flood control / rainwater drainage (adapted to concepts of DE GROOT ET AL. 2002; COSTANZA ET AL. 1997; BOLUND & HUNHAMMAR 1999; GIVONI 1991) Refugia (adapted to concepts of COSTANZA ET AL. 1997; DE GROOT ET AL. 2003) Air filtering/ climate regulation (adapted to concepts of Costanza et al. 1997; BOLUND & HUNHAMMAR 1999; DE GROOT ET AL. 2002, 2003) Pollution control (adapted to concepts of DE GROOT ET AL. 2002)

Social cohesion and local identity

Current literature promotes the cultural components of ecosystem services and ecosystems¹⁵². As defined in PRIEGO ET AL (2008, p.2), “urban nature opens a wide field of human interactions promoted by natural environments”¹⁵³. In their paper “peoples need in the urban landscape” MATSUOKA &

¹⁴⁷ GILL ET AL. 2007, p. 116

¹⁴⁸ see also PAULEIT ET AL. 2005

¹⁴⁹ BOLUND & HUNHAMMAR 1999

¹⁵⁰ COSTANZA ET AL. 1997

¹⁵¹ SCHETKE ET AL.*

¹⁵² MEA 2003, 2005, COSTANZA ET AL 1997; DE GROOT ET AL. 2002

¹⁵³ see also BARNHART ET AL. 1998; GOBSTER 1998; OGUZ 2000 IN MATSUOKA & KAPLAN 2008

KAPLAN (2008) provide a wide international literature review¹⁵⁴ on the analysis of human interactions and outdoor urban environments.

Beside aesthetic enhancement, psychological benefits and spiritual enrichment are valuable contributions of urban green¹⁵⁵. MATSUOKA & KAPLAN (2008, p.11)¹⁵⁶ define a green residential atmosphere as the “most important community feature contributing to inhabitants’ appreciation of their neighborhood.” According to their literature review, some researchers follow the idea that an enhanced identity of the physical environment can increase the sense of community attachment¹⁵⁷. Moreover, COLEY ET AL. (1997, p. 471) see “a greater sense of territoriality” according to the availability of natural settings within the neighborhood. And urban green spaces can play an important role smoothing the perforation of the urban structure and the loss of significant orientation and identification marks in shrinking cities¹⁵⁸.

Table 5 shows major ESF and UES that determine the need “social cohesion/local identity” as the third essential contribution of urban green to QoL as discussed in current literature. Whilst major ESF and social amenities are resulting from consolidating influences by providing privacy and space for interaction¹⁵⁹, scientists highlight especially psychological benefits and information functions as essential ESF as provided by urban green spaces. Associated UES, as presented in the right column, were adapted to concepts on ESS, which are discussed in the literature. They were translated into selected quantifiable indicators as described above.

The elaboration of indicators needs to be sensitive towards the multifarious effects and benefits of urban green. Here, WICKOP ET AL. 1998¹⁶⁰ clearly distinguish between the total provision with green and its actual usability. Social and psychological benefits and acceptance of urban green go hand in hand with an active use and the accessibility of green spaces. This demands a distinction between public, semi-public and private green spaces¹⁶¹. Whilst public green spaces provide with possibilities for interaction between neighbors, private green spaces enhance the feeling of security¹⁶², the possibility to emerge from urban life itself¹⁶³ and a “sense of ownership and territoriality”¹⁶⁴. A first conceptual approach of an operationalization of this third need also derives from SCHETKE ET AL.*. It is presented in tab. a3 in the annex. It presents possible indicators as discussed in current literature and science. The indicators of this theoretical approach were then adjusted to existing data-sets used for the impact assessment of this study and substituted or slightly modified.

¹⁵⁴ This analysis reflects issues of *Landscape and Urban Planning*, Elsevier.

¹⁵⁵ a.o. DE GROOT ET AL. 2002

¹⁵⁶ Also KUO ET AL. (1998)

¹⁵⁷ Here MATSUOKA & KAPLAN mention the works of HULL ET AL. (1994) who evaluated the meaning of physical and natural features after their removal by a hurricane for residents and of LUCY & PHILLIPS (1997) who work on the connection with symbols as means for place identity. Additionally, STEWARD ET AL. (2004) are mentioned as they stress that the persistence of public and semi-public outdoor places where people can gather promote community identity.

¹⁵⁸ SCHETKE & HAASE 2008

¹⁵⁹ a.o. PRIEGO ET AL. 2008; MATSUOKA & KAPLAN 2008; DE GROOT ET AL. 2002

¹⁶⁰ (exhausted) CITED IN WERHEIT 2002, p. 93

¹⁶¹ SEE ALSO GÄLZER 2001

¹⁶² WERHEIT 2002

¹⁶³ MATSUOKA & KAPLAN 2008

¹⁶⁴ COLEY ET AL. 1997, p. 470f

Table 5 Social Cohesion/ Local Identity: Ecosystem Functions, Social amenities and associated UES

Ecosystem Functions (ESF) & Social Amenities	Urban Ecosystem Services
<ul style="list-style-type: none"> • Consolidation of a community, Privacy, Identity, (PRIEGO ET AL. 2008; MATSUOKA & KAPLAN 2008; SCHETKE ET AL.*) • psychological benefits (DE GROOT ET AL. 2002) • contact with nature (PRIEGO ET AL. 2008) • Information function (DE GROOT ET AL. 2002) • Provision of meeting facilities, design of the public domain, Interaction of different social groups (HAJER & REIJNDORP 2001; BURGESS ET AL. 1988; SCHETKE ET AL.*) • strengthening of the social network (CITY OF SYDNEY 2006) • attractiveness of a place (MATSUOKA & KAPLAN 2008) • fulfillment of privacy needs (WERHEIT 2002) 	<ul style="list-style-type: none"> • Recreational & Cultural values (adapted to concepts of BOLUND & HUNHAMMAR 1999; DE GROOT ET AL. 2002, 2003) • Spiritual and historic information, education, aesthetic information (adapted to concepts of DE GROOT ET AL. 2003)

The methodology of operationalization and translation of the two concepts of QoL and UES into quantifiable indicators comprised the following analytical steps: First, within an exhaustive and broad literature-review as described above, three categories of needs urban green fulfils, which can also be regarded as dimensions of QoL related to urban green (see fig. 10), were deduced.

In doing so, this first step forms the framework of the operationalization of the linkages between QoL and UES with special regard to urban green and its quantity, quality and distribution. Therefore, a selection of UES from the broad concept of ESS¹⁶⁵ was elaborated within a second step. Additionally, related social functions, amenities, values and associated ESF were identified. They underpin the basic needs urban green fulfils in our context. Finally, a set of quantitative indicators, according to empirical evidence as established in the presented literature, was elaborated in a third step. It enables a scenario steered socio-environmental impact assessment of future settlement-development using existing communal data-sets.

¹⁶⁵ a.o. COSTANZA ET AL. 1997; DE GROOT ET AL. 2002; CHAN ET AL. 2006; NORBERG 1999

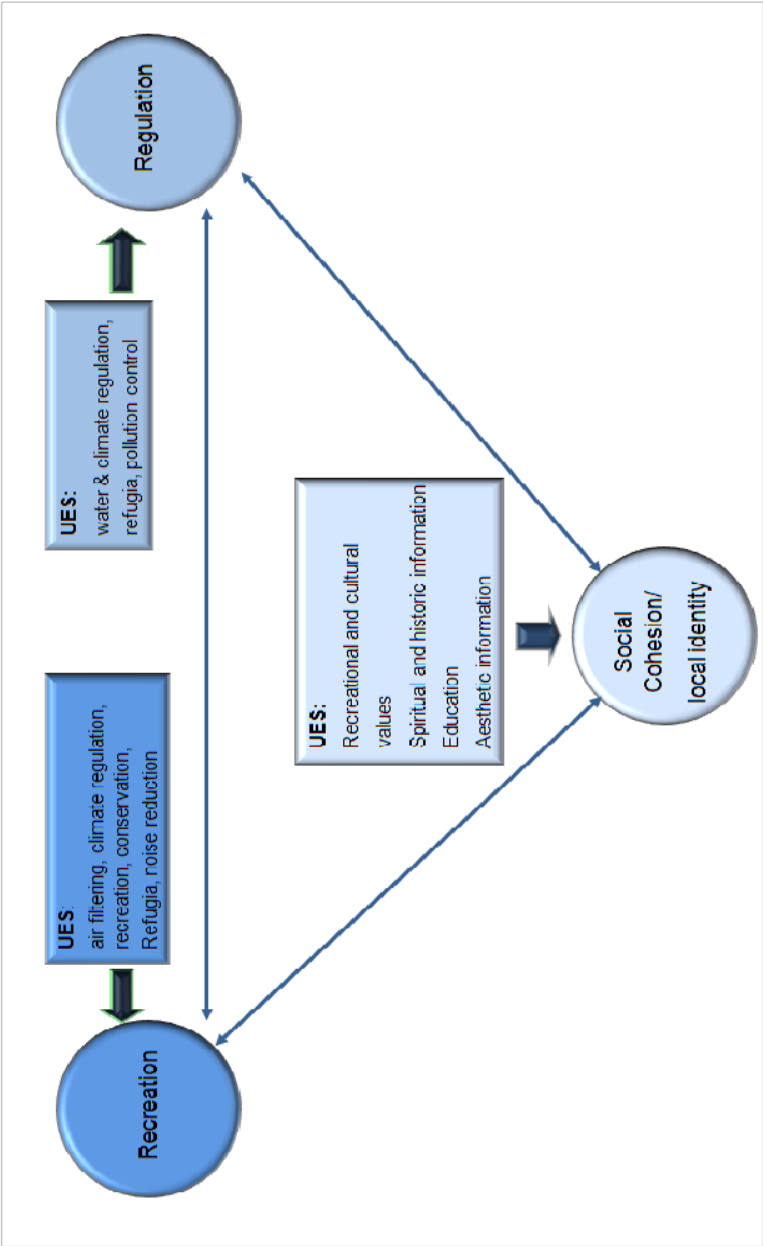


Figure 10 Definition of central needs linking the concepts of QoL and UES (author’s draft)

Excursus: Infill and Greenfield Development

In this work, the term “infill development” is equally used to the German term “Innenentwicklung”. It needs clarification as its use is highly diverse throughout the literature. First of all, very selective definitions of infill development exist: KOLL-SCHREZENMAYR (1999) solely opposes brownfield development to the term greenfield development whilst BUCHERT ET AL. (2003) equal it with “building within built-up areas (see “Nachverdichtung”).

According to HUTTER (2003) “infill development” is used in a broader sense synonymously to the terms “inward urban development” (HUTTER 2003) or “urban intensification (WILLIAMS 2001; WILLIAMS ET AL. in JENKS ET AL., p. 83ff.). The latter includes processes of urban compaction, densification, and the development of vacant land in urban areas in order to deliver a sustainable urban environment (WILLIAMS 2004b). In that context LOCK (1995, p. 173) defines intensification as a process, “which ensures that we make the fullest use of land that is already urbanized, before taking greenfields”.

The municipality of OREGON (OTAK 1999) names infill development in the same breath with redevelopment. This goes hand in hand with the definition of the CITY OF ESSEN (2008), to which this study refers. Here, infill development does not refer to a legally binding state (see “Innenbereich”), but characterizes (re-)development/ re-use of land within urban limits, which has been structurally used during the last 100 years.

SIEDENTOP (2001, p.39) defines infill development according to its measures: the closure of gaps between buildings, reconstruction of buildings, redensification and re-use of vacant land. The COUNCIL FOR EUROPEAN URBANISM (2003) opposes peripheral development (“Außenentwicklung”) to infill development and characterizes it with protection and careful renewal of existing inner-city areas. In its paper the term infill development is equaled with the German term “Innenentwicklung”.

GUTSCHE (2007, p. 127) speaks of “Innenbereich” and „Außenbereich“ in terms of the location of new housing areas to existing facilities of infrastructural provision. He distinguishes this wording from the legal definitions of §§ 34 and 35 (BauGB, German Federal Building Code).

JERING ET AL. (2003) define infill development (Innenbereichsentwicklung) as housing development on former industrial sites (ehemaligen Gewerbeflächen). In accordance to that ARLT ET AL. (2005) define three possibilities to execute of infill development: rounding off (Arrondierung), redensification (Nachverdichtung) and brownfield development (Brachflächenrecycling).

Examples from the USA define this term as follows “Infill development sites are best characterized as neglected public spaces and clusters of vacant or nearly-empty buildings and land.”¹⁶⁶

In contrast to that, the definition of the term greenfield development (“Außenentwicklung”) becomes clearer. According to KOLL-SCHREZENMAYR (1999), greenfield sites are sites without a previous history of development. This goes hand in hand with the definition of the City of Essen (2008) and solely refers to non-developed land, which has not been used for structural purposes during the last years. It does not refer to a legally binding state (“Außenbereich” according to § 35 BauGB).

¹⁶⁶ <http://infillphiladelphia.org/about-infill-philadelphia.php>

According to a British and US-American understanding greenfield land “Is simply land that has not been developed before”¹⁶⁷ or land “not previously developed for urban uses such as residential, commercial or industrial”¹⁶⁸.

¹⁶⁷ www.buildinglanduk.co.uk

¹⁶⁸ County of Sacramento under <http://www.planning.saccounty.net/gpupdate/pdf/Notes-for-Web-Focus-Group-Session-1.pdf>, without year

3 Methodology

Following the compact insight into the theoretical foundation and drivers of this study outlined in the previous chapter, this third chapter explains the methodological translation of the theoretical concepts and their application to the outlined research questions.

It presents their methodological realization and analysis within a Multicriteria Assessment (MCA) and the associated prototype of a Decision Support System (DSS). This DSS-prototype sketches a simultaneous assessment of both ecological and social framework-conditions of a housing site and associated socio-environmental impacts due to housing development. Housing sites of different size, which are displayed in a draft of the regional land use plan (status 2008) of the case-study City of Essen, at a scale of 1:50.000 (see tab. a1), are subject of the assessment.

Chapter 3.1 gives a short insight into the conceptual design of the MCA. The chapters 3.2 and 3.3 will outline the conception of indicators underpinning the MCA according to the target systems QoP, QoL and UES. The methodological chapter will be closed with a brief introduction into the concept of a Visual Basic-based Decision Support System (chapter 3.4) supporting the MCA and a presentation of the case-study of this work (3.5.).

3.1. Multi-Criteria Assessment (MCA)

The methodological core of this study is a spatial and GIS-supported MCA. Basically, the field of MCA is broad and associated literature on multicriteria decision making abundant¹⁶⁹. Most of the literature in this field focuses on the mathematical core of the MCA, its decision rules and associated methods. In contrast to that, the application of spatial MCA is “a relatively new but growing field which is still developing with the further improvement of GIS”¹⁷⁰. MCA allows the integration of manifold aspects of a problem and considers conflicts of points of view and interests of different stakeholders (e.g. residents) within a planning process¹⁷¹. It is a helpful instrument to realize sustainable settlement development when being integrated into spatial planning¹⁷².

The conceptual structure of the MCA of this thesis harks back to the concepts of QoP, QoL and associated UES. Essential interconnections between urban development and the central concepts of this study QoP, QoL and UES were highlighted in figure 5. Figure 11 refers to that and introduces the methodological determinants of the two steps of the MCA. *Moreover, the integration of both ecological and social aspects into one MCA and into decision making is an essential innovative approach of this concept.* Regarding its spatial and executive reference, the MCA is strictly related to the structure of German land use planning. It considers both the preparatory land use planning on the level of a land use plan and the binding land use planning at the level of a legally binding land-use

¹⁶⁹ see MEYER ET AL. 2008 for a concise analysis

¹⁷⁰ MEYER ET AL. 2008, p. 19; see also the concise overview of MALCZEWSKI (2006) highlighting the potentials of linking MCDA and GIS-techniques and further research on a close “understanding of the benefits of such integration” (p. 718)

¹⁷¹ NIJKAMP ET AL. 2002, SCHETKE & HAASE 2008

¹⁷² NIJKAMP & OUWERSLOOT 2003; THÉRIVEL 2004

plan (see fig. 11 below). The systematization and development of indicators for both steps of the MCA were executed according to empirical evidence as discussed in scientific literature and substantiation by communal GIS-datasets. Individual technical and content-related prerequisites of indicators, their relevance for the analysis and their significance will be discussed within the next sub-chapters.

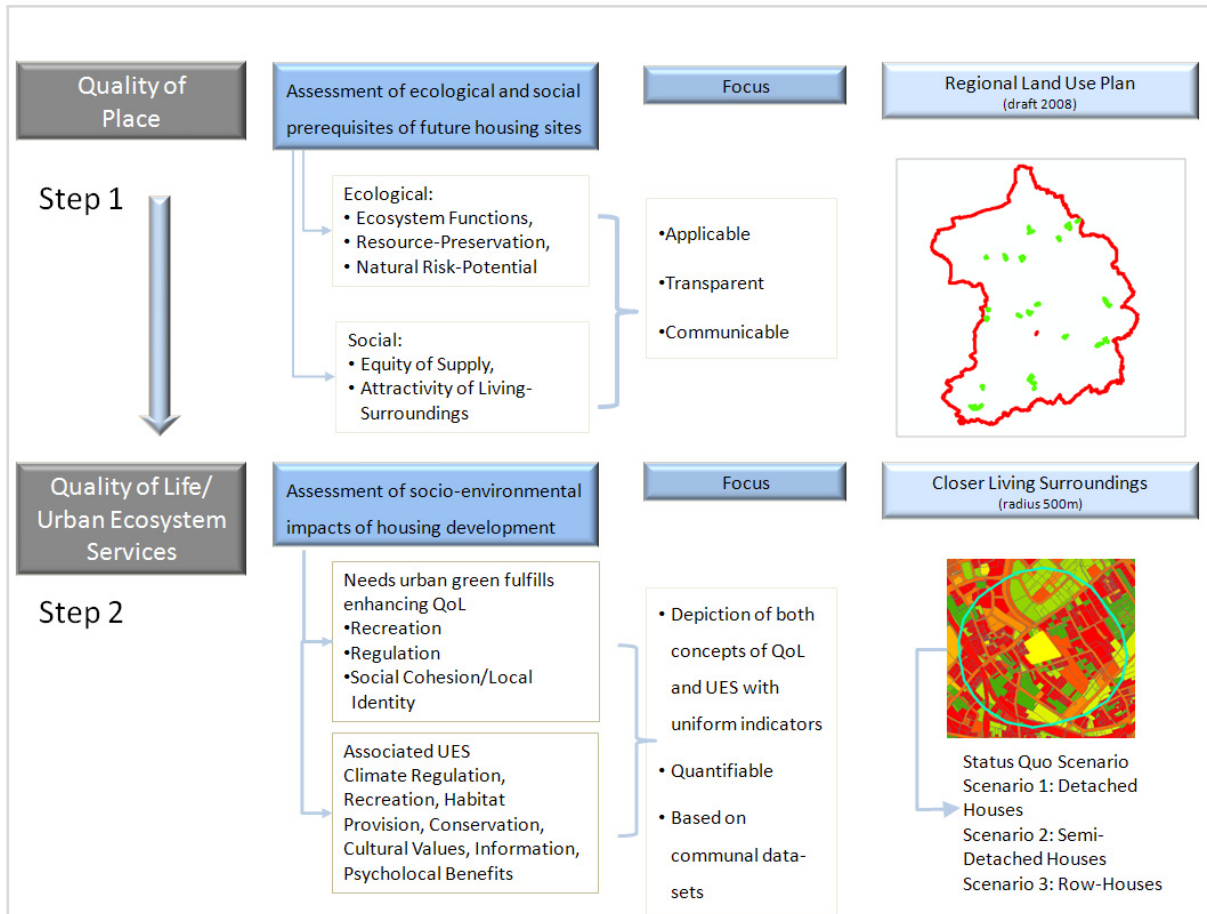


Figure 11 Scheme and content-related specifications of the MCA (author's draft)

Step 1:

The first step of the MCA provides an assessment of socio-environmental prerequisites and objective framework-conditions for future housing-sites, which are displayed in the land use plan of the City of Essen. These framework-conditions – in the following referred to as *QoP*- are analyzed under the premise of the contribution of the respective future housing estates to a sustainable and resource-protecting settlement-development. The focal points of the analysis of ecological and social framework-conditions are displayed in figure 11 and were outlined in chapter 2. The indicator-setup itself is strongly oriented towards the applicability of all indicators within the planning process and their transparency and communicability towards urban planners as the aspired user-group (further outlines in chapter 3.2)¹⁷³.

¹⁷³ According to KÖTTER ET AL. 2009b, SCHETKE ET AL. 2009a, SCHETKE ET AL. (in prep.)

As the land use plan describes the strategic level of German land use planning and performs steering effects for settlement development, the assessment of socio-environmental prerequisites (QoP) as the first step of the MCA – *physiocentric* in nature – on that level can point out, which future housing estates contribute to a sustainable and resource-preserving settlement development. Simultaneously, it depicts the fields and areas of a city where settlement-development and urban planning itself follows the unintended negative trend of ongoing land-consumption and the current paradox of settlement- growth as outlined in chapter 2.

Step 2:

After a first assessment of socio-environmental framework conditions (QoP), the second step of the MCA assesses concrete socio-environmental impacts of housing-development. The intensity of these impacts alters according to different housing-densities and modified land uses at each future housing site of the case-study. Three scenarios, which represent different housing densities, will be used for the assessment.

The concepts of QoL and UES are used as target systems to provide an objective, scenario-based and quantifiable analysis of future impacts due to housing-development. As outlined in chapter 2, the sensitivity of QoL and UES against housing-development and each change of the built environment is to be analyzed using the significant contribution of urban green to the two systems and its modification under processes of settlement-growth.

Three main needs as determinants of QoL were extracted from a broad literature review (see chapter 2.5). The provision with uniform and quantifiable indicators, which link QoL and UES as described in SCHETKE ET AL.*, are entirely based on official, communal data-sets.

Compared to the assessment of QoP, this second level of the MCA is *anthropocentric* in nature. It provides a different indicator-set compared to step 1. This is not only emphasized by an analytical focus on two highly human-related concepts of land use development such as QoL and UES. Moreover, both the impact assessment and its quantification of land use change are bound to the housing areas itself together with its closer living surroundings. It is expected that a direct land use change at a housing site will also have eradiating effects on its surroundings. In current planning literature “closer living surroundings” or “free space close to living to apartment” are set as a radius of 500m around a site¹⁷⁴.

¹⁷⁴ The definitions of closer living surroundings are deriving from planning standards. The CITY OF LEIPZIG (2004, p. 27) defines a walking distance of 500m to green spaces of closer living surroundings. This implies a smaller air-line distance taken into account for GIS-analysis. Compared to that, the CITY OF BERLIN (Umweltatlas Berlin 2009) calculates an air-line distance of 450m including approximately 10%-deduction from walking distance. According to these notions a walking distance of 500m was taken as a reference for closer living surroundings. To derive the correct air-line distance a distance coefficient of 1.2 (KORDA 2005, p. 289) has been applied for GIS-analysis leading to an air-line distance of 416.67m.

3.2. MCA-Step 1: Assessment of QoP

On the one hand, the operationalization of the term QoP is strongly dependent of technical and data-related determinants. On the other, there are content-related determinants based on empirical evidence as established in the literature¹⁷⁵ focusing on the socio-environmental impacts of land use planning and settlement growth and determining the QoP of future housing sites. Insights into this could be given in chapter 2.1. Additional valuable information on indicators of land use change and especially ecological impact assessment could be derived from the European research-project URGE-conducted between 2001 and 2004¹⁷⁶.

The indicators of QoP-analysis are set against a set of threshold values derived from literature or legally binding planning fundamentals. These QoP-indicators are strongly oriented towards the requirements of an application within land use planning. This means, that most of the communal data, which undermine each indicator, are used as provided by the state agencies and administrative offices of the City of Essen. Conceptual and functional framework-conditions also have to be taken into account. The indicator-set considers both the practical applicability and communication to urban planners and the representativeness by communally available data (see figure 12).

Technical influences, such as the availability of data, essentially determine the choice and applicability of the indicators. They also limit the complexity of the MCA. Additionally, the quality of data has crucial influence on the main focus of the MCA-scheme. Additionally, it is of great importance to adopt the demands of future users for their decision-processes (municipalities and local decision-makers)¹⁷⁷, in order to ensure an integration of the MCA into current planning processes and to address issues of sustainability. In doing so, empirical findings of stakeholder-workshops executed within a recent research-project¹⁷⁸ at the Department of Urban Planning and Real Estate Management at the University of Bonn were used. The author was entrusted with the elaboration of the ecological and social indicators discussed within the workshops. Closer information will be given in the next excursus. The presented indicator-scheme is the result of these workshops between 2006-2009. Planners of three cities in North Rhine-Westphalia – Essen, Erftstadt and Euskirchen- and external experts from different disciplines¹⁷⁹ were involved into this process.

Based on this, the focus was on local models to reduce an often fairly high level of abstraction and to achieve a direct and comprehensible reference to land. Basically, a comprehensible MCA-scheme is an important step towards a transfer and communication of scientific knowledge into local assessment and land management approaches. Additionally, such an approach requires a sound scientific concept, “but has to bridge the gap towards municipal planning practice and subsequent

¹⁷⁵ Compare chapters 2.1 and 2.1.1. and the following explanations according to each indicator.

¹⁷⁶ WWW.URGE-PROJECT.UFZ.DE/ URGE RESEARCH-TEAM (2001-2004)

¹⁷⁷ KÖTTER ET AL. 2009a; KÖTTER ET AL. 2009b; SCHETKE ET AL. (in prep.)

¹⁷⁸ This refers to the research project FIN.30 from 2006 to 2009 (Grant ID 0330733).

¹⁷⁹ Urban planning, landscape planning, sociology and law (and entire list is mentioned in the final report of the project FIN.30 of Kötter et al. (forthcoming))

user-friendliness”¹⁸⁰. Finally, these requirements lead to four priority tasks as the formal reference for the indicator-setup assessing QoP:

- Deduction and thus operationalization of complex system- interrelationships to provide a broad understanding of practitioners and to allow its communicability (analysis function).
- Reduction of complexity and information to depict reality (communication and information function).
- Control, warning and decision-making function: Within the planning process a sustainable regional development can be partially controlled using appropriate indicators. Planning alternatives can be evaluated based on an assessment framework using MCA.
- Monitoring function: A target-performance comparison of different planning scenarios allows a monitoring of human settlements development using sustainability indicators

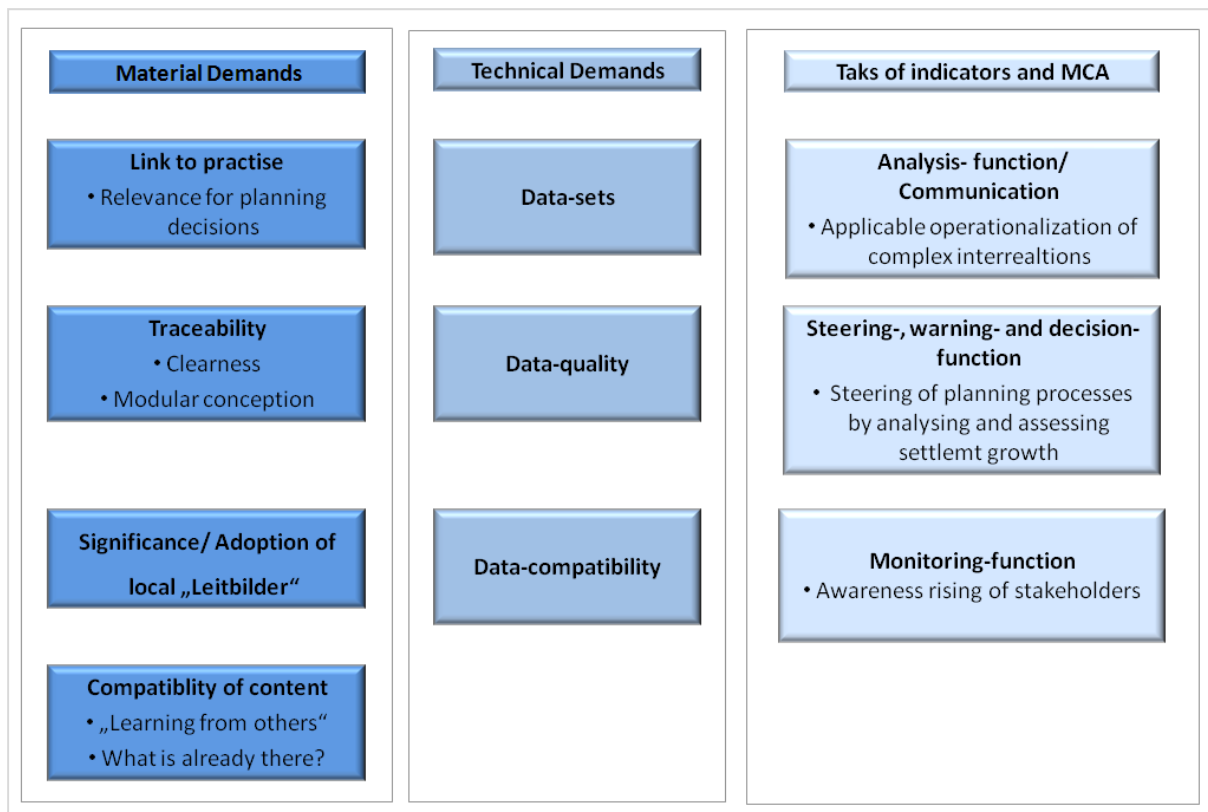


Figure 12 Demands and constraints of an MCA (author’s draft referring to HEILAND ET AL. 2003; NIJKAMP & OUWERSLOOT 1998: 6; KORCZAK 2002; WOLTER 2001; BRÜCKNER 2001; WRBKA ET AL. 2003

The following paragraphs give a concise overview of the categories associated to each dimension of QoP. They hold all indicators, which were applied for a qualified potential-analysis of housing sites displayed in the draft (status 2008) of the regional land use plan of the City of Essen. These indicators were used to assess the QoP of all selected housing sites and to determine their support of a sustainable and resource-preserving settlement development due to their respective location¹⁸¹.

¹⁸⁰ KÖTTER ET AL. 2008, p. 1

¹⁸¹ Note that all indicator-performances are derived from a spatial GIS-comparison of the housing-site itself and the respective underlying data. Due to the fact that the housing-potentials are derived from a draft (status 2008) of the

These categories define the framework which determines the ecological and social suitability of a site for housing-purposes. At the end of the QoP-assessment, all indicators were aggregated to one final ecological and social QoP-result for each housing-site. Closer insights into the methodology of aggregation of all indicators to one complex QoP-performance value will be given in chapter 3.2.3. Due to their association to either the ecological or social dimension and to a broad variety of background data, major tasks of MCA-DSS was the aggregation of qualitative and quantitative indicators.

In doing so, a standardization of all indicator-performances into one threefold classification scheme was necessary¹⁸². This follows the outlined demands for a MCA within processes of decision-making, which are a reduction of complexity and applicability within planning processes. And it enables the integrated assessment of qualitative and quantitative indicators. The statistical evaluation of the results of QoP-analysis in chapter 4 will consider this high level of standardization.

Note: All QoP-Indicators, their class values and data-sources are listed in table a2 in the annex.

Excursus: Elaboration of QoP-Indicators

The elaboration of QoP-indicators was part of the research-project “FIN.30- Flächen intelligent nutzen” (Innovative land use). FIN.30 was conducted between 2006-2009 at the Department of Urban Planning and Real Estate Management of the University of Bonn, Germany. Target of FIN.30 was the integrative assessment of housing development in three cities of North Rhine-Westphalia (NRW): Essen, Euskirchen and Erftstadt. And its focus lied on the development of a Decision Support System (DSS), which can be used to assess future housing sites displayed in a land use plan with regard to the three dimensions of sustainability.¹⁸³

The author was responsible for the following sections within the project: *i)* the scientific elaboration of indicators representing the ecological and social dimension of sustainability, *ii)* the discussion of these indicators with planners from the three partner cities in NRW and external experts within workshops, and *iii)* for the acquisition and overworking of underlying data-sets derived from the partner-cities and federal agencies and local consultations. This process was accompanied by *i)* workshops with local planners and *ii)* workshops with local planners together with external experts from various disciplines¹⁸⁴ under the following conditions:

Workshops with planners were executed in a frequency of up to three times a year. The target was to select suitable and planning –relevant indicators in a collaborative process between scientists and planners. The presented ecological and social QoP-indicators are the result of this collaborative approach. Additionally, all indicators were assigned with weights, in order to provide an aggregated QoP-result, which matches the demands of local planners and represents the importance of single

regional land use plan scaled 1:50.000 and most of the data applied are derived from survey maps, the slight spatial uncertainties have to be taken into account. It is therefore the task of the respective evaluator to integrate his personal local knowledge into the QoP-analysis of a single housing-site and individually adjust the communal data to small-scale local conditions.

¹⁸² Compare closer insight given in chapter 3.2.3.

¹⁸³ See also SCHETKE ET AL. 2009a; KÖTTER ET AL. 2009a, b

¹⁸⁴ Such as landscape planning, sociology, law and urban planning.

indicators within planning processes. These weights will be picked up in chapter 4 and addressed as expert-weights.

Workshop with planners and experts were executed once a year between 2006 and 2009. The external experts proofed all presented indicators against their scientific value. Additionally, urban planners from the three partner-cities were involved into this discussion. The remaining QoP-indicators, as presented within this study, are the final approved and tested indicator-set.

Additionally, all indicators have been tested by urban planners in all three partner-cities under the supervision of the author and the research-team of FIN.30 within two additional workshops.

3.2.1. Ecological Indicators

The assessment of favorable ecological surroundings, which enables a resource-preserving settlement development, is restrictive in nature. As settlement growth is perceived to have basic negative ecological impacts¹⁸⁵, future housing sites displayed in a land use plan promoting at least reduced negative impacts are to be favored. This stresses the promotion of sites, which are characterized by highly humanely modified natural resources and functions. In doing so, it limits the loss of subnatural resources and nature-oriented areas providing high-capacity ecological functions within a city.¹⁸⁶ Three major ecological categories, which were used to elaborate indicators, are outlined within the next paragraphs: ecosystem functions, resource preservation and natural risk¹⁸⁷. Closer information on indicators and graphical examples are provided in the annex.

3.2.1.1. Category “Ecosystem Functions”

According to ALBERTI (2009) urban development strongly influences urban ecosystems by degrading natural habitats and by simplifying and homogenizing species composition. Urban landscapes also differ “from natural ecosystems also in microclimate (they are warmer and have greater precipitation), hydrology (increased runoff), and soils (...)”¹⁸⁸. Furthermore, nutrient cycling, biochemical processes, geomorphic process and biotic interaction are being influenced by urbanization. Ecosystem functions are significantly affected by fragmentation and alteration of the patch structure. Size, shape, interconnection and composition- of natural patches are modified by urbanization processes¹⁸⁹. ALBERTI (2005) therefore launches the hypothesis that urban patterns can be linked to ecological conditions and the provision with ecosystem functions testable¹⁹⁰.

Derived from these statements, the following indicators were elaborated assessing the QoP of a housing site¹⁹¹ with regard to the provision with ESF. The QoP of a site rises, as its surroundings do

¹⁸⁵ Compared outlines in chapter 1.1.

¹⁸⁶ In this context the book “Urban Ecology” by MARZLUFF ET AL. (2008) provides a wide range of assessment approaches for the suitability of land in urban areas for to settlement development and patterns of urbanization from an ecological perspective. Selected aspects mentioned in this issue will be reflected in the following paragraphs.

¹⁸⁷ SCHETKE ET AL. 2009a

¹⁸⁸ ALBERTI 2005, p. 170

¹⁸⁹ ALBERTI 2009

¹⁹⁰ ALBERTI 2005

¹⁹¹ SCHETKE ET AL. 2009a; SCHETKE ET AL (in prep.); KÖTTER ET AL. 2009a

not provide with especially high-qualitative ESF and undisturbed green-structures but as they are integrated into already humanely modified urban patterns and landscape elements. Note that the following indicators do not refer to the analysis of landscape metrics due to enhanced applicability within planning processes. The question of different impacts on ecosystems related to alternative urban patterns as highlighted in ALBERTI (2005) will be addressed in the second part of the MCA within QoL/UES-assessment.

Closer information on indicator-performances and derived class-values can be obtained from table a2 in annex A.

*Indicators: Climate Regulation & Biotope Quality*¹⁹²

The calculation of these indicators demanded the attribution of cadastral land use classes from ALK (layer 21 “current land use”). This is due to the fact that cadastral land use data do not *per se* provide additional information on climate regulation and biotope quality. The attribution was executed using look-up tables of SINGER (1995)¹⁹³. The values of regulative function and biotope quality refer to the open areas of each land use class and range from 0 (no regulative function, e.g. supply infrastructure) to 4 (very high regulative function, e.g. public parks).

The indicator **climate regulation** describes the contribution of open space structures of different land uses within a city. Open space structures contribute to climate-regulation, regulation of the urban heat island and enhancement of human health. Additionally, they contribute significantly to a reduction of pollutants, humidation of the air and production of cold air¹⁹⁴.

The indicator **biotope quality** describes the capability of the open and green structures of cadastral land use classes to be habitat to flora and fauna and to sustain and enhance their vital processes. It was calculated in accordance to the previous indicator. Despite the fact that the quality of a habitat also depends on its size and shape¹⁹⁵, this indicator focuses on the naturalness and state of human modification of each cadastral land use class. As the provision with regulative functions and habitats essentially¹⁹⁶ determine people’s QoL, those sites, which provide high-qualitative land uses, score lower than already modified sites and are to be preserved. Due to the fact, that not only the site’s characteristics but overall regulative preconditions¹⁹² are taken into account, the indicator performance was calculated based on a 500*500m raster (see fig. 13). Therefore, a raster-based weighted mean value was calculated.

The applied threshold values derived from the upper and lower limits according to SINGER (1995). The five-stepped classification of SINGER had to be transferred into three simplified values in order to be able to provide a practicable assessment of low (1), medium (2) and high performance (3). They will

¹⁹² See also URGE-RESEARCH TEAM (2001-2004)

¹⁹³ The approach of SINGER (1995) providing information on the ecological performance of open spaces associated to cadastral land use types is an essential part of the data-attribution and will be outlined in Annex C5.

¹⁹⁴ SINGER 1995, p. 44

¹⁹⁵ See MARZLUFF ET AL. (2008) and the works of ALBERTI (2005, 2009) on land use patterns within urban surroundings highlighting the patch as centre of investigation.

¹⁹⁶ MEA 2005; see also ECOTEC 2006; ARLT ET AL. 2005

be outlined in chapter 3.2.3. The derived values accommodate the fact that one housing site can cover more than one raster-cell and therefore more than one value of regulative performance.



Figure 13 Grid-based calculation of the regulative performance and the biotope quality of cadastral land use data (author's draft, Data-source: Cadastral Land Use Data (ALK), Office of Geoinformation, Measurement and Cadastre, City of Essen/Amt für Geoinformation, Vermessung und Kataster der Stadt Essen (2007))

*Indicator: Sealing Rate*¹⁹⁷

The indicator sealing rate is a significant indicator to monitor the consequences and intensities of ongoing land use by. Sealed surfaces are replete with an “ecological deficit providing regulative, productive or information functions”¹⁹⁸. It goes hand in hand with the loss of the resource soil and the associated hydrological and soil-biological ESS such as self regulation and – regeneration.¹⁹⁹

The attribution of characteristic values of sealing rates using cadastral land use data was executed according to look-up tables of SINGER (1995)²⁰⁰ and to the attribution of the indicators climate regulation and biotope quality as mentioned above. The indicator-performances at all sites are set against local threshold values derived from the climate-analysis of the Environmental Agency of the City of Essen

¹⁹⁷ See also URGE-research team (2001-2004)

¹⁹⁸ ARLT & LEHMANN 2005, p. 39 (translation of German original)

¹⁹⁹ Also the BMVBS, BBR (2007a, p. 58) highlights in its issue “Nachhaltigkeitsbarometer Fläche) the indicator 'sealing rate' as a cross-sectional indicator referring to varying ecological impacts due to settlement growth such as modified soil and climate conditions.

²⁰⁰ Here the equivalent to SINGER's defined share of open spaces (unsealed, unbuilt) has been applied. Comparable studies on characteristic sealing rate according to urban structure types (HEBER & LEHMANN 1993) confirm the deriving values. Still, ranges of sealing rate according to urban structure types are wide and difficult to systematize (see HEBER & LEHMANN 1993, CITY OF BERLIN 2007).

(2002). It proofs whether critical sealing rates were already exceeded before new constructions and where –in consequence- additional houses would mean an alarming increase of small-scale sealing rates. It does not mean a double-counting of climate effects with regard to the indicator **regulative function**.

Whilst the indicator **climate regulation** promotes positive regulative effects due to composition and degree of modification of open space structures, the indicator **sealing rate** extends it in terms of an increased sensitive heat flux due to soil sealing. Not only the site's characteristics but overall regulative preconditions are taken into account. The indicator performance was therefore calculated based on a 500*500m raster (see accordingly fig. 13 above).

Indicator: Seepage

According to GÖBEL ET AL. (2007, p.189) “the decentralized infiltration of rain water, which accumulates on sealed surfaces in urban areas, causes a change of the water balance parameters which in consequence leads to a rise of the groundwater level, in particular in areas with an increasing degree of surface sealing and low soil permeability.”

To assess the positive effects (and reduced additional negative effects), which can still emerge also during processes of settlement development due to pedological and hydrological prerequisites, the solely pedologic indicator **seepage** is implemented. It outlines the possibilities of a more nature-oriented rainwater management but does not imply further influencing factors for a decentralized rainwater management such as stagnant moisture or thickness of loose rock. Soil data derived from the soil map 1:50.000 of North Rhine-Westphalia enable an indication of this capability via the Kf-value (see fig. 14). Sites with higher Kf-value score higher in QoP as preservation of natural hydro-pedological functions and the implementation of a decentralized rainwater management are still possible. Moreover, this is economically profitable as capital costs for expansion of canal system and additional fresh drains can be reduced. The classification of simplified values was executed according to the Geological Service of North Rhine-Westphalia (see appendix)^{201, 202}.

²⁰¹ The classification has been slightly modified according to the three-stepped increment values of QoP-assessment. According to the Geological Service North Rhine-Westphalia a medium seepage is provided as Kf ranges between 10-40 cm/d which is the lowest class of QoP-assessment. But as threshold values of decentralized rainwater management are set at a value of 86 cm/d, the new classification determining a medium seeping rate at values between 40 and 100 cm/d, is closely oriented towards the framework conditions of decentralized rainwater management.

²⁰² Note: due to heterogeneous actuality of soil data and current sealing rates at the respective housing-sites, the user is demanded to take possible changes of the imperviousness into account when assessing soil characteristics. This also counts for the assessment of soil quality (see indicator “soil quality”).

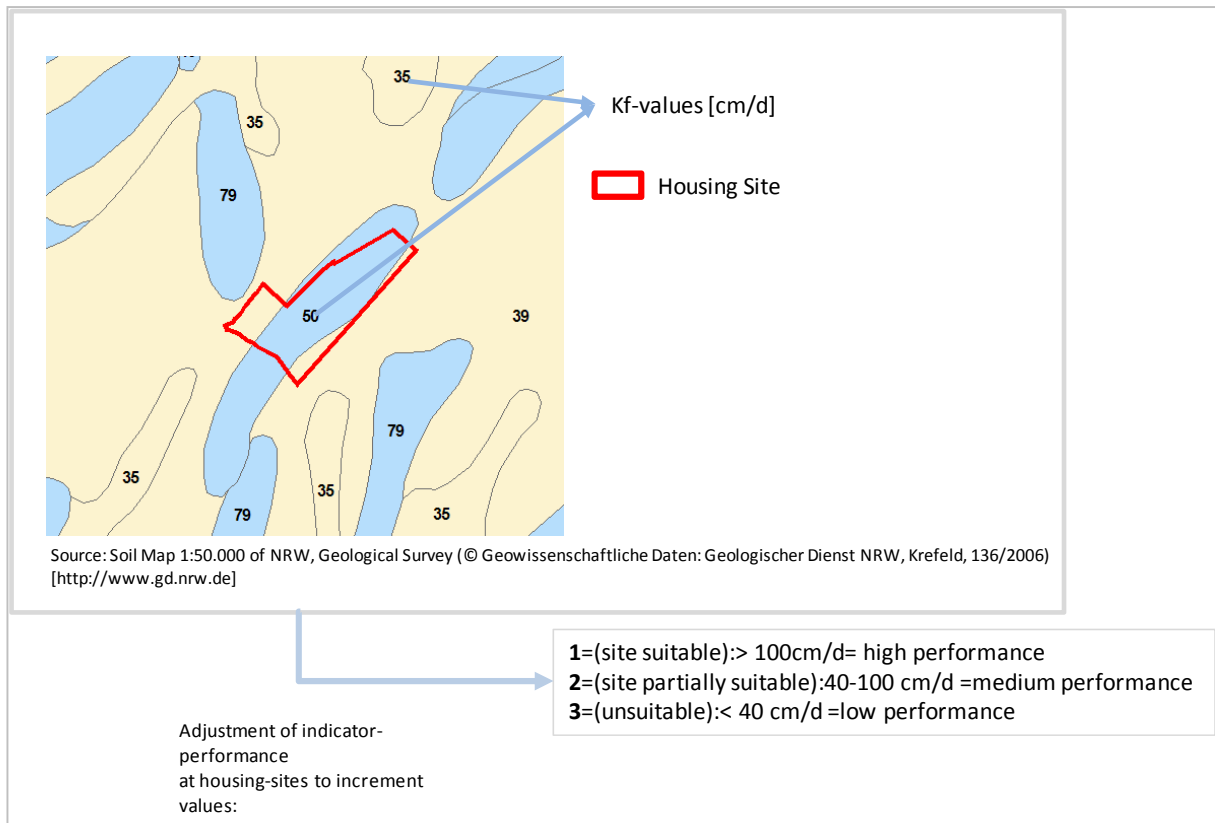


Figure 14 Assessment of seeping-rate at a housing-site (source: Soil map 1:50.000, Geological Survey NRW 2006)

3.2.1.2. Category “Resource Preservation”

In contrast to the preservation of distinct ecological functions this category focuses on the preservation of single resources during the process of settlement development. According to SCHETKE ET AL. 2009a & KÖTTER ET AL. 2009a the focus is put on the preservation of protected areas and soils of high quality. Statistical analyses stress the point that in historical context settlement growth has traditionally been affecting soils of high productivity²⁰³ and therefore need protection from additional land consumption. The named criteria are also restrictive in nature implying that protected areas are preserved partially including buffer areas limiting direct impacts and to dedicate soils of high quality to its productive function of e.g. crops and not to be used as building land. Closer information on indicator-performances and deriving increment values can be obtained from table a2 in annex A.

Indicator: Isolation/ use of connected habitats

The isolation of habitats, decreasing sizes of biotopes and diminished edge-effects are perceived as the main reasons of decreasing biotope quality and biodiversity in urban regions²⁰⁴. According to

²⁰³ SIEDENTOP 2005, JERING ET AL. 2003; BMVBS, BBR 2007a

²⁰⁴ See URGE-RESEARCH TEAM (www.urge-project.ufz.de)

ALBERTI (2005, p. 169) “urban development fragments, isolated, and degrades natural habitats.”²⁰⁵ In order to depict these issues without diminishing the applicability of this indicator during planning processes, data referring to defined biotope structure, which are of special or extraordinary meaning, are implemented. Here biotope-data of the Linfos-Database (State Office of the Environment, Landscape and Consumer Protection of North Rhine-Westphalia (LANUV), received 2007) were applied regarding their disturbance by additional housing sites.

The indicator-performance is derived from a simple spatial comparison of location of housing-sites and biotopes belonging to distinct habitat-structures as determined by the LANUV (see fig. d1 in annex D for graphical explanation).

Indicator: Protected Areas

This indicator proofs the location of future housing sites directly within and also in the closer surroundings of legally defined protection areas. The protection categories, which are depicted by this indicator, are nature protection and landscape conservation areas, § 62-Biotopes, Natura-2000-areas, further valuable biotopes and water protection areas^{206 207}.

According to GENELETTI ET AL. (2007, p. 416) the assessment of negative impacts on protected areas has to include both the areas themselves and their closer surroundings of 250 and 500m.²⁰⁸ Hence, effects of additional housing can be assessed during the time of construction and afterwards. He promotes the integration of these buffer areas within an impact assessment.²⁰⁹

The indicator-performance is derived from a simple spatial comparison of housing-sites, protection areas as determined by the LANUV and the respective buffers (see fig. d2 in annex D for graphical explanation).

Indicator: Soil Quality/ Yield stability

The loss of the resource soil and related ecological processes are central issues within the debate of ongoing land consumption. Nevertheless this issue has to be put into perspective and should be assessed according to its respective severity. Within this study, special attention will be drawn to the preservation of UES, which are provided by the resource soil, such as the production of food and energy crops. It can be stated that soils of high quality in terms of yield stability are to be dedicated to these functions and services instead of acting as building land. Here, § 1a of the German Federal Building Code (“soil conservation clause”/ “Bodenschutzklausel”) requests a sparing use of this resource. Therefore, sites, which provide a very low soil quality, score high in QoP as they do not diminish the named UES of the soil and promote a misuse (see fig. 15).

²⁰⁵ Additionally, the BMVBS, BBR (2007a) integrates a similar indicator “unfragmented habitats” in its issue “Nachhaltigkeitsbarometer Fläche” and also GÄLZER (2001) stresses the issue of implementation of biotope networks as a central task in landscape planning in Germany.

²⁰⁶ Dt.: *Wasserschutzzone Typ 1 und 2*

²⁰⁷ See also the example of a conflict analysis for housing development in Karlsruhe and in the Federal State Saarland presented in the “Nachhaltigkeitsbarometer Fläche” (BMVBS, BBR 2007a, p. 67) comprising an analogous complexity of protected areas as presented in the paragraph before.

²⁰⁸ Also GÄLZER (2001) stresses the implementation of buffer zones around biotopes.

²⁰⁹ In its issue “Städte der Zukunft”, the BBR (2004b) highlights the protection of distinct areas especially in urbanized areas to enhance reduced land consumption and natural perception of citizens.

The quality of the applied data derived from the soil-map 1:50.000 does not entirely provide in-depth data of a pedological analysis of urban soils. Not only has a rough sample-scale and a relatively rough scale of 1:50.000 actually prohibited a lot-sharp analysis. The fact that the City of Essen is highly built-up diminishes the quality of the data and the provision with a close net of sample points.

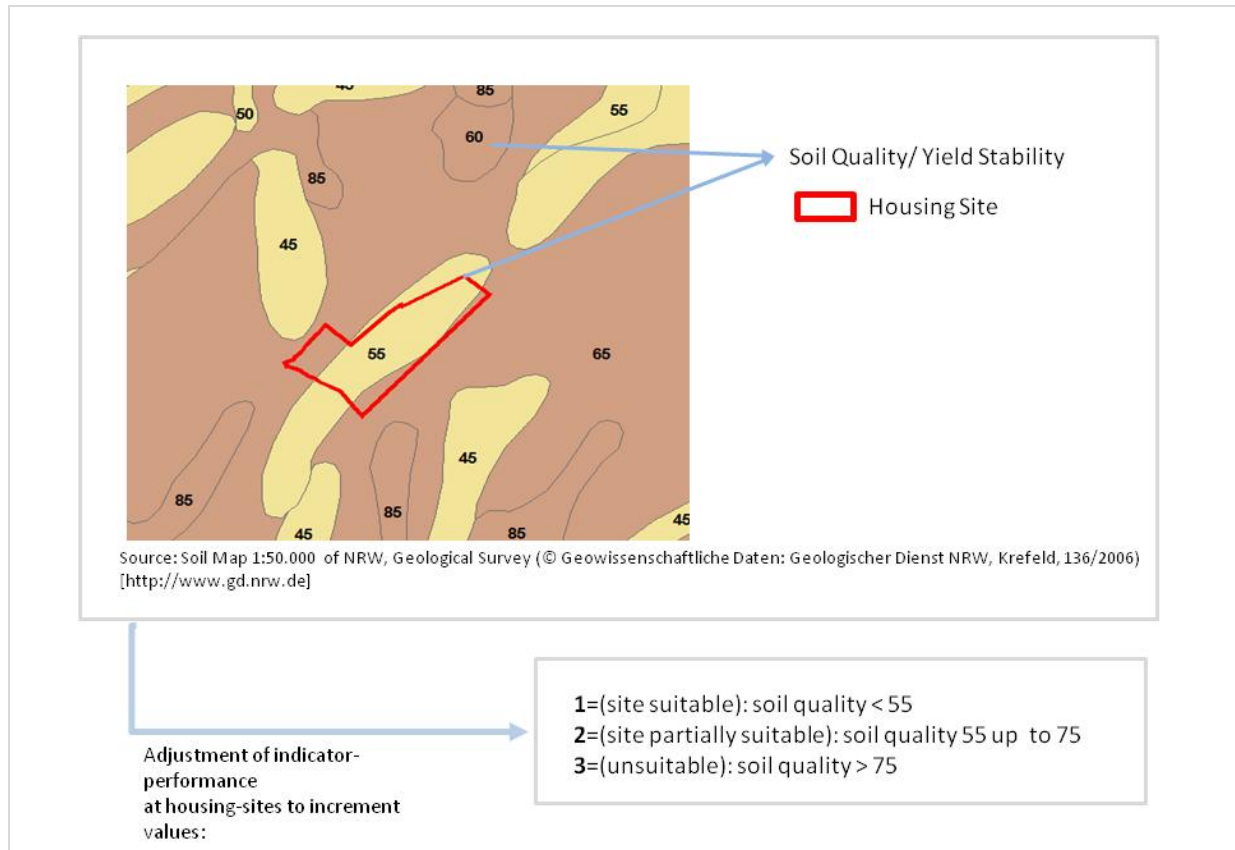


Figure 15 Assessment of soil quality/yield stability at a housing-site (source: Soil map 1:50.000, Geological Survey NRW 2006)

3.2.1.3. Category “Natural Risk”

According to legal framework-conditions also defining the QoP of a site in juridical terms, natural risk potentials limiting or even endangering the suitability of a site for settlement-development need consideration within the planning-process (see § 1 clause 6. 12 German Federal Building Code²¹⁰, § 31a & 31b Federal Water Act²¹¹, § 63 Federal Nature Conservation Act²¹²). Beside ecological concerns in terms of negative impacts on vulnerable ecosystems or the loss of natural flood protection areas, simple economical issues, which refer to higher investment costs due to additional protection measures, are related to this indicator²¹³. Closer information on indicator-performances and deriving simplified values can be obtained from table a2 in the annex.

²¹⁰ Dt.: Baugesetzbuch (BATTIS ET AL. 2007)

²¹¹ Dt.: Wasserhaushaltsgesetz (<http://bundesrecht.juris.de/whg/index.html>)

²¹² Dt.: Bundesnaturschutzgesetz (http://www.gesetze-im-internet.de/bnatschg_2002/)

²¹³ SCHETKE ET AL. 2009a & KÖTTER ET AL. 2009a

Indicator: Flood risk

The flood-risk is a very significant indicator and is of major importance within the planning process. At the scale of a land use plan it assesses whether future housing areas are risk-exposed or not and therefore provide a bad or good QoP. In terms of climate change, this indicator gets special attention as extreme flood events exceed the legally defined protection areas of centennial flood events²¹⁴. Therefore, also potential²¹⁵ flood-affected areas and the extensions for bicentennial flood-events, which are provided for the river Ruhr, only, are implemented within the assessment (see fig. d3 in annex D for graphical explanation)²¹⁶.

3.2.2. Social Indicators

The assessment in terms of *social* suitability of new residential land focuses on the technical and nature-oriented quality of living surroundings and human well-being. Major determinants are firstly the provision and accessibility of adequate recreational facilities as well as social and technical infrastructure²¹⁷ satisfying daily needs. They are assessed in the category “equity of supply”. Besides these structural benefits to QoP, a second QoP-focus in terms of social demands is put on the attractiveness of a site for residential purposes. This includes recreational facilities, noise exposure and perception within the category “attractiveness of living surroundings”.

A calculation of follow-up and investment costs due to different patterns of settlement development and resulting expansion or new construction of social and technical infrastructure will not be executed within this study²¹⁸. Here, the analysis of reasonable distances of existing facilities will be executed as these are driving factors of a resource-preserving and compact settlement development.

3.2.2.1. Category “Equity of Supply”

Following SCHETKE ET AL. 2009a & KÖTTER ET AL. 2009a, this category is specified by the criteria “supply with infrastructure” aiming at reasonable access to infrastructural facilities, which need to be within closer distance to residential areas. These are local food suppliers, playgrounds, kindergartens and primary schools and satisfy daily needs.²¹⁹ Future settlement growth is supposed to take place within existing settlement-structures and to use efficiently existing infrastructure. The proximity to facilities

²¹⁴ Dt.: HQ-100

²¹⁵ Dt.: Potentielles Überschwemmungsgebiet

²¹⁶ According to the LANUV 2009 (www.lanuv.nrw.de/wasser/hwbumf.htm) From 1975 water management in North Rhine-Westphalia started to determine flood areas according to new calculation-methods. Basis of these methods are:

Hydrological models and statistical methods calculating dimensioning run-offs (e.g. HQ100)

Hydraulic calculations of water-table-positions and intersection with elevation-models

One important application of these models determining flood-affected areas is the determination as flooding-area according to the Federal Water Act (“Wasserhaushaltsgesetz”) in a scale of 1:5.000. The applied data refer to the year 2001. Note, that also flood-areas which are not determined according to Prussian Flood Monitoring or hydrological models (such as floor-areas between dikes in the Emscher-area in the northern part of Essen) are included within the assessment.

²¹⁷ SCHETKE & HAASE 2008; USBECK & USBECK in BRAKE & RICHTER 1996; PRINZ 2004 in STROBL ET AL. 2004; PRINZ & REITHOFER in SCHRENK. 2005; KÖTTER ET AL. 2009a; SCHETKE ET AL. 2009a

²¹⁸ See here the dissertation (currently under preparation) of FRIELINGHAUS

²¹⁹ USBECK & USBECK in BRAKE & RICHTER 1996

of daily needs reduce path lengths, individual traffic, enhances the use of public transport systems and supports a use-to-capacity of existing social infrastructural facilities²²⁰. The accessibility of social infrastructure closely corresponds with housing densities. Dispersed settlement structures need to be avoided in order to reduce infrastructural costs and to provide a good accessibility of facilities of social infrastructure, especially in rural areas. Moreover, according to an ongoing demographic change and reduced population numbers, a smart localization of housing areas can help to reduce “remanence effects” and rising costs for the community²²¹. And as cities tend to perforate from the inside, a persistence of the economic viability is a central challenge for services of public interest and urban planning.²²² The economic and financial consequences of ongoing urban sprawl affect residents and communes²²³. Different types of social infrastructure, such as schools or kindergartens, are robust in terms of cost due to decreasing demands²²⁴.

But still, the provision with facilities of social infrastructure is reacting sensitively towards needs and demands of the society. Within the abundance of possible facilities, only a reduced number is under public authority²²⁵. The following indicators are adjusted to that and depict a selected choice of facilities to be integrated within the MCA.

Closer information on indicator-performances and deriving increment values can be obtained from table a2 in annex A. Figure d4 in annex D provides additional graphical explanations for all indicators.

Indicator: Distance to Playgrounds

The provision with infrastructure, which is suitable for children such as playgrounds, is an essential contribution to favorable living conditions²²⁶. It is one the major targets of a suitable and attractive supply of living spaces - especially for younger families in inner urban areas²²⁷. Currently, young families with children are the major target group to be attracted in times of demographic change, over-aging and decreasing population numbers.

This indicator analyses the distance to playgrounds and includes the suitability for older children and families, as well. These are playgrounds of a minimum size of 600m² within a distance of 750m. Distances and sizes of playgrounds are defined according to standards, which are derived from

²²⁰ PRINZ 2004, p. 551ff in STROBL ET AL.; PRINZ & REITHOFER 2005a in STROBL ET AL.; KÖTTER ET AL. (acc.)

²²¹ GUTSCHE 2007; GUTSCHE 2006; EINIG & SPANGENBERG in BBR 2006

²²² BMVBS & BBR 2007b

²²³ DOSCH 2006

²²⁴ GUTSCHE 2006

²²⁵ Within its publication “Siedlungsentwicklung und Infrastrukturfolgekosten”, the BBR (2006) presents a systematization of facilities of social infrastructure under public authority in accordance to –above others- KGSt.

²²⁶ PRINZ & REITHOFER 2005a in STROBL ET AL. ; PRINZ & REITHOFER 2005 in SCHRENK; KÖTTER ET AL. (acc.)

²²⁷ AGDE ET AL. 2003

planning literature²²⁸. Figure 16 introduces into the scheme of buffer-analysis, which is applied accordingly to the following indicators including a walking-distance coefficient of 1,2²²⁹.

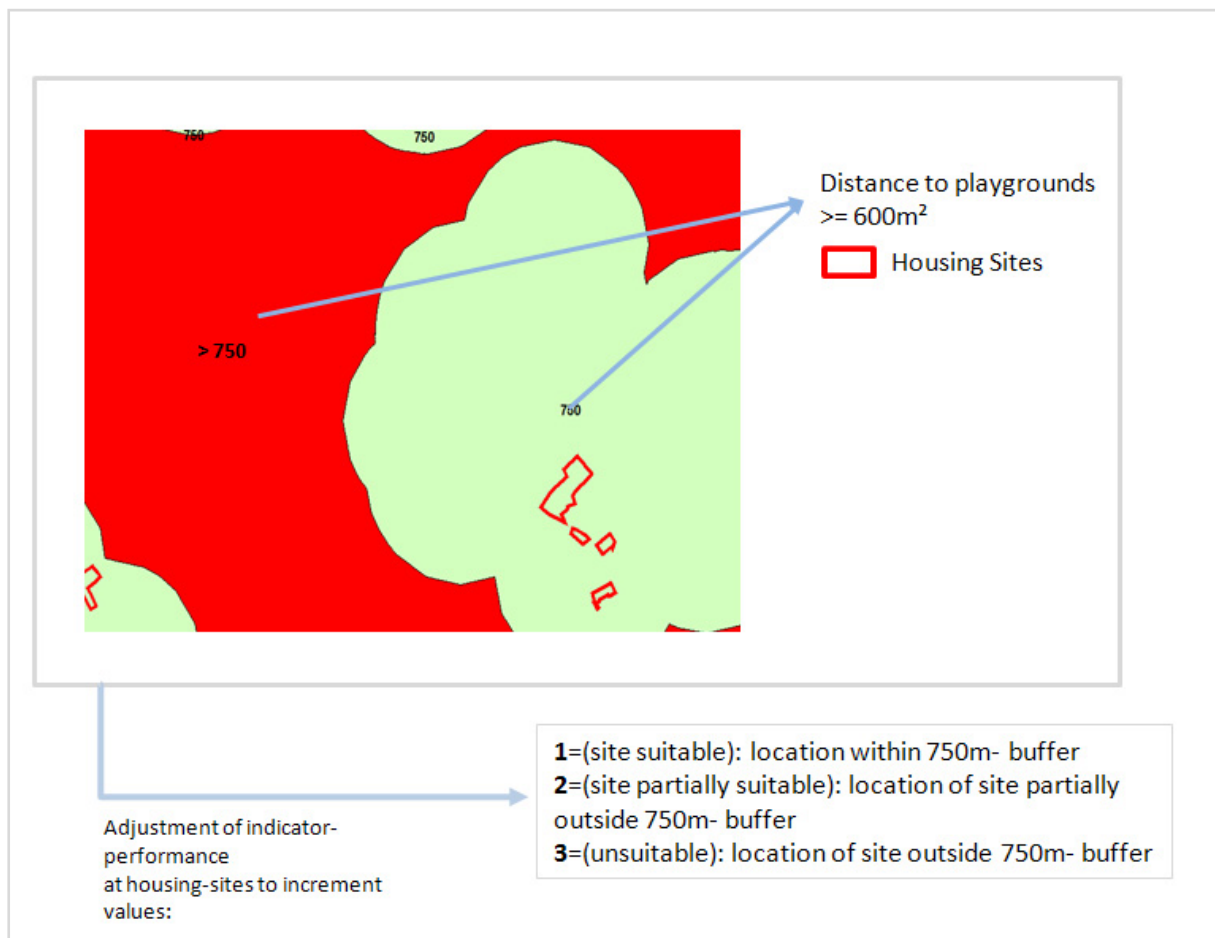


Figure 16 Buffer-analysis of distance to playgrounds to housing-sites (source: Cadastral playground- database, City of Essen 2002)

Indicator: Distance to local suppliers

The assessed distance to local suppliers of this indicator is exclusively related to the accessibility of district or neighborhood centers (“Stadtteilzentrum”) according to the masterplan of local supply²³⁰ of the City of Essen (2006). This indicator highlights essential contributions in satisfying daily needs. Moreover, this approach enables to analyze grown centers of supply and their promotion of local identity, provision with additional facilities (e.g. cultural) and urban functional diversity in contrast to suburbia. The promotion of local centers goes hand in hand with an efficient use of the resource soil

²²⁸ For this analysis only playgrounds with a central function and a suitability for older children and youths have been taken into account (DIN 18034 defines an appropriate size for youths from 12 -18 of 600m²). According to planning standards, the distance has been defined with 750m. KRAPPWEIS (without year) and SCHROETER (2008) mention a distance of 750m to playgrounds of closer living surroundings and 800m for playgrounds appropriate for youths. Accordingly, examples from current planning (e.g. BUILDING DEPARTMENT FELLBACH (2008) defines a distance of 750m for children older than 12.

²²⁹ KORDA 2005

²³⁰ Dt.: “Masterplan Einzelhandel”

within settlement development due a fostered decentralized network of local suppliers²³¹. Moreover it limits individual traffic and ensures the provision with daily goods in a short distance facing an ageing and more and more immobile society²³². The accessibility analysis was conducted including a walking-distance coefficient of 1,2²³³.

Indicator: Distance to primary schools

Regarding limited distances to primary schools no legally binding threshold value are defined. Only § 83 of the School Act North Rhine-Westphalia ²³⁴ promotes a provision „in close distance“ to place of residence promoting a „suitable“ distances (§ 80 Abs. 4) and also mentions the claim of each pupil for an admission to the closest school from his/her place of residence (§ 46, Abs. 3). The decree of travel costs for pupils of North Rhine-Westphalia²³⁵ defines a maximum distance of 2000m (§5 Abs.2).

Nevertheless there are many restriction of the use of threshold values. Firstly, since 2008/2009 this decree has become valueless. The choice of a school is not any more dependent of the districts, in which pupils live, but can be applied freely²³⁶. Secondly, parents' individual decisions concerning the suitability of a school cannot be denied. Thirdly, facing demographic changes and decreasing population numbers, the aspired use to capacity of existing infrastructures forces planners to distribute places in primary schools across the whole city.

The accessibility analysis was conducted including a walking-distance coefficient of 1,2²³⁷.

Indicator: Distance to kindergartens

Varying values of an optimal distance are spread around planning literature and communal planners²³⁸ for kindergartens. For this assessment, a distance of 500m²³⁹, which is equivalent to a walking distance of 10 minutes, was applied.

Indicator: Distance to public transport

According to current planning literature²⁴⁰ a sufficient supply with public transport facilities diminishes individual traffic and promotes a sustainable settlement development. According to the different means of public transport this indicator is divided into three sub- indicators. Also here, planning literature suggests varying distance values. SCHÖNING & BORCHARD (1992) promote a distance

²³¹ PRINZ & REITHOFER 2005 IN SCHRENK; VALLÉE (without year)

²³² CITY OF ESSEN 2006 (MASTERPLAN EINZELHANDEL)

²³³ KORDA 2005

²³⁴ Dt.: SchulG NRW

²³⁵ Dt.: „Schülerfahrtkostenverordnung NRW“ (Federal State of North Rhine-Westphalia 2009a)

²³⁶ See § 46 (Abs.5f.) of the School Act NRW (Federal State of North Rhine-Westphalia 2009b); see also press release of the Federal State Government of North Rhine-Westphalia from 25.08.06

²³⁷ KORDA 2005

²³⁸ Whilst SCHÖNING & BORCHARD (1992) propose a distance of 300-500m, the working group Bonn/ Rhein-Sieg/ Ahrweiler promotes a distance of 750 m.

²³⁹ see SCHÖNING & BORCHARD 1992, p. 48

²⁴⁰ BIEHLER 1999; PRINZ 2004 IN STROBL ET AL.; PRINZ & REITHOFER 2005 IN SCHRENK; BBR 2004b „STÄDTE DER ZUKUNFT“

to the next bus-stop of 200-300m²⁴¹, whilst the working group Bonn/ Rhein- Sieg/ Ahrweiler promotes a distance of 500 m. They further mention a maximum distance to subways of 1000m and to train stations of 2000m²⁴². Especially a close distance to train stations and subways is very attractive for commuters and promotes settlement development within existing structures and around those neuralgic points. Note that the clock rate of the different means is not included within the indicator. It is highly flexible and easy to modify as demands increase.

3.2.2.2. Category “Attractiveness of Living Surroundings”

According to current literature²⁴³, attractiveness of living surroundings can be specified by highlighting the provision with recreational areas, the influence of noise and the quality of the building ground in terms of suspicious contaminations. Closer information on indicator-performances and deriving simplified values can be obtained from table a2 in the annex

Indicator: Distance to recreational areas

According to current literature, three factors are to be taken into account for determining the recreational value of green spaces and their benefits for adjacent housing areas: size, distance and composition. HARRISON ET AL. (1995, p. 30) claim that a suitable size of green spaces determines its recreational values to a greater extent than an appropriate distance. Current literature on green planning²⁴⁴ discusses minimum size-values of 0.5 hectare. GÄLZER (2001) also distinguishes between different functions and compositions of green spaces.

The definition of recreational area and the extraction from cadastral data-sets in this study differs from the classical definition of recreational spaces²⁴⁵. It was elaborated according to the approach of SINGER 1995 (defining recreational capability of land use classes from values of 0 – 4)²⁴⁶. Green structures such as parks, cemeteries or forests score very high compared to farmland or lawns. Also land along waterway tracts were taken into account, as they provide especially high scenic and structural features in rural areas and²⁴⁷ tract “encapsulate countryside” within a “formally designated open space”²⁴⁸. But following COMBER ET AL. (2008), sites such as golf courses, school playgrounds or camping sites are excluded from the analysis as these are “not accessible to the general public for everyday use”²⁴⁹. See tab. d1 in annex D for closer information on classification.

²⁴¹ See also VöV 1981

²⁴² http://www.wohnregion-bonn.de/cms/cms.pl?Amt=RAK&set=0_0_0_0&act=0

²⁴³ KÖTTER ET AL. 2009a ; SCHETKE ET AL.2009a; USBECK & USBECK IN BRAKE & RICHTER (1996)

²⁴⁴ a.o. CITY OF LEIPZIG, 2004; CITY OF BERLIN 2009; GÄLZER, R. 2001

²⁴⁵ According to the STATE OFFICE OF STATISTICS AND DATA-MANAGEMENT of NRW recreational areas are defined as undeveloped areas suitable for exercises, recreation and showing plants and animals. This includes green spaces, parks, allotment gardens, sports grounds and camping sites (cit. in ENGELHARDT 2004, p. 12).

²⁴⁶ Compare: FEDERAL AGENCY FOR NATURE CONSERVATION/ BfN 2008: „Erholungsflächen sind unbebaute Flächen, die vorherrschend dem Sport, der Erholung oder dazu dienen, Tiere und Pflanzen zu zeigen (z.B. zoologische oder botanische Gärten und Wildgehege)“.

²⁴⁷ These recommendations result from repeating stakeholder-workshops accompanying the research-project FIN30. Especially in rural areas the named components form valuable structural elements defining and up valuing monotonous agrarian landscapes.

²⁴⁸ COMBER ET AL. 2008, p. 103

²⁴⁹ COMBER ET AL. 2008, p. 106

Indicator: Noise exposure

This indicator assesses the noise emission in general living areas²⁵⁰ of the emitter *street, industry and rail*.²⁵¹ Noise emission is one of the most important environmental stresses and is caused by traffic, airplanes, rail and industry. Moreover, it affects health and residents' Quality of Life²⁵². The location of residential areas near main roads is one of the most significant criteria within urban planning. § 47d of the Federal Immission Protection Law²⁵³ continually highlights the necessity and obligation of planning-frameworks of noise-reduction. Additionally, planning literature provides threshold values assessing the limitation of recreational values of a landscape due to noise emission²⁵⁴. The indicator selectively assesses noise emission during day- and nighttime. The scheme of analyzing noise-exposure at future housing-sites is shown in fig. 17.

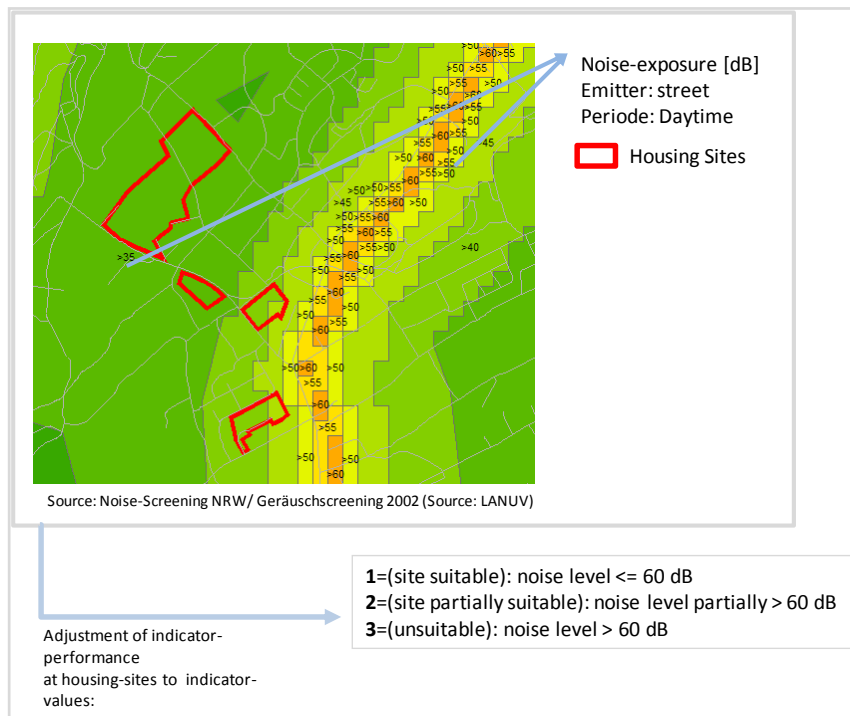


Figure 17 Analysis of noise-exposure at sites (source: noise screening NRW/ Geräuschscreening, LANUV 2002)

Indicator: Suspected Contamination

Generally, the suspicion or knowledge of pollutants is an economically limiting factor for brownfield revitalization²⁵⁵. But also the perception of a side alters according to the public knowledge of former or potential contaminations. The locations of sites of suspicious contaminations within the City of Essen are underpinned by cadastral data of the City of Essen monitoring the suspicion of pollutants

²⁵⁰ Dt.: „Allgemeines Wohngebiet“

²⁵¹ According to the „Technische Anleitung zum Schutz gegen Lärm“ see www.umweltbundesamt.de

²⁵² KORDA 2005

²⁵³ Dt.: „Bundesimmissionsschutzgesetz“

²⁵⁴ GASSNER ET AL. 2005

²⁵⁵ JERING ET AL. 2003

due to former uses (chemical industries, gas stations, handcraft companies). It does not give detailed information of confirmed contaminations, severeness and extension (see fig. d5 in annex D).

3.2.3. Transformation and Aggregation of QoP-Indicators

Derived from the previous paragraphs, the indicators assessing QoP are highly diverse in content, meaning and background-data and comprise both the ecological and social dimension of sustainability. Moreover, unevenly available threshold values and quality of background-data crucially determine their qualitative or quantitative character. Figure 18 shows the challenge of integrating all indicator-types into one assessment-scheme and the transformation into one rank-scale. Derived from different dimensions and data-backgrounds, each indicator can be associated to one of the two major scales, which determine its qualitative or quantitative character.

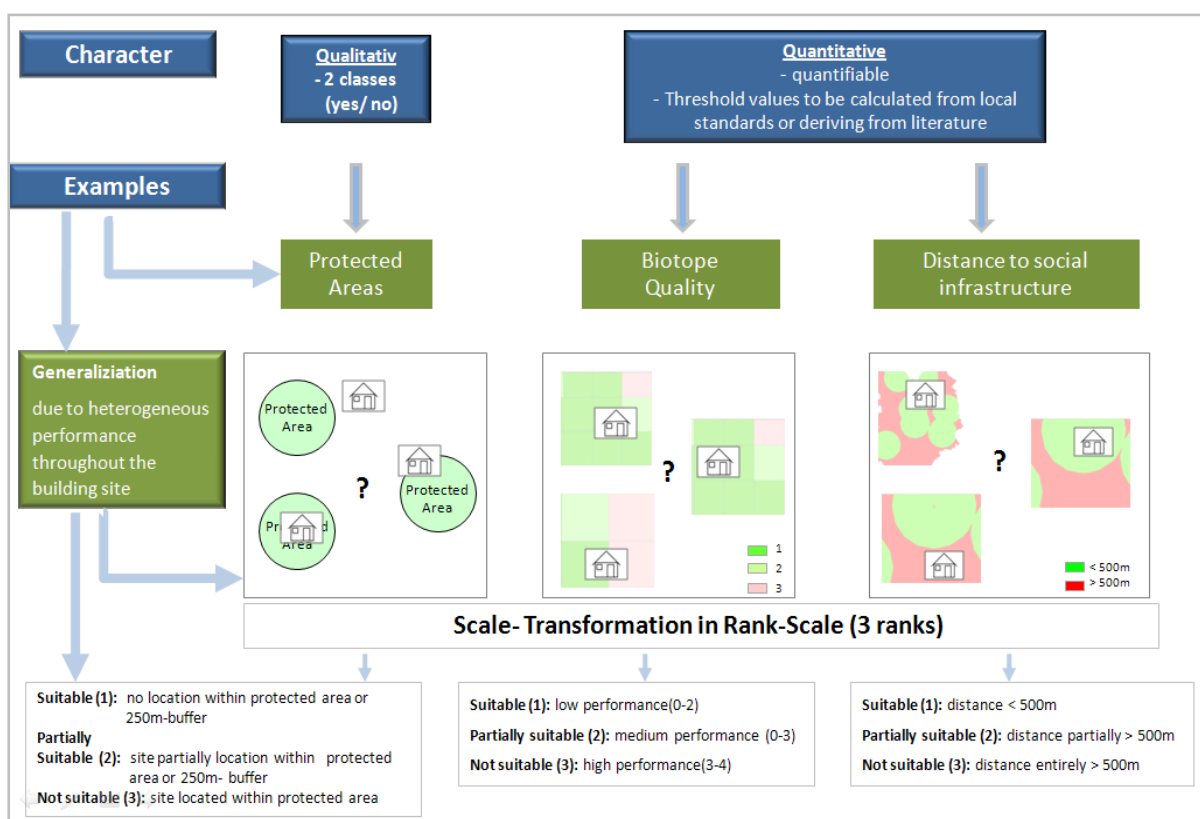


Figure 18 Indicator-aggregation-scheme (author's draft)

Transformation

On the one hand, *qualitative indicators* such as the indicator “protected areas” are applied. They provide qualitative statements of the position of a housing-site compared to the location of protected-areas (see fig. d2 in the annex). By processing a GIS-based overlays of both data-sets, we derive information if a housing site is not located, entirely or partially located within a protected area. The following general statements are derived from this procedure: suitability of a site due to no overlay (*value 1*), limited suitability of a site due to partial overlay (*value 2*) and no suitability of a site as it is located entirely within a protected-area (*value 3*). Whilst such qualitative indicators are not associated to pre-determined threshold values, the provision with threshold values differs

throughout the section of *quantitative indicators* (see both examples at the right columns of fig. 18). Two different types of quantitative indicators can be described: indicators with and without predefined threshold values.²⁵⁶

The indicator “biotope quality” is an example for a quantifiable indicator whose threshold values need to be defined. They are determined by its upper and lower limits and provides a five-stepped scale of possible indicator-values from 0 (low biotope quality) to 4 (very high biotope quality). Figure 18 above highlights the further translation into a threefold classification.

Compared to that, indicators, which assess the distance to various facilities of social infrastructure are set against a set of threshold values. These threshold-values derive from planning literature and legal frameworks as defined above. The calculations of individual buffers around the facilities of social infrastructure are executed according to distance-standards applied in urban planning. Therefore, a translation of these indicator-values into a simplified threefold classification is very convenient and is based on the spatial overlay of housing-sites and the respective distance-buffers. We derive information, if both sites overlay completely, partially or if they do not, which means that a housing-site is in close, medium or large distance to the closest facility. These simplified values are derived from this procedure: suitability of a site due an entire position with the buffer of a facility (*value 1*), limited suitability of a site due to partial overlay with a buffer (*value 2*) and no suitability of a site as it is located entirely outside a buffer-area (*value 3*) and therefore demands longer ways as proposed by urban planning-standards.

The outlined measures of generalization (see also fig. 18) form the crucial step of indicator aggregation and translate both indicator-groups to one scale. Each rank defines a value, which is later on used to quantitatively aggregate all indicators including individual weights within a Decision Support System (see chapter 3.4).

We have learnt that both data-background and the origin of threshold-values are highly variable within the indicator-framework. Therefore a transfer into three outlined simplified values appears to be the best way to integrate both qualitative and quantitative indicators. It provides a comprehensive opportunity to assess each housing site according to local conditions. Moreover, an assessment of each housing-site stating a complete, limited or no suitability facing their contribution to a sustainable and resource-preserving settlement-development will be enabled. This threefold distinction smoothes the consequences of the assessment and provides a more flexible approach as it does not lead to a complete exclusion of a housing-site from the pool of future housing sites but indicates necessary revisions (e.g. modification of spatial extension of a site).

Weighting and Aggregation

To provide an integrated assessment and to derive a final QoP-result for each of the two dimensions of QoP, the aggregation of all indicators forms the final step. The implementation of individual indicator-weights is a necessary prerequisite to provide not only a comprehensive but also planning-relevant QoP-analysis. Therefore, planners of the City of Essen have been asked to assign individual indicator-weights, so-called “expert-weights”. This was explained in the preceding excursus. The

²⁵⁶ Further information on general indicator characteristics can be given in annex C2.

following figure 19 outlines the major steps of indicator-aggregation which was the following step after the derivation of weights.

The transformed indicator-performances as outlined in figure 18 and the paragraphs above indicate the suitability of a site for housing purposes²⁵⁷. For each indicator – qualitative and quantitative- the following simplified values were applied:

- Value 1 indicates an *unlimited suitability* and a *good performance* of the housing site.
- Value 2 indicates a *limited suitability* and a *medium performance* of a site.
- Value 3 indicates *no suitability* regarding the respective indicators and therefore a *bad performance* of a housing site.

Following this, an aggregation of these statements leads to final aggregated QoP-value for both the ecological and social QoP. The aggregation of all indicators requires the expert-weights derived from planners or the respective person executing the QoP-analysis as discussed in the excursus above. As the aggregation then does not provide integers such as 1, 2, 3 anymore, a new translation into classes of QoP is needed in order to derive statements about a good, medium or low QoP of a housing site.

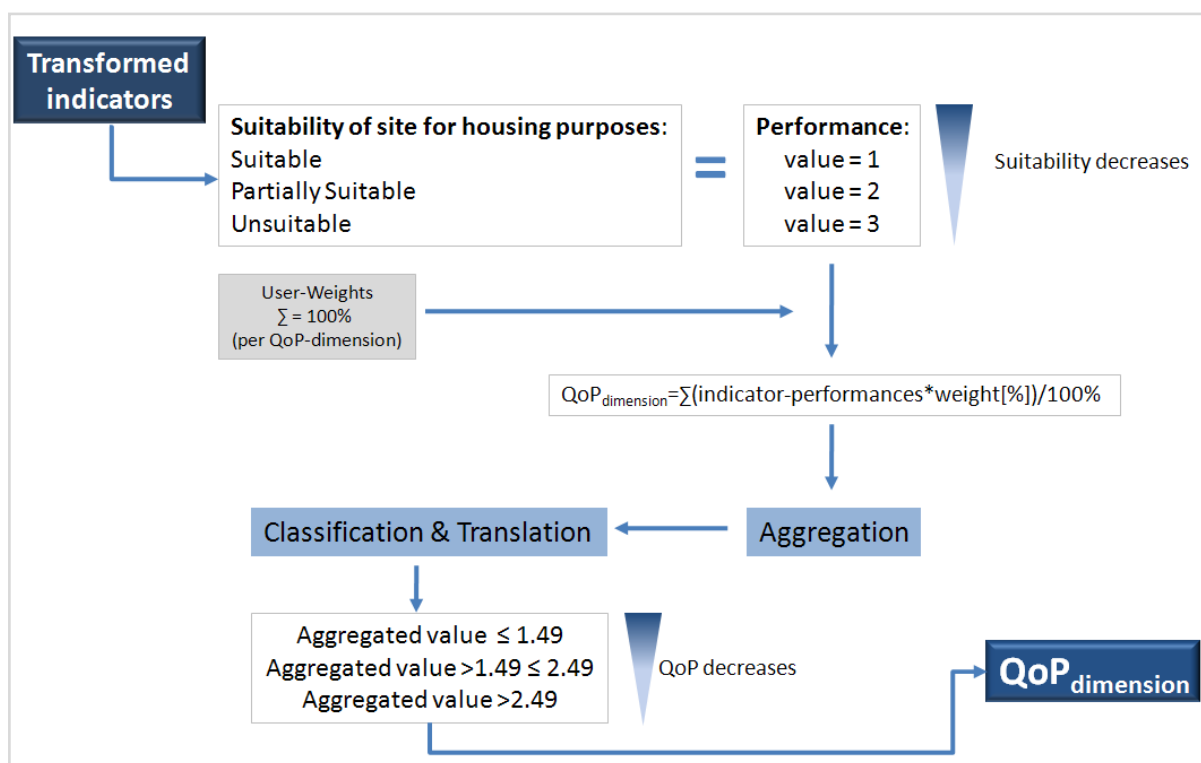


Figure 19 Indicator-aggregation assessing QoP (author's draft)

Following KÖTTER ET AL. (forthcoming) and the findings from the research project FIN.30, the following normative systematization of QoP-values has been applied for an integrated QoP-assessment: An

²⁵⁷ Chapter 4 and 5 will refer to this classification in terms of analysis and wording.

aggregated QoP-performance value of 1.00 to 1.49 indicates a high suitability as the majority of indicators show a value of 1 (high QoP and suitability). Values of $1.49 < 2.49$ indicate a medium suitability and QoP and values $2.49 < 3.00$ indicate a low QoP and no suitability for a site according to the principles of sustainability.

The value 1.49 is defined as a threshold value for a high QoP. Its value increases, as the amount of single indicator performances of 2 (limited suitability) and 3 (no suitability) increases to such an extent, that an unlimited suitability and QoP is not given any more. The aggregated value of 2.49 indicates the threshold for a medium suitability and QoP was defined accordingly. That means, the higher the aggregated QoP-value, the lower the actual suitability for sustainable settlement development.

The definition of equal intervals of QoP-values was rejected as the planning oriented QoP-assessment is restrictive in nature, but shall also provide enough flexibility to adjust planning targets according to the outcomes of the QoP-assessment. Restrictions are given in the classes indicating a high and a low QoP²⁵⁸. Only those sites will be awarded with a high QoP, as their aggregated value approaches 1.49. Also the class indicating a low QoP and no suitability is restrictive in nature. The class of medium QoP forms the largest class and follows a flexible and planer-oriented approach: sites of that class are not immediately to be excluded from housing development, because they still provide a limited but not overall bad suitability according to ecological and social indicators. The adjustment of a medium QoP acts as an alert and indicates single bad indicator performances. As this is the case, two kinds of adjustment can be applied by the user/ planner:

1. Spatial adjustment as a site is –for instance- partially located within a protected area.
2. Adjustment of expert-weights to indicators according to local requirements. As –for instance- the future demographic structure of a site is adjusted to an ageing society, a limited accessibility of kindergartens, primary school or playgrounds is not of prime interest. If this is the case, the respective indicators can be assigned with lower weights. The aggregated QoP-value will then perform differently at this site.

²⁵⁸ A normative definition of threshold values has been inevitable as both the number of indicators and indicator-weights assigned by planners/ experts are flexible. The definition of these threshold values has been discussed within the research project FIN.30 together with planners from three partner communes of the consortium.

3.3. MCA-Step 2: Assessment of QoL and UES

The preceding paragraphs presented a concise overview of the first step of the MCA. This step focuses on an assessment of socio-environmental prerequisites (QoP) of future housing-sites.

This first part of the MCA is followed by a second prominent innovative issue of this study. It introduces the second step of the MCA. This step is determined by a theoretical concept to bridge the gap between the two concepts of QoL and UES. It provides a quantitative indicator-set, which is used to assess socio-environmental impacts of settlement-growth according to varying housing-densities. Following the outlines in chapter 2.5, three major human needs, which urban green fulfills and which strengthen both QoL and UES, were defined: *recreation, regulation and social cohesion/local identity*. According to these needs, indicators were elaborated.

The development of indicators was executed according to empirical evidence as discussed in scientific literature (see chapter 2). The valuable substantiation by communal land use datasets was another very important aspect, which needed to be taken into account. The following paragraphs outline the meaning and quantification of the indicators throughout scenarios of varying housing-densities. The respective housing-scenarios will be explained in chapter 3.3.1. Following that, a close insight into the indicators of the impact-assessment and linking the two concepts of QoL and UES will be given (chapter 3.3.2.).

3.3.1. Housing-Scenarios

Socio-environmental impacts, and impacts on the environment itself, accompany each change of the built environment and of changing land use patterns. Within this study, housing-scenarios, which represent different housing-densities, were defined. They were used to quantify the intensity of socio-environmental impacts and land-use change due to new housing-development. Accordingly, the intensity of these impacts differs according to the altered provision with urban green and open spaces. For instance, ALBERTI ET AL. (2005) state clear interactions between humans and biophysical processes, which are mediated by patterns of urban development and a change in land cover. A quantification scheme based on a set of indicators combines the concepts of QoL and UES and is an integral part of the scenario-based assessment of this thesis.

According to FÜRST & SCHOLLES²⁵⁹ (2004), scenario-technique is applied to develop realistic pathways or corridors of a development. This development depends on framework conditions for a comparable distant future and according to relatively high uncertainties. This method is applied as especially quantitative forecasting methods fail or as uncertainties forbid a simulation. In contrast, the probability or accuracy of an event is less important compared to the derivation and description of distinct factors and interdependencies. Scenarios present many of the possible future developments without prescribing any likelihood to any of the outcomes. Each scenario should present a plausible future in its own right.

²⁵⁹ Original German expression p. 206

Following ROTMANS ET AL. 2000²⁶⁰ scenarios are defined by the following characteristics:

- Scenarios are hypothetical and describe possible future pathways
- Scenarios consist of states and derived forces, events, consequences and actions, which are causally related
- Scenarios start from an initial state (usually the present) and depict a final state

Figure 20 shows three defined scenarios for each single-family homes and multi-story housing. The allocation of scenarios of single-family-homes or multi-story-houses was executed according to specifications by the City of Essen²⁶¹. Additionally, the current land uses at each site are named “status-quo-scenario”.

Each following scenario (1, 2, and 3) represents a distinct housing-type and its associated housing-density. The density is defined according to planning-standards²⁶². The housing-density increases from scenario 1 to scenario 3 (see figure 20). This leads to altered land use structures as well as to a modified provision with patterns of urban green spaces and associated socio-environmental impacts.

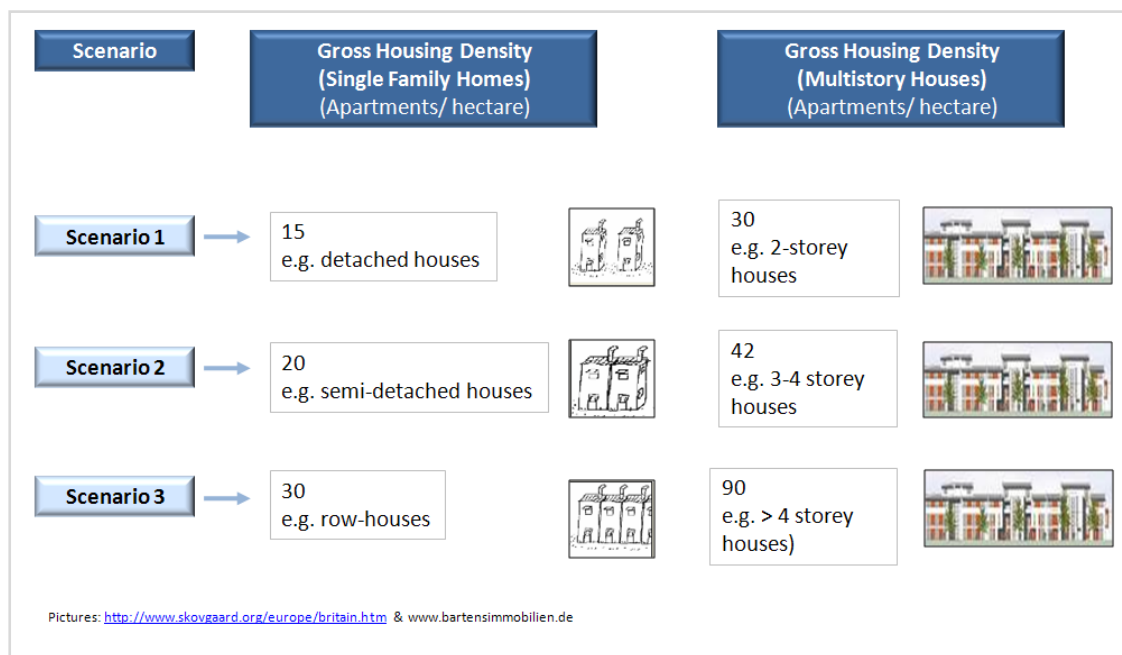


Figure 20 Housing-scenarios and associated housing-densities (author’s draft)

Land use structures and the provision with urban green spaces react sensitively towards altered housing-densities and land-use patterns. As a consequence, the provision with UES and their contributions to QoL alter. According to JAMES ET AL. (2009, p. 68) “ecosystem services provided by urban green spaces are related to the physical aspects of these spaces”. These interrelations also include the physicality and ecological performance of green spaces²⁶³. Defined indicators (see ch.

²⁶⁰ cit in. LOBO ET AL. 2005, p. 3

²⁶¹ See SCHAUERTE 2007

²⁶² a.o. KORDA 2005; PRINZ 1995

²⁶³ See definition of green spaces according to JAMES ET AL. (2009, p. 66).

3.3.2.) will be used to quantify and assess the modification of land use patterns and its effects on QoL and UES due to housing-development.

Table a5 (see annex) indicates, to what respect QoL/UES-indicator-values change within each scenario. As mentioned, a status-quo-scenario was calculated²⁶⁴. It is used as a reference-scenario in order to quantify the intensity of each altered indicator-value throughout the following scenarios 1 to 3. This intensity will be represented by the *percental deviation* in chapter 4.

As housing-sites are still subject of preparatory land use planning, their display in the draft (status 2008) of the regional land use plan is executed at a scale of 1:50.000 and does not provide lot-sharp limits of each site. Therefore the application of gross housing-density compared to net housing-density is the most appropriate way.

3.3.1.1. Quantification of Housing-Scenarios

The system of scenario-quantification and indicator-calculation will be presented in the next paragraphs (see figures 21 and 22).

The *first* step of the quantification represents the attribution of land use data and initial standard-calculation, in order to get a closer insight into their socio-environmental performance (see fig. 21). Closer information on that will be given within the indicator-explanation (chapter 3.3.2). This enables the calculation of the status-quo-scenario.

The *second* step comprises these GIS-based allocation of indicator-values for each land use class (see also table a5 in annex A) in accordance to varying housing-densities. The *third* step comprises the calculation of weighted mean values, in order to quantify the modified indicator-performances.

The spatial extensions of scenario-analysis refer the future housing-sites together with their closer living surroundings (see fig. 21). This follows the *anthropocentric* approach in this second step of the MCA compared to *physiocentric* direction of the QoP-assessment as outlined in chapter 3.1. According to planning literature²⁶⁵ “closer living surroundings” are defined as a radius of 500m which are adequate to 5-10 min walking distance²⁶⁶. Therefore, a buffer of 500m (including a walking distance coefficient of 1.2) was created around each analyzed housing-site. All presented results of impact assessment in chapter 4 refer to these spatial extensions. (see fig.21).

²⁶⁴ Note: The scenarios do not refer to the most appropriate housing-structure to achieve an optimum of QoL and UES. The housing-scenarios refer to standardize mono-structural housing types. The optimum to what they are compared is marked by the status-quo-scenario.

²⁶⁵ CITY OF LEIPZIG 2004

²⁶⁶ See also CITY OF BERLIN 2009 defining a distance to open spaces of closer living surroundings of 500m and the definition of the URGE-RESEARCH TEAM (2001-2004).

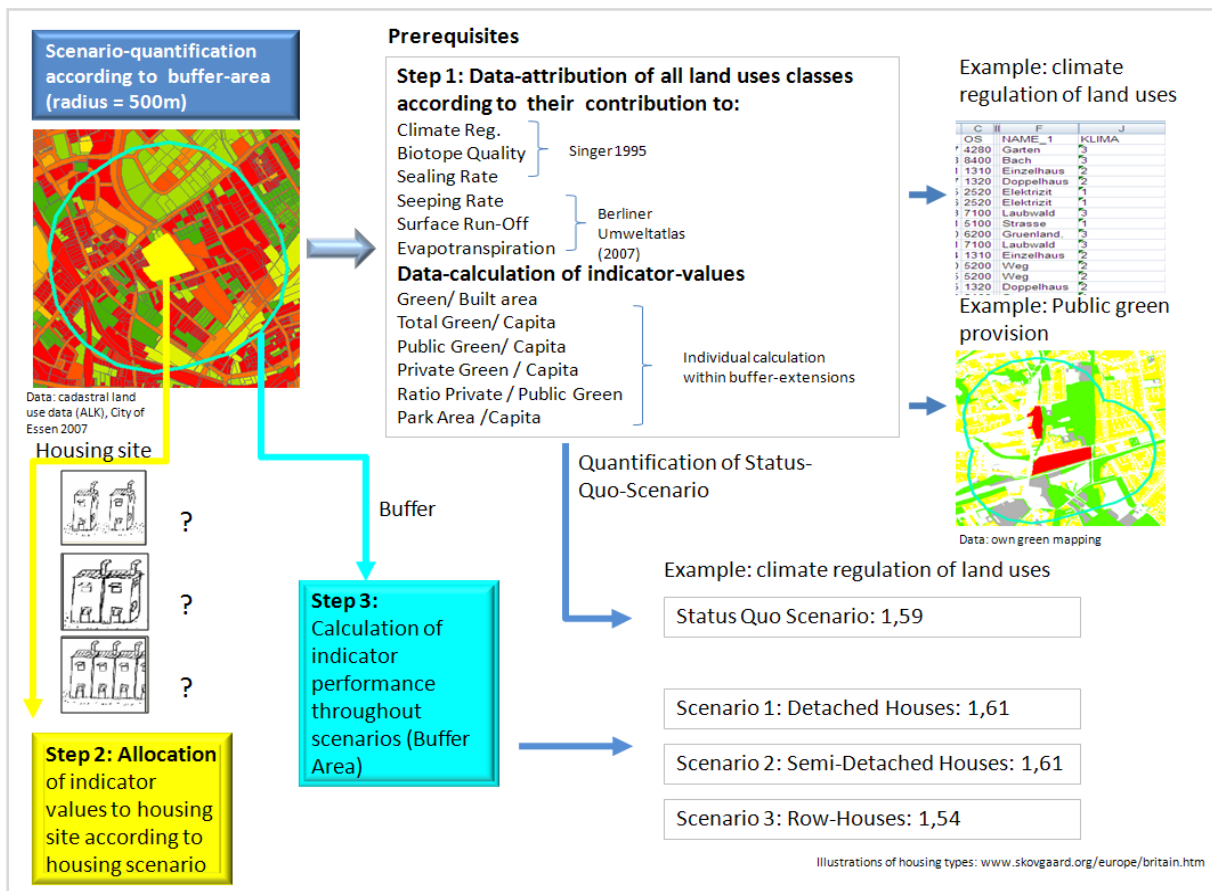


Figure 21 Quantification of scenarios (author’s draft)

Looking back at the first step of figure 21, we see that two different types of indicators are mentioned. This aspect needs special attention, because it influences the quantification of socio-environmental impacts and the calculation of indicator-values.

The *first* indicator-group (regulation, biotope quality, sealing rate, seeping rate, surface run-off and evapotranspiration) is subject to data-attribution. That means, an allocation of values indicating the individual contribution of each cadastral land use class to its indicator value was executed in advance. In doing to, look-up tables referring to the reference-values of cadastral land use data and their individual performance of climate regulation, biotope quality (SINGER 1995²⁶⁷) or hydrological standards such as characteristic sealing rates, seeping rate, surface run-off and evapotranspiration²⁶⁸.

²⁶⁷ The study of SINGER (1995) aims at assessing the ecological performance of urban open spaces associated to cadastral land use data. In doing so, elaborated reference values focusing on the regulative function, biotope quality, sealing rate, recreational values and soil quality for most of the cadastral land use classes (ALK). These reference values have been applied in attributing cadastral land use data of the City of Essen provided on lot-level. Singer defines three classes ranging from 0 (no performance) to 4 (very high performance).

²⁶⁸ City of BERLIN 2007 (www.stadtentwicklung.berlin.de/umwelt/umweltatlas) It provides hydrological reference values of characteristic land use structures within the city of Berlin. A distinction between different housing types and open space structures has been made even though it refers to a very rough spatial resolution. Therefore the calculation of individual standards for the City of Essen is necessary.

The *second* indicator-group covers all indicators of green provision per resident. It is based on the calculation of local standards of green provision, which is based on own green-mapping (see the following excursus). In doing so, standard values on green shares per gross building-land were calculated according to comparable housing types within the city of Essen. The additional residents, who will be attracted by new housing construction, were calculated according to the outlined housing structure types of the scenarios with reference to planning literature. Factors such as household-size, living space per resident and gross housing-density²⁶⁹ were taken into account.

3.3.2. QoL/UES-Indicators

The assessment is executed with regard to local and status quo conditions, which define the original state of the system. It sets the reference, against which the socio-environmental impacts of settlement-growth are measured. Concerning the definition of a sustainable state of a system or an urban region, NIJKAMP & OUWERSLOOT (2003) suggest a critical (or minimum) framework of the research area using respective critical threshold values (CTV) for assessment purposes.

According to these notions, two CTV for each indicator can be defined. As the City of Essen itself is very heterogeneous in structure and design, settlement development will have differing impacts on the state of the system due to the individual preconditions on neighbourhood level. Determining factors for that are a) the measurements of settlement development and b) the resilience of the system.

One threshold value is defined as the urban average value of Essen (CTV_{city}). The other threshold value is flexible. To facilitate the impact-assessment, chapter 4 refers to the status-quo-scenario as a second reference value. Another possible reference-value can be based on the wider living surroundings (radius of 1000m) highlighting the local state of a system, against which the socio-environmental impacts of settlement-growth are assessed (CTV_{neighborhood1000m})²⁷⁰. This value has not been used for the assessment.

The associated formulas (table a4 in annex A) and standards (table a5 in annex A), to which the calculations of threshold values refer are found in the annex (tables a 4, 5). The following paragraphs explain the meaning of each indicator. Each indicator is presented in the context of the respective *need*, which it represents for the QoL/UES-assessment. After that, the calculation of each indicator-performance for the i) status-quo scenarios and for ii) the scenarios 1 to 3 will be described.

3.3.2.1. Recreation

Indicators: Climate Regulation/ Biotope Quality

Recreational benefits –and their quantification and operationalization via indicators - are essentially determined by natural prerequisites and composition (e.g. diversity of habitats, amelioration of air pollution)²⁷¹. They influence factors such as the feeling of naturalness and undisturbed landscapes²⁷².

²⁶⁹ see KORDA 2005; PRINZ 1995; SCHMIDTKE & BERKE 2005, Band 25

²⁷⁰ The single indicator and reference values will be presented in the annex (tab. a6)

²⁷¹ TZOULAS ET AL. 2007

²⁷² BURGESS ET AL. 1988

These indicators focus on green-composition and their modification by humans. This has significant impacts on their capability of climate regulation and biotope quality and to provide recreational benefits²⁷³.

Data Base & Data Compilation: The attribution of cadastral land use classes was executed using data from ALK (layer 21 “current land use”) according to the approach of SINGER (1995). The values of climate regulation and biotope quality for each land use class refer to shares of open areas within each land use class and are range from 0 (no regulative function, e.g. supply infrastructure) to 4 (very high climate regulation, e.g. public parks). The indicator-performances are represented by a weighted mean value according to formula A and A1, respectively.

Status-Quo Scenario: The status-quo-scenario was calculated according to the indicator-values of all existing land uses within the buffer-area (radius = 500m) (Formulas A and A1 respectively; table a4).

Scenarios 1-3: The scenarios 1 to 3 were calculated according to the indicator-values of all existing land uses within the buffer area (formula A and A1 respectively; table a4). The values of climate regulation and biotope quality of the specific housing site were modified according to its varying housing types in accordance to SINGER (1995) (see table a5 annex). The rest of the buffer remained constant.

The principle of data-attribution and scenario-based calculation of indicator-performances is explained in figure 22 using the example of the indicator biotope quality.

²⁷³ In contrast to that, the URGE-RESEARCH TEAM (2001-2004) stresses the capacity of urban green spaces to improve air quality but implements the indicator leaf area index, instead. Due to a lack of adoptable background data, this proposal has been modified following the approach of SINGER (1995).

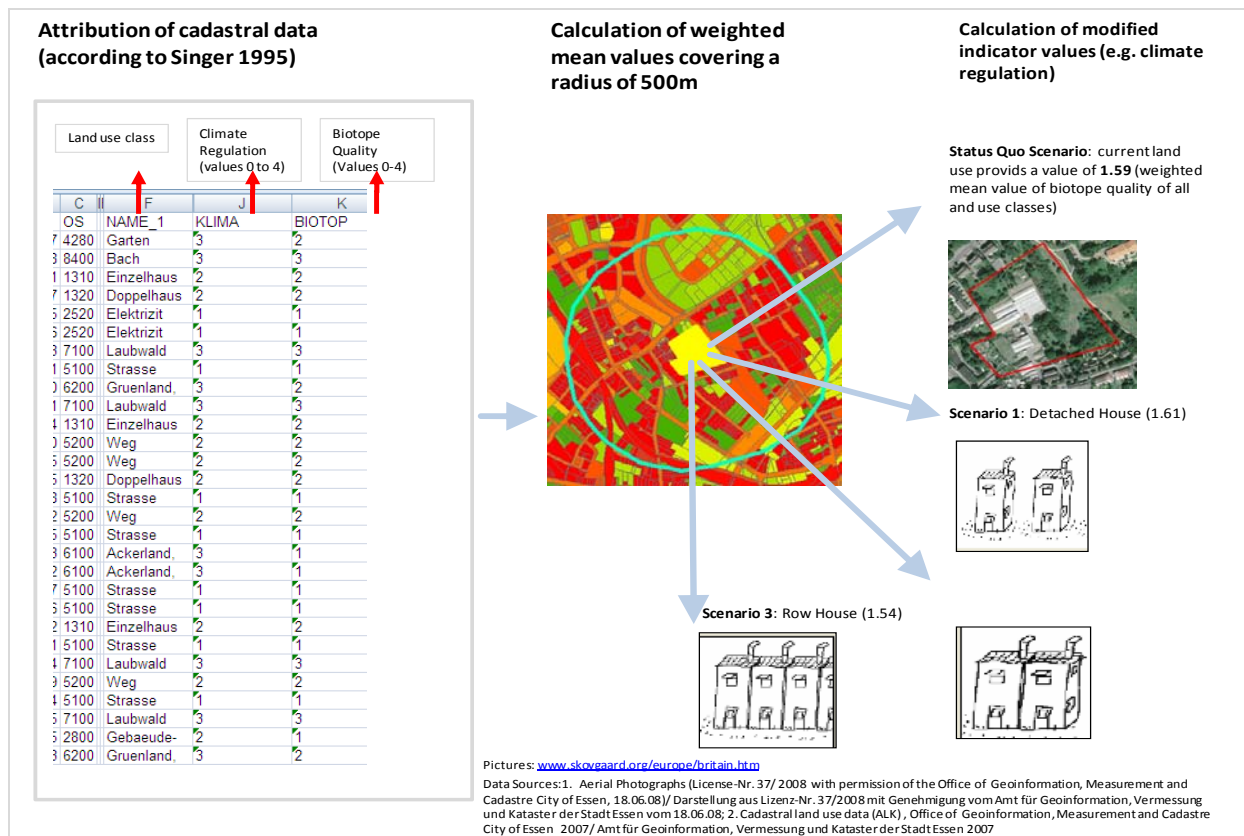


Figure 22 Principle of data-attribution and scenario-based calculation of indicator-performances (author's draft)

3.3.2.2. Regulation

Indicators: Sealing Rate, Seeping Rate, Surface Runoff, Evapotranspiration

The following indicators assess the benefits of green spaces due to their biophysical features. This means e.g. the provision with cooler microclimates by altering the hydrological regime of an area or even moderating the effects of climate change. In addition to the aforementioned indicators, the following indicators highlight the special role of vegetated surfaces for the modification of not only the climatic regime but also the hydrological framework conditions of an area due to land use change²⁷⁴. According to GILL ET AL. (2007, p. 115) "less vegetated surfaces lead to a decrease in evaporative cooling, whilst an increase in surface sealing results in increased surface runoff" and reduced seeping rates.

Data Base & Data Compilation: The data-compilation of these indicators varies according to land use data-sets and respective look-up table being used for attribution.

The indicator sealing rate spatially refers to cadastral land use classes (ALK), which were attributed according to characteristic sealing rates referring to the approach of SINGER (1995). Originally, he indicated the share of open areas according to each land use class. The term "open area" is heterogeneously discussed within scientific literature. Here, SINGER (1995, p. 23) applied (amongst others) the characteristics of "open space" as a lack of buildings and – more important – of sealing,

²⁷⁴ PAULEIT ET AL. 2005; SCHETKE & HAASE 2008

too. Therefore, the indicated values of open space provisions of land use classes were directly transferred to the corresponding sealing rate as its reciprocal value.

The indicators seeping rate, surface-runoff and evapotranspiration refer to an attribution according to hydrological classifications of the UMWELTATLAS BERLIN (CITY OF BERLIN 2007) and are spatially bound to the land use data of the land use mapping of the Regional Association Ruhr RVR (©Regionalverband Ruhr, Essen, Flächennutzungskartierung Stand 2005). This database classifies land uses on block level (not on lot-level as cadastral data) and comprises 150 classes across the municipal area of Essen. It complies best with the merely rough hydrological classification of land use classes used in the UMWELTATLAS BERLIN. In order to downscale hydrological attributions of land use classes on block-level and to derive hydrological information according to selected housing –types (scenarios), additional standards were calculated in advance (see fig. 23 below). They form a sound basis for a hydrological characterization of settlement growth within the scenarios.

Status-Quo Scenario: The status-quo-scenario was calculated according to the values of sealing rate, seeping rate, surface run-off and evapotranspiration allocated to present land uses within the buffer-area (radius = 500m) using formula B (sealing rate) and C, respectively. The deriving indicator-performances are provided as weighted mean values.

Scenarios 1-3:

Indicator Sealing rate: The scenarios 1 to 3 were calculated according to the indicator-performance of all existing land uses within the buffer area (formula B; table a4). Solely the indicator-performance of the specific housing site was modified according to its varying housing types (see table a5 annex). The rest of the buffer remained constant.

Indicators Seeping Rate, Surface Runoff, and Evapotranspiration: The scenarios 1 to 3 were calculated according to the seeping rate, surface run-off and evapotranspiration of present land uses within the buffer area (formula C). Solely the hydrological attributes of the specific housing sites alter according to calculated standards representing the selected scenario-housing-types i across the municipal area of Essen (see table a4 annex and fig. 23). For this standard-calculation, reference values had to be calculated using 10 reference-sites (reference values) for each of the scenario-housing-types i . Subsequently these 10 single reference values were concentrated to one standard for each housing type i provided by their average. The process of standard calculation for the indicators seeping rate, surface runoff and evapotranspiration is subsumed in formula D table a4 annex. These standards (tab.a5 annex) were then assigned to the housing site throughout varying housing densities within the three scenarios. The rest of the buffer remained constant.

A differentiation according to location in the northern or southern part of the City of Essen was applied as lot-size and building density differ significantly between the two parts.

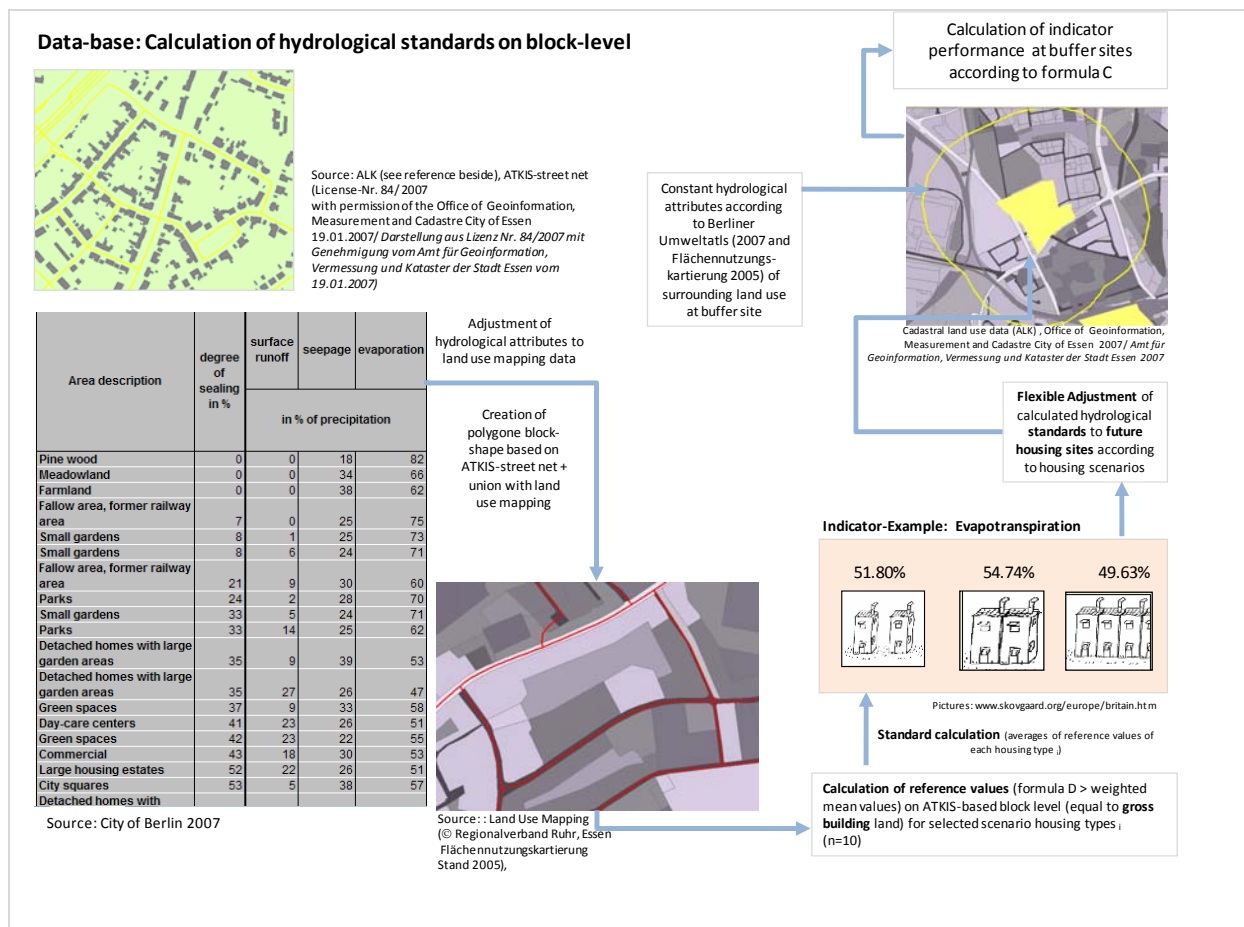


Figure 23 Principle of data-attribution and scenario-based calculation of hydrological indicator-values (author's draft)

3.3.2.3. Social Cohesion and Local Identity

Indicators: Total, Public and private green provision per resident

According to WICKOP ET AL. (1998), the social and psychological effects and benefits of urban green spaces are clearly determined by their accessibility and differentiation usability in terms of public, semi-public and private green spaces. Whilst public green spaces such as parks or roadside greenery enhance the interaction between people, private green spaces enable to retreat from public life and provide security²⁷⁵. The URGE-RESEARCH TEAM does not provide an according distinction within their interdisciplinary catalogue of criteria (ICC) but stresses the significant positive effects on human health and well-being due to a sufficient provision with urban green²⁷⁶. GÄLZER (2001) discusses the term "Aneignung" (adoption) of public green in terms of physical and mental adoption going hand in hand with identification.

²⁷⁵ (exhausted) cit. in WERHEIT 2002

²⁷⁶ See also TAKANO ET AL. (2002)

Data Base & Data Compilation: The indicator-calculation refers to a data-set of a green-classification based on cadastral data (ALK) and land use mapping of the Regional Association Ruhr RVR (©Regionalverband Ruhr, Essen, Flächennutzungskartierung Stand 2005) distinguishing between the threefold classification of urban green as named above. The procedure of the green-mapping is outlined in the following excursus. Additionally to that, future numbers of residents have been calculated according to the pre-defined housing densities referring to current household sizes for the City of Essen²⁷⁷ (formula F; table a4 annex A).

Status-Quo Scenario: The status-quo-scenario was quantified according to the provision with different forms of urban green within the buffer-area (radius = 500m) provided by the GIS-based green classification (see chapter 3.2.3.). The number of current residents within the buffer was calculated according to local standard values of building area per residents (see formula E; table a4 annex). This calculation provides individual values for each district of Essen as housing density and population numbers are highly variable and were adjusted to each buffer according to its total building area (m²). This was extracted from cadastral data of ALK, layer 11. The amount of public and private green could be derived directly from the green classification. The indicators public green/resident and private green/ resident have then been calculated according to formula F1_1 and F1_2 respectively (tab. a4 annex).

Scenarios 1-3: The scenarios 1 to 3 were quantified as follows. The absolute share of public green within the buffer area was quantified according to formula E2_1 (tab. a4 annex). After that, the provision with public green/ resident for each scenario was calculated according to formula F2_1 (tab. a4 annex and tab. a5 annex).

The provision with private green²⁷⁸ according to each housing scenario demanded a calculation of standard values according to formula E1 (tab. a4 annex and tab. a5 annex). In doing so, local conditions of housing patterns were considered. The calculation of reference values per housing-type was executed according to 10 reference-sites each.²⁷⁹ Here, private green shares (%) per reference-site are derived from the applied green-classification. Subsequently, these 10 single site-values were then concentrated to one standard value for each housing type i provided by mean values (formula E1). A differentiation according to location in the northern or southern part of the City of Essen was applied as lot-size and building density differ significantly between the two parts. The standard values (tab. a5 annex) provided in [%] were converted into m² according to the size of the gross building land of each housing site and integrated into the general provision with private green within the buffer (formula E2_2 tab. a4 annex). The provision of private green per resident was then executed according to formulas F2_2 (tab. a4 annex).

The future residents allocated to the scenarios were calculated according to formula F (table a4 annex A).

²⁷⁷ see KORDA 2005; PRINZ 1995; SCHMIDTKE & BERKE 2005

²⁷⁸ Both private gardens and courtyards.

²⁷⁹ Here, no shares of public green could be detected. Therefore, no additional public green was calculated within scenario analysis.

Indicator: Ratio Private / Public Green

According to the differentiation between public and private green spaces as outlined above, this indicator gives insight into current tasks of urban green spaces and their changing ability to fulfill all the demands related to private and public green during the process of settlement growth. It highlights whether the equilibrium between private and public functions remains or if certain functions are lacking (e.g. security of private green) by enhancing the provision with distinct green types.

Data Base & Data Compilation: The data-base refers to the mentioned references as for the indicators on private, public and total green-provision.

Status-Quo Scenario: The status-quo-scenario has been quantified according to the provision with private and public green within the buffer-area (radius = 500m) derived from GIS-data of the green classification (formula F3 table a4 annex).

Scenarios 1-3: The scenarios 1 to 3 were quantified according to formula F3 referring to remaining shares of public green [m²] due to building measures and calculated standards of private green shares [m²] according to formula E1 (see table a4 annex).

Indicator: Park Area /Resident

According to the differentiation of urban green as outlined above, public parks take up a special position as places for interaction (different cultures and user-groups). They have to be distinguished from the general term “public green” in terms of inventory, composition, function and use²⁸⁰ and have significant influence on QoL²⁸¹.

Data Base & Data Compilation: The data-base refers to cadastral land use classifications of ALK (layer 21) extracting all park-areas.

Status-Quo Scenario: The status-quo-scenario was quantified according to the provision with park areas within the buffer-area (radius = 500m) and the respective current amount of residents (formula G; table a4 annex A). The provision of park area/resident was calculated according to formula I (tab.a4 annex).

Scenarios 1-3: The scenarios 1 to 3 were quantified using only varying the total number of residents for each scenario according to formula H (table a4 annex). No standards for additional park-area were calculated, as any additional park areas for a single housing site are not probable or expectable. The provision of park area/resident has been calculated according to formula J (tab.a4 annex).

²⁸⁰ GÄLZER 2001

²⁸¹ ECOTEC 2006

Excursus: Green-Classification

According to WERHEIT (2002, p. 93), social demands concerning usability and accessibility of urban green spaces need definition. Besides climatic and ecological benefits of urban green, significant influences on residents are found in the social, psychological and recreational realm. According to MATSOUKA & KAPLAN (2008)²⁸² a clear distinction between green spaces for public, semi-public or private use has to be made, because they fulfil different demands. MATSOUKA & KAPLAN (2008) define social interaction and the fulfilment of privacy needs as major tasks of urban green. WESTPHAL (2007) states that “in addition to different densities, the housing types also provide different living conditions: single family homes offer a comparatively large proportion of private garden but no public green and open space. Prefabricated housing blocks lack private open space and provide some public open space; however they often have a monotonous design”²⁸³.

Following SCHETKE ET AL.*, we are faced with difficulties implementing the indicator “accessibility” when considering green space property types and their consequences for usability by residents. This counts especially for densely urbanized areas. At least *public* (e.g. parks) and *private* (e.g. allotment gardens, courtyards) green spaces have to be distinguished within the assessment. Moreover, a third type of green space needs to be implemented: private green spaces on industrial/ factory premises. These green spaces are legally defined as private green but due to accessibility and usability they will be classified as *semi-public* green within this study. Generally, they are not available for the general user, but influence their surroundings scenically and aesthetically.

In that context the definition is displayed as following²⁸⁴:

- private green spaces such as private gardens; courtyards or, allotments gardens
- semi-public green spaces such as sports grounds, school yards or industrial/ factory premises which are per se dedicated to a reduced user circle and do not always provide recreation facilities for the general user
- public green areas such as parks, farmland, roadside greenery

It gives no information on the legal status “private” or “public” of a property but distinguishes between the accessibility and usability of green space.

The technical background of the green-classification can be described as following: *Firstly*, the elaborated classification of urban greenery in the City of Essen (fig. 24) is based on the intersection of two major data sets (see *step 1* fig. 24 below): firstly, the land use mapping of the Regional Association Ruhr RVR (provided by Regionalverband Ruhr, 2005) and secondly, cadastral data (ALK, layer 21). Both data sets provide information on land use structures but differ in spatial resolution. Whilst cadastral data (ALK) provide information on lot-level, the land use mapping of the RVR is based on block-level. After that, the extraction of all buildings and non-green uses, such as streets, from the data-sets needs to be executed. Whilst the extinction of all streets is executed simply via

²⁸² Also WERHEIT 2002

²⁸³ WESTPHAL in LANGNER & ENDLICHER (Hrsg.) 2007, p. 106

²⁸⁴ Compare also the accordant definition of RICHTER (1981, p. 17)

the ArcGIS-query builder (ESRI[®]), the extinction of buildings demands the intersection with the cadastral data as provided in layer 11 of the ALK²⁸⁵.

The *second step* is dedicated to the proof of all combinations of land use classes, which result from the intersection of the cadastral (ALK) and RVR-dataset. Whilst the cadastral data give valuable information on the adjustment of most land use classes to either the private or public domain (e.g. the land use class “detached houses” clearly implies the private accessibility of gardens and backyards), the RVR-dataset cannot provide those information. This is due to its rather rough scale. Still, especially the contribution of industrial/ factory premises to the urban green-amount needed a closer look and was valuably supported by the combination of both datasets.

In doing so, an additional analysis of all combinations from the intersected data-sets was needed using aerial photographs. Basically, an extinction of most industrial/ factory premises from the dataset became inevitable, but the application of the combined dataset enabled a more sensitive execution avoiding the deletion of selected parts. These parts, such as areas of succession, were indicated as industrial premises according to the RVR-classification, but turned out to belong to either grassland or adjacent road-side green (a.o.). Note, that these sites can contribute to local climate conditions and still provide habitats. But still, they are highly impervious in most cases.

A *third step* of the green-mapping was integrated to classify new green types such as road-side green which is relevant according to regulative and aesthetic purposes but not implemented within the cadastral dataset.

Finally, the combined dataset was dissolved to get solely information on the accessibility and availability of green and open areas distinguishing between private, public and semi-public greenery. After that, the extinction of splinter-polygons smaller than 50m²²⁸⁶ was executed.

²⁸⁵ Note, that the deriving dataset shall give a rough insight into the usability of green spaces and their probable influences of QoL/UES but does claim neither an absolute accurateness nor the display of solely unsealed areas. The green-spaces displayed by that dataset comprise of both unsealed and partially sealed surfaces. Solely entirely sealed surfaces which state can be approximated from cadastral land use classification (e.g. streets) or turned out the be after a revisions with aerial photographs have been removed from the dataset.

²⁸⁶ This refers to a normative value suspecting that green areas < 50m² lack of sufficient possibilities for different uses.

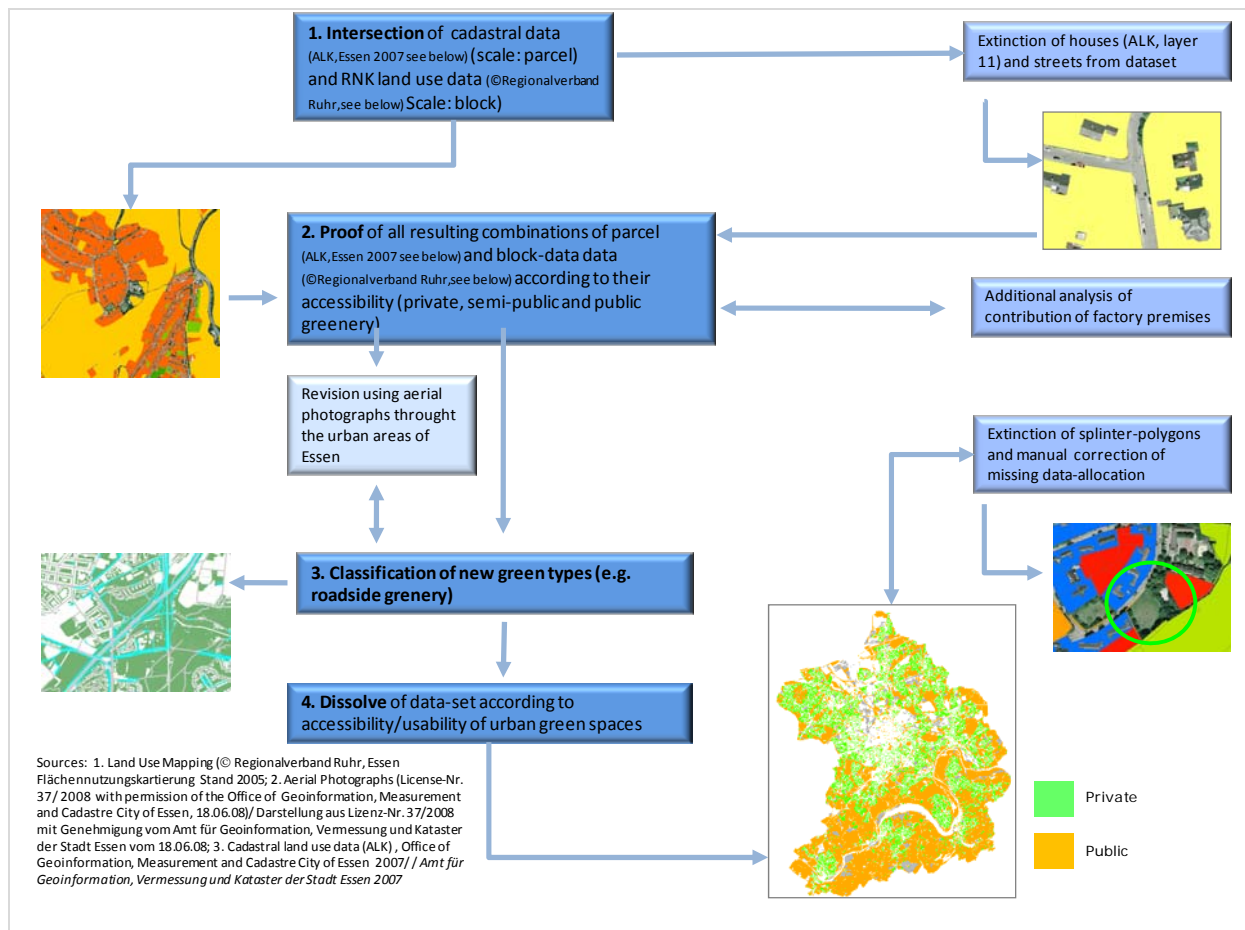


Figure 24 Green-classification due to accessibility and usability (author's draft)

Continuative information on the green-mapping are provided in annex C3.

3.4. Decision Support System (DSS)

The preceding paragraphs gave a close insight into the operationalization of the concepts of QoP and QoL/UES via indicators. These concepts form two steps of a MCA, which assess the suitability of a housing-site in terms of socio-environmental framework-conditions (QoP) but also quantifies and executes a scenario-based impact assessment due to building-development against the target-concepts QoL and UES.

In order to execute both steps of the MCA simultaneously a prototype of Decision Support System (DSS) was elaborated and is executed via a Visual-Basic-based user-interface (VB-DSS).

Note, the part of QoP-assessment was successfully tested within various stakeholder workshops accompanying the research project FIN.30. The second part of the DSS is an extension of the first part and puts emphasis on QoL/UES-assessment. This second part has the status of a conceptual translation of a scenario steered impact assessment of QoL/UES into a DSS. According to these notions and due to the fact that the DSS aims at a strong aggregation of information from both steps of the assessment, the presentation of results of QoP-and QoL-assessment will be provided analytically and in a detailed manner. A close insight into the characteristics of both housing sites of infill and greenfield development will be given. In order to provide a close understanding of the two

steps of the MCA and individual results, the application of the DSS will not be used in chapter 4. The DSS is to be considered as a merely feasible structure to integrate both steps of the MCA than as a fixed model.

Besides the MCA, decision support systems (DSS) represent a valuable instrument in urban planning. They bundle planning alternatives and scientific knowledge and facilitates consensus between the stakeholders. Consequently, a combined approach of MCA and DSS – as presented within this chapter- offers a tool to handle spatial decision problems quantitatively. Valuable results derived from stakeholder-workshops, where the first step of the MCA and of the VB-DSS was tested successfully. However, the tool does not give an objective answer in the sense of “what to do best”²⁸⁷. But, it supports decision makers by *firstly* identifying (sustainable) decision indicators and *secondly* by assessing action options, which refer to these indicators, and *thirdly* by merging the assessments analytically²⁸⁸. They integrate assessment techniques with judgement methods and form a sound analytical basis for decision analysis²⁸⁹.

The VB-DSS is separated into two different levels according to the steps of the MCA. Its structure is outlined in figure 25. A closer insight into the scheme and functions of the VB-DSS will be given in annex C4.

The first two sheets enable the assessment of QoP using ecological and social indicators described in chapter 3.2. This assessment provides the application of indicator-values as deriving from background-data and enables an individual indicator-weighting. The following sheets promote the assessment of socio-environmental impacts according to the indicators on QoL/UES and defined housing-scenarios as outlined in chapter 3.3. A final sheet of the VB-DSS merges the analysis of socio-environmental framework-conditions and scenario-based impact-assessment.

²⁸⁷ RAUSCHMAYER 2000 & BELTON & STEWARD 2002 cit in SCHETKE & HAASE 2008, p. 489

²⁸⁸ RAUSCHMAYER 2000

²⁸⁹ NIJKAMP ET AL. 2002

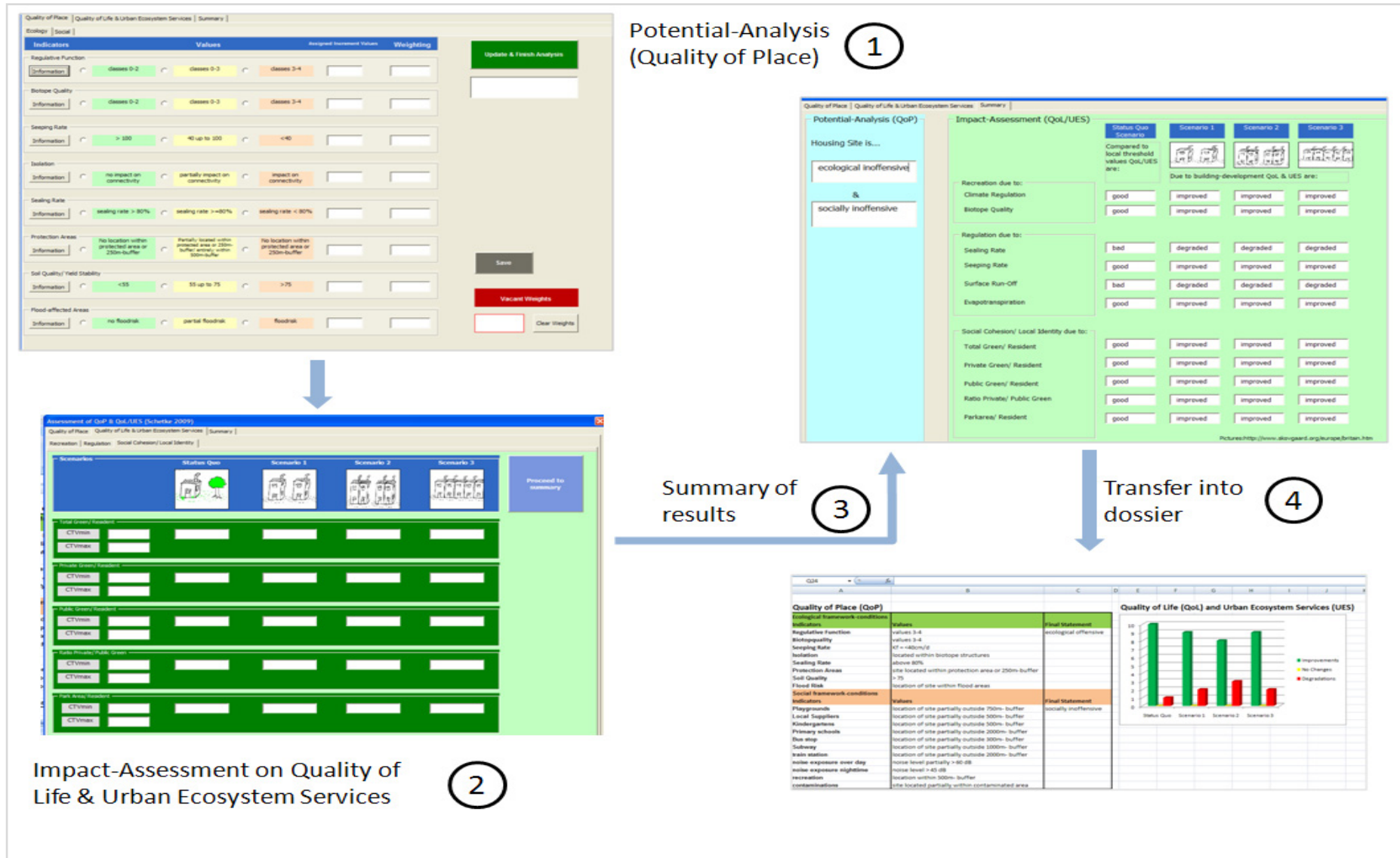


Figure 25 Systematic of VB-DSS enabling simultaneous socio-environmental potential-analysis and impact assessment (authors draft)

3.5. Case Study

The City of Essen with around 580.000 inhabitants serves as case study of this study. It is situated in the Ruhr-area of Germany. As cities tend to merge towards each other in this region, housing-development is characterized by spatially limited urban expansion and challenging infill development with brownfield (re-)development of former industrial sites and re-densification. Due to its past as a highly-built up city of heavy industry, it is assumed that especially socio-environmental conditions related to urban green provision are very tensed within Essen and vulnerable towards measures of settlement-development. Still, planners are also facing a continuous high development pressure and demand of greenfield sites.

Accordingly, the preservation of the very few natural resources within the municipal area takes up a prominent position for the assessment of QoP. Moreover, due to decreasing population numbers (see fig. 26 below), the location of housing sites close to existing facilities of social infrastructure gains importance, as it supports its consolidation and use to capacity. In times of tensed communal budgets, this aspects needs to be taken into account. The promotion of compact settlement-structures, reduced individual traffic and the re-use of formerly built-up areas are also possible positive side-effects.

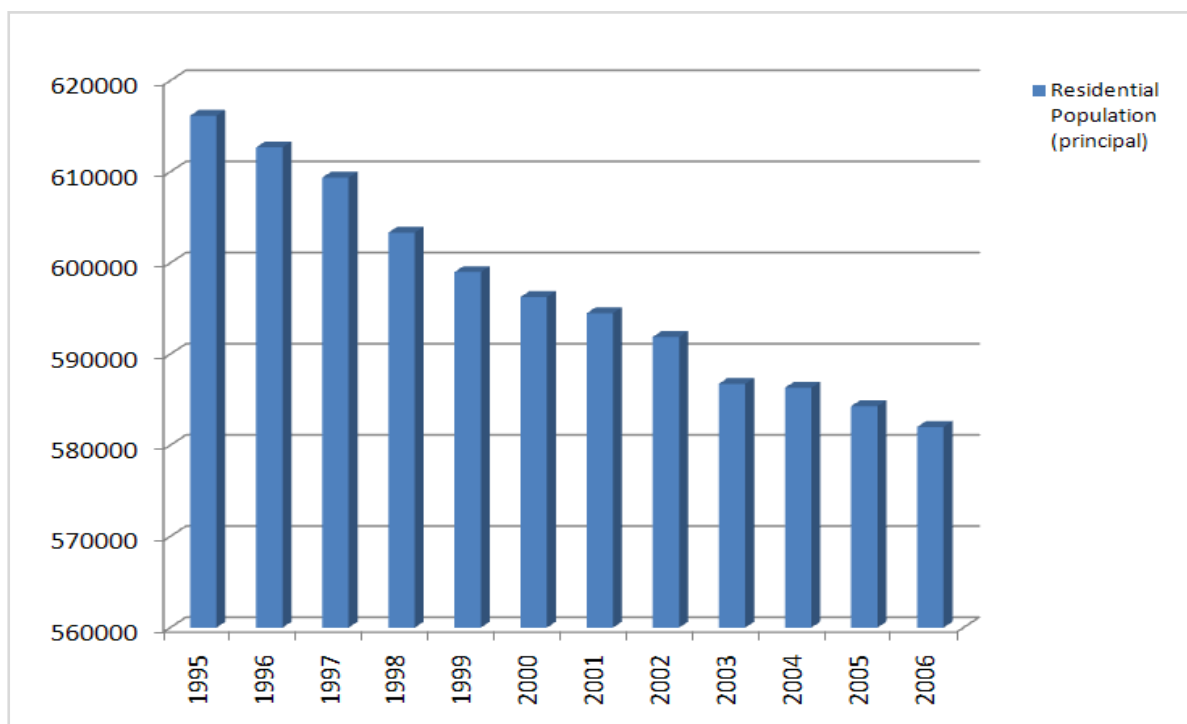


Figure 26 Population development City of Essen (modified according to SCHAUERTE ET AL. 2007)

Because of the continuously decreasing population numbers, a surplus of more than 16.000 apartments is predicted until 2015. Still, a great share of housing potentials is not marketable anymore. It cannot satisfy the ongoing demand of single-family homes and high-qualitative housing.

In line with changing preference patterns²⁹⁰, a current analysis of housing demand until 2020 demands almost e.g. 2700 single family homes covering an area of 123 ha²⁹¹.

3.5.1. Introduction to Test-Sites

The two-stepped MCA of this study refers to 31 single future housing sites at 22 locations within the City of Essen. These sites comprise different legal status and are subject of both preparatory and binding land use planning. Together, they are derived from an analysis of housing demands until 2015²⁹² and displayed in the draft (status 2008) of the new regional land use plan. These sites differ in size, aspired housing-densities, building-structures, legal status and preceding land use²⁹³. The regional land use plan covers the municipal areas of *the case study city Essen* and Bochum, Gelsenkirchen, Herne, Mülheim an der Ruhr and Oberhausen in a scale of 1:50.000 (see fig. 27). The plan only displays sites larger than 5 ha²⁹⁴. But also current future housing-sites, which have already been displayed in binding land use plans but not developed until 2008 together with sites of preparatory land use planning smaller than 5 ha, were included into the assessment in accordance with planners of the City of Essen.

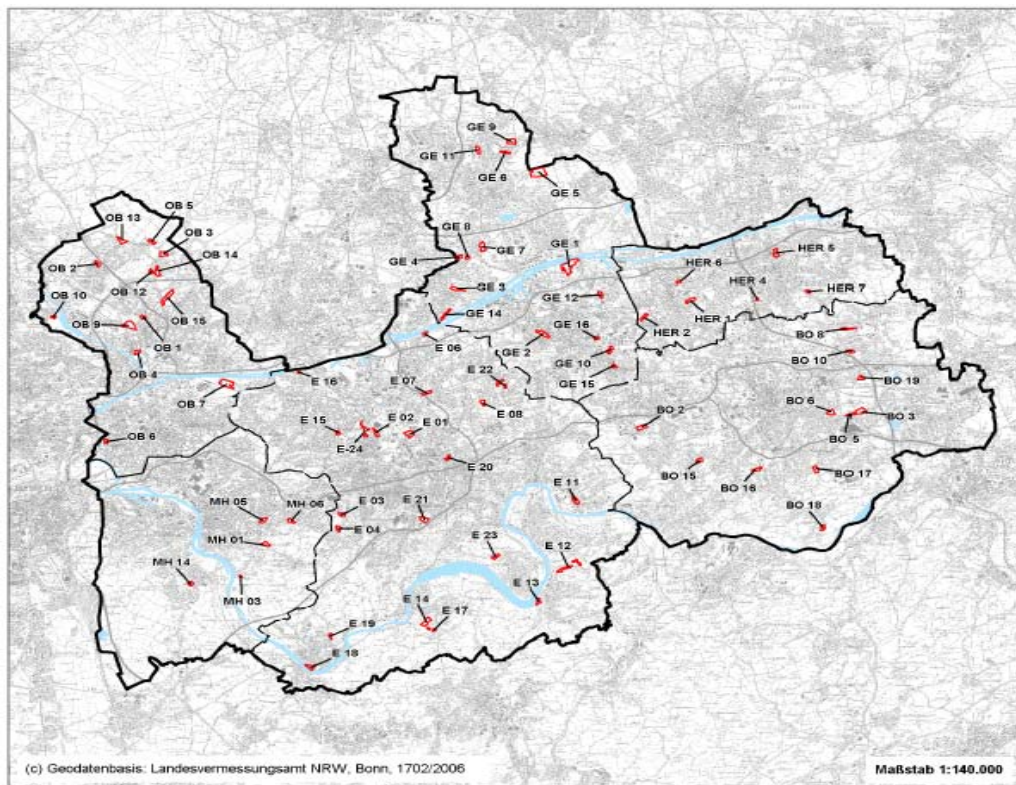


Figure 27 Extends of the Regional Land Use Plan (source: www.staedteregion-ruhr-2030.de)

²⁹⁰ COUCH & KARECHA 2006

²⁹¹ SCHAUERTE 2007

²⁹² See SCHAUERTE 2007 and the „Wohnungsnachfrageanalyse 2015+ Stadt Essen“

²⁹³ Background data and the permission for analysis within this thesis are provided by the City of Essen (Departments 61 and 68). As the housing sites are derived from a draft (status 2008) of the regional land use plan which is the instrument of preparatory planning no legal claims can be asserted. The compilation of the analyzed sites does not entirely match with those displayed in the final version of the regional land use plan (03.05.2010). The status infill and greenfield development also refers to the reference-year 2008.

²⁹⁴ www.staedteregion-ruhr-2030.de/cms/planinhalt.html

19 out of the 31 single sites are sites of infill-development, other 12 sites are subject of greenfield-development (see fig. 28 below). The association to either infill- or greenfield-development refers to the definition of the City of Essen as described in the excursus in chapter 2. A close insight into the characteristics of each site can be derived from table a1 in the annex.

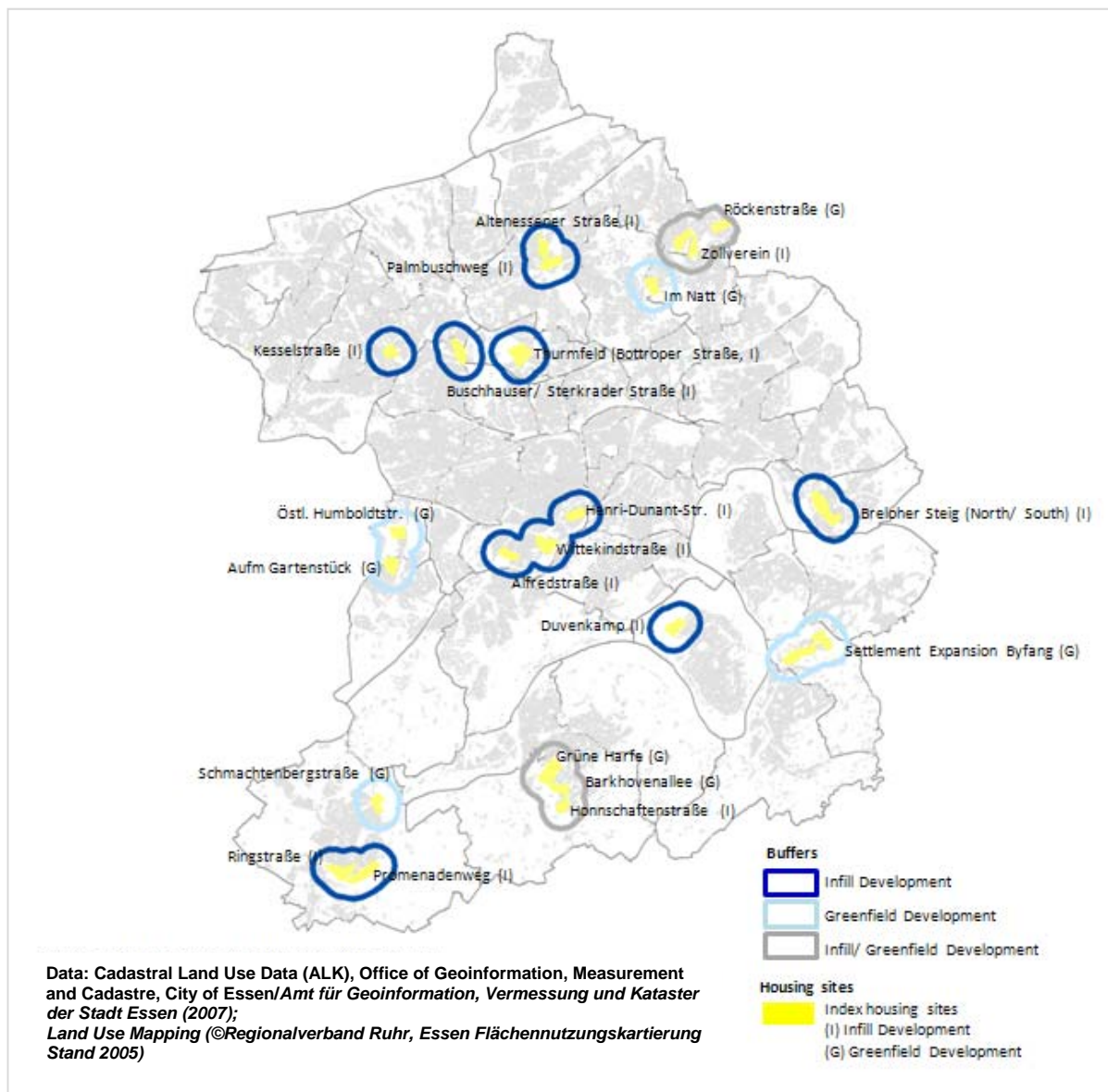


Figure 28 Analyzed housing sites in Essen (status 2008)*

*The following sites displayed in the above standing figure 28 which are analyzed within this work originate from the RFNP draft (regional land use plan) of the year 2008 but are not potential housing sites in the legally effective RFNP of 03.05.2010 any more: Henri-Dunant-Str., Alfredstr./ Moritzstr., Altenessener Str./ Kaiser-Wilhelm-Park, Rössenstr./ Bonnekampstr., Breloher Steig (South), Settlement Expansion Byfang, Honnschaftenstr./ Friedrich-Küpper-Weg, Promenadenweg/ Güterstr. (see also table a1 of the analyzed housing potentials in the annex).

Note: Due to a better readability, the selected sites' names are indicated in a shortened form in the above-standing figure and also in most of the following diagrams. All sites' full names can be retrieved from table a1 in the annex.

With reference to the MCA of this thesis, the following aspects need closer insight: As mentioned in chapter 3.1. the MCA is divided into two analytical steps: 1) the assessment of QoP and socio-environmental prerequisites and 2) the scenario-steered impact-assessment of QoL/ UES.

Whilst the first assesses the 22 locations comprising 31 single sites in total, the latter refers to closer surroundings indicated by a buffer of 500m around each housing site (compare chapter 3.3.1.). Figure 28 above shows the buffer areas. Due to the fact that several housing sites displayed in the regional land use plan are situated in close proximity to each other, they share the same buffer-ring. Table a1 (annex A) provides closer information about the belonging of each housing site to the respective buffer (column "buffer name"). Note that the presentation of the results of the impact-assessment on QoL/UES (see the following chapter) refers unexceptionally to the buffer's extends and not the sites itself. The presentation of the results of QoP will refer to the sites itself, as it describes individual site conditions which are exclusively related to the exact position and extension of each site. Table a1 in the annex will give a brief introduction into name, location, measure of settlement development, size and current land use of the sites.

The following maps (fig. 29-31) give us an overview of major selected characteristics of the case-study itself which directly refer to the indicators applied for QoP-analysis. Closer insight into selected issues of the assessment will then be given in chapter 4 and 5. The maps show us a clear division between the northern and the southern part of the city. It becomes clear, that in terms of e.g. green provision and determinants such as biotope quality, climate regulation and existing protected areas, the southern part of the city is favoured compared to the northern part of the city. This is due to denser building structures and a higher degree of industrial premises and therefore humanely modified land uses in the north. These aspects of distribution of natural resources within a city have to be taken into account during settlement-development and were considered during the assessment of QoP and QoL/UES in this study.

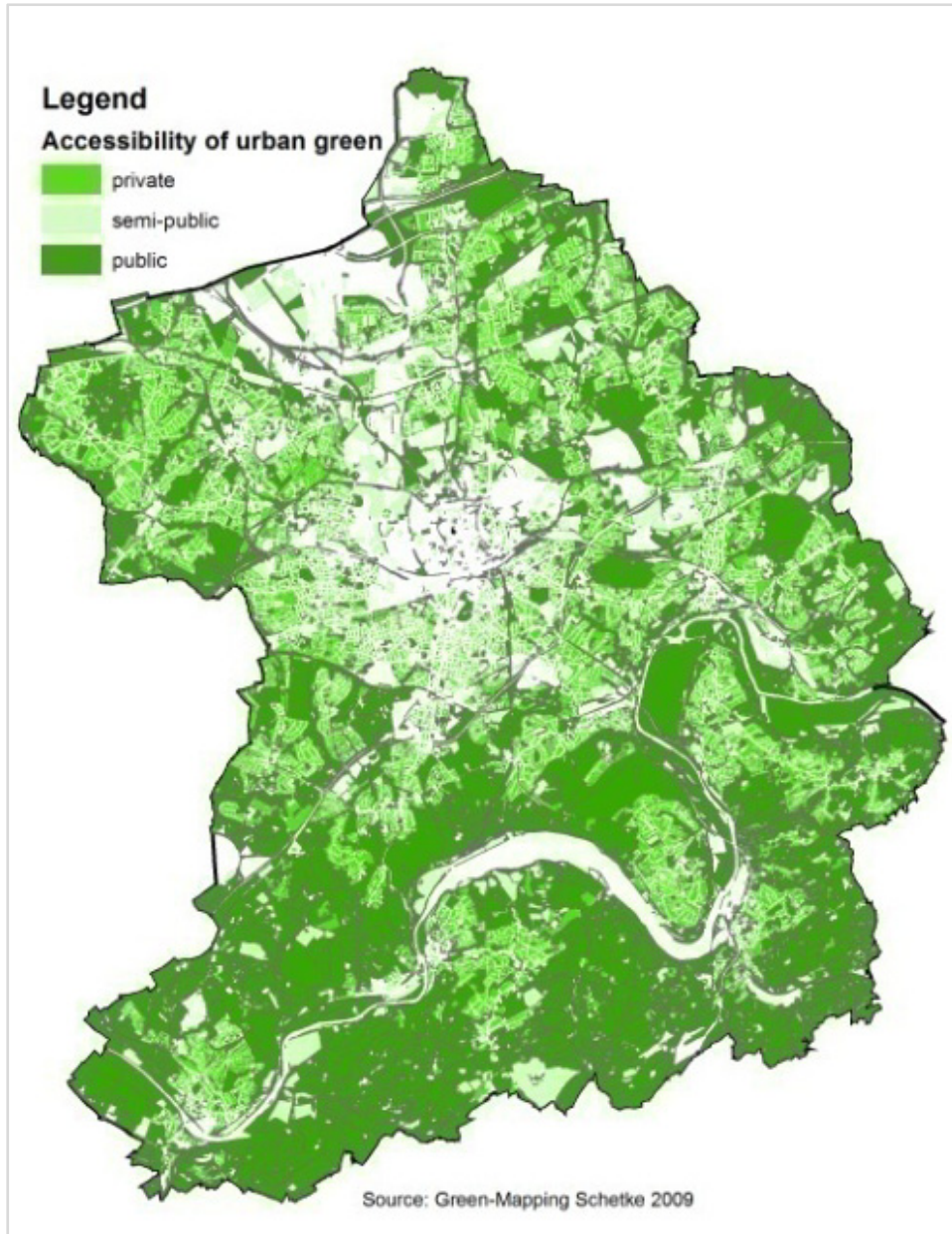


Figure 29 Accessibility of urban green spaces in the City of Essen

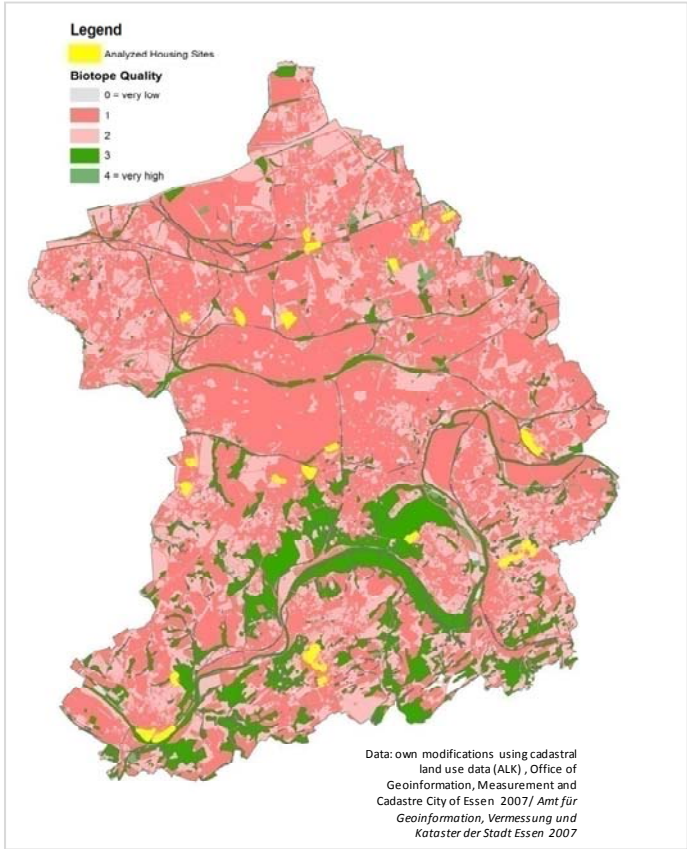
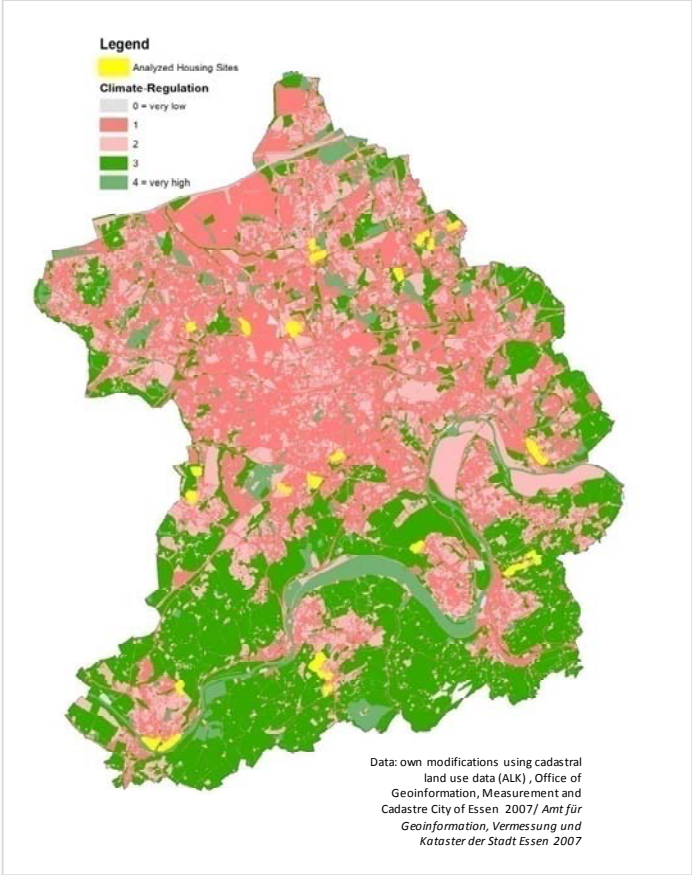


Figure 30 Climate regulation and biotope quality in the City of Essen

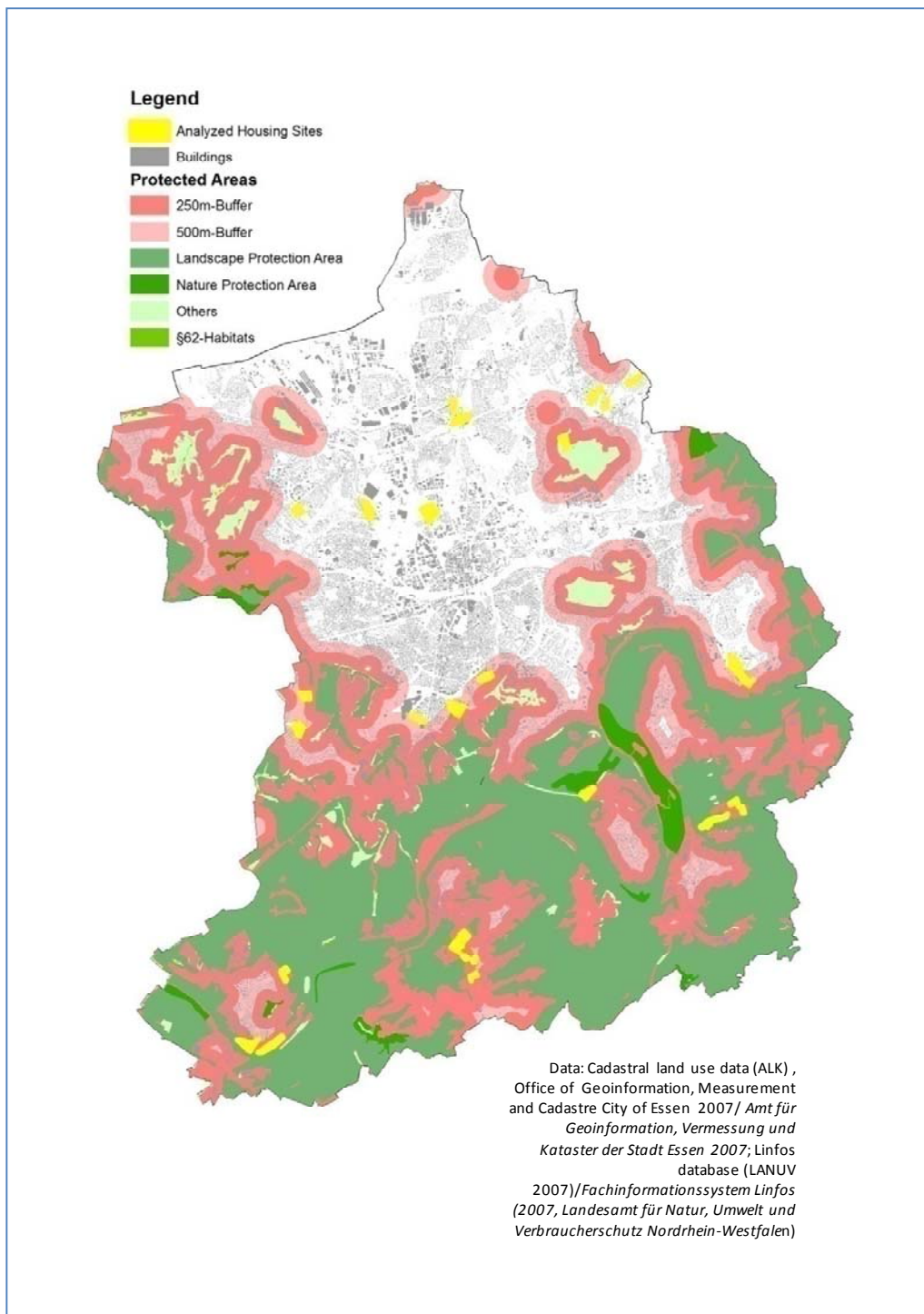


Figure 31 Location of protected areas within the City of Essen

Caesura

The first chapter provided a close insight into current patterns of settlement growth and settlement development in a broader sense, deriving social and environmental deficits and political strategies—such as the two targets of the German Council of Sustainability to enhance sustainable settlement growth. We learnt that three target concepts play an integral role in doing so. First, we had to assess the QoP of each future housing-site. This assessment referred to ecological aspects of resource protection, but also social aspects such as a good access to social infrastructure and adequate living surroundings. In doing so, future housing sites displayed in the regional land use plan (under elaboration) of the case study Essen were assessed. This set of future housing-sites comprised sites of both infill and greenfield development. The strategic level of land use planning was chosen, in order to assess both prerequisites and impacts of settlement-growth at an early planning state. This helps to adjust settlement development to the goals of sustainability in the long-term. The QoP-assessment was followed by the assessment of socio-environmental impacts of settlement-growth using the concepts of QoL and UES.

The first paragraphs of the next chapter will give insight into the QoP of each housing site of the analysis in order to give an answer on research question 1²⁹⁵. Part of this answer could be given in the preceding paragraphs by operationalizing the concept of QoP for both the ecological and social dimension of sustainability. These indicators form the first part of the twofold MCA-scheme. A distinction of the QoP of infill- and greenfield-sites and their direct contribution to the targets of sustainability will be provided in chapter 4.

After the QoP-assessment, we will deal with answering research question 2²⁹⁶. In doing so, the two target concepts QoL and UES were outlined in chapter 2. Chapter 3 provided a detailed insight into the indicators, which not only link the two concepts, but also are used for a scenario-steered impact assessment. If land use planning indeed follows a fostered infill development, socio-environmental impacts, which are widely discussed amongst scientists, need to be observed and assessed. This second part of the MCA gives insight into that.

After the presentation of the assessment-results of socio-environmental prerequisites (QoP) for and socio-environmental impacts (QoL/UES) of settlement growth due to housing development, a discussion will be presented in chapter 5. This chapter will also provide with a typology of housing-sites according to the two steps of the MCA.

Chapter 6 is foreseen for the major conclusions of this work. Chapter 7 will close this work with an outlook and demands for further research.

²⁹⁵ Which socio-environmental prerequisites exist in inner-urban and suburban areas determining the suitability of site (“QoP”) for housing purposes against the demand for sustainable and resource-preserving settlement-growth? How can Quality of Place be operationalized by indicators applicable and understandable for both planners and scientists?

²⁹⁶ What socio-environmental impacts can be stated due to infill-and greenfield development? And can we *per se* state positive or negative effects on Quality of Life (“QoL”) and Urban Ecosystem Services (“UES”) of a strategy of fostered infill development or do we need to consider additional external effects?

4 Results

The following paragraphs provide a differentiated and concise insight into the results of the MCA of this study. The MCA was conducted using the 31 potential single housing sites in the case-study Essen.²⁹⁷

The first part will highlight the results of the assessment of socio-environmental prerequisites of future housing-sites displayed in a land use plan. They determine the QoP of each housing-site and assess their contribution to a sustainable and resource-preserving settlement-development. The assessment of these housing-sites according to socio-environmental prerequisites at the strategic level of a land use plan is embedded into the discussion of political benchmarks to reduce land consumption, such as the 30-hectare target and a critical analysis of the success or failure of either infill- or greenfield-development. This *first* set of indicators is presented in table a2 in the annex. All ecological and social indicators of QoP were successfully tested. In doing so, stakeholder-workshops together with planners from the City of Essen were conducted within the research project FIN.30²⁹⁸. Following the planner-oriented purpose of this step, the indicators will be presented in an aggregated manner.

But as an assessment of preconditions may help to steer and promote a sustainable settlement-development, we still are not aware of its effects and socio-environmental impacts. Leaving the arena of political targets and planner-oriented assessment-schemes, the second part of the results – as promoted in chapter 3- will be dedicated to the on-site impact-assessment of settlement-growth under different scenarios of housing density. For this impact-assessment, the concepts of QoL and UES were used to assess the impacts of settlement-growth on residents and their living surroundings. This *second* set of indicators is presented in table a3 in the annex. In order to assess the heterogeneous and differentiated impacts of settlement-growth using the concepts of QoL/UES, the results of step 2 of the MCA will be presented according to the three needs and determinants of QoL.

4.1. Step 1: Assessment of QoP

The QoP-assessment forms the first step of the MCA developed within this study. It gives insight into the socio-environmental suitability of housing sites according to their contribution to a sustainable and resource-preserving settlement development. Several significant characteristics of the data-set determine the following statistical analysis of QoP as the first step of the assessment:

According to a planner-oriented and collaborative approach of QoP-assessment²⁹⁹ an integration of qualitative and quantitative data to one final aggregated result of QoP was executed. All indicators within this analysis had to be standardized following a threefold ordinal classification. They indicate a good indicator performance or good suitability (value 1), a limited performance/suitability (value 2) or a bad performance/suitability (value 3) at each housing site. The translation scheme for each

²⁹⁷ Note, that the presentation of the results does not refer to direct outputs of the prototype of the VB-DSS. Instead the results are presented in a more differentiated manner.

²⁹⁸ Compare the outlines of the excursus in chapter 3.2.

²⁹⁹ Compare chapter 3

indicator is outlined in tab. a2 in the annex and in chapter 3. Following this collaborative approach, the standardization of indicator performances takes a prominent position. This is due to two reasons: *i)* it enables an aggregation of different indicator types to one final statement on the ecological and social QoP of a site. And *ii)*, it allows the integration of expert-weights for each indicator into the final assessment of QoP. Therefore, not e.g. the exact distance of a housing site to a kindergarten is of prime importance, but whether its location matches planners' distance thresholds. In doing so, the complexity of a MCA can be reduced and an aggregation of several decision-relevant indicators to one final statement be provided. Accordingly, an implementation of original indicator-performances will not be subject, of discussion but also limits the possibility for statistical analysis.

Due to the fact that a Gaussian distribution of most of the QoP-indicators in both the ecological and social dimension was not given³⁰⁰, multivariate statistical analysis, such as cluster analysis or discriminant analysis to derive concentrated information, could not be executed.

Following these notions, the effect of an additional aggregation of the results is doubtful. Both indicators and analyzed housing-sites were selected argumentatively within a planner-oriented process, in order to elaborate a MCA-scheme applicable and communicable within processes of municipal land use planning³⁰¹.

The presented result will give an insight into characteristic QoP of sites of infill- and greenfield-development. They allow first statements on socio-environmental QoP and on overall tendencies of the contribution of infill- and greenfield-development to a sustainable and resource-preserving settlement development. Therefore, the analysis of QoP-assessment is descriptive in nature. It will discuss individual indicator performances at sites of both infill- and greenfield-development. And it focuses on their embedding into their structural and spatial context of their neighborhoods with regard to ecological and social questions.

According to a planner-oriented approach, individual weighting of QoP-indicators derived from stakeholder-workshops within the research project FIN.30, was used for the assessment. Here, one focus of the analysis will be put on the individual weighting, as it significantly defines the decision-relevance of indicators within decision making and influences the aggregated results of QoP. Another focus will lie on the individual indicator performances as presented in figures 1r & 2r in the annex, which determine the specific socio-environmental QoP of sites of infill- and greenfield-development.

4.1.1. Ecological Indicators

The results of QoP-assessment considering ecological preconditions of housing-development in the City of Essen will be outlined in the following paragraphs. Major focus of ecological QoP-assessment is the protection of natural resources within processes of settlement-development. This means that those housing sites, which are located at already humanely modified locations and provide the least use of natural und undisturbed resources, such as ecosystem functions and the spatial avoidance of protected areas, are to be favored for housing-development. Additionally, also the natural risk exposed on housing-sites is an important category, which needs to be considered during the

³⁰⁰ The critical benchmark of the asymptotic significance calculated using SPSS (JANSSEN & LAATZ 2007; DULLER 2008; FACINETTI & CHIODINI 2008; TREIBER 2009) indicating a Gaussian distribution of 0.05 has been undercut in most cases (see tab. 1r and 2r in the annex).

³⁰¹ KÖTTER ET AL. 2009b; SCHEKKE ET AL. 2009a; SCHEKKE ET AL. (in prep.)

assessment.³⁰² The positive or negative contribution of either infill or greenfield-development to a resource-preserving and sustainable settlement-development is shown in figure 32.

All analyzed future housing sites are ranked according to their aggregated ecological QoP-performance value as described in chapter 3.2.3. The annotation at the left hand side indicates the overall QoP-performance of each housing-site.³⁰³ Each site is represented by two bars. The bars indicate the equal-weight and the expert-weight of each indicator within the aggregated QoP-value.

The ecological QoP decreases as the QoP-value rises (indicated by the arrow). According to the expert-weighted assessment of QoP³⁰⁴, most of the sites of *infill-development* provide a very good QoP³⁰⁵ and therefore an unlimited suitability for housing development under ecological purposes compared to *greenfield-sites*.

The QoP-values, as presented in figure 32, are aggregated and are a composition of single indicator-performances and weights. They allow first statements on the planner-oriented QoP-assessment of each housing-site. In order to provide a concise insight into indicator-performances and importance/decision-relevance of single ecological indicators, the ranking of housing-sites (fig. 32) is followed by an excursus on that.

This excursus will present mean values of each indicator-performance at sites of infill-development and at those of greenfield-development. Special attention will also be drawn on expert-weights for each ecological indicator (fig. 33), which gives an insight into its *decision-relevance* within planning processes and their effect on the aggregated QoP-value.^{306,307} A first insight into this last issue can be derived from the comparison of both expert (dark bars) and equally-weighted (light bars) QoP-values in fig. 32.

A synthesis of figures 32 and 33 will be given at the end of this sub-chapter. We will get an insight into the meaning and decision-relevance of selected indicators and their influence on the aggregated QoP-value of each site.

³⁰² SCHETKE ET AL. (in prep.)

³⁰³ Single indicator performances for each housing site can be found in fig. 1r in the annex.

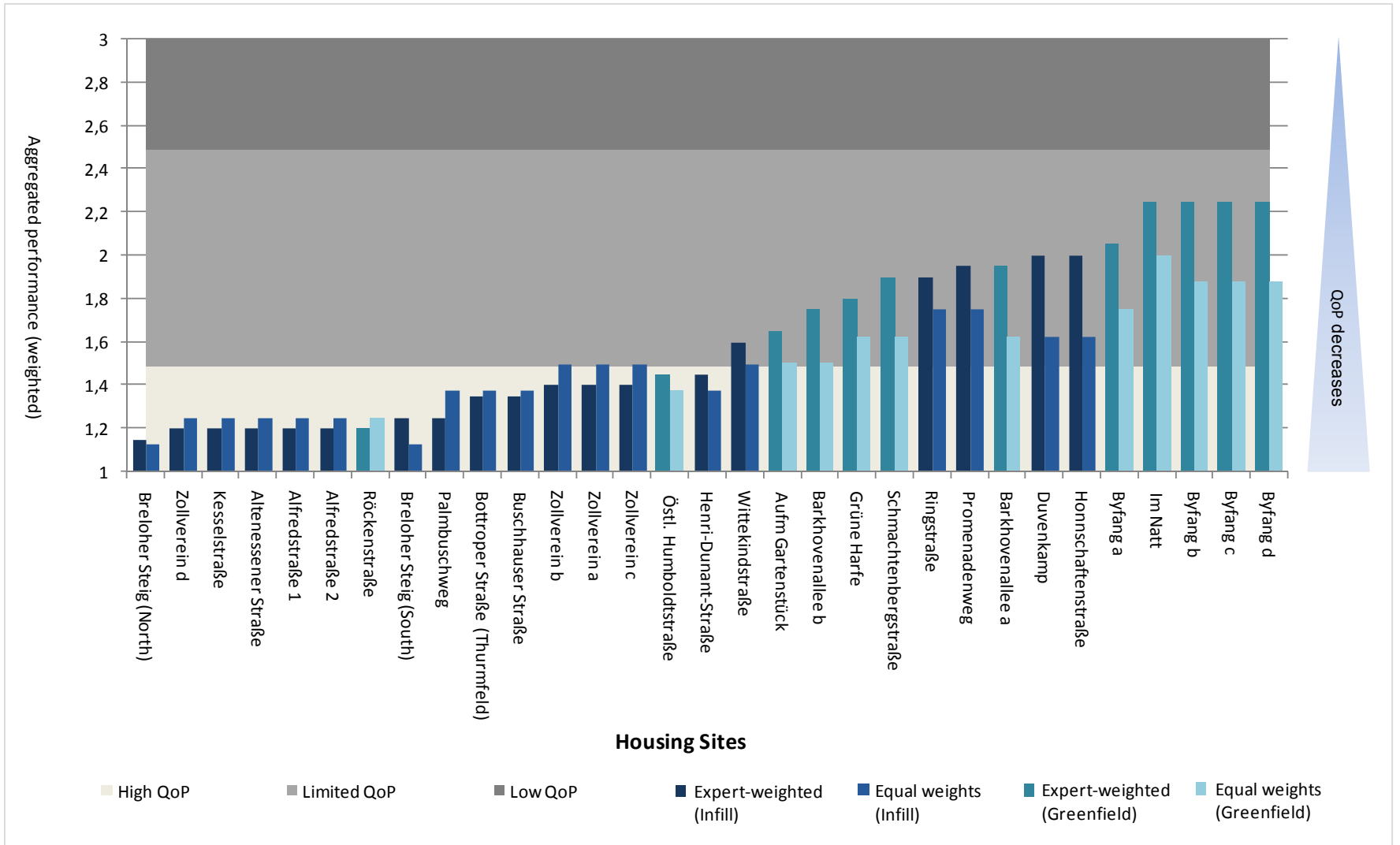
³⁰⁴ The indicator-weighting is derived from local planners of the City of Essen within the research project FIN.30. See excursus in chapter 3.2.

³⁰⁵ indicated by the value of 1.49 (compare chapter 3)

³⁰⁶ See also figure 1r in the annex. For each single indicator performance the classification of 1 (unlimited suitability), 2 (limited suitability) and 3 (no suitability) needs to be considered

³⁰⁷ Note that within the following paragraphs a distinction is made between *single indicator performances* indicating their levels of ecological suitability (values 1, 2, 3) and an *aggregated QoP-performance value* including all indicator performances and their weights.

Figure 32 Aggregated and expert-weighted results of ecological QoP-analysis ordered according to their QoP-performance value



Excursus to mean value of indicator-performances³⁰⁸ & decision-relevance: Figure 33 indicates the mean value of ecological indicator performances at both types of housing-sites. The mean values do not introduce an additional measure of classification, but are applied to get an insight into indicator-performances at housing-sites differentiated according to infill- and greenfield-development. Overall tendencies of indicator performances according to their threefold suitability-classification³⁰⁹, will be shown. The argumentation is executed according to the notion: *the higher the mean value, the worse the performance* and is introduced to compare the performance of sites of greenfield- and infill-development. The mean values do refer to single indicators only and must not be mixed up with aggregated QoP-values.

According to the preceding statements, greenfield sites show a higher performance, and therefore lower suitability, than sites of infill development for 3 out of 9 indicators.³¹⁰ This affects the indicators *climate regulation*, *protected areas* and *seepage*, which also belong to the highest weighted indicators and therefore explain the above show ranking of infill and greenfield sites of figure 32. Figure 33 gives a clearer insight into that. Each bubble in figure 33 represents an indicator. The size of each bubble differs according to the height of the individual expert-weight.

The expert indicator-weighting within the ecological dimension of QoP shows a *decision-relevant meaning* of the indicators *climate regulation*, *seepage*, *isolation* and *protected areas*. Together they hold 75% of all possible expert-weights. They need to be considered as *decision-relevant* within the ecological site-assessment. Especially low weights and therefore limited importance fall upon the indicators *soil quality* and *flood risk*.³¹¹

³⁰⁸ All sites of either infill or greenfield development are equally weighted.

³⁰⁹ According to the notions of chapter 3.2.3: value 1 (unlimited suitability), value 2 (limited suitability), value 3 (no suitability).

³¹⁰ See also fig 33 and fig. 3r in the annex

³¹¹ See fig 4r in the annex for expert-weights in comparison to equal weights.

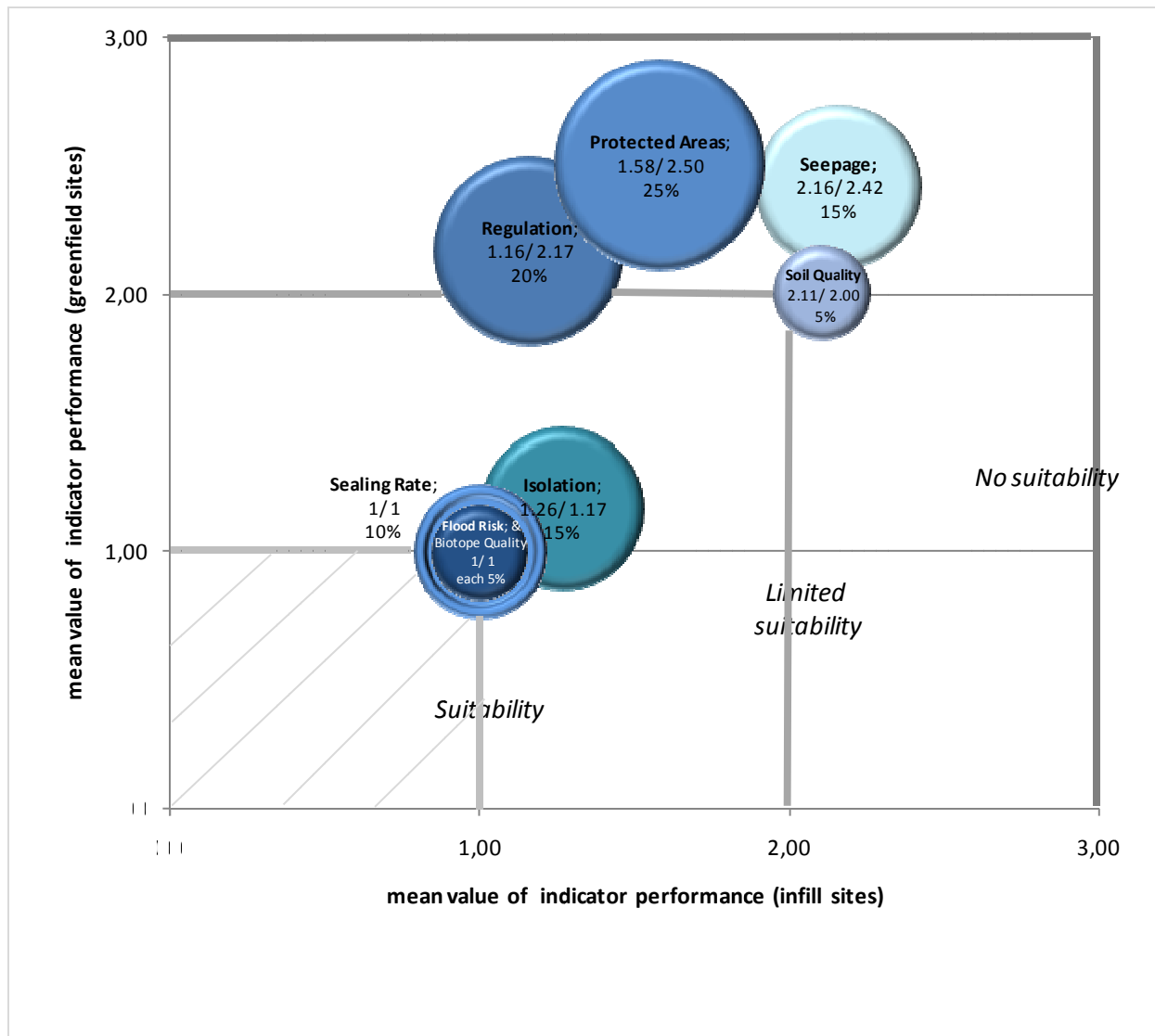


Figure 33 Ecological indicator performance and suitability-levels at infill and greenfield sites in connection to expert-weights of the indicators indicated by size of the circle

Synthesis

Infill development: Especially the avoided use of undisturbed ecosystem functions contributes to the positive assessment of infill-sites. According to the definition of infill development as outlined in chapter 1, solely already humanely modified and therefore ecologically stressed areas will be/ are used. The indicator **climate regulation** in figures 33 and 1r clearly supports this statement. Here, the mean value of all infill-sites shows values, which are slightly above the value 1 (unlimited suitability). Compared to that, sites of greenfield-development show a mean value > 2 (limited suitability). The indicator **seepage** also approaches limited suitability at these sites³¹². Against these notions, the indicators **biotope quality** and **sealing rate** do not indicated specific limitations at sites of both infill and greenfield development³¹³. This is also indicated by a mutual mean value of 1 indicating unlimited suitability.

Moreover, the use of static natural resources represented by the indicators **isolation** and **protected areas** approaches unlimited suitability at sites of infill development. This is due to their integration into already built up and urbanized neighborhoods. It is indicated by mean values of 1.26 (isolation) and 1.58 (protected areas). Only selected sites of infill-development show the partial use of connected habitats or are located very close to protected areas. The indicator **soil quality** approaches limited suitability at sites of infill development.³¹⁴ Note that, here a limited accuracy of the soil map within urbanized areas and its rough scale of 1:50.000 can express these misleading values. We have to consider that the pedological regime at these sites is rather significantly disturbed. As it refers to an identical data-base, the same counts for a careful consideration of the indicator **seepage**. In terms of natural risk potentials represented by the indicator **flood risk**, sites infill-development are unlimited suitable for housing development.

Greenfield development: According to figure 32, the suitability of greenfield sites for housing development under ecological preconditions needs to be questioned³¹⁵. The majority of all selected sites exceeded the aggregated QoP-value of 1.49, which indicates a good QoP.³¹⁶ In terms of ecosystem functions used and modified due to housing development, the indicator **climate regulation** approaches limited suitability.³¹⁷ The indicators **biotope quality** and **sealing rate** show basically indifferent but positive values for both types of sites. Additionally, the disturbance of **protected areas** significantly influenced the above shown results and leads to a limited aggregated QoP-performance value of greenfield-sites³¹⁸. Comparable results for the use of valuable soils cannot be stated and also need to be critically assessed according to the above mentioned restrictions of the pedological data-base. Limited suitability due to **flood risk** could not be indicated.

³¹² Compare fig. 33 above and fig. 1r in the annex.

³¹³ fig. 1r in the annex.

³¹⁴ Mean value of 2.11; single indicator-performances can be obtained from fig. 1r in the annex.

³¹⁵ fig. 1r in the annex and mean values of fig. 33.

³¹⁶ fig. 32.

³¹⁷ Mean value of 2.17 (fig. 33).

³¹⁸ Mean indicator-value of 2.5, fig. 33.

4 Results

Resulting from the analysis of figures 32 and 33, the following statements can be derived: The majority of infill-sites indicate a good QoP and undercut the value of 1.49³¹⁹. Three of four decision-relevant indicators³²⁰ show better performances at *infill-sites* than at *greenfield sites*. The majority of greenfield-sites only provides a medium QoP and exceeds the value of 1.49.

³¹⁹ Within the group of sites of infill development, two sites peak out in figure 32 and show rather characteristics of greenfield sites along with all characteristic of limited suitability and low QoP. Due to their past of structural use, the sites **Duvenkamp** and **Honnschaftenstrasse** are indicated as infill sites. Referring to their embedding in a rather suburban neighborhood, these controversy results can be explained.

³²⁰ Climate regulation, protected areas and seepage

4.1.2. Social Indicators

The social dimension of QoP-assessment focuses on major determinants of suitable social preconditions for housing-development which can be defined as both the provision with daily goods and infrastructure and the attractiveness of living surroundings³²¹. The contributions of infill and greenfield development to a sustainable settlement development with respect to social preconditions are presented in figure 34. The presentation of the results of social QoP will be executed according to the preceding ecological dimension.

The sites are ranked according to their aggregated social QoP-performance as described in chapter 3.2.3. The annotation at the left hand side indicates the overall aggregated social QoP-performance value of each housing-site.³²² Each site is represented by two bars. The bars indicate the equal-weight and the expert-weight of each indicator within the aggregated QoP-performance value. The social QoP decreases as the QoP-value rises (indicated by the arrow).

It becomes clear that an unambiguous and clear differentiation of sites of infill and greenfield development according to their social QoP-performance is not easy to derive. Despite the fact that all sites of greenfield development do not provide a good QoP and exceed the value of 1.49, also a considerable number of infill sites is similarly characterized.

The QoP-values as presented in figure 34 are also aggregated and are a composition of single indicator-performances and weightings. They allow first statements about the planner-oriented social QoP-assessment of each housing-site. In order to provide a concise insight into indicator-performances and *decision-relevance* of single social indicators, the ranking of housing-sites (fig. 34) is followed by an excursus.

The excursus will present mean values of each indicator-performance at sites of infill- development and at those of greenfield-development. Special attention will also be drawn on expert-weights for each social indicator (fig. 35), which gives an insight into its decision-relevance within planning-processes and their effect on the aggregated QoP-value.^{323,324} A first insight into this last issue can be derived from the comparison of both expert (dark bars) and equally-weighted (light bars) QoP-values in figure 34.

A synthesis of figures 34 and 35 will be given at the end of this sub-chapter. We will get an insight into the meaning and decision-relevance of selected indicators and their influence on the aggregated QoP-value of each site.

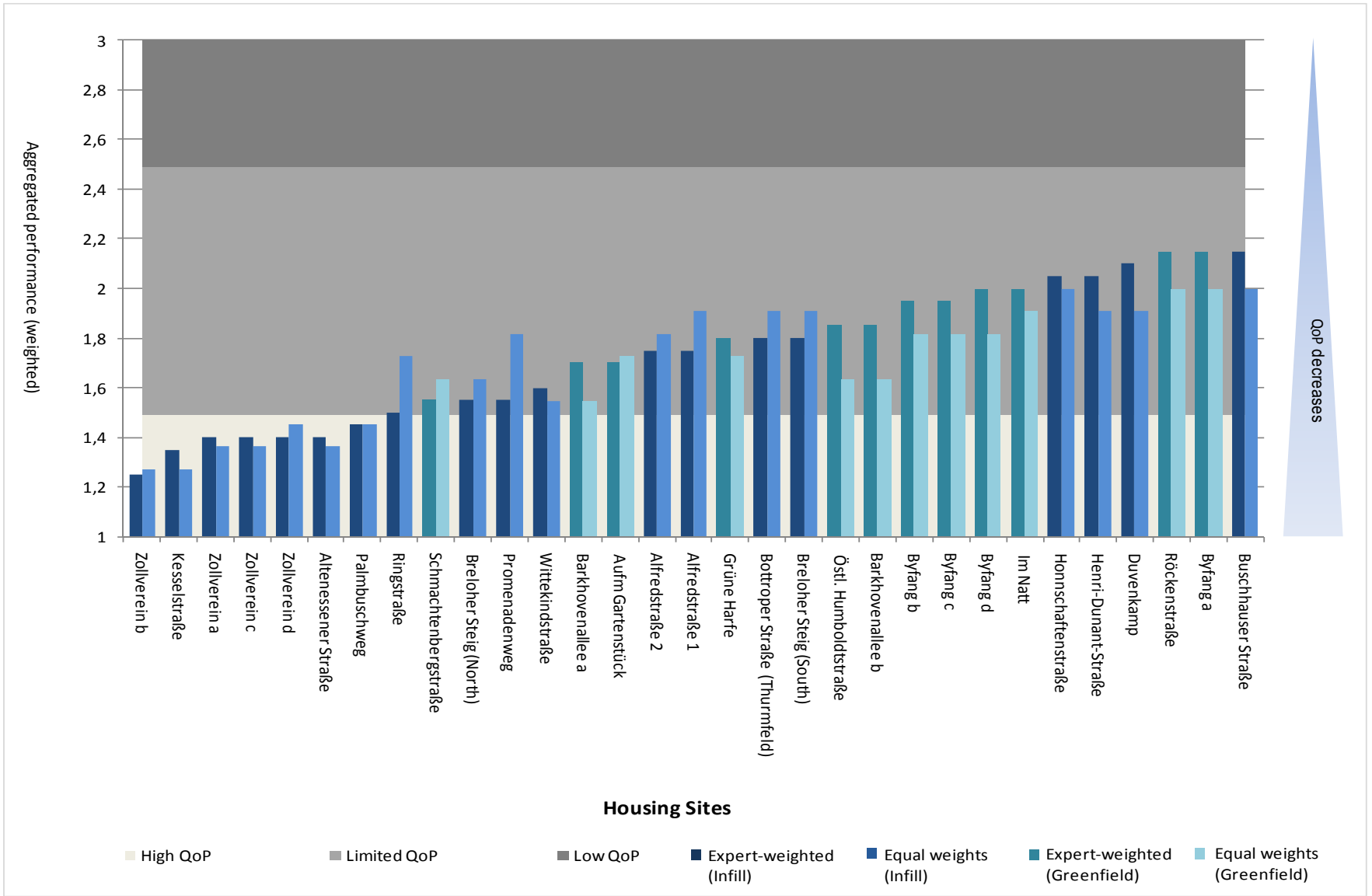
³²¹ See KÖTTER ET AL. 2009a; SCHETKE ET AL. 2009a or literature references in chapter 3.2.2 for a condensed overview.

³²² Single indicator performances for each housing site can be found in fig. 2r in the annex.

³²³ See also figure 2r in the annex. For each single indicator performance the classification of 1 (unlimited suitability), 2 (limited suitability) and 3 (no suitability) needs to be considered

³²⁴ Note that within the following paragraphs a distinction is made between *single indicator performances* indicating their levels of social suitability (values 1, 2, 3) and an *aggregated QoP-performance value* including all indicator performances and their weights.

Figure 34 Aggregated and expert-weighted results of social QoP-analysis ordered according to QoP-performance



Excursus to mean value of indicator-performances³²⁵ and decision-relevance: To get a brief overview of the general performance of each indicator at sites of infill and greenfield development, figure 35 indicates the *mean value* of indicator performances at both types of housing sites. The mean values do not introduce an additional measure of classification, but are applied to get an insight into indicator-performances at sites of infill and greenfield development. Overall tendencies of indicator-performances according to their threefold suitability-classification for a sustainable settlement growth under social framework conditions³²⁶ will be shown. The argumentation is executed according to the notion: *the higher the mean value, the worse the performance* and is introduced to rather compare the performance of sites of greenfield and infill development amongst each other. The mean values do refer to single indicators only and must not be mixed up with aggregated QoP-values.

According to the preceding statements greenfield sites show for 6 of 11 indicators a higher performance and therefore lower suitability than sites of infill development.³²⁷ This affects the indicators **playgrounds, local suppliers, kindergartens, primary schools, subway and train station**. But we also see that the differences between most of these values are not very large and that the indicator performance of infill-sites is, in some cases, very similar to that of greenfield-sites. This explains the ambiguous ranking shown in fig. 34. Each bubble in figure 35 represents an indicator. The size of each bubble differs according to the height of the individual expert-weight.

It goes without question that individual indicator weights had visible influences on the total assessment of QoP under social preconditions. The indicator-weighting within the social dimension of QoP shows a prominent and *decision-relevant meaning* of the three indicators **distance to local suppliers; subway and inner urban trains and noise exposure at nighttime** which together hold 45 % of all weights for 11 indicators for site-assessment. Compared to that, the indicator **distance to kindergartens, bus-stops, train stations, noise exposure at daytime and suspected contaminations** received limited attention and are supposed have a limited influence on the QoP-assessment under social preconditions³²⁸.

³²⁵ All sites of either infill or greenfield development are equally weighted.

³²⁶ According to the notions of chapter 3.2.3: value 1 (unlimited suitability), value 2 (limited suitability), value 3 (no suitability).

³²⁷ See fig. 35 and fig. 5r in the annex.

³²⁸ See also fig 6r in the annex for expert-weights in comparison to equal weights.

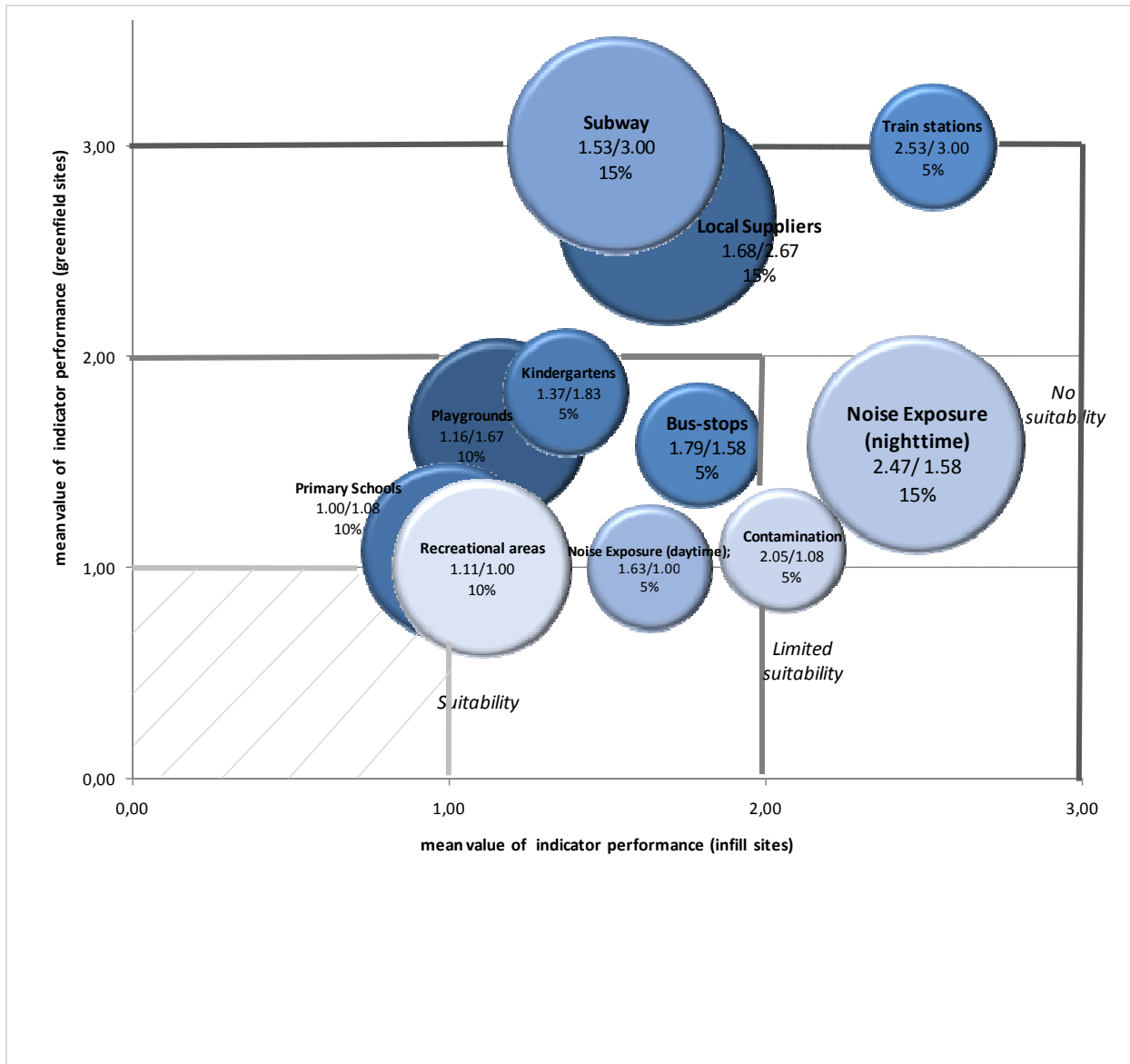


Figure 35 Social indicator performance and suitability-levels at infill and greenfield sites in connection to expert-weights indicated by size of the circle

Synthesis

Single sites of infill-development show a very similar performance compared to greenfield-sites. But the rather better performance of most sites of infill-development can be explained by the embedding into already existing built up structures and neighborhoods. Therefore, a closer distance to means of social and technical infrastructure is given. Despite these facts, the following paragraphs will highlight the difficulty of an unambiguous distinction between a better social QoP of either sites of infill- or greenfield-development. In doing so, mean values and pure indicator-performances at all sites will be subject of closer analysis.

Infill & Greenfield Development: Regarding the category *equity of supply* as displayed in fig. 2r in the annex and represented by the indicators *distance to playgrounds*, *local suppliers*, *primary schools* and *kindergartens*, a clear distinction between a better aggregated social QoP of either infill or greenfield sites is difficult to state.

The first indicator shows a very heterogeneous performance at sites of greenfield-development³²⁹, but still approaches unlimited suitability at infill-sites. The accessibility of *local suppliers*, as a representative of daily needs, is consequently low at greenfield-sites³³⁰ and shows a heterogeneous, but still better performance, at sites of infill development³³¹ including the whole bandwidth of good to limited to bad suitability³³². According to its expert-weights (fig. 35), this indicator is *decision-relevant*. In terms of the provision with *primary schools* in an adequate distance, both site-types do show a very good performance.³³³ Compared to that, also the accessibility of *kindergartens* is very heterogeneous in nature at sites of both infill- and greenfield-development but - regarding its mean value - slightly better at infill-sites.³³⁴

A very important group of indicators is bound to the accessibility of public transport in order to avoid individual traffic and to promote limited negative environmental impacts.³³⁵ Whilst the *accessibility of bus-stops* is rather bad and shows mean values approaching a limited suitability at infill- and greenfield-sites³³⁶, the *accessibility of subways and inner urban trains* shows an overall bad and unacceptable performance at greenfield-sites. This is indicated by a mean value of 3.00. In contrast to that, sites of infill-development are better connected to that mean of public transport and only show mean values approaching a limited suitability at single sites³³⁷. According to its expert-weights (fig. 35), also this indicator appears *decision-relevant*. Additionally, the indicator *distance to train-stations* shows a quite bad performance at sites of greenfield-development. But also, only single sites of infill

³²⁹ Mean values of infill/ greenfield development: 1.16/ 1.67 (fig.35)

³³⁰ Mean value: 2.67 (fig. 35)

³³¹ Mean value: 1,68 (fig. 35)

³³² See single indicator-performances in figure 2r.

³³³ Mean values of infill/ greenfield development: 1.00/ 1.08 (fig. 35). Except one performance of limited suitability at the greenfield sites in Essen-Byfang.

³³⁴ Mean values of infill/ greenfield development: 1.37/ 1.83 (fig. 35)

³³⁵ See individual indicator performances in fig. 2r in the annex.

³³⁶ Mean values of infill/ greenfield development: 1.79/ 1.58 (fig. 35 and single indicator-performances as shown in fig. 2r)

³³⁷ Mean value: 1.53 (fig. 35)

development show a good performance. Also here, the majority of infill-sites are located outside planning distance thresholds.³³⁸

The category *attractiveness of living surroundings* represented by the indicators *distance to recreational areas*, *noise exposure* and *suspected contaminations* provides a clearer distinction between sites of infill and greenfield development. Individual indicator performances are also displayed in fig. 2r in the annex.

Sites of greenfield development provide an overall good *accessibility of recreational areas* larger than 0.5 hectare.³³⁹ But still, also the majority of infill sites are characterized by that provision. In terms of noise exposure no limitation of QoP due to *noise exposure at daytime* could be assessed. But *noise exposure at nighttime* approaches a limited suitability at single greenfield-sites and threshold values are partially exceeded.³⁴⁰ Compared to that, the mean value at sites of infill development approaches a limited suitability due to *noise exposure at daytime* and approaches even no suitability in its mean value of *noise exposure at nighttime*.³⁴¹ According to its expert-weights, also this last indicator appears *decision-relevant*. The problem of a limited perception and quality of living surroundings, due to *suspected contaminations*, is foremost an issue of infill-sites approaching limited suitability. Compared to that, QoP at greenfield sites is almost unlimited due to these issues and a limited suitability indicated at only one site.³⁴²

4.1.3. Intermediate Summary of QoP-Assessment

A clear distinction between a better *ecological* QoP of either sites of infill or greenfield development is equivocal. But still, the preceding paragraphs showed that most of the sites of infill development (14 out of 19) remain below the aggregated QoP-benchmark of 1.49. They provide a very good QoP and suitability as defined in chapter 3.³⁴³ Only 2 out of 12 greenfield-sites show comparable QoP-Values. These results are - amongst others - due to the fact, that the named decision-relevant indicators³⁴⁴ have shown better performances at sites of infill-development than at greenfield-sites.

It becomes evident, that compared to the ecological dimension of QoP, also a clear distinction between a better QoP under *social* prerequisites of either sites of infill or greenfield development shows analogous tendencies. Most of the sites of infill development exceed the aggregated QoP-benchmark of 1.49 which indicates a very good QoP and suitability. Therefore, they only provide medium social QoP. These results are - amongst others - due to the fact, that selected of the named decision-relevant indicators³⁴⁵ still have shown worse performances³⁴⁶ at sites of infill-development. But a minority of infill-sites (7 out of 19) still provides with a very good QoP and undercuts the value

³³⁸ Mean values of infill/ greenfield development: 2.53/ 3.00 (fig. 35 and single indicator-performances as shown in fig. 2r)

³³⁹ Mean values of infill/ greenfield development: 1.11/ 1.00

³⁴⁰ Mean value: 1.58

³⁴¹ Mean value day/ night: 1.63/ 2.47

³⁴² Mean values of infill/ greenfield development: 2.05/ 1.08

³⁴³ See fig. 32 above.

³⁴⁴ climate regulation, seepage, isolation and protected areas

³⁴⁵ Distance to local suppliers, subway and inner urban trains and noise exposure at nighttime

³⁴⁶ This counts for the indicator noise exposure at nighttime.

1.49. Compared to that, all sites of greenfield development have exceeded the benchmark of 1.49 and provide therefore only medium QoP and suitability.³⁴⁷

³⁴⁷ See fig. 34 above.

4.2. Step 2: Assessment of QoL and UES

After having derived an insight into the *quality/suitability* of future housing sites (QoP) according to socio-environmental planning-oriented indicators, the following paragraphs give a concise insight into the second step of the MCA. They highlight the performance of QoL/UES at local level and the socio-environmental *impacts* of settlement-growth within scenarios of varying housing densities³⁴⁸. Compared to the first step of QoP-assessment which was executed referring to the housing site itself, this second step of the MCA includes also its closer living surrounding indicated by a radius of 500m. This procedure leads to the effect that single housing (n= 31) sites will be aggregated as they are located within one buffer (n=14).³⁴⁹

The following presentation of the assessment as the second step of the MCA will highlight individual indicator performances, which are set against calculated local threshold values. It is descriptive in nature. Herewith, a sound insight into the status quo scenario/conditions of QoL/UES at the respective housing sites can be given. Interpretations on the impacts of settlement-growth according to varying housing densities and surrounding neighborhoods - see research question 2 – can be derived. Therefore, further statistical measures, such as cluster analysis, were avoided, as a further aggregation or classification of the results would have prohibited a clear and site-related interpretation.

The presentation of all indicator performances will be executed in comparison to local standard values represented by the individual urban mean values calculated for the City of Essen. The socio-environmental impacts of housing development will be discussed against the status quo performances of each site-buffer³⁵⁰. After a differentiated presentation of the results according to the three major needs and contributions of urban green and open spaces for QoL and UES³⁵¹ in parts 4.2.2.- 4.2.4.

³⁴⁸ In the following paragraphs the author will refer to scenarios 1,2 and 3 meaning:

Scenario 1: detached houses (for single family homes) & 2-storey houses housing

Scenario 2: semidetached houses/ 3-4-storey houses

Scenario 3: row houses/ >4 storey houses

³⁴⁹ A classification of all housing sites and their associated buffer name is given in tab.a1 in the annex.

³⁵⁰ To enhance the readability of this chapter, the threshold values of wider living surroundings as presented in chapter 3.3.2 indicated by a buffer of 1000m will not be taken into account.

³⁵¹ Recreation, regulation and social cohesion/local identity.

4.2.1. Recreation

Indicators: Climate Regulation & Biotope Quality

According to these indicators, a clear distinction between the status quo provision with recreational functions by urban green and open spaces at sites of either infill or greenfield development can be stated. Whilst most housing sites of infill development provide closer living surroundings with both a lower climate regulation and biotope quality than the urban average (fig.36), most sites of greenfield development exceed it.

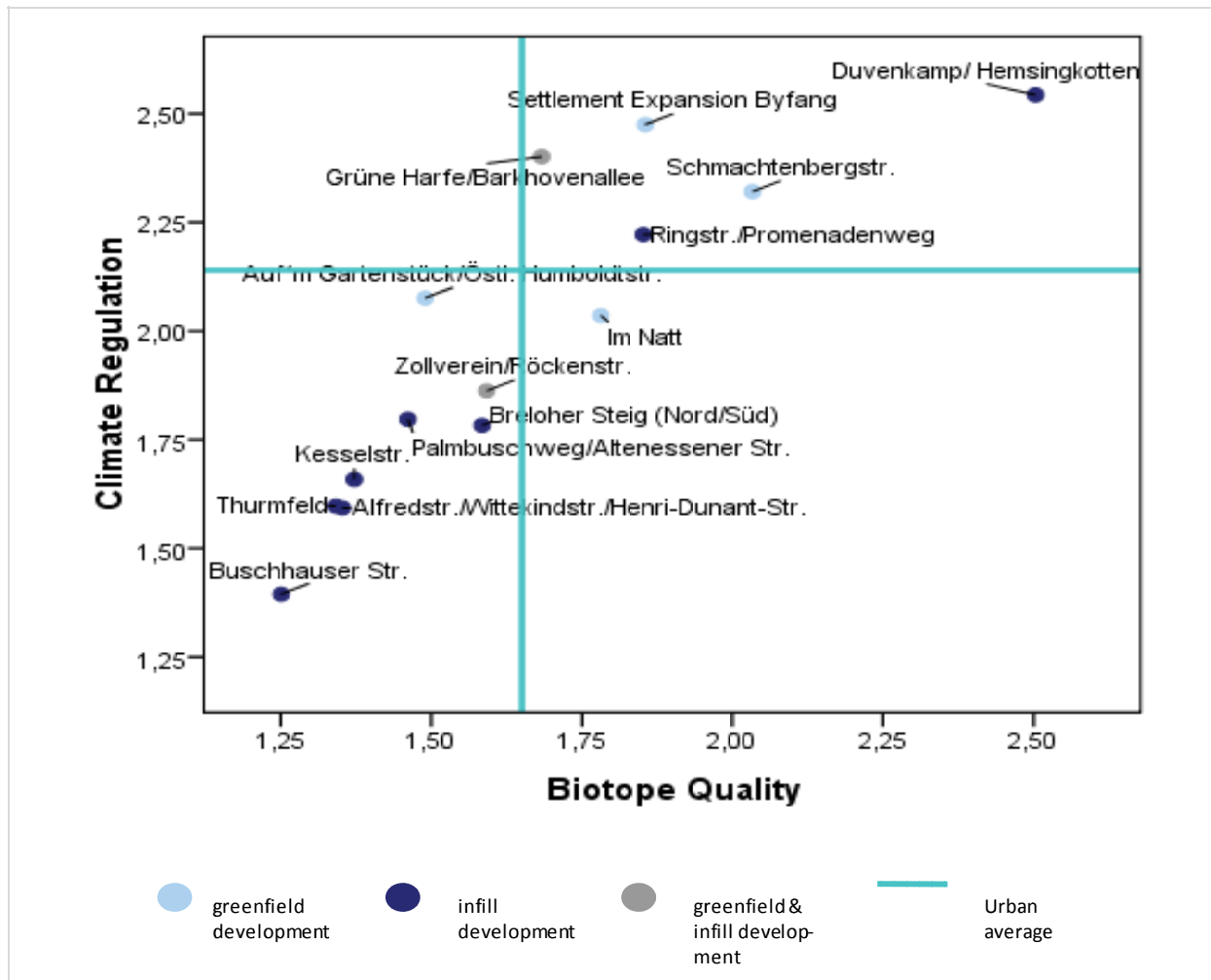


Figure 36 Indicator performances of climate regulation and biotope quality at housing sites and closer surroundings (500m-buffer) at status quo

Also the impacts of settlement-growth throughout three predefined housing scenarios cannot be differentiated unambiguously according to the respective development strategy: Only selected sites of infill development and the process of brownfield revitalization benefit from additional settlement-growth during the first two scenarios regarding climate regulation (fig. 37)³⁵². Sites of greenfield development show overall negative impacts throughout all scenarios. For the last and most dense

³⁵² Palmbuschweg/Altenessener Strasse; Breloher Steig (North/ South); Ringstr./Bachstr.; Buschhauser Strasse; Thurmfeld

scenario³⁵³, negative impacts at closer living surroundings due to housing development have to be stated at all sites.

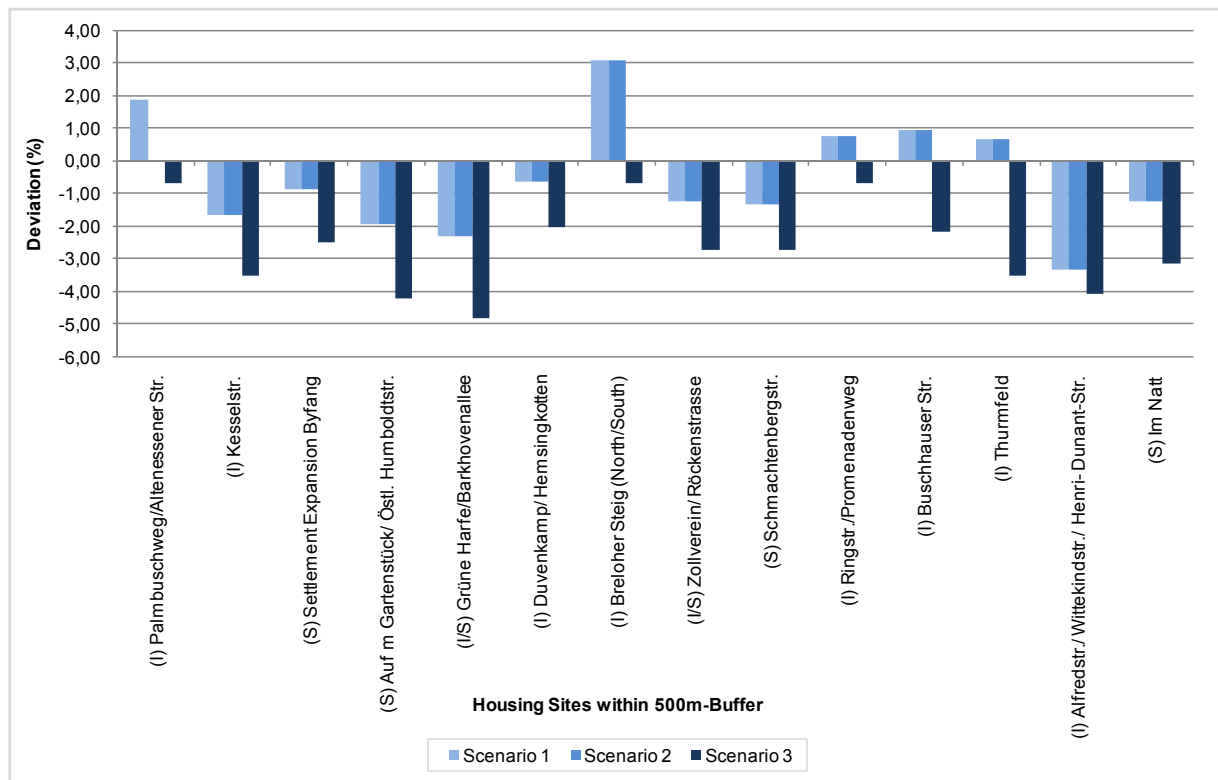


Figure 37 Percental deviation of climate regulation of closer living surroundings compared to status quo³⁵⁴

Having a look at the modification of the indicator *biotope quality* under conditions of housing development, a separation of selected benefits of the provision with UES at either sites of infill or greenfield development cannot be supported (fig. 38). The first two scenarios show both benefits and negative impacts, which are not related to either the one or the other development path. Evident negative impacts of housing development on closer living surroundings can be stated for the last housing scenario at all sites.

³⁵³ Row houses at sites of single family houses and > 4-storey houses at sites of multi-storey housing

³⁵⁴ Infill sites are indicated with „I“, greenfield-sites with „S“ (counts also for the next figures of percental deviation)

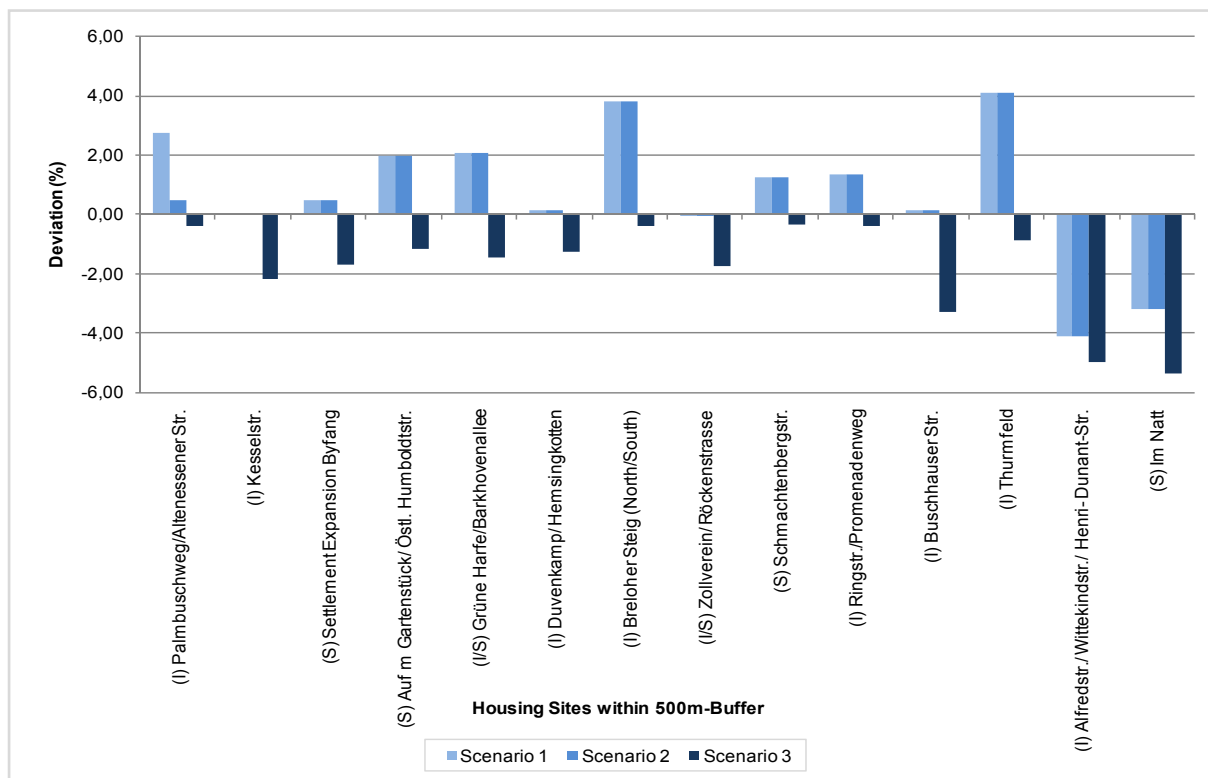


Figure 38 Percental deviation of biotope quality compared to status quo

4.2.2. Regulation

Indicators Sealing Rate, Surface runoff, seeping rate and evapotranspiration

Figure 39 below indicates that mostly sites of greenfield development show a status quo performance of the indicator **sealing rate** below the urban average, compared to most sites of infill development, which exceed the urban average. The indicator **surface runoff** indicates values above the urban average at sites of infill development and below at mainly sites of greenfield development.

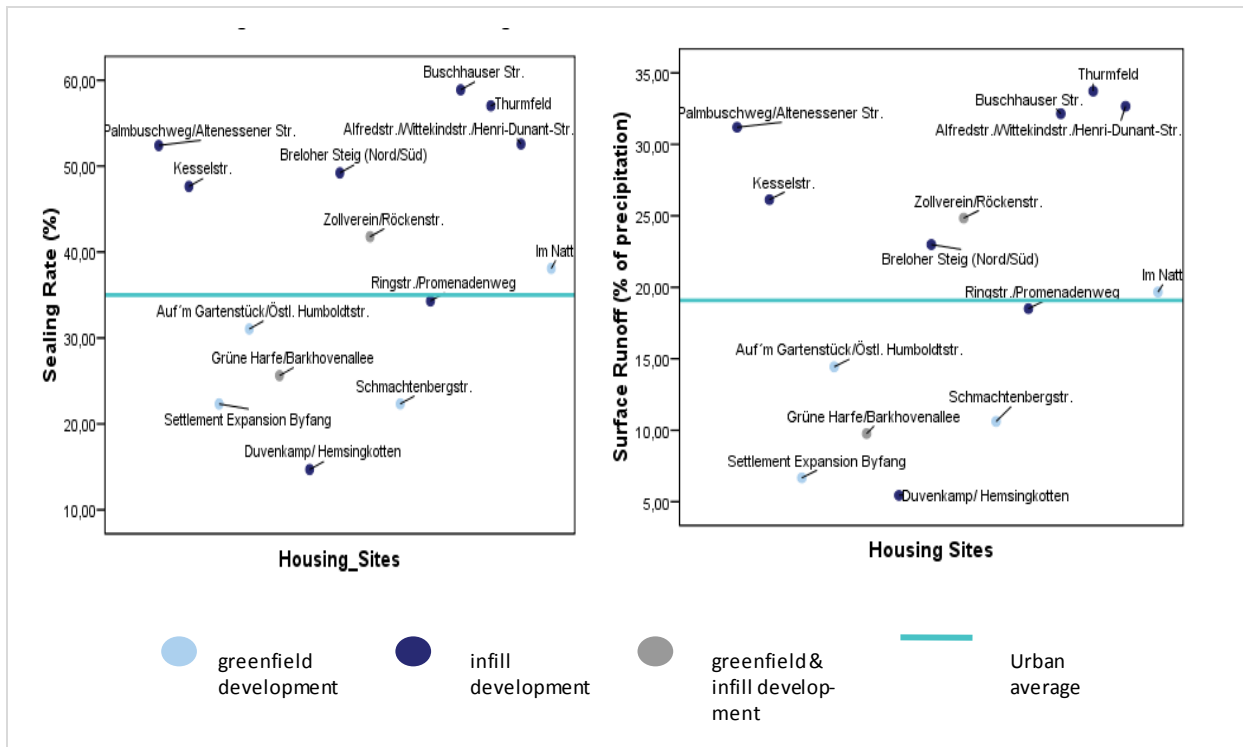


Figure 39 Performance of sealing rate and surface runoff at housing sites and closer surroundings (500m-buffer) at status quo

Regarding the benefits and negative impacts of settlement-growth throughout different housing scenarios, we see that in most cases surroundings of sites of greenfield development have to state an overall increase of the local **sealing rate**. Compared to that, selected sites of infill development, which are subject of brownfield revitalization, observe a decrease due to housing-development (fig. 40)³⁵⁵. Although, sites of infill development focusing on redensification (eg. Zollverein) or being embedded into a rather suburban surrounding (e.g. Duvenkamp), also show rising sealing rates. Similar results can be found for the local development of **surface runoff** due to housing-development (fig. 41)³⁵⁶..

³⁵⁵ Palmbuschweg/ Altenessener Strasse; Breloher Steig (North/South); Ringstr./ Bachstr.; Buschhauser Strasse; Thurmfeld

³⁵⁶ Palmbuschweg/ Altenessener Strasse; Breloher Steig (North/South); Ringstr./ Bachstr.; Thurmfeld

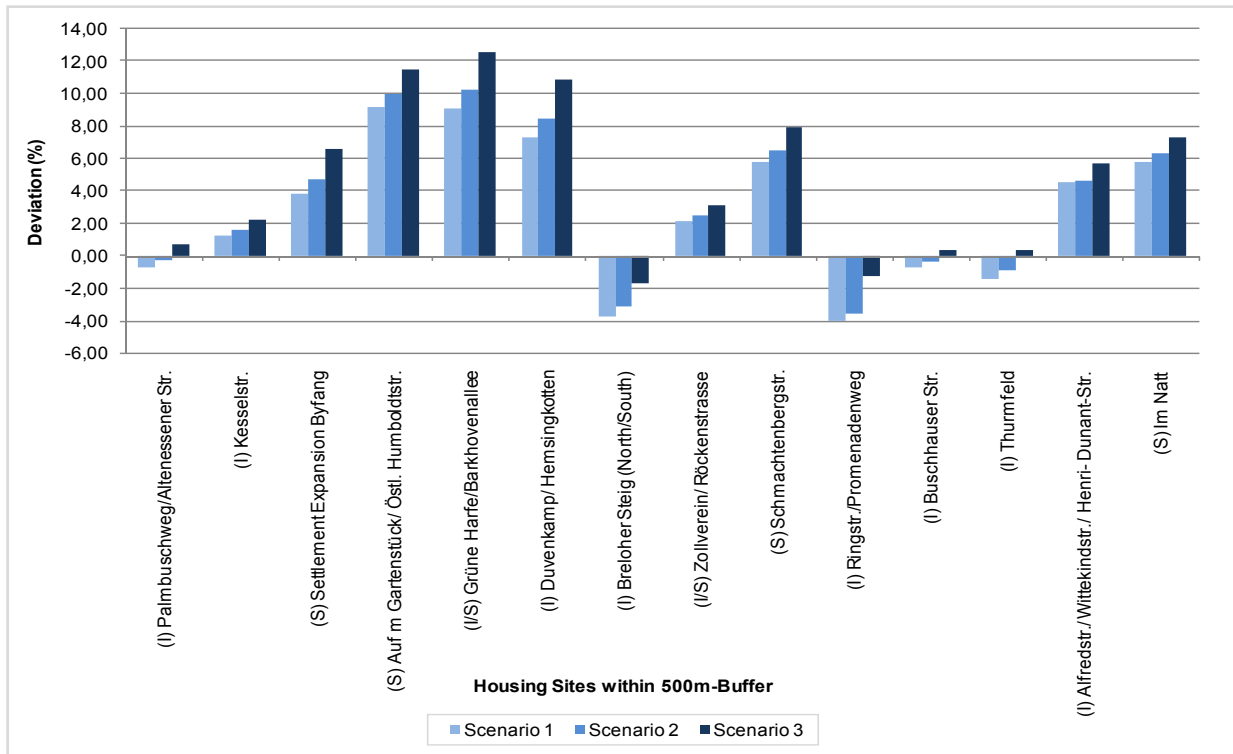


Figure 40 Percental deviation of sealing rate compared to status quo

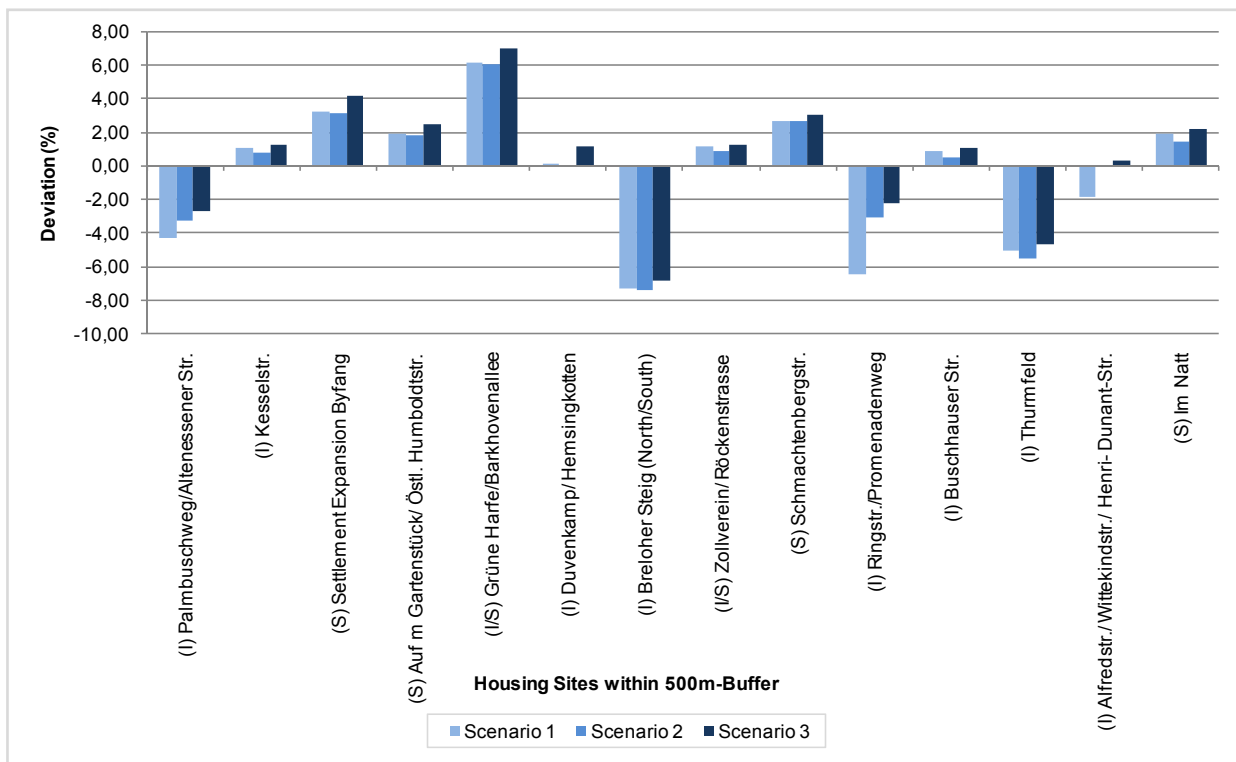


Figure 41 Percental deviation of surface runoff compared to status quo

Regarding the indicator *seeping rate* (fig. 42), a reduced status quo performance at sites of infill development compared to the urban average and an overall better performance at sites of greenfield development can be stated. But a closer look at the data-set shows that its values do not correspond very well with the other indicators throughout the scenarios (see tab. a6 in the annex).

The indicator *evapotranspiration* confirms the findings from the indicator *biotope quality* and indicates status quo values above the urban average for sites of greenfield development and the opposite for infill sites (fig. 42).

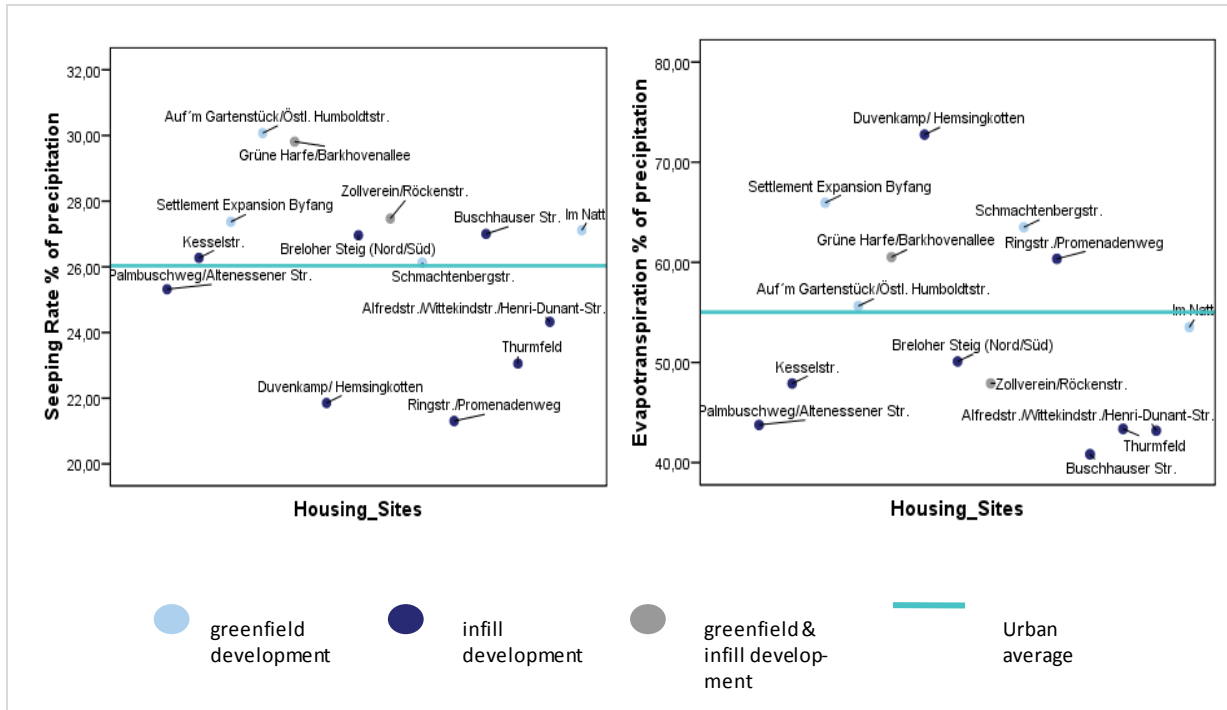


Figure 42 Performance of seeping rate and evapotranspiration at housing sites and closer surroundings (500m-buffer) at status quo

Having a look at the impacts of settlement-growth according to the predefined housing scenarios of varying densities, it becomes clear that positive effects of a rising *evapotranspiration* are found at sites of infill development sites in accordance with brownfield development³⁵⁷ (fig. 43). A decrease of the *evapotranspiration* is reported at greenfield sites and closer surroundings. The same can be stated for sites of infill development, which are embedded into a rather suburban structural context (eg. Duvenkamp/ Hemsingkotten) or of redensification (eg. Zollverein).

³⁵⁷ Palmbuschweg/ Altenessener Strasse; Ringstr./ Bachstr.; Buschhauser Strasse; Thurmfeld, Breloher Steig (North/ South)

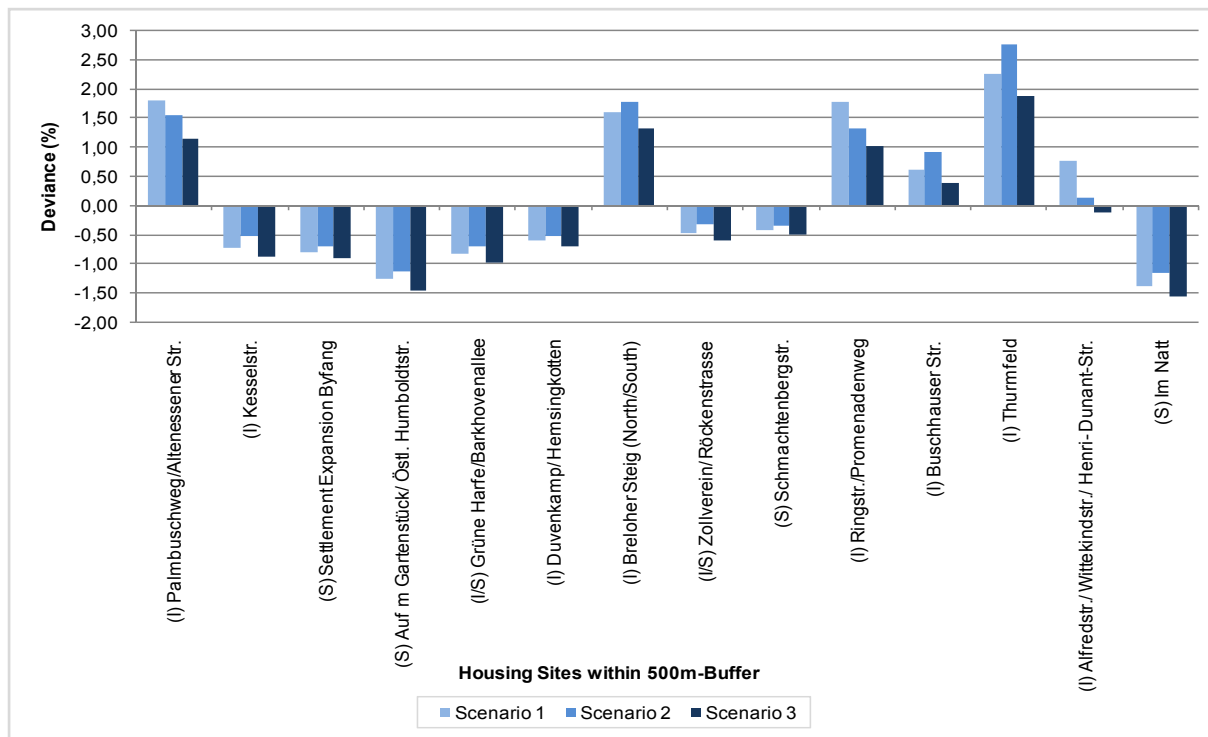


Figure 43 Percental deviation of evapotranspiration compared to status quo

4.2.3. Social Cohesion/Local Identity

The analysis of status quo conditions and the impacts of settlement-growth on indicators contributing to social cohesion and local identity show a quite diverse picture.

Indicators: Private Green/Resident, Public Green/ Resident

The status quo provision with private green per resident presents an urban average of more than 50m²³⁵⁸. Compared to that, the provision is lower at sites of infill development than at those of greenfield development. The status quo provision with public green per resident shows similar results (fig. 44). Note, that all numbers of green provision do not solely refer to unsealed green spaces, but also include partially sealed areas. Herewith, an urban mean value of more than 100m² per resident can be explained.

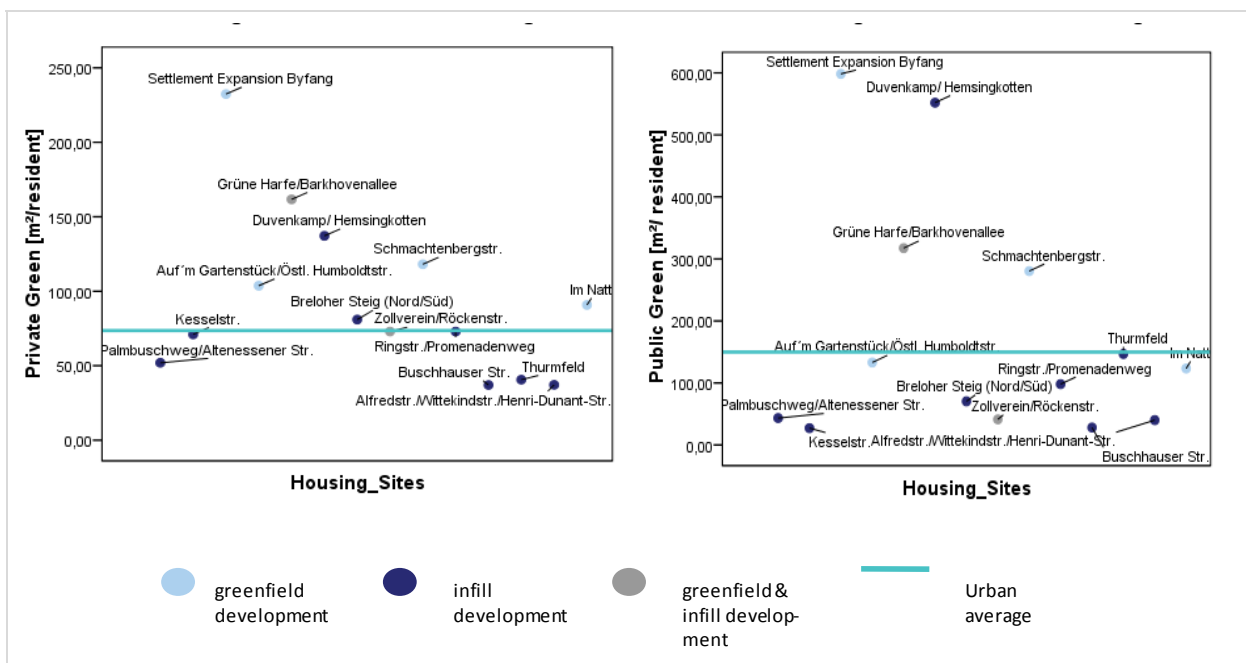


Figure 44 Performance of private and public green provision at housing sites and closer surroundings (500m-buffer) at status quo

Despite rising population numbers due to settlement development (see fig. 7r in the annex), the provision with private green spaces per resident at most sites of infill development shows positive impacts in scenarios 1 and 2 but negative impacts in scenario 3³⁵⁹. Similar findings can be stated at single sites of greenfield development³⁶⁰ (fig. 45). Due to an enhanced usability of formerly closed up green spaces of industrial premises and increase of private green provision per resident can be explained at sites of brownfield development. Still, the impact factor of rising population numbers has to be taken into account, which blurs a clear statement of positive impacts at sites of either infill or greenfield development.

³⁵⁸ Note that this only includes principal residents. The deviation of residents within each scenario from status quo conditions is given in fig. 7r in the annex.

³⁵⁹ Palmbuschweg/Altenessener Strasse; Kesselstrasse; Breloher Steig (North/South); Ringstr./Bachstr.; Buschhauser Strasse; Thurmfeld; Alfredstr./Henri-Dunant-Str./Wittekindstr.

³⁶⁰ Schmachtenbergstrasse; Im Natt

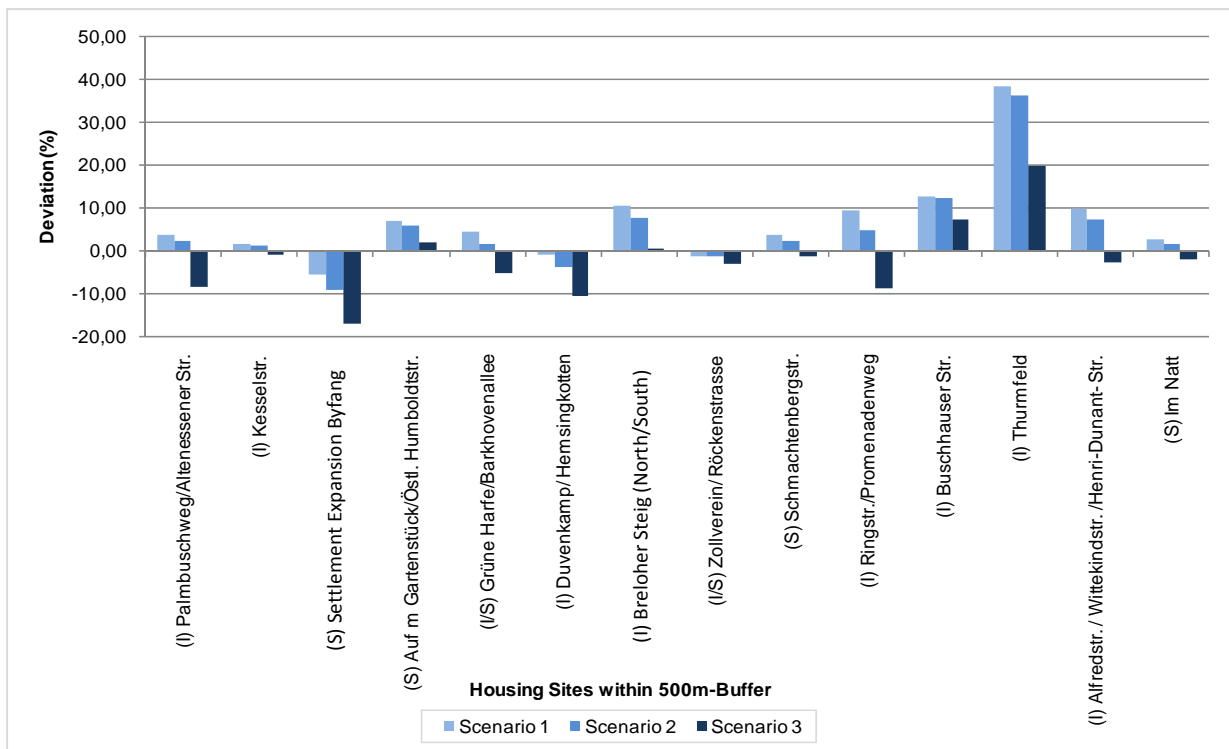


Figure 45 Percentual deviation of private green provision per resident compared to status quo

Regarding the impacts on public green provision the impacts of settlement growth show diverging results (fig. 46). Here, declining numbers of public green provision per residents have to be stated at all sites.



Figure 46 Percentual deviation of public green provision per resident compared to status quo

Indicators: Total Green/ Resident, Ratio Private/ Public Green per resident

In contrast to the aforementioned findings, the provision with total green per resident³⁶¹ shows a significant differentiation between sites of infill and greenfield development compared to the urban average (fig. 47). Due to a use of public green and inner urban brownfields combined with rising population numbers in the wake of housing development, the provision of public and total green per resident decreases at all sites regarding the three different housing scenarios (fig. 46, 48).

An integrated analysis of the share of private and public green provision is derived from the indicator ratio private/public green. Here, the urban mean value of around 0.5 indicates an amount of public green twice as much as the amount of private green. But a great share of the analyzed housing sites indicate a larger ratio and therefore more private than public green (fig. 47). Due to a transformation of public green and open spaces to private green in the wake of housing development, the ratio of private/public green provision also increases at all sites. This means, that the possibility to personally benefits from private space to escape from urban life³⁶² increase. Here, scenario 1 shows the overall highest positive impacts whilst scenario 2 and 3 show – in most cases- reduced benefits (fig. 49).

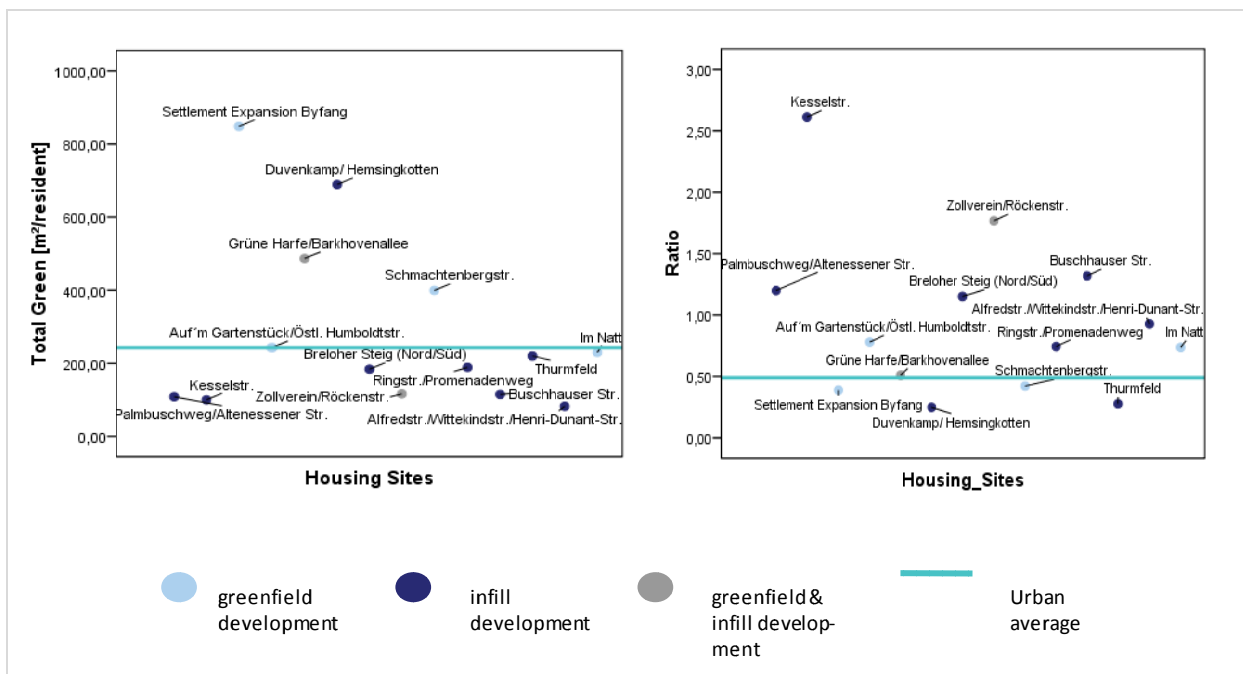


Figure 47 Performance of total green provision and ratio private/public green provision at housing sites and closer surroundings (500m-buffer) at status quo

³⁶¹ This also includes green and open spaces at industrial premises.

³⁶² see PRIEGO ET AL. 2008

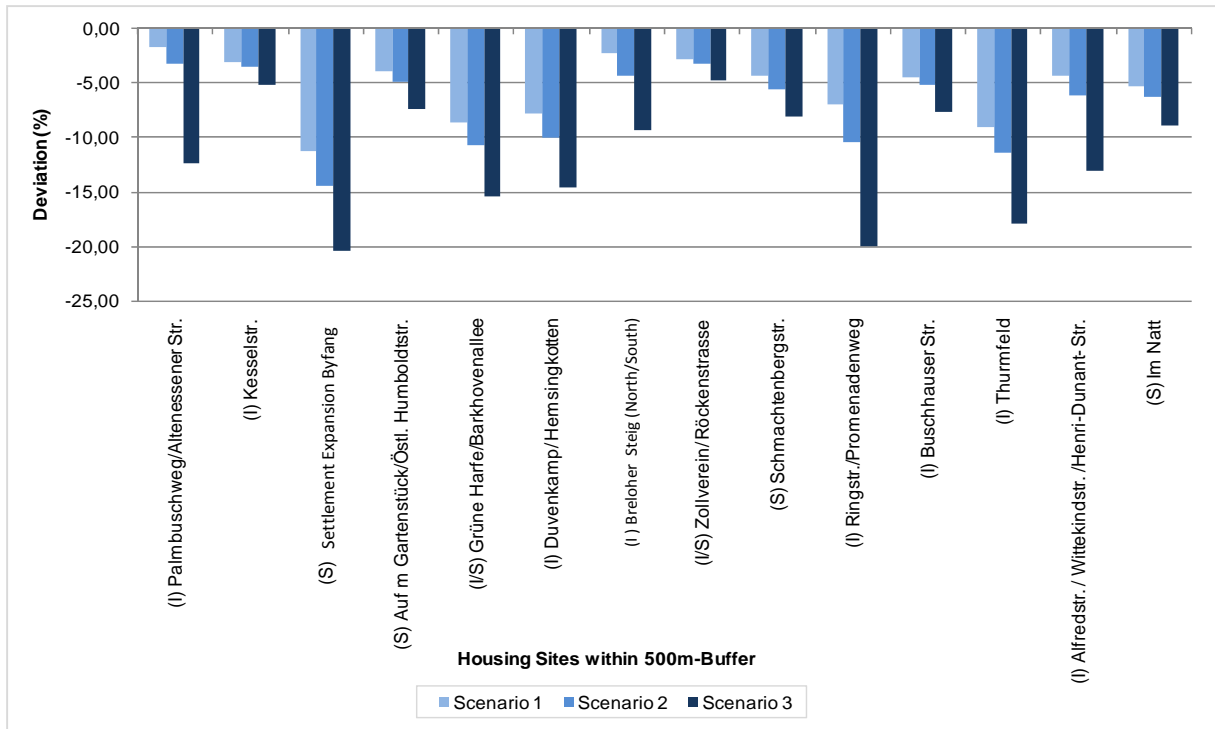


Figure 48 Percent deviation of total green provision per resident compared to status quo

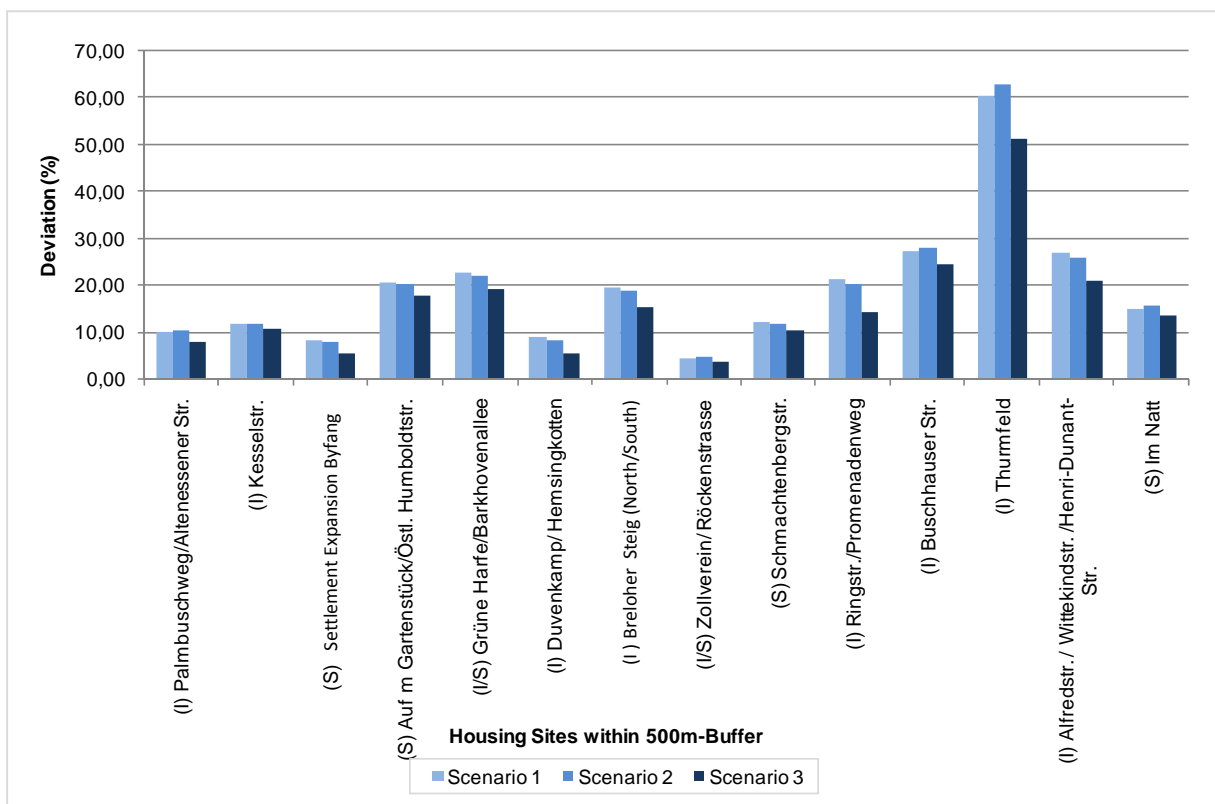


Figure 49 Percent deviation of ratio of private/public green provision per resident compared to status quo

Indicator: Provision with public parks

The provision with public parks does not allow a distinction between sites of different development strategies compared to the urban mean value (fig. 50) which is still above planning standards^{363,364}.

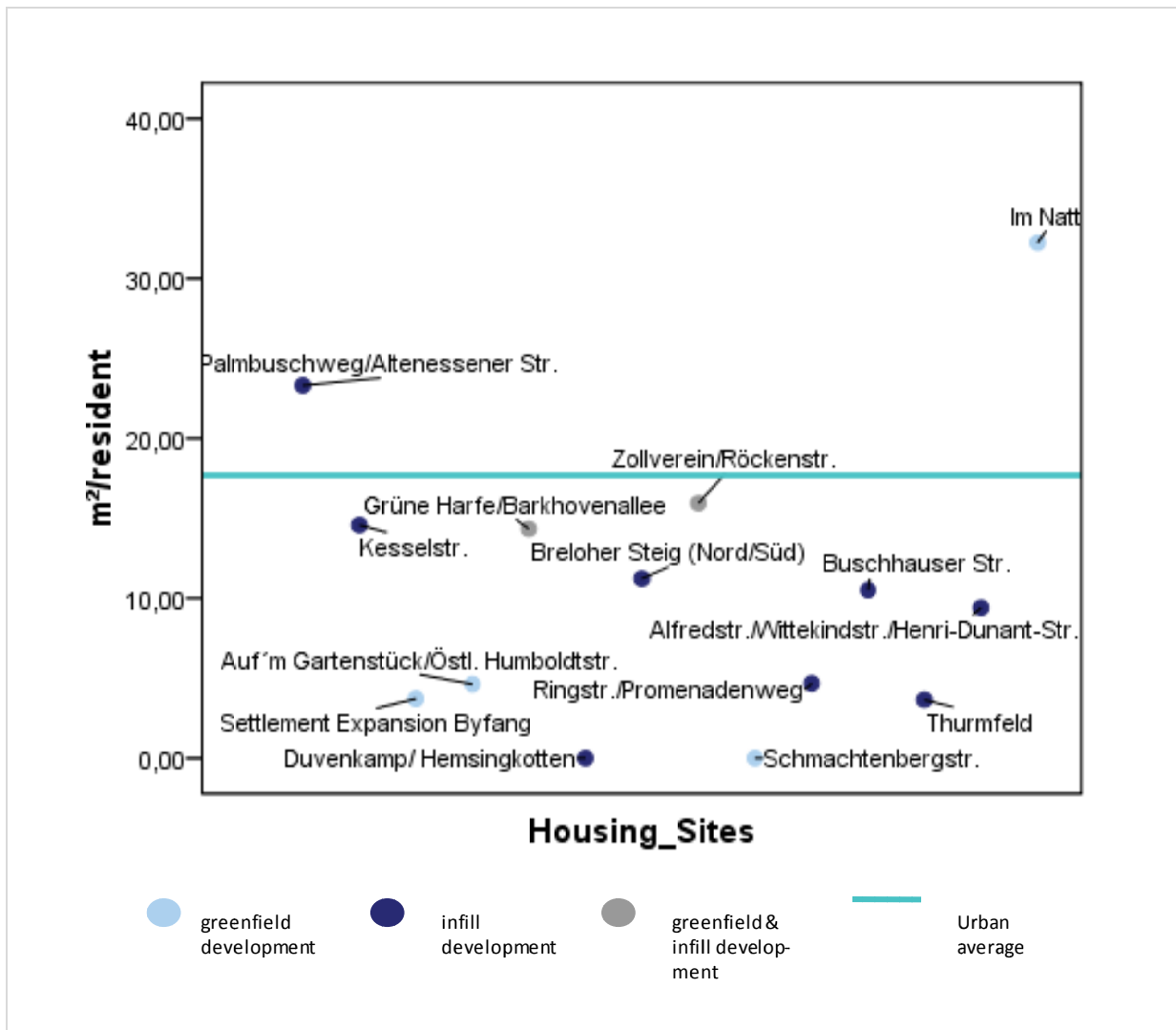


Figure 50 Performance of public park provision per resident at housing sites and closer surroundings (500m-buffer) at status quo

Due to increasing population number in the wake of housing development, the impacts of provision with public parks per resident show an overall decrease (see fig. 51). The total amount of public parks has not been altered during housing scenarios.

³⁶³ see GÄLZER 2001

³⁶⁴ The performance of greenfield sites is very heterogeneous in nature as selected sites do not even provide an access to public parks (eg. Schmachtenbergstrasse) and therefore blur significant results.

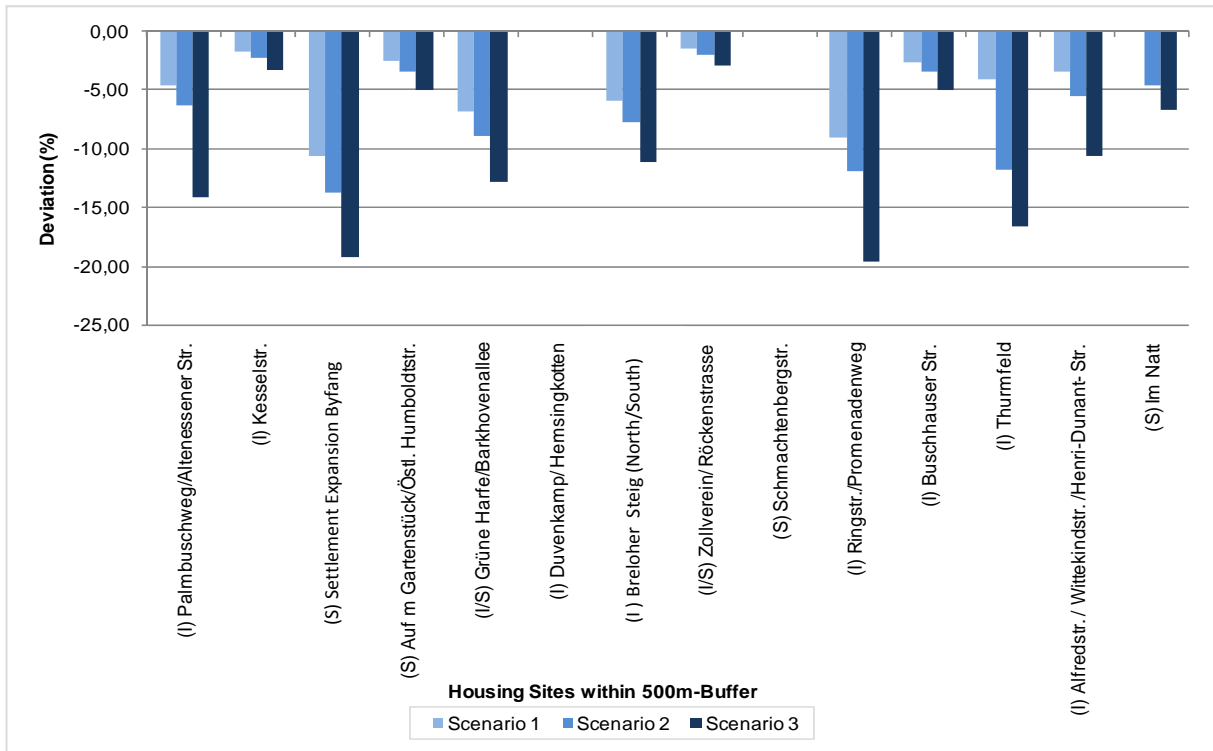


Figure 51 Percent deviation of public park provision per resident compared to status quo

4.3. Integrated Analysis of QoP & QoL/UES

The following paragraphs present a synthesis of step 1, *QoP-assessment*, and step 2, *impact assessment on QoL/UES*, of the MCA. Despite the fact that both concepts – QoP and QoL/UES – comprise of *different indicators* and follow *different purposes*, this step becomes necessary for an on-site-analysis of both socio-environmental prerequisites of future housing sites (QoP) and direct socio-environmental impacts (QoL/UES). This synthesis will result in a *typology* of future housing sites exemplified with regard to the case-study Essen. The typology will be presented in chapter 5.3.

In contrast to step 1 (QoP), the results of step 2 (QoL/UES) were not presented in an aggregated manner and followed a different methodology. Due to the fact, that impacts of QoL and its manifold dimensions are very heterogeneous in nature and not to be generalized, an aggregation would have led to invaluable results and an immense loss of differentiated results of socio-environmental impacts on QoL/UES. Therefore, the next outlines of an integrated assessment of both steps of the MCA follows content-related reasons. They will be presented with an ongoing focus on the three needs and determinants of QoL.

As explained in chapter 3, the analysis of socio-environmental QoP does not follow different housing-scenarios but focuses on the socio-environmental quality of a place according to planning-relevant indicators in a first step of the assessment. The second step is dedicated to a socio-environmental impact assessment during varying scenarios of settlement growth according to the concepts of QoL and UES and uses a different indicator set.

The following results of an integrated analysis of step 1 and 2 shall answer the question whether the impacts on both QoL/UES show any congruency to the suitability assessment (QoP) of the same sites according to planning-relevant indicators or if a high QoP corresponds with also possible positive impacts on residents' QoL.

As reference values the value of 1.49 indicating the limit of unlimited QoP (x-axis) and a baseline (y-axis) indicating the reference of status quo conditions of QoL/UES-indicators are used. The following graphs firstly highlight scenario 1 (detached houses) of the QoL/QoP-assessment. The outcomes of QoP-analysis are set against the three major needs urban green fulfills: *recreation, regulation* and *social/cohesion & local identity*.

4.3.1. QoP and Recreation

According to the following two graphs a significant relation between the socio-environmental QoP-value of each analyzed housing site and impacts on both indicators representing the recreational function (see fig. 52) due to housing development cannot be reported. Whilst most of sites of greenfield development are registering negative impacts during scenario 1 and are assessed with a medium QoP ($>1.49 \leq 2.49$), sites of infill development show absolute heterogeneous values of QoP and are unevenly benefitting from housing development. Only two sites of infill development report both a rising climate regulation and a good QoP³⁶⁵. The indicator *biotope quality* shows also a very limited dependence between QoP-assessment and the impacts due to settlement-growth. But also

³⁶⁵ Palmbuschweg/ Altenessener Strasse & Breloher Steig (North/South)

here, greenfield sites are assessed with a medium QoP ($> 1.49 \leq 2.49$) but selectively show positive impacts on biotope quality already during scenario 1³⁶⁶.

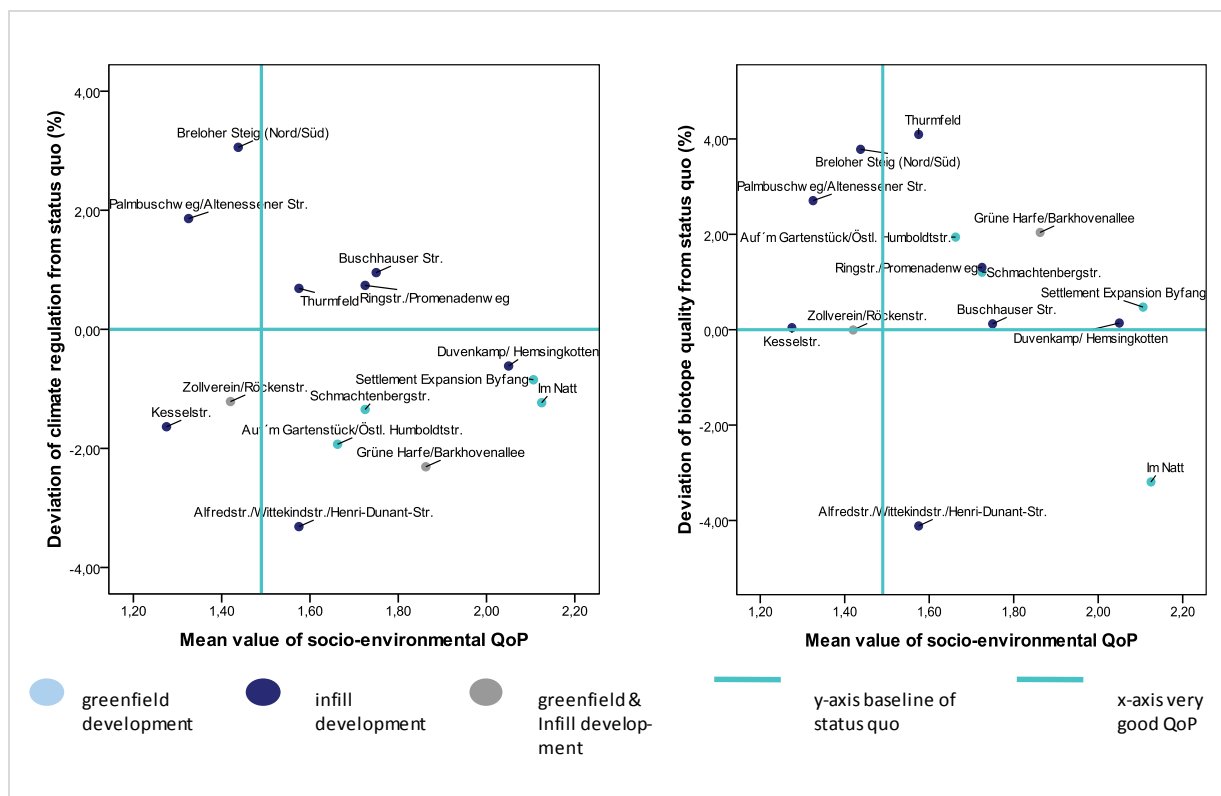


Figure 52 Integrated QoP/ QoL assessment: Percental deviation of recreation (climate regulation & biotope quality) within scenario 1 from status quo scenario and associated expert-weighted socio-environmental QoP of housing sites

4.3.2. QoP and Regulation

Set against the integrated assessment of QoP (socio-environmental) the following four hydrological indicators, which represent the regulative function (see fig. 53, 54) as a liking element between QoL and UES, show the following picture:

According to the aforementioned analysis, also a selected number of sites being subject of infill development³⁶⁷ are assessed with a high QoP (≤ 1.49) and unlimited suitability for housing purposes and show overall positive regulative impacts at all of the four indicators. In addition to that, two more sites of infill development³⁶⁸ are assessed with a high QoP but report slight negative regulative impacts of settlement-growth.

Contrary to that, a clear result can be derived for sites of greenfield development: Most of them are assessed with only a medium QoP and limited suitability. They also report overall negative regulative impacts due to settlement-growth within the first scenario.

³⁶⁶ Despite the site „Im Natt“.

³⁶⁷ Palmbuschweg/ Altenessener Strasse & Breloher Steig (North/South)

³⁶⁸ Kesselstrasse and Zollverein/Röckenstrasse. The buffer surroundings of the sites of Zollverein/Röckenstrasse and Kesselstrasse are strictly speaking regarded as infill/greenfield and infill-development, respectively. The site Röckenstrasse is subject to greenfield development whilst the sites of Zollverein and Kesselstrasse are subject of infill development

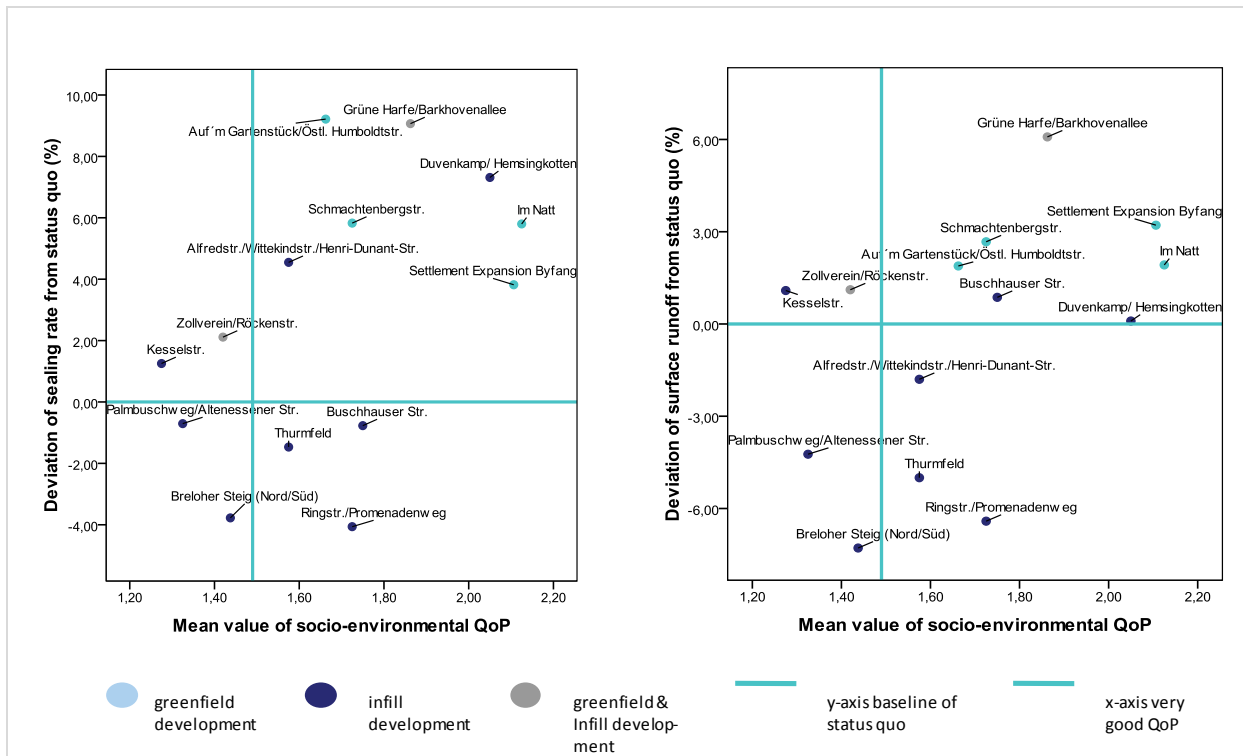


Figure 53 Integrated QoP/ QoL assessment: Percental deviation of regulation (sealing rate & surface runoff) within scenario 1 from status quo scenario and associated expert-weighted socio-environmental QoP of housing sites

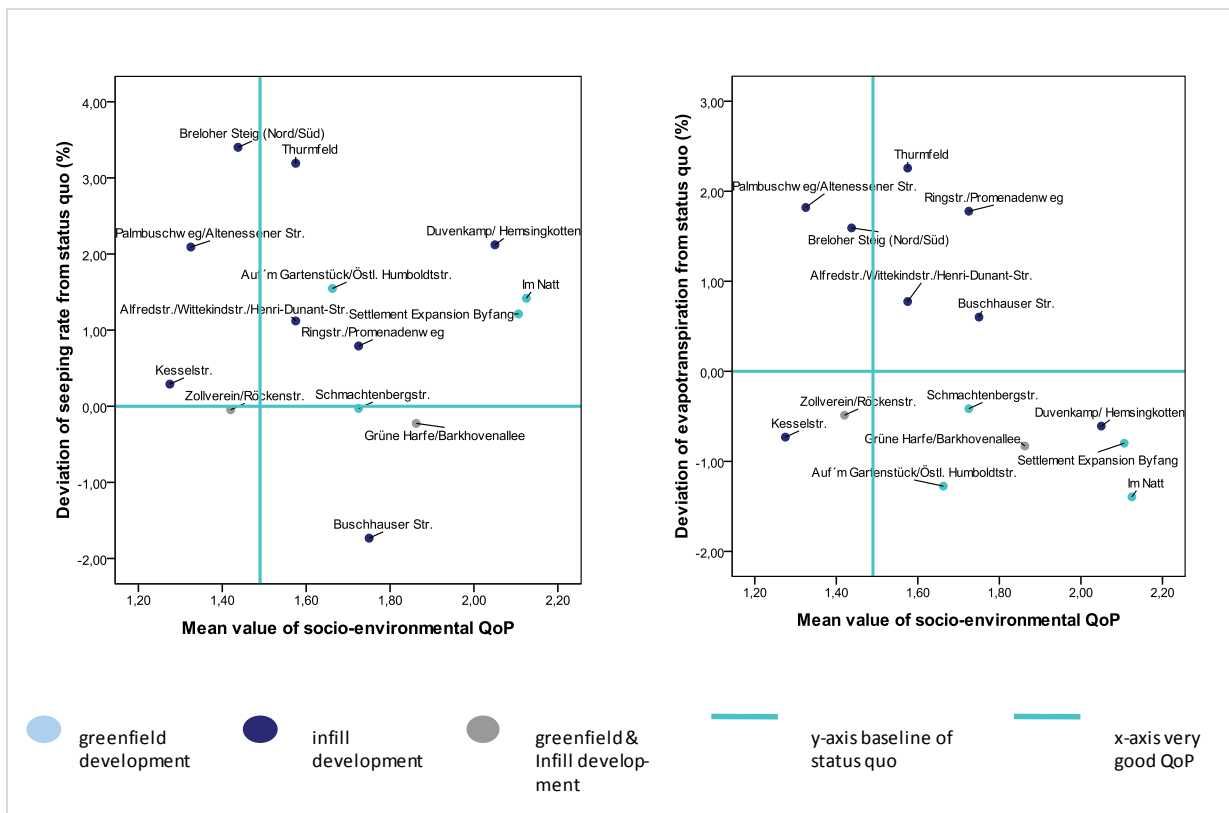


Figure 54 Integrated QoP/ QoL assessment: Percental deviation of regulation (seepage & evapotranspiration) within scenario 1 from status quo scenario and associated expert-weighted socio-environmental QoP of housing sites

4.3.3. QoP and Social Cohesion/ Local Identity

The combination of QoP-assessment and the following five indicators of social cohesion/ local identity (see fig. 55, 56, 57) linking the concepts of QoL and UES show a very heterogeneous picture:

Three sites³⁶⁹ of infill development are assessed as unlimited suitable for housing purposes and provide a high QoP (≤ 1.49). Regarding the indicator private green provision, these three sites positively benefit from housing development whilst on site (Zollverein/ Röckenstrasse) reports negative impacts on its closer surroundings. This is due to the fact that formerly allotment gardens will be used for housing purposes within the process of re-densification.

The ratio of private/public green provision per resident increases at all four sites and intensifies the possibility for private refuge compared to social interaction. Here, negative impacts have to be stated at all sites – both sites of infill and greenfield development- regarding the provision with public green and public parks. Still, negative impacts on public green provision are less severe than at other sites.

Despite the four exposed housing sites, majorly positive impacts of housing development regarding private green provision per resident can be stated regardless infill or greenfield development although a medium QoP has been assessed. The loss of public green per resident is stronger than at sites with unlimited suitability and high QoP (≤ 1.49). An improvement of private/public green per resident and therefore intensified opportunities for private recreation and refuge could be stated at all sites. The same counts for public park provision per resident.

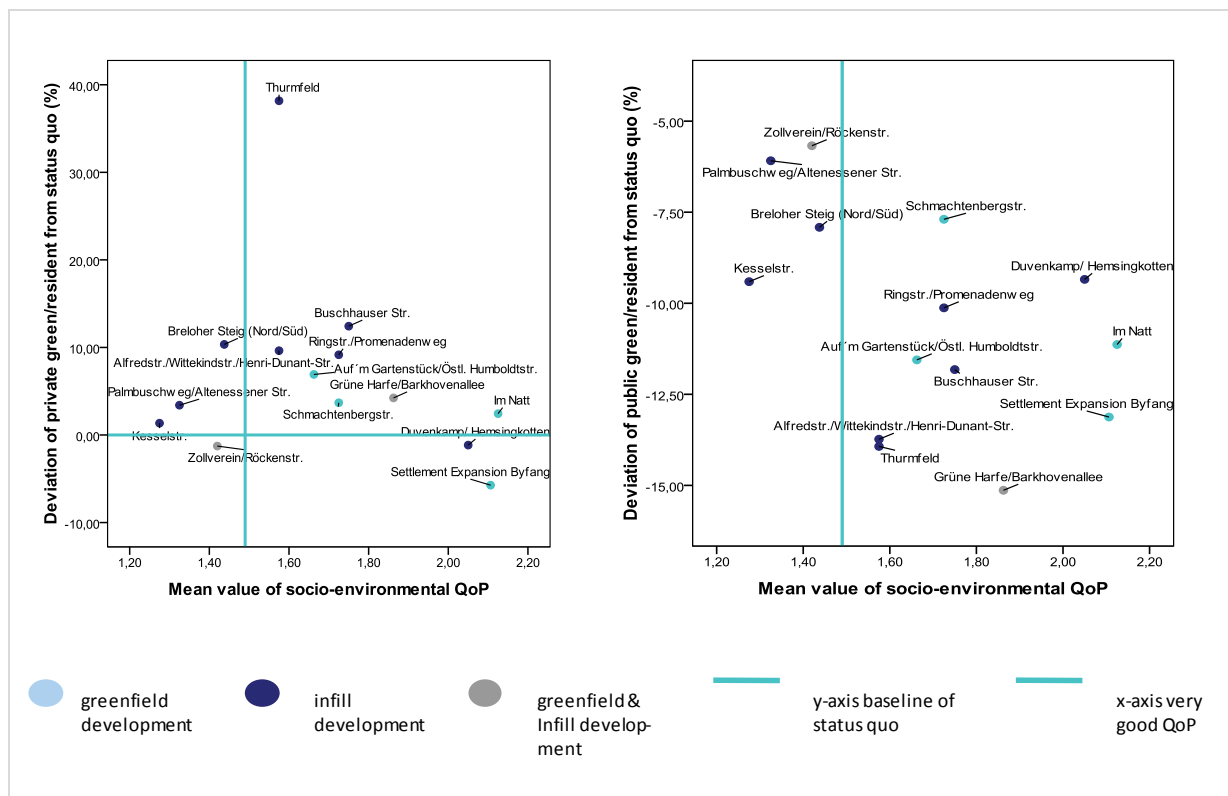


Figure 55 Integrated QoP/ QoL assessment: Percental deviation of social cohesion/local identity (private and public green per resident) within scenario 1 from status quo scenario and associated expert-weighted socio-environmental QoP of housing sites

³⁶⁹ Palmbuschweg/Altenessener Strasse (infill), Kesselstrasse (infill), Breloher Steig (North/South; infill)

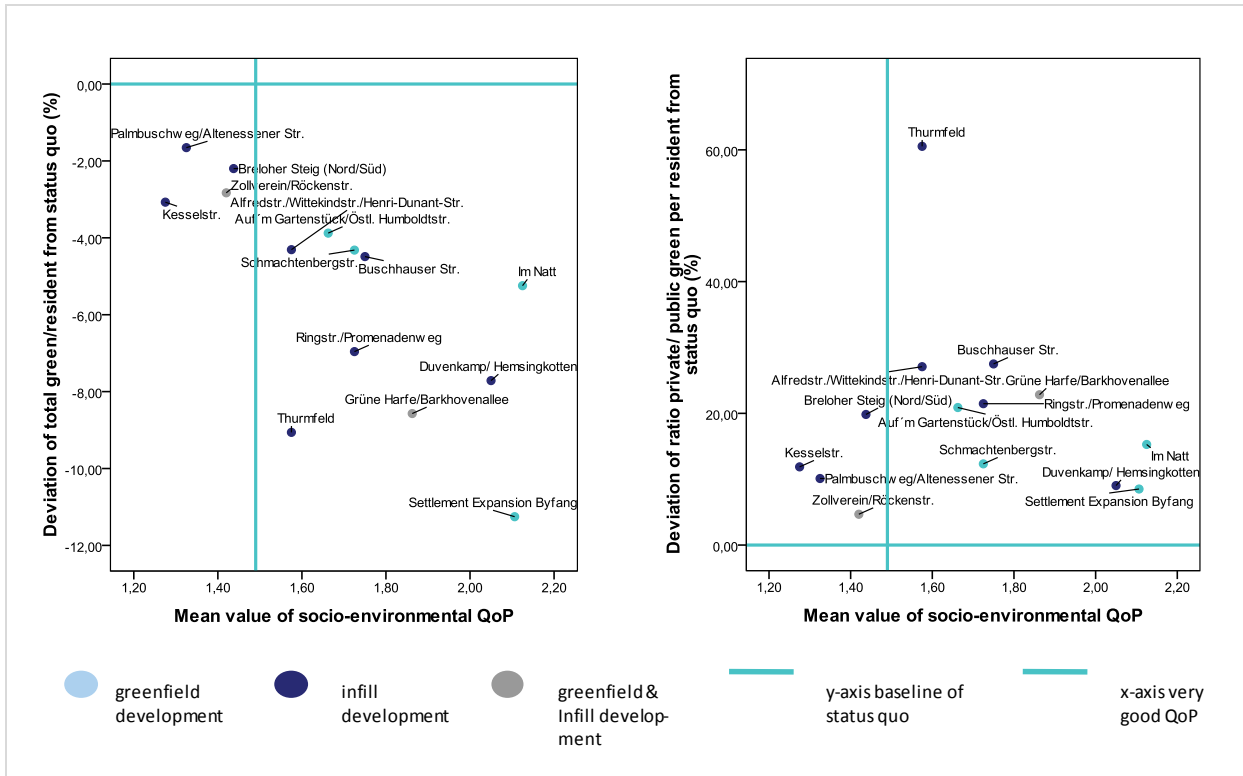


Figure 56 Integrated QoP/ QoL assessment: Percental deviation of social cohesion/local identity (total green and ratio private/ public green per resident) within scenario 1 from status quo scenario and associated expert-weighted socio-environmental QoP of housing sites

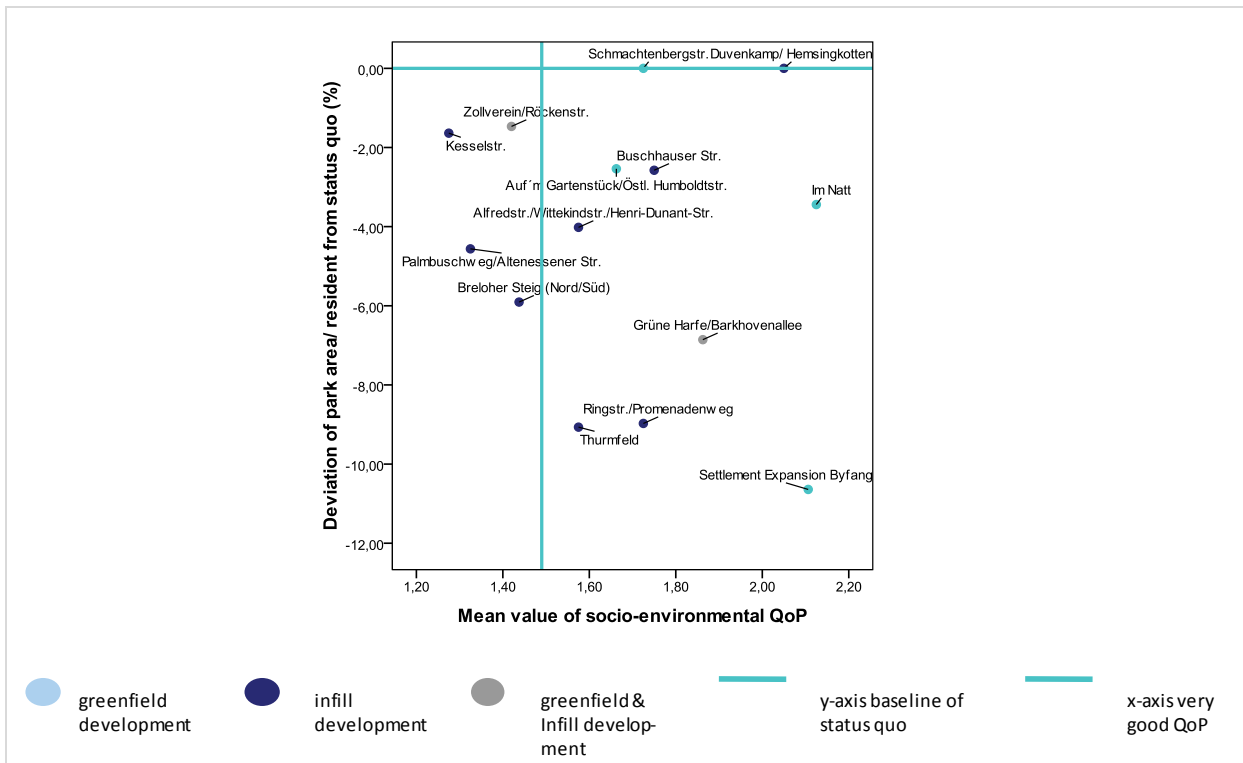


Figure 57 Integrated QoP/ QoL assessment: Percental deviation of social cohesion/local identity (provision with public parks per resident) within scenario 1 from status quo scenario and associated expert-weighted socio-environmental QoP of housing sites

A general overview of the interrelations of QoP and QoL/UES-analysis showed significant results for sites of greenfield development. We have learnt that these sites not only provide the least favorable socio-environmental QoP. But they also generally report negative impacts on QoL/UES according to the recreational and regulative functions of urban green (fig. 52, 53) and partially positive impacts on the function of social cohesion/local identity (fig. 55, 56, 57) throughout all scenarios.

Compared to that, the analysis of infill sites shows a heterogeneous picture as already assumed within QoL/UES-analysis. Two sites – Breloher Steig and Palmbuschweg/Altenessener Straße – show overall positive results including a very good QoP³⁷⁰ together with positive impacts on QoL/UES according to all three functions of urban green and open spaces.³⁷¹ The rest of the sites of infill development show both very heterogeneous values of QoP in accordance with ambiguous impacts on the recreational function (fig. 52), positive impacts on the regulative function (fig. 53, 54) and again equivocal impacts on the function of social cohesion/local identity (fig. 55-57) of urban green and open spaces and their effects on QoL and the provision with UES.

³⁷⁰ As QoP-analysis does not refer to buffer extensions, mean values have been calculated according to the sites represented within the respective buffers of QoL/UES-analysis.

³⁷¹ This refers exemplarily to scenario 1.

4.4. Critique of Methods

To get a closer insight into possible sources of uncertainty and the validity of both QoP- and QoL/UES-indicators a qualitative critique of methods will be executed.

All indicators have been elaborated according to empirical evidence as discussed in current scientific literature. Whilst the indicators of QoP are deriving from planning literature and workshops with planners executed during the research project FIN.30, the indicators of QoL/UES were elaborated according to the UES they should represent. These UES have been widely discussed within scientific literature. The respective sources were outlined in chapter 3. Moreover, a second integral part of indicator-development was dedicated to the depiction with existing communal analogous and digital data sets.

For the QoL/UES-indicators a third driving factor needs consideration: all indicators needed to be quantifiable and entirely based on digital cadastral data in order to provide a scenario steered impact assessment according to scenarios of varying housing densities.

4.4.1. QoP-Assessment

Beside the individual qualitative uncertainty analysis explained within table 6, general sources of uncertainty are inexact spatial extensions of potential housing sites deriving from the draft (status 2008) of the regional land use plan (1:50.000). In consequence a lot-sharp demarcation is not possible.

Table 6 Critique of methods for QoP-indicators due to applied data

Ecological	Indicator	Uncertainty
	Regulation	Attribution of cadastral land use data according to look-up tables of Singer (1995), no on-site data-acquisition Raster-based approach does not differentiate between land use patterns
	Biotope Quality	See above
	Seepage	Scale of 1:50.000 hinders spatially exact assessment and implies a strong spatial aggregation of individual soil types and their associated characteristics A limited actuality expected (state of analogous data 1984, of digital equivalent 2006) Recent modifications and sealing measures of the surface cannot be taken into account
	Isolation/ use of connected habitats	
	Sealing Rate	Attribution of cadastral land use data according to look-up tables of Singer (1995), no on-site data-acquisition Raster-based approach does not differentiate between land use patterns
	Protected Areas	Possible disturbances due to building measures cannot be quantified
	Soil Quality/ Yield stability	See indicator „seepage“
	Flood risk	
Social	Indicator	Uncertainty
	Distance to playgrounds	Despite of implementation of walking distance coefficient of 1,2 obstacles (such as waterbodies, fences, walls, main roads) cannot be taken into account for automatically assessment
	Distance to local suppliers	See above
	Distance to primary Schools	See above No digital original data > manual spatial adjustment using cadastral data and analogous data
	Distance to kindergartens	See above No digital original data > manual spatial adjustment using cadastral data and analogous data
	Distance to public transport	See above No digital original data > manual spatial adjustment of route maps provided in pdf-files
	Noise exposure	See above Uncertainty of spatial adjustment of data due to scale of 1:100.000 Selective survey of emitters street, rail and industry behalf aircraft noise Check www.lanuv.nrw.de/geraeusche/pdf/bericht.pdf for further information
	Distance to recreational areas	Despite of implementation of walking distance coefficient of 1,2 obstacles (such as water bodies, fences, walls, main roads) cannot be taken into account for automatic assessment
	Suspected contamination	No exact definition of actual severeness of contamination

4.4.2. QoL/UES-Impact Assessment

First essential sources of uncertainty are inexact spatial extensions of potential housing-sites, which are displayed in the draft (status 2008) of the current regional land use plan (1:50.000). In consequence, a lot-sharp demarcation was not possible. The following general elements of uncertainty mainly refer to the conceptualization of scenario-analysis itself.

Housing scenarios: According to the differentiation between single family homes and multistory housing as provided by the City of Essen and published within the INWIS-analysis (SCHAUERTE ET AL. 2007), according housing types have been derived from planning literature. As housing sites are seldom built according to only one housing structure, the presented housing densities of the scenarios are standardized and present a merely monotonous design.

Data attribution: The attribution of cadastral data was executed in order to get insight into ecological performances of the respective cadastral land use classes in order to provide a quantitative and scenario-based impact assessment. The attribution was executed according to standards derived from current scientific literature³⁷² and according to calculated local standards. On-site field studies were not executed. As no hydrological standards/targets for cadastral data exist alternative data sources such as the coarser land use mapping of the Regional Association Ruhr RVR (©Regionalverband Ruhr, Essen, Flächennutzungskartierung Stand 2005) were applied and broken down to block level again. Here uncertainties are inevitable.

Calculation of current population: to get an insight into the current residential population within the buffer areas of 500m radius indicating closer living surroundings, the current building areas were set in accordance to the residential population³⁷³. This procedure does not distinguish between different housing structures leading to only average factors of residents/ housing area.

³⁷² e.g. SINGER 1995

³⁷³ See equations in tab. a4 in the annex.

5. Discussion

Coming back to the central hypothesis of this study³⁷⁴, this chapter aims *first* at discussing socio-environmental prerequisites, which determine QoP and suitability a site for further development. This assessment was executed using planner-oriented indicators and tested together with local stakeholders within a participative approach. The indicators are entirely based on digital communal data sets and applicable within the planning process. *Second*, socio-environmental consequences and impacts of settlement-growth will be discussed against the concepts of QoL and UES within pre-defined housing scenarios. This level of assessment differs from the first of QoP and takes a step forward. It assesses concrete impacts of additional housing development at local level of varying densities on the provision with UES as important contributors to residents' QoL³⁷⁵. Due to the fact, that infill development, as an important mean to reduced land consumption, is under serious discussion of negative socio-environmental impacts, special attention was drawn to its concrete impacts at future housing sites *together with* their closer living surroundings.

The assessment of housing sites displayed in a land use plan ("Flächennutzungsplan"), which is the tool of preparatory land use planning in Germany ("Vorbereitende Bauleitplanung"), enables an ex-ante analysis of both prerequisites, which determine a strategic steering of development, and of concrete impacts of two different development strategies: infill and greenfield development. In doing so, political ambitions to reduce land consumption³⁷⁶ could be assessed exemplarily at local level. This knowledge provides planners with more transparency and enables them to steer settlement development according to the principles of sustainability. A reduction of the use of natural resources and promotion of the use of existing infrastructural resources can lead to compact urban structures, in reverse. Practical insights into concrete socio-ecological characteristics of each site and its contribution to a sustainable settlement development were given and valuable contributions towards a strategic land management derived. Following that, ecological and social concerns as expressed by scientist³⁷⁷ were investigated and doubts about the success or failure of infill development put into perspective analyzing its impacts on the concepts of QoL and UES.

According to the central hypothesis of this work³⁷⁸, a synthesis of the two levels of the MCA – QoP-analysis and scenario-steered QoL-impact-assessment- was drawn. It answers the questions, whether the assessment of planner-oriented socio-environmental prerequisites, which determine the QoP of

³⁷⁴ "The success of a strategy of fostered infill development cannot be generalized. Both the suitability of a site for housing purposes and its socio-environmental impacts at local level – due to either infill or greenfield development – are significantly determined by individual prerequisites and framework-conditions."

³⁷⁵ SCHETKE ET AL.*; SCHETKE ET AL.**; SCHETKE ET AL. 2009b; BOLUND & HUNHAMMAR 1999

³⁷⁶ See publications of the German Government and the associated research initiative REFINA of the German Ministry for Education and Research at www.difu.de; <http://www.refina-info.de>, <http://www.fona.de/de/7039> (Federal Environment Agency); www.bbr.bund.de and also associated authors (a.o.) discussing the 30-ha –goal from various perspectives: HESSE & KALTENBRUNNER 2005; HAASE & NUISSL 2007; NUISSL ET AL. 2009; DOSCH 2001b; SIEDENTOP 2001, 2002 & 2004; BRANDTL ET AL. 2009; KÖTTER ET AL. 2009a; JERING ET AL. 2003; BACHMANN 2005; SIEGEL 2005.

³⁷⁷ TYRVÄINEN ET AL. 2007; SIEDENTOP 2005, PAULEIT ET AL. 2005; COUCH & KARECHA 2006; JENKS & BURGESS 2000; BANZHAF & HÖFER 2008; KÜHN 1998; WHITFORD 2001; WILLIAMS 2004a; MAAS ET AL. 2006; HOWLEY 2009

³⁷⁸ See footnote above.

a housing-site, can be related to its impacts on QoL and UES, which are caused by housing development. The general success or failure of a fostered infill development needs to be questioned. A typology of housing-sites derived from both steps of the assessment will provide with a condensed insight and will present future recommendations for housing-development.

5.1. QoP: Research question 1

According to research question 1³⁷⁹, the following paragraphs present the assessment of socio-environmental prerequisites existing in inner-urban and suburban areas, which determine the suitability of a housing-site (“QoP”) regarding the demand for sustainable and resource-preserving settlement development. A special focus on the participative operationalization of QoP was drawn in chapter 3, which resulted in an indicator framework communicable and applicable for both planners and scientists.³⁸⁰

First insights into a systematization and separation of sites of infill and greenfield development according to their socio-environmental prerequisites could already be derived from chapter 4. But having a closer look on the expert-weighted aggregated QoP-value on the one side and individual site-specific indicator-performances on the other, we also saw that a clear differentiation of the socio-environmental QoP of infill and greenfield sites need further discussion and consideration.

In most cases sites of infill development showed suitable *ecological preconditions*, which favour a housing development, because they contribute to a resource-preserving and sustainable development (fig.32). According to the identified indicators ecological resources and ecosystem functions, such as climate regulation and biotope quality, have already been modified to such an extent at the respective sites, that their development for housing purposes is to be favoured compared to unaffected greenfield sites. Also frequency of the use of natural resources, represented by static elements such as protected areas, was lower at sites of infill development compared to greenfield sites. The partial or entire use of protected areas could be indicated due to the addition of buffer areas according to proposals of GENELETTI ET AL. (2007) and their studies on the spatial effects of the land use plan in Naples. According to their studies surrounding settlements “were considered as a remarkable weakness factor”³⁸¹. The same counts for building measures and influences of future housing sites. In hand with the high weighting of the two indicators *climate regulation* and *protected areas* by local stakeholders³⁸², remarkable distinctions between sites of infill and greenfield development were derived. Compared to that, indicators such as *biotope quality*, *sealing rate* or *flood risk* did not show any diverging but overall good performances at both types of housing sites, but were not assigned with a significant decision relevance represented by their low weights as well.

Due to its industrial past, infill development in the City of Essen is forced to switch to former industrial brownfield sites, which explains the high degree of physical modification. This leads us to a

³⁷⁹ Which socio-environmental prerequisites exist in inner-urban and suburban areas determining the suitability of a site (QoP) for housing-purposes against the demand for sustainable and resource-preserving settlement-growth? How can Quality of Place be operationalized by indicators applicable and understandable for both planners and scientists?

³⁸⁰ Compare chapter 1.2

³⁸¹ GENELETTI ET AL. 2007, p. 418

³⁸² See fig. 4r & 6r in the annex.

more critical interpretation of the pedological indicators seepage and soil quality/ yield stability and their underlying data base. These indicators showed very heterogeneous performances, which disturbed a clear distinction of infill and greenfield development, compared to the remaining ecological indicators. These values and their validity need special and cautious consideration as the data –base is provided in a scale of 1:50.000. It does not include modifications of the soil structure due to urban development measures such as e.g. sealing. In a further research new on-site samples would be needed to be derived in order to get a distinct insight into local characteristic of urban soils. The applied data-base was integrated to get an overview of pedological characteristics derived from public data-sets. But they do not replace on-site assessments for measures of decentralised rainwater drainage or the assessment of yield stability.

In terms of ecological QoP-assessment, we have learnt that an expert-weighted indicator-aggregation can lead to a practicable integrated assessment and differentiation of the ecological suitability of housing strategies according to infill or greenfield development. As highlighted in chapter 4.1.1, the aggregated QoP-performance of each housing site was a composition of both indicator-performance and assigned weight. The selected analysis of pure indicator performances showed that not all indicators show clear differentiations between their performance at infill and greenfield sites. But it also becomes clear that the assignment of expert-weights was a major and essentially determining variable for a concentrated, focused and planning-relevant assessment of both development strategies. Figure 33 in chapter 4 gave a concise overview on the respective QoP performances in relation to expert-weights for each ecological indicator.

According to *social preconditions* determining QoP and the suitability of each housing site supporting a resource-preserving and sustainable settlement growth, the distinction of a better performance of either infill or greenfield sites also demands closer attention and discussion. The comparison of figures 34 and 35 in chapter 4 could shed light on these issues. Greenfield sites showed a worse performance than infill sites at 6 out of 11 indicators. Their overall unfavourable aggregated social QoP-performance in accordance with respective indicator weighting exceeded a value of 1.49 and therefore indicating only overall medium QoP. Here, reasons for the clear limited QoP of all greenfield sites can be found.

Compared to that, the QoP-values of infill sites described the range from good to medium QoP (figure 34). Whilst the accessibility of social infrastructure, everyday commodities and public transport showed general good performances, indicators such as noise exposure - in combination with selectively high weightings – showed bad performances. This led to a decrease of overall social QoP of infill sites. Along with these aspects, also suspected contaminations have supported these negative effects. Figure 35 in chapter 4 gave a concise overview on the respective QoP performances in relation to expert-weights for each social indicator.

Conclusively, sites of infill development still proved a good QoP and a high contribution to a resource-preserving and sustainable settlement development. This is due to the avoided use of unmodified and valuable resources compared to greenfield sites, which selectively affect protected areas and connected habitat structures. In social terms, infill sites proved a general good accessibility of daily commodities and therefore a valuable contribution to a sustainable settlement development. But compared to greenfield sites, issues such as nuisance and suspected contaminations can limit

their attractiveness for selected social groups and raise development costs due to protective measures. Here, a selected number of infill sites achieved a good QoP and undercut the critical benchmark of 1.49 compared to greenfield sites, which generally exceeded it.

5.2. QoL and UES: Research question 2

Beside the presentation of objective results of the socio-environmental impacts of settlement-growth on the provision with UES and residents' QoL in chapter 4.2.1, the following paragraphs shall also give an insight into these impacts in relation to demographic factors. According to the formulated research questions as presented in the introduction, we have to carefully focus on prerequisites, preconditions and socio-environmental circumstances. They accompany each change – both reduction and expansion – of the urban fabric³⁸³ and research question 2 is repeated: What socio-environmental impacts can be stated due to infill-and greenfield development? And can we *per se* state positive or negative effects on Quality of Life (“QoL”) and Urban Ecosystem Services (“UES”) of a strategy of fostered infill development or do we need to consider additional external effects? (Research question 2)

Firstly, sites of infill development will be discussed and followed by an analysis of greenfield sites. The discussion will focus on the provision with UES as major and significant contributor to QoL³⁸⁴ due to modified land use patterns under the process of settlement growth.

Infill development

As presented in the preceding chapter 4, we learnt that most of housing sites of infill development show values below the urban mean values of all the functions of urban green and open spaces to provide UES and significantly influence residents' QoL (see fig. 36, 39, 42, 44, 47, 50). Analyzing the status quo conditions and indicator performances representing selected UES, this confirms the hypothesis of BOLUND & HUNHAMMAR (1999, p. 299) of urban ecosystems being of “poorer quality than their rural equivalents”. The quality of local UES was lower than the urban average, and also than at greenfield sites. Diminished contribution to residents QoL were expected.

Following the social and ecological concerns of a fostered infill development as formulated in the introductory part of this study³⁸⁵, the statement of DOUGLAS (1989), describing cities as “suffering from environmental stress”, seems all too plausible. But according to the results of the socio-environmental impacts of additional housing development, presented in chapter 4, we know better. Moreover, we need to differentiate between prerequisites of the surroundings, status quo conditions of the site itself and possible positive or negative impacts of varying housing-densities. Due to the fact that most of the sites of infill development within the City of Essen are subject of brownfield revitalization, a distinction of impacts according to measures appears as too weak. But focusing on surroundings and physical framework condition, into which the sites are embedded, significant results can be derived.

³⁸³ SCHETKE ET AL. *

³⁸⁴ a.o. BOLUND & HUNHAMMAR 1999; JAMES ET AL. 2009

³⁸⁵ TYRVÄINEN ET AL. 2007; SIEDENTOP 2005; PAULEIT ET AL. 2005; COUCH & KARECHA 2006; JENKS & BURGESS 2000; BANZHAF & HÖFER 2008; KÜHN 1998; WHITFORD 2001; WILLIAMS 2004a; MAAS ET AL. 2006; HOWLEY 2009

Selected sites of infill development indeed showed significant *positive impacts* due to additional housing development of scenarios 1 and 2. Especially the buffers “Buschhauser Strasse”, “Thurmfeld”, “Palmbuschweg/ Altenessener Strasse” and “Breloher Steig North/ South” benefit from brownfield revitalization contributing to the *recreational* and *regulative need* and the provision with associated UES³⁸⁶. Here, positive contributions to QoL/UES can be stated.

Compared to that, the impacts on the *need of social cohesion/ local identity* were equivocal. The amount of private green per resident and therefore the possibilities for privacy and intimacy as valuable factors of local identity³⁸⁷ increase. Simultaneously, the provision with public green spaces and parks per resident decreased due to increasing population numbers in the wake of housing development and transformation of former public into private green³⁸⁸. But according to studies of TYRVÄINEN ET AL. (2007), also the use of green spaces is widely varying permitting one-sided interpretations of the modifications of different groups of green spaces and their social impacts. According to studies of PRIEGO ET AL. (2008) “private green space ... is the first choice of ... citizens who prefer to spend free time in contact with nature”³⁸⁹ highlighting the significant positive meanings of rising indicator values.³⁹⁰

According to BURGESS ET AL. (1988, p. 471), “public open spaces are valued especially because they have the potential to enhance those positive qualities of urban life: variety of opportunities and physical settings, sociability and cultural diversity.” Still, the resulting amounts are far above planning standards of 5-6 m²/ resident³⁹¹ (see fig. 44 & 47). Therefore, the provision with locations of interaction and communication as essential parts of the fulfillment of collective needs³⁹² will not be seriously endangered. The impacts on the provision of public parks as important means of interaction but also privacy and anonymity³⁹³, are also decreasing due to increasing population numbers. Here existing deficits of provision at some sites³⁹⁴ will be even aggravated due to housing development³⁹⁵. But as the impact-assessment only focuses on the closer living surroundings, these specific impacts will be smoothed taking larger catchments of public parks exceeding a distance of 500m into account.

Still, these outcomes of the indicators of green provision have to be put into perspective and demand a merely differentiated interpretation concerning their impacts on QoL. Moreover, “urban nature is important in all its manifestations I...I. This wide range of option permits users to select what is best for them and makes nature as part of their daily lives.”³⁹⁶ Discussing the dependence of different

³⁸⁶ See fig. 37, 38, 40, 41, 43 in chapter 4

³⁸⁷ MATSOUKA & KAPLAN 2008

³⁸⁸ See fig. 45, 46, 48, 49, 51 in chapter 4

³⁸⁹ PRIEGO ET AL. 2008, p. 17

³⁹⁰ But also note the studies of BARBOSA ET AL. (2007) clearly distinguishing between the different functions of private and public green and who have promoted a separated analysis of the two types around Sheffield.

³⁹¹ E.g. CITY OF LEIPZIG 2003; DEUTSCHER RAT FÜR LANDESPFLEGE (without year); CITY OF BERLIN 2009

³⁹² a.o. CHIESURA & DE GROOT 2003; PRIEGO ET AL. 2008; BURGESS ET AL. 1988; TYRVÄINEN ET AL. 2007; MATSOUKA & KAPLAN 2008

³⁹³ THOMPSON 2002

³⁹⁴ eg. Thurmfeld

³⁹⁵ RICHTER (1981) proposes 6 – 15m² according to site occupancy index

³⁹⁶ PRIEGO ET AL. 2008, p. 18)

types of nature according to cultural background, accessibility, tradition and social status, the presented results of the function of social cohesion/ local identity do not give serious reasons for concern. The absolute amounts of different green types are not entirely reduced, but remain shifting between different forms of design, composition, accessibility and forms of either private or public use.

In addition to these findings, infill development also demands a critical analysis. The following findings need to be highlighted: Also critical impacts due to additional housing development could be ascertained and negative results not only regarding green space provision but also for the *recreational* and *regulative need* were shown. Buffer sites such as “Alfredstrasse/ Wittekindstrasse/ Henri-Dunant-Strasse”, “Kesselstrasse”, “Duvenkamp”, “Zollverein/ Röckenstrasse³⁹⁷” or “Grüne Harfe/ Barkhovenallee³⁹⁸” are examples for also selected *negative impacts* of infill development. Despite the fact, that the buffer sites already provide UES worse than the urban average, additional densification is assumed to have much more serious impacts on locally provided UES according to the UES individually provided at the respective housing site. In that case, concerns related to infill development and negative consequences due to increasing densities as expressed by scientists³⁹⁹ can be confirmed.

The first of the named buffers is firstly already embedded within dense settlement structures and secondly will be subject of partial multi story housing meaning even more negative impacts on urban ecosystem according to increasing housing densities⁴⁰⁰. In that case, assumption of JENKS & BURGESS (2000, p. 15) that “the sustainability gains of further densification will be limited under conditions where densities are already high” can be confirmed.

The other buffers are either subject of re-densification⁴⁰¹ or are merely embedded within suburban structures. Here, housing development means a modification of almost or less modified land use pattern and therefore a decrease of the provision with selected UES⁴⁰². The fulfillment of collective needs indicated by the provision of private and public green and parks is variable in nature and can be described according to the already analyzed sites of infill development.

Greenfield Development

Merely negative socio-environmental impacts of greenfield development related to the provision with UES were seen throughout all scenarios. Behalf of selected ameliorations of biotope quality and the provision with private green per resident, all other indicators show decreasing performances of the *recreational* and *regulative need-fulfillment*. According to SIEDENTOP (2005)⁴⁰³, urban settlement patterns can mean enrichment to biodiversity due to heterogeneous structures compared to mono-

³⁹⁷ Buffer comprises sites of both infill and greenfield development.

³⁹⁸ See above

³⁹⁹ TYRVÄINEN ET AL. 2007; SIEDENTOP 2005; PAULEIT ET AL. 2005; COUCH & KARECHA 2006; JENKS & BURGESS 2000; BANZHAF & HÖFER 2008; KÜHN 1998; WHITFORD 2001; WILLIAMS 2004a; MAAS ET AL. 2006; HOWLEY 2009

⁴⁰⁰ BOLUND & HUNHAMMAR 1999

⁴⁰¹ Site Zollverein within buffer “Zollverein/ Röckenstrasse”

⁴⁰² E.g. Regulative UES

⁴⁰³ Citing KOWARIK 1992

structural farmlands. Distinct negative biotic influences of suburban settlement development cannot be confirmed.

But still, the negative social and environmental impacts of urban sprawl, as highlighted in the introductory part and expressed by various authors⁴⁰⁴, could be partially confirmed. The use of natural resources due to housing development has much more negative impacts as formerly unmodified land uses and patterns are now under use and transformation. Also significant negative impacts can be stated facing the provision with collective needs with parks and valuable public green spaces. Due limited provision with public parks in that area⁴⁰⁵, an additional decrease of the provision with public green per resident will limit the possibilities for interaction and communication.

Intermediate Conclusion on QoL/UES

Conclusively and in order to answer research question 2⁴⁰⁶, which focuses on the socio-environmental impacts of settlement growth and put special attention to infill development, three significant factors influencing either negative or positive socio-environmental impacts of housing development were defined. They highlight the influence of land use structures and patterns and can also be confirmed by current literature:

1. *Site characteristics*: The previous land use of the housing site and its degree of modification play an integral role. Whilst the first group of sites showing positive impacts of infill development is characterized as industrial brownfields, sites with merely negative impacts on UES have been less modified before. Here, previous use was mainly subject to agrarian structures than to industrial uses and lead to a smaller extent of UES-modification and limitation. According to ZERBE ET AL. (2003) who highlight “the potential for nature conservation in urban industrial areas”, positive ecological impacts influencing the social domain due to infill development could be confirmed within this study. This is due to the fact that “anthropogenous sites with a long continuity of the same kind of management are particularly valuable for nature conservation.”⁴⁰⁷ In terms of previous site characteristics influencing impacts of housing development, also PAULEIT ET AL. (2005) have stated significant ecological differences of impacts due to infill development, which depend on preceding land use and land cover types in different housing areas at the example of Merseyside, UK. Moreover, ZERBE ET AL. (2003) expand their statement as followed, which can be adapted in putting ecological concerns of infill development into perspective⁴⁰⁸: “a) In the course of colonization of urban-industrial sites new plant communities and habitats can evolve. b) Directly and indirectly imported non-native species and a great variety of anthropogenic

⁴⁰⁴ A.O. HAASE & NUISSL 2007; NUISSL ET AL. 2009; SIEDENTOP 2005; PAULEIT ET AL. 2005; MCKINNEY 2002; WHITFORD ET AL. 2001; KRAMPULZ 2005

⁴⁰⁵ See buffers “Schmachtenberg” or “Byfang”

⁴⁰⁶ What socio-environmental impacts can be stated due to infill-and greenfield development? And can we *per se* state positive or negative effects on Quality of Life (“QoL”) and Urban Ecosystem Services (“UES”) of a strategy of fostered infill development or do we need to consider additional external effects?

⁴⁰⁷ ZERBE ET AL. 2003, p. 146; see also the issue “Gestaltung urbane Freiräume” of the BMVBS (2008) stressing the multifarious possibilities of restructuring measurements in inner urban areas for open space development and possible positive effects for living conditions.

⁴⁰⁸ ZERBE ET AL 2003, p. 146

mechanisms of species dispersal contribute to the richness of species in cities. c) A more rapid speciation can occur on anthropogenic disturbed sites (e.g. in settlements) than on natural sites.”

2. *Surroundings*: Surrounding land use and development structure form the second important influencing factor of socio-environmental impacts of settlement growth at both sites of infill and greenfield development. Therefore, the impact assessment has been extended to closer living surroundings. We learnt that impacts at either greenfield sites or sites of infill development embedded into suburban structures⁴⁰⁹ show clear negative impacts of housing development. Contrary to that, sites of infill development, which were embedded into already existing and considerable modified urban structures, benefitted from housing development going along with lower densities and possible ameliorations of land use patterns⁴¹⁰. If local ecological conditions are tensed⁴¹¹, a new development of the site introducing new land use patterns and measures of revitalization can mean significant benefits and positive socio-environmental impacts. Here, LEUNG (2003) stresses the impact assessment of densification as mandatory for urban planners within neighborhood contexts. These findings connect to the following statements and can be embedded into the discussion of built densities and sustainability.
3. *Housing densities*: Regarding results presented in chapter 4⁴¹², another factor needs consideration: housing density. Whilst positive impacts at sites of infill development could be stated during scenario 1 and 2, overall negative impacts could be stated at scenario 3, no matter of the surrounding land use structures⁴¹³. But according to WHITFORD ET AL. (2001) “negative consequences of densification may be ameliorated by good design”. This statement gives us the possibilities to reflect on the socio-ecological concerns introduced in the beginning of this work and to launch the issue of an ideal density in urban areas very shortly. Especially the works of JENKS ET AL. (1996), JENKS & BURGESS (2000) or WILLIAMS ET AL. (2001) give a broad and international insight into the multidimensional discussion of urban compaction and are to be named in this context⁴¹⁴. HUTTER ET AL. (2004) discuss strategies and obstacles on the way of an infill development providing economical efficiency but also favorable living conditions and stresses the issue of qualified infill development (“Qualitätvolle Innenentwicklung”) and adequate built densities (“Angemessene bauliche Dichte”)⁴¹⁵. According to his findings fostered infill development can only then have positive effects as it improves existing settlement areas both socially and ecologically.⁴¹⁶ Adequate built densities are to a large extent dependent on surrounding structures and cannot be

⁴⁰⁹ These characteristics are also shown by the respective indicator performance of UES.

⁴¹⁰ See also BMVBS, BBR 2008

⁴¹¹ E.g. buffer “Buschhauser Strasse”, “Kesselstrasse”, or „Alfrestr./ Wittekindstr./ Henri-Dunant-Str.“

⁴¹² Figures 37, 38, 40, 41, 43, 45, 46, 48

⁴¹³ Compare results as presented in chapter 4.

⁴¹⁴ See also the concise overview of JABAREEN 2006 about typologies, models and concepts of sustainable urban forms

⁴¹⁵ See also a.o. WESTPHAL 2008 discussing the issue of adequate built densities against a historical and planning context being applicable for both growing and shrinking cities. According to her the variability of objectives and arguments pro and con increasing built densities are numerous and accompanied with conflicts (p.94).

⁴¹⁶ HUTTER ET AL. 2004, p. XXIII

generalized. But still, sustainability of urban areas is a matter of “density and dwelling type”^{417, 418}. This could be confirmed within this work and corresponds with the preceding statement 2.

Excursus: Impact Assessment for different Residential Groups

According to current literature⁴¹⁹ infill development is mostly related to negative impacts on residents’ QoL. As outlined in chapter 2 the conceptual approach of linking QoL and UES focused on a *homo uniformus* and objective determinants of QoL. Still two selected residential groups which are closely linked to their closer living surroundings - the young and senior residents⁴²⁰ - need to be mentioned. Possible deficits of acceptance as assumed by TYRVÄINEN ET AL. (2007, p. 14)⁴²¹ stating that “infilling of existing housing areas (is) strongly disapproved, which highlight the gap in values and goals between local residents and compact city policies” can be explained.

According to figure 58 (below) and the selected housing sites analyzed within this study, we learnt that infill development⁴²² in the City of Essen is mainly found in districts with younger residents exceeding the average youth rate of 15.86%⁴²³ and smaller households⁴²⁴. Housing sites of greenfield development are mainly located in districts of higher elderly rate exceeding the average rate of 22.08 %⁴²⁵ and larger households significantly exceeding the urban mean value of Essen⁴²⁶. According to these notions and the preceding chapter 5.2, which discussed the general negative socio-environmental impacts at greenfield-sites, we get the impression that especially the group of senior residents is affected by this. They represent a group, which is bound to their closer living surroundings. And a lacking acceptance of additional housing-development can be expected.

Due to lacking fine-grained demographical data and valid tendencies on the age-structure of residents at future housing-sites, a closer insight into the selected affectedness of different residential group will be subject for further studies. Moreover, due to very heterogeneous impacts at infill-sites affecting young and small households, valid connections to demographical data need to be set against a larger amount of analyzed sites.

⁴¹⁷ JABAREEN 2006, p. 41

⁴¹⁸ In this context ALBERTI 2005 discusses the close interplay between built densities, patterns of land uses and varying impacts on the ecosystem. She stresses the need for further research on the oversimplified interplay between socioeconomic patterns and environmental factors. Moreover “strategies devised to minimize ecological impacts of urban growth often fail to identify key underlying mechanisms that link urban patterns to ecosystem functions I...I (p. 171”.

⁴¹⁹ a.o. TYRVÄINEN ET AL. 2007; SIEDENTOP 2005, PAULEIT ET AL. 2005; COUCH & KARECHA 2006; JENKS & BURGESS 2000; BANZHAF & HÖFER 2008; KÜHN 1998; WHITFORD 2001; WILLIAMS 2004a; MAAS ET AL. 2006

⁴²⁰ This study will exemplarily focus on groups of the population bound to their closer living surroundings which are families with children and senior residents (according to MAAS ET AL. 2006; TAKANO ET AL. 2002).

⁴²¹ See also HOWLEY 2009

⁴²² Dark blue dots

⁴²³ In the year 2007

⁴²⁴ Average future household size in 2007 according to STATISTICAL OFFICE NRW 2005: 1.94

⁴²⁵ In the year 2007

⁴²⁶ Compare formulas in tab.a5a annex

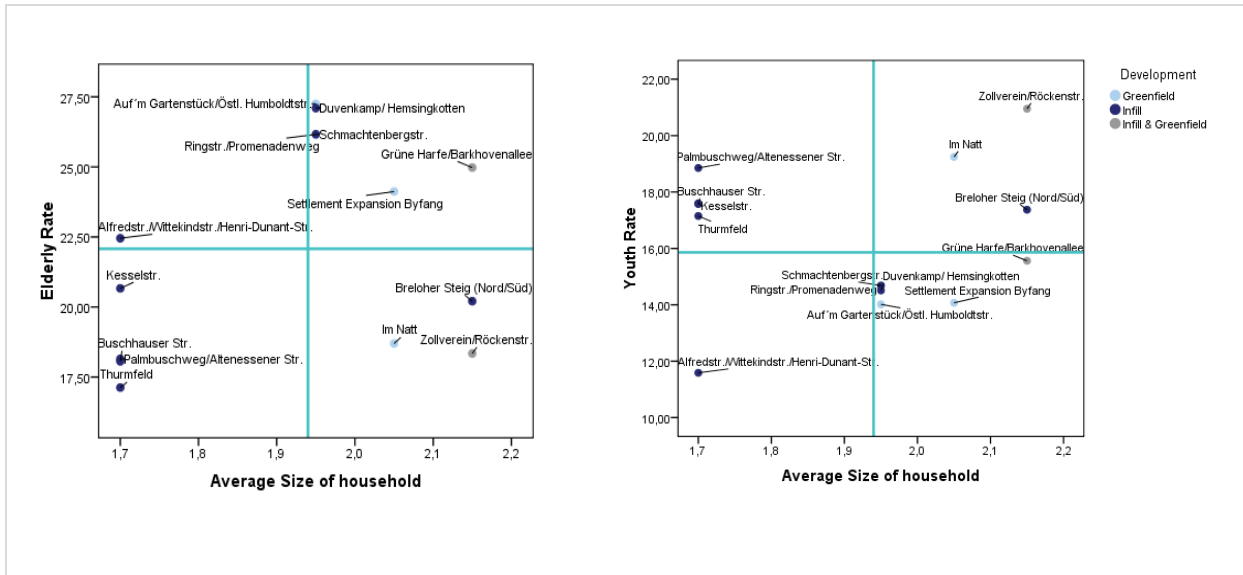


Figure 58 Elderly (left) and youth (right) rate⁴²⁷ of associated districts in Essen put into relation with average size of household size; turquoise lines indicate urban mean value (source: author)

⁴²⁷ See formulas tab. a5a

5.3. Typology of Housing-Sites

After a complex presentation of the results of both steps of the MCA and a discussion of both research-questions the following sub-chapter provides with a typology of future housing-sites. It derives directly from the presented findings and shall help to derive future recommendations for sustainable settlement-development.

The typology comprises four types of housing-sites. Table 7 presents all housing-sites according to this typology. First insights into this could be derived from chapter 4.3. Here, the combined presentation of results from QoP-assessment and QoL/UES-assessment has set two benchmarks for each step of the MCA. For the QoP-assessment the benchmark of 1.49 indicating good QoP was set. For the impact-assessment on QoL/UES the percental deviation from the status-quo-scenario was used. Scenario 1 was used to give first insights into socio-environmental impacts of housing-development. As the impact-assessment was executed referring to the extensions of the closer living-surroundings using buffers, the typology will also refer to these buffers. According to these notions, the typology of housing-sites will present four types of sites.

Type A: Sites have a general good socio-environmental QoP (≤ 1.49) and show positive socio-environmental impacts for the majority of the eleven QoL/UES-indicators. These sites are recommended for further development, because they support sustainable settlement-development by avoiding the use of undisturbed natural resources, providing good access to existing social infrastructure and show positive socio-environmental impacts⁴²⁸.

Type B: Sites have a general good socio-environmental QoP (≤ 1.49) but show negative socio-environmental impacts for the majority of the eleven QoL/UES-indicators⁴²⁹. These sites are only conditionally recommended for further development, because they support sustainable settlement-development by avoiding the use of undisturbed natural resources and by providing good access to existing social infrastructure. From a planner's point of view, they provide with very suitable socio-environmental prerequisites. Their socio-environmental impacts are to be questioned but could be counteracted within binding land use planning.

Type C: Sites have a general medium socio-environmental QoP (> 1.49) but show positive socio-environmental impacts for the majority of the eleven QoL/UES-indicators. These sites are only conditionally recommended for further development. They only partially support sustainable settlement-development due to either the selective use of undisturbed natural resources or the limited provision with good access to existing social infrastructure. From a planner's point of view, they provide with medium suitable socio-environmental prerequisites. As the assessment was executed at the level of preparatory land use planning, adjustments could be made. The general socio-environmental impacts are positive⁴³⁰.

Type D: Sites have a general medium socio-environmental QoP (> 1.49) and show negative socio-environmental impacts for the majority of the eleven QoL/UES-indicators. These sites are only conditionally recommended for further development. They only partially support

⁴²⁸ Exemplified for scenario 1.

⁴²⁹ See footnote above

⁴³⁰ See footnote above

sustainable settlement-development due to either the selective use of undisturbed natural resources or the limited provision with good access to existing social infrastructure. From a planner’s point of view, they provide with medium suitable socio-environmental prerequisites. As the assessment was executed at the level of preparatory land use planning, adjustments could be made. The general socio-environmental impacts are negative⁴³¹ and also demand spatial or density-related adjustments for further development.

Table 7 Typology of housing-sites (own draft)

Type A		Type B	
Development	Buffer’s name	Development	Buffer’s name
Infill	Breloher Steig (North/South) Palmbuschweg/Altenessener Str.	Infill/Greenfield	Zollverein/Röckenstr.
Infill		Infill	Kesselstrasse
Type C		Type D	
Development	Buffer’s name	Development	Buffer’s name
Infill	Buschhauser Strasse Thurmfeld Ringstr./Promenadenweg	Infill	Duvenkamp/Hemzingkotten
Infill		Greenfield	Settlement Expansion Byfang
Infill		Greenfield	Im Natt
		Greenfield	Schmachtenbergstrasse
		Greenfield	Aufm Gartenstück/ Östl. Humboldtstr.
		Infill/Greenfield	Grüne Harfe/ Barkhovenallee
		Infill	Alfredstr./Wittekindstr./Henri-Dunant-Str.

Table 7 shows clearly that the majority of buffers comprising infill-sites are belonging to type A, B and C. Sites of greenfield –development are generally belonging to the least favorable type of the four and provide mostly medium socio-environmental prerequisites for a sustainable settlement-growth and also negative socio-environmental impacts.

⁴³¹ See footnote above

5.4. Plausibility of the MCA-Scheme

Within the following paragraphs, the presented MCA-approach will undergo a concise discussion of content and methodology. The two-fold design of the MCA bridges the gap between *i)* the orientation towards demands of urban planning for a reduction of land consumption, which go hand in hand with a fostered infill development, and *ii)* a scientific consistent analysis of both the socio-environmental prerequisites of sustainable housing development (QoP) and its impacts using the concepts of QoL and UES.

The *first level* – QoP-assessment- demands answers, in how to qualitatively assess housing sites against the demands of sustainability. And it questions, how to translate quantitative political goals into standards of quality for future housing sites and assessment schemes, in order to execute a strategic land management that follows the goals of reduced consumption of land and resources. This level comprises planning-oriented indicators and is entirely underpinned by public and communal data sets. It is *physiocentric* in nature assessing the ecological and social quality of a site.

Compared to that, a *second level* of the assessment was introduced dealing with concerns expressed against fostered infill development. This indicator-scheme *varies* from indicators of QoP and focuses on a scenario-steered assessment of socio-environmental impacts of housing development against the concepts of QoL and UES. The concepts were used to assess the provision of UES and ecological impacts of settlement growth in a already highly modified urban ecosystem⁴³² and deriving effects on residents' QoL. As expressed by scientist, infill development is not always welcomed as it influences residents' living surroundings and QoL. This level of the assessment has an *anthropocentric* focus and does not demand an application within planning processes. It is oriented towards the integration of the concepts of QoL and UES within a quantitative impact assessment according to scenarios of varying housing densities. This depicts the effects of housing development on residents living surroundings.

Quality of Place

The first step of the assessment, as executed via QoP-analysis highlighted essential possibilities of a preliminary quality assessment of future housing sites displayed in a land use plan. Valuable contributions to the current plan elaboration procedure could be given by formalized ecological and social indicators. They help to assess the suitability of each housing site according to reduced consumption of natural resources and sustainable settlement growth. Following the critical statement of SIEDENTOP (2002) on a minimization of issues of land consumption by formulating quantitative targets, the indicator set of QoP-assessment focuses on concrete local ecological characteristics to be preserved and social determinants⁴³³. They are of essential importance to redirect strategies of reduced land consumption to a qualitative approach. According to own previous studies "unilateral quantitative planning targets aiming at an arbitrarily fixed figure of 30-hectares blur the sight for protection of natural resources and qualitative on-site assessment. Until

⁴³² a.o. DE RIDDER ET AL. 2004; ALBERTI 2009

⁴³³ eg. social infrastructure

now, few practical proposals have been made to put the 30-ha-goal into practical planning. But significant spatial steering effects remain doubtful.”⁴³⁴

As presented in chapter 3, the QoP-assessment rigorously followed material demands such as links to practice, traceability, significance and compatibility and technical demands such as data quality and availability as expressed in chapter 3⁴³⁵. The chosen data base, comprising of solely communal and public data, could bridge the gap between a scientific approach and practical use within current planning processes. First positive experiences could be derived from the research project FIN.30 within which the author has been responsible for the processing of the ecological and social domain of an integrated assessment of housing sites. Moreover, the presented indicator set was the result of an intensive collaborative process between scientists and planners.⁴³⁶ Beside the target of communicability and transparency, the numbers of indicators determining its applicability within planning processes were essential demands and determinants of QoP-assessment. The indicator-set of QoP-assessment does not aim at an all encompassing operationalization of the term “sustainability” and “sustainable settlement development”.⁴³⁷

The definition of indicator-classes focused on planning and legal standards. It remains to discuss whether a threefold classification⁴³⁸ has led to a sufficient assessment of QoP. But according to practicability of the indicator-scheme and keeping the outcomes of stakeholder participation in mind, this classification can be considered as maintainable. In this context, the integration of all QoP-indicators into a DSS needs to be highlighted. The DSS, as executed and tested also within the research project FIN.30, was designed according to applicability within processes of land use planning and according to the integration of individual indicator weights derived from stakeholders⁴³⁹. Consequently, a standardization of qualitative and quantitative indicator types and performances to a three-stepped ordinal classification was necessary. The evaluation of QoP of future housing sites in Essen was executed according to this standardization as QoP-analysis is at all times adjusted to the question whether a housing site fulfills planning standards entirely, partially or not at all⁴⁴⁰. The presentation of the results in chapter 4 took this into account. Therefore a multivariate statistical analysis of the original metric indicator performances was not executed which may have enabled different means of analysis. For the DSS, more relevance was drawn to the analysis whether a housing sites is or is not located within predefined accessibility distances. For instance, as the critical distance to a bus-stop is defined with 300m, it does not matter whether the site is located within 250 or 280 distance. But it would matter if it exceeded the threshold value of 300m.

⁴³⁴ SCHETKE ET AL. (2009a, p. 117)

⁴³⁵ KÖTTER ET AL. 2009a; see also HEILAND ET AL. 2003; NIJKAMP & OUWERSLOOT 1998; KORCZAK 2002; WOLTER 2001; BRÜCKNER 2001; KÖTTER ET AL. 2009b; WRBKA ET AL. 2003; SCHETKE ET AL. (in prep.)

⁴³⁶ SCHETKE ET AL. (in prep.)

⁴³⁷ KÖTTER ET AL. (2009a)

⁴³⁸ Compare chapter 3.2.3.

⁴³⁹ Compare chapter excursus in chapter 3

⁴⁴⁰ Compared classification of QoP-indicators as outlined in chapter 3.

The synthesis of existing communal data highlighted the possibilities of QoP-analysis planners have and are able to integrate within planning processes such as the plan elaboration procedure. It also contributed to a better understanding of the approach and increases the chance of its implementation⁴⁴¹. A further step towards a better integration of scientific and practical demands could be achieved via the implementation of individual indicator weighting within the MCA-scheme⁴⁴². They represent planners' attitudes towards the meaning of single indicators for the decision-making process. Conclusively, it could be shown "that a planning-oriented MCA for on-site assessment incorporating the concepts of ecosystem functions (and) human well-being of living surroundings I...I can be an effective tool to implement reduced land consumption within strategic spatial planning."⁴⁴³

Quality of Life and associated Urban Ecosystem Services

This second level of the assessment was implemented in order to obtain a closer insight into feared possible negative social and ecological impacts of infill development⁴⁴⁴ and to assess impacts of also greenfield-development. First insights into the acceptance of infill-and greenfield-development could be given in the excursus of chapter 5.2. The second level of the assessment clearly focused on the human-related side of infill- and greenfield-development. Therefore, it gave indispensable information on the impacts of strategies of settlement development on residents' and the urban ecosystem. If planners and scientist want to get through to the blurred and complex system of sustainability, they have to be aware of both the prerequisites and framework-conditions of their actions⁴⁴⁵ and the consequences⁴⁴⁶ of their policies. Therefore the concepts of QoL and UES were chosen in addition to the first step of the MCA.

It goes without question that QoL is determined by many factors⁴⁴⁷. Within this study, a selected view on the immaterial needs natural ecosystems are able to fulfill⁴⁴⁸ was set. According to a broad literature review three major need, which are fulfilled by urban green and open spaces⁴⁴⁹ as contributors to QoL, were selected.⁴⁵⁰ Urban green spaces significantly contribute to QoL⁴⁵¹ by

⁴⁴¹ These experiences could be made during workshops with planners from three communes within North Rhine-Westphalia acting as practical partners within the research project FIN.30 in the years 2006-2009.

⁴⁴² See chapters 3.4 and 4.1.

⁴⁴³ SCHETKE ET AL. 2009a, p. 117

⁴⁴⁴ TYRVÄINEN ET AL. 2007; SIEDENTOP 2005, PAULEIT ET AL. 2005; COUCH & KARECHA 2006; JENKS & BURGESS 2000; BANZHAF & HÖFER 2008; KÜHN 1998; WHITFORD 2001; WILLIAMS 2004a; MAAS ET AL. 2006

⁴⁴⁵ See QoP-analysis

⁴⁴⁶ See QoL-impact-assessment

⁴⁴⁷ See eg. SANTOS & MARTINS 2007; COSTANZA ET AL. 2007; MEA 2005, PACIONE 2003; JIRÓN & FADDA 2000; FADDA & JIRÓN 1999

⁴⁴⁸ CHIESURA & DE GROOT (2003)

⁴⁴⁹ a.o. MEA 2003, 2005; PRIEGO ET AL. 2008; BURGESS ET AL. 1988; SCHETKE & HAASE, 2008; SCHETKE ET AL.*; SCHETKE ET AL.**; WERHEIT 2002, p. 93; DE RIDDER ET AL. 2004; MITCHELL & POPHAM 2008; DE GROOT ET AL., 2002, DE GROOT ET AL. 2003; CHIESURA & DE GROOT 2003; DE GROOT 2006; RICHTER 1981; JAMES ET AL. 2009; THOMPSON 2002, MATSUOKA & KAPLAN 2008

⁴⁵⁰ Compare SCHETKE ET AL.*

⁴⁵¹ a.o. SANTOS & MARTINS 2006; PRIEGO ET AL. 2008; SCHETKE ET AL.*; SCHETKE ET AL.**; MATSUOKA & KAPLAN 2008; DE RIDDER ET AL. 2004; TZOULAS ET AL. 2007; MEA 2005; COSTANZA ET AL. 2007; JAMES ET AL. 2009; TYRVÄINEN ET AL. 2007; BURGESS ET AL. 1988; BARBOSA ET AL. 2007; COSTA ET AL. 2008

providing UES⁴⁵². These UES were translated to quantifiable and objective indicators as presented in chapter 3.⁴⁵³

The indicators were elaborated according to three principles: *i*) Empirical evidence as discussed in current literature on the subject of ESS and UES, *ii*) a depiction with cadastral data and *iii*) their attribution according to existing look-up tables⁴⁵⁴. This procedure enabled to adjust ecological indicator performances to cadastral land use classes and therefore enabled a scenario based impact assessment. Ostensible fears of negative impacts of infill development could be put into perspective and drivers of socio-environmental impacts such as socio-ecological preconditions, sites conditions of the housing site before development and housing density, be identified.

Therefore, an insight into to the possible provision with UES according to different housing structures and general influences on QoL could be given and valuable information about socio-environmental impacts of infill development be obtained. In order to derive individual and site-specific UES and information about their quality and intensity, on-site analyses and further modeling will be subject to further research and discussed in the outlook.

Moreover, the presented indicator-set needs to be seen as a first concept in bridging the gap between QoL and UES by integrating them into common and quantifiable indicators.⁴⁵⁵ Further research about these issues will be needed facing an inherent multidimensionality of the indicators in depicting the defined tasks of urban green towards QoL. According to JAMES ET AL. (2009, p. 72), issues of QoL and the quality of urban green spaces and related research issues such as “ecosystem services, drivers of change, pressures, social processes and goals of provision associated with urban green space are interrelated. [...] changes in the urban environment [...] are the result of complex interactions of natural and spontaneous processes as well as of the planned actions by humans. [...] themes of urban green space are inextricably linked and include physical and social systems and processes.”⁴⁵⁶ According to these notions and the deriving findings from this study, closer attention will be drawn on social respondents towards green space management and land use change as well as distinct and small-scale assessment on the provision with UES according to varying strategies of settlement growth. In accordance to that, an expansion of both QoP-assessment and QoL-impact-assessment to other case studies could lead to more generalizable findings about the success or failure of infill development and distinct socio-environmental impacts of this development strategy.

The used housing scenarios and related socio-environmental impacts impressively showed that UES and QoL sensitively react towards alterations of the built environment indicated by varying housing densities. It goes without question that the development of a housing site implementing only one housing type is not probable and the derived results remain exemplary and static to some extent. Still, the implementation of uniform housing scenarios has been necessary to get comparable results

⁴⁵² CHAN ET AL. 2006; DE GROOT ET AL. 2002; DE GROOT 2006; BOLUND & HUNHAMMAR 1999; COSTANZA ET AL. 1997

⁴⁵³ According to SCHETKE ET AL. *

⁴⁵⁴ Derived from e.g. SINGER 1995 or UMWELTATLAS BERLIN 2007

⁴⁵⁵ Compare SCHETKE ET AL. *, SCHETKE ET AL. **

⁴⁵⁶ JAMES ET AL. 2009, p. 72

of the socio-environmental impacts of housing development throughout a city. Moreover, with the analysis of housing sites still displayed in a land use plan, assumptions have to be made regarding:

Structure: In contrast to the aforementioned static housing scenarios, the implementation of dynamical scenarios promoting more than one housing structure being realized at a single site would have given a clearer insight into more planning-associated impacts due to housing development.

Time: The impact assessment assumes a simultaneous realization of all housing sites within each buffer. According to realistic planning procedures, this would probably not be the case. Moreover, an omitted development of single sites can occur, having also significant influences at the impacts within each buffer. Still, the implementation of a timely dynamical development would have been bound to many assumptions being difficult to undermine. As the plan elaboration procedure of the regional land use plan of the City of Essen was not finished at the time⁴⁵⁷ when its respective future housing sites were integrated into the analysis⁴⁵⁸, no concrete general information about their realization can be given. By now, a delayed realization of single sites due to varying interests amongst planners and politicians is already expected by urban planners of the City of Essen.⁴⁵⁹

5.4.1. Caesura

The MCA-scheme proved as essentially valuable to assess both socio-environmental prerequisites and impacts of and due to both infill and greenfield development. It follows a participatory approach in determining planning-relevant QoP- indicators and implemented expert-weights deriving from workshop together with planners of the City of Essen. In terms of impact assessment the gap between the two concepts of QoL and UES could be bridged in presenting a first approach of this issue. QoL/UES-assessment not only enabled an assessment of socio-environmental impacts due to varying housing densities, but also referred to closer living surroundings.

Both steps of the MCA proved also valuable in executing a demographic oriented assessment. The social dimension of QoP-assessment was underpinned with a broad range of valuable social indicators for different groups of the population. A suitable weighting enables the planner to assess a housing site according to socially specific demands. Within the socio-environmental impact assessment of QoL/UES the selected affectedness of different social groups was mentioned.

Integrated conclusions on the MCA-scheme and findings for the sustainability of either infill or greenfield development will be given in the next chapter.

⁴⁵⁷ Closure of the procedure is expected for Mai 2010 (<http://www.staedtregion-ruhr-2030.de/cms/planverfahren.html>).

⁴⁵⁸ August 2008

⁴⁵⁹ Oral information from Department of urban planning and construction regulation, City of Essen (Mai 2009).

6. Conclusion

Following the major hypothesis of this study⁴⁶⁰, the aforementioned paragraphs discussing findings from both the assessment of QoP and impact assessment of QoL/UES will be synthesized and put into relation with the preceding chapters of this work. Two research questions and one major hypothesis of this work shall guide us on this way.

The results presented in chapter 4 gave a valuable and significant differentiation of two different strategies of settlement development against their contribution to the principles of sustainability: infill and greenfield development. In doing so, a highly innovative and planning-oriented indicator-framework was presented in chapter 3 and applied in a first pilot study of the City of Essen (chapter 4). Accordingly, an answer on research question 1 and focusing on the first part of the MCA could be given:

1. Which socio-environmental prerequisites exist in inner-urban and suburban areas determining the suitability of site (“QoP”) for housing purposes against the demand for sustainable and resource-preserving settlement-development? How can Quality of Place be operationalized by indicators applicable and understandable for both planners and scientists?

The interplay of indicators and expert-weights, as outlined in chapter 4, did reveal a differentiation of the QoP of greenfield- from infill sites and significantly detected decision-relevant indicators on socio-environmental prerequisites. In chapter 4 and 5, we learnt that the overall QoP of greenfield sites is generally limited compared to the QoP of *infill sites* which is very good in ecological terms and quite heterogeneous in social terms. Chapter 3 gave an answer on the second part of the question and presented a highly innovative indicator-framework for QoP-assessment. The indicators derived from a participative approach of scientists and planners and are supported by findings from current literature and planning as outlined before. The requirements of this step of the MCA were set clearly and three major tasks had to be fulfilled: *i)* it has to fulfill scientific demands, *ii)* to be applicable within the planning process, *iii)* to assess socio-environmental prerequisites of housing sites under the headline of sustainability.

Highly valuable results on a general classification of infill and greenfield sites support an especially critical discussion of urban sprawl, as presented in chapter 1, and on finding new ways to adjust settlement growth according to its contribution to sustainability and resource-preservation. It supports planners to assess the suitability of future housing sites at the strategic level of land use planning against the principles of sustainable settlement growth and demographic oriented land use planning. Using such a tool can help to achieve goals of reduced land consumption such as the 30-ha-goal as they shed light on the potentials cities hold in favor of a fostered infill development.

Here, the gap between science and planners could be bridged but also claimed concession especially at the side of complexity and scientific demands. Following a participative approach, the indicator-framework of QoP was highly condensed and limited the capacity for in-depth analysis and

⁴⁶⁰ “The success of a strategy of fostered infill development cannot be generalized. Both the suitability of a site for housing purposes and its socio-environmental impacts at local level – due to either infill or greenfield development – are significantly determined by individual prerequisites and framework-conditions.”

extensively diverse assessment in its single dimensions of sustainability. Moreover, future housing sites deriving from one case study were chosen and according to current planning frameworks⁴⁶¹. An expanded indicator-framework together with an expanded set of future housing sites could have improved the differentiations of QoP at infill and greenfield sites leading to unambiguous statements but would have counteracted the requirements of a planner-oriented MCA as presented above.

The second part of the MCA, as presented in chapter 3.2, shed light on the consequences and impacts of a fostered infill development in order to answer *research question 2*:

2. What socio-environmental impacts can be stated due to infill-and greenfield development? And can we *per se* state positive or negative effects on Quality of Life (“QoL”) and Urban Ecosystem Services (“UES”) of a strategy of fostered infill development or do we need to consider additional external effects?

This part of the MCA enabled a clear and quantified insight into socio-environmental impacts due to infill and greenfield development. It could state overall negative consequences of *greenfield development*. In terms of *infill development* both very positive but also single negative impacts had to be stated according to characteristic of the sites themselves, surrounding conditions and according to housing density. Whilst positive socio-environmental impacts could be stated at brownfield sites, sites of infill development integrated into merely rural surroundings showed negative impacts.

The major hypothesis of this work therefore has to be partially verified:

“The success of a strategy of fostered infill development cannot be generalized. Both the suitability of a site for housing purposes and its socio-environmental impacts at local level – due to either infill or greenfield development – are significantly determined by individual prerequisites and framework-conditions.”

Following these findings, the question emerged in chapter 4.3 and 5.3, whether sites of positive QoP meaning positive socio-environmental prerequisites for housing development, will also benefit from positive socio-environmental impacts or if they –due to their integrated location and embedding into existing settlement structures- will suffer from negative impacts on QoL and UES. This would confirm the restrictive expressions towards infill development which have already been mentioned in the introductory part.

In terms of *greenfield development* a clear picture was derived from both assessments. Proving a merely low QoP because of the partial use of natural resources and the limited accessibility of daily commodities also negative impacts on the provision of UES and their influences on residents’ QoL could be stated in the second step of the MCA. In doing so, findings from current literature as presented in chapter 2 about clearly negative effects of greenfield development could be confirmed.

The results of *infill development* could not be harmonized and generalized at all. Proving a general better QoP due to the avoided use of natural resources and unmodified land use classes in most cases and a general good accessibility of daily commodities despite limitations due to nuisances and

⁴⁶¹ Sites of RFNP-draft of 2008 for the City of Essen and analyzed of SCHAUERTE ET AL. 2007.

contaminations, positive preconditions of infill development could be stated.⁴⁶² Still, the results from QoL/UES- impact assessment showed the second part of the medal of socio-environmental impacts due to infill development, which is reflected within this integrated assessment of QoP and QoL/UES.

This very heterogeneous picture tells us an important lesson: The prerequisites/QoP of *infill development*, indicated according to this study, show a general positive picture and would recommend a fostering of infill development according to political notions and evident negative impacts of urban sprawl and greenfield development. In terms of socio-environmental impacts and related concerns as expressed by scientists, a possible limited acceptance of infill development amongst selected groups and additional ecological problems at selected sites as mentioned above could be indicated but cannot be generalized at all. Referring to chapter 5.3 major positive socio-environmental impacts could be stated for infill-sites. Here, the MCA-scheme proved suitable for land use assessment adjusted to demographic features and prerequisites.

It can be concluded, that a strategy of fostered infill development cannot be rejected unbiased, demands further in-depth analysis but still proves general positive effects.

And as a matter of fact, it can be stated, that infill development needs to be regarded mandatorily as an alternative to greenfield development and urban sprawl and demands to be fostered in current urban planning. Moreover, social and ecological concerns as expressed by scientists as discussed in chapter 1 could be widely smoothed out and put into perspective by highlighting selected means of infill development and external surroundings of each site.

We have learnt, that not only a quantitative and political target such the 30-ha-goal and a qualitative 3:1 regulation of fostering infill development are sufficient to effectively influence and promote sustainable settlement growth. Moreover local framework conditions, demographic aspects and the integration of future housing sites into their surroundings are of prime importance. Additionally, the issue of paradox settlement growth as outlined in chapter 1.1 expands this problematic and adds the topic of uneven settlement patterns planners have to deal with. The question is not about the legitimacy of the development of a certain amount of land but moreover about the use of existing infrastructure, the provision with adequate living surroundings, environmental health, resource preservation and a good QoL. This count for both growing and shrinking cities and best depicts the tasks of current urban planning. Here, the question of how to adjust current planning strategies to these demands will endure.

⁴⁶² See comparable results of HOWLEY 2009 for the UK.

7. Outlook

Both the QoP- and the QoL/UES-assessment were applied using the pilot case study of Essen. In order to optimize the presented MCA-scheme and to derive more generalizable findings on both the success and failure of infill development, an expansion to further additional case is aspired. This will not only give chance of further proving of the indicators' significance and possible revisions of the indicator-set but will also strengthen their transferability to other cities and regions. The following paragraphs will provide approaches in doing so.

The presented methodology of the MCA-scheme highlighting means and indicators to both assess socio-environmental prerequisites of housing sites demanded by the target of sustainable settlement growth and limited land consumption (QoP) and the impact-assessment of different scenarios against the concepts of QoL and UES has given a very complex insight into issues of as operationalization, conceptualization and quantification. The general focus of this study was put on the methodological design of a MCA fulfilling these demands and to provide first results of a practical implementation. The preceding chapters presented valuable and significant findings on housing development under the discussion of infill versus greenfield development and were embedded into a highly innovative MCA-approach piloting the case- study of the City of Essen. Accordingly, the presented MCA-scheme is to be understood as a valuable structure to assess both prerequisites and impacts of fostered infill development than a fixed tool. Still, tasks of further research are identified in order or optimize these findings, to integrate them into a self standing DSS and to translate them to a broader and more general understanding.

The presented *first* indicator-scheme of QoP-assessment was developed in a participative approach together with urban planners from different cities in North Rhine-Westphalia. Still, the integration of political aspirations towards settlement growth forming the determining variable and their translation into valuable indicators need to be strengthened henceforth. This gap needs to be bridged in further MCA-development to enhance a strategic and sustainable land management. In addition to that, we learnt that the socio-environmental QoP-assessment was not entirely unambiguous regarding a clear differentiation of greenfield from infill sites. This especially counts for the social dimension. Further research on QoP-assessment will therefore put a focus on selected additional indicators which can help to detect further significant differences of infill and greenfield site according to their socio-environmental character.

The presented *second* indicator-scheme of QoL and UES combining the two concepts is notably highly innovative in nature and presented an integrated approach of both. The indicators were elaborated according to empirical evidence and according to a possible undermining and quantification according to existing cadastral data and look-up tables derived from current scientific literature. Here, the demand for further field studies⁴⁶³, on-site analyses of locally provided UES and

⁴⁶³ Such as biotope mapping

modeling approaches⁴⁶⁴ of land use and land cover change is high. It enables an even more individual assessment of future housing sites and will be subject of further research. Moreover, the implemented look-up tables indicating the socio-ecological performances of cadastral land use data can be adjusted to local specifications and will improve the elaborated UES-indicators.

The effects of urban green and open spaces according to the presented recreational and regulative indicators are additionally affected by external conditions. According to the modelling approach of GILL ET AL. (2007, p. 129) green spaces for instance reduce surface runoff but this is still variable according to seasons. This track will be intensified within further research.

Not only is the calculation of an overall sealing rate but also the assessment of the quality of open spaces determining the used hydrological indicators of importance. During scenario calculation special contributions to an improvement of hydrological indicators by e.g. green roofs or distinct seeping constructions⁴⁶⁵ or rainwater management have not been taken into account and could necessarily be integrated in future assessment approaches.

According to BOLUND & HUNHAMMAR (1999) discussing locally generated and distant ecosystems being of different importance for QoL, further research on this topic will be inevitable to get a better insight into specific UES having a distinct influence on residents' QoL. Moreover, a questionnaire-driven approach of residents' QoL will not only highlight additional impacts but will also shed light on the meaning of UES for their individual QoL. Moreover, the integration of actors and stakeholders regarding questions of sustainable land and green management will be needed in order to elaborate individual drivers for altered land use patterns and pressures on socio-environmental systems. Open questions regarding the acceptance of infill development and the implementation of reduced land consumption will be answered. The strengthened integration of social findings and determinants into the research on UES and their responds to QoL is inevitable in order to "acknowledge that coupled human-natural systems require us to revise our disciplinary assumptions so we can study the complex interactions and subtle feedback of urban ecosystems."⁴⁶⁶

Additionally, further research will be on the question of the extend urban green itself or a specific green distribution provides a consolidation of numbers of residents or of single population groups as a continuous analysis of past and current building activities, the correlating residential structures and a varying green composition is not the focus of the presented work. As disaffection and a loss of population are – as QoL itself- determined by many objective and subjective factors, also the analysis is reduced to express findings of green composition being relevant for certain groups of population. A shift from the determinations of objective and physical conditions influencing QoL to a more subjective approach could give valuable answers on that. Also this demands additional questionnaire-related study on residents' QoL.

Finally, as UES and natural resources are under continuous pressure of varying land use demands within a city, their monetary valuation will need further research and concepts. The issues of

⁴⁶⁴ See here e.g. the integrated urban development and ecological simulation model UrbanSim model of ALBERTI & WADDELL 2000 or the approach of GILL ET AL. 2007

⁴⁶⁵ Compare GÖBEL ET AL. 2007

⁴⁶⁶ ALBERTI 2009, p. 10

valuation of Ecosystem Services have been long on the scientific agenda.⁴⁶⁷ But until now, no concise and practicable concepts could be developed. As this seems to be a very individual and stakeholder-dependent task, further concepts should focus on communicable and individually adjustable designs.

The presented MCA-scheme gave an essential insight into transferring ecological and social planner-oriented indicators into one approach in order to derive aggregated results of socio-environmental QoP of future housing sites assessing their suitability for further development. Moreover it integrates a scenario-based impacts assessment on UES and QoL as major drivers of urban development. In doing so, widely expressed concerns of scientists towards urban compaction could be dealt with and have been put into perspective. The search for the adequate built density which has gained ground in planning and research will endure. Still it is such a MCA-scheme which essentially contributes to that discussion and depicts the contrast between greenfield and infill development.

Conclusively, this work and its findings can only join the numerous advocates for a fostered infill development and presents distinct statements on the conditions determining its success both in ecological and social terms.

⁴⁶⁷ See first concepts of COSTANZA ET AL. 1997

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<http://www.un-documents.net/ocf-02.htm> (last check 19.12.09)

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Applied official data sources

Data	Source
Cadastral land use data/ Automatisierte Liegenschaftskarte (2007)	Office of Geoinformation, Measurement and Cadastre, City of Essen. <i>Amt für Geoinformation, Vermessung und Kataster der Stadt Essen</i>
Aerial photographs/ Luftbilder (2005)	From licence number 37/2008 with permission of the Office of Geoinformation, Measurement and Cadastre, City of Essen, 18.06.2008. Owner: GeoBasisNRW <i>Aus Lizenz Nr. 37/2008 mit Genehmigung vom Amt für Geoinformation, Vermessung und Kataster der Stadt Essen vom 18.06.2008.</i> <i>Dateneigentümer: GeoBasisNRW</i>
ATKIS®-Data/ ATKIS®-Daten (2007)	From licence number 84/2007 with permission of the Office of Geoinformation, Measurement and Cadastre, City of Essen, 19.01.2007. Owner: GeoBasisNRW <i>Aus Lizenz Nr. 84/2007 mit Genehmigung vom Amt für Geoinformation, Vermessung und Kataster der Stadt Essen vom 19.01.2007. Dateneigentümer: GeoBasisNRW</i>
Land Use Mapping/ Flächennutzungskartierung (2005)	© Regional Association Ruhr, Essen/ <i>©Regionalverband Ruhr, Essen</i>
Soil Map of North Rhine- Westphalia/ Bodenkarte NRW 1:50.000 (2006)	Geological Survey (© <i>Geowissenschaftliche Daten: Geologischer Dienst NRW, Krefeld, 136/2006</i>)
Linfos-Database/ Fachinformationssystem Linfos (2007)	State Office of the Environment, Landscape and Consumer Protection of NRW/ <i>Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)</i>
Digital Map of flood-affected areas/ Karte der hochwassergefährdeten Bereiche in NRW (2003)	State Office of the Environment, Landscape and Consumer Protection of NRW/ <i>Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)</i>
Noise-screening NRW/ Geräuschscreening NRW (2002)	State Office of the Environment, Landscape and Consumer Protection of NRW/ <i>Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)</i>
Cadastre of suspected contaminations/ Altlastenverdachtskataster (2007)	Environmental Agency of the City of Essen/ <i>Umweltamt der Stadt Essen</i>
Climate Analysis/ Klimaanalyse Stadt Essen (2002)	Kommunalverband Ruhrgebiet und Roßmann & Koch GbR. Hrsg. Stadt Essen Umweltamt 2002/ <i>Environmental Agency of the City of Essen 2002(ed.)</i>
Demographical data on number and age per resident per district/ Demographische Daten (2007)	Office of Statistics, Urban research and Elections of the City of Essen/ <i>Amt für Statistik, Stadtforschung und Wahlen der Stadt Essen</i>

Glossary

acc.	accepted
ALK	Automatisierte Liegenschaftskarte/ cadastral land use
a.o.	among others
ASP	Amt für Stadtplanung
ATKIS	ATKIS® Amtliches Topographisch-Kartographisches Informationssystem
BauGB	Baugesetzbuch/ Federal Building Code
BK	Bodenkarte / soil map
BBR	Bundesamt für Bauwesen und Raumordnung/ Federal Office for Building and Regional Planning
BMVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung/ Federal Ministry of Transport, Building and Urban Development
ch.	chapter
cit.	citing
cm	centimeter
CTV	
d	day
DIFU	Deutsches Institut für Urbanistik/German Institute of Urban Affairs
DIN	Deutsche Industrienorm/ German Industrial Standard
DSS	Decision Support System
dt.	Deutsch/ German
EEA	European Environment Agency
e.g.	for example
ESF	Ecosystem Function
ESS	Ecosystem Services
et al.	et alii
f.	following

Annex

Fig.	Figure
GIS	Geographic Information Systems
ha	hectare
HQ100	Centennial Flooding Area
IA	Impact Assessment
LANUV	Landesamt für Natur, Umwelt und Verbraucherschutz NRW/ State Office of the Environment, Landscape and Consumer Protection of North Rhine-Westphalia
MCA	Multicriteria Assessment
MEA	Millennium Ecosystem Assessment
min.	minimum
MS	Microsoft
no	number
NRW	North Rhine-Westphalia
p.	page
QoL	Quality of Life
QoP	Quality of Place
RAK	Regional working group of development, planning and transport Bonn / Rhein-Sieg / Ahrweiler/ Regionale Arbeitskreis Entwicklung, Planung und Verkehr Bonn / Rhein-Sieg / Ahrweiler
REFINA	Reduzierte Flächeninanspruchnahme/ reduce land consumption (BMBF-research initiative)
RFNP	Regionaler Flächennutzungsplan/ regional land use plan
RVR	Regionalverband Ruhr/ Regional Association Ruhr
tab.	table
UES	Urban Ecosystem Services
URGE	Urban Green Environment
VB	Visual Basic
VöV	Verband öffentlicher Verkehr/ Association of public transport

Definitions

Ecosystem Function: “Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems.” (COSTANZA ET AL. 1997, p. 253). “...ecosystem functions are defined as the capacity of natural processes and components to provide goods and services” (DE GROOT ET AL. 2003, p. 190)

Ecosystem Service: “Ecosystem [...] services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions.” (COSTANZA ET AL. 1997, p. 253).

Housing Site: Within this work the term housing site is described by the German term “Wohnbaufläche” and describes an area of gross building land for housing development displayed in a land use plan.

Land use class: Within this work the term land use class is bound to either cadastral land use classes as defined in layer 21 of the ALK (Automatisierte Liegenschaftskarte) providing actual land use or the land use mapping deriving from the Regional Association Ruhr (RVR 2005). Land use classes as defined in both data sets comprise both built and open spaces within a class.

Land use plan: Instrument of preparatory German land use planning. It contains general planning objectives and proposals for a commune and is elaborated at a scale of 5.000 – 15.000. A special type is the regional land use plan. It covers more than one commune and enhances the regional cooperation between communes.

Green Space: This study follows the definition of green spaces according to JAMES ET AL. (2009, p. 66) describing it as consisting of “predominantly unsealed, permeable, soft surfaces such as grass, soil, shrubs, trees I...I“. Differing to JAMES ET AL (2009), the component “water” will not be taken into account.

Need: Following MATSOUKA & KAPLAN (2008) need indicate how humans interact with outdoor urban environments and distinguish between nature needs and social interaction needs. Nature needs refer “to the wide range of ways in which human needs or purposes are met by the natural environment” (p. 9). Social interaction needs “focus on human interaction promoted by the environment” (p. 12).

Sustainability: According to the BRUNDTLAND-REPORT, sustainability “[...]meets the needs of the present without compromising the ability of future generations to meet their own needs”. (<http://www.un-documents.net/ocf-02.htm>)

Annex

Annex

Annex A

Table a1 Housing sites and detailed information on legal state and measurements of settlement-development

District	Housing site	Name Buffer	Number of aspired apartments	Size [ha]	Potential within RFNP-draft (status 2008)	Develop-ment status	Re-use	Display with RFNP-draft (status 2008)	Comment
Nordviertel	Bottroper Str. / Grillostr.	Thurmfeld	100 (Single family homes)	8.6	Preparatory	Infill	Yes	Housing Area	Current competition
Rütten-scheid	Henri-Dunant-Str.	Alfredstr./ Wittekindstr./ Henri- Dunant-Str.	70 (Single family homes)	3.2		Infill	Yes	Housing Area	Covered with houses until 2010, no RFNP-potential any more, competition)
Rütten-scheid	Wittekindstr.	Alfredstr./ Wittekindstr./ Henri- Dunant-Str.	400 (Multi Storey Houses)	6.0	Binding	Infill	Yes	Common Use	According to Thyssen Krupp Expansion of "Krankenanstalten"
Rütten-scheid	Alfredstr. / Moritzstr. (comprising 2 parts > A & B)	Alfredstr./ Wittekindstr./ Henri- Dunant-Str.	200 (Multi Storey Houses)	1.8		Infill	Yes	Housing Area	Covered with houses until 2010, no RFNP-potential any more
Fulerum	Östlich Humboldtstrasse	Auf'm Gartenstück/ Östl. Humboldtstr.	90 (Single Family Homes)	3.9	Preparatory	Green-field	No	Housing Area	Reserve for housing purposes according to "Gesamtkonzept Haarzopf/ Fulerum)
Haarzopf	Auf'm Gartenstück / Haarscheidweg	Auf'm Gartenstück/ Östl. Humboldtstr.	90 (Single Family Homes)	4.1	Preparatory	Green-field	No	Housing Area	Reserve for housing purposes according to "Gesamtkonzept Haarzopf/ Fulerum)

Table a1 Housing sites and detailed information on legal state and measurements of settlement development

District	Housing site	Name Buffer	Number of aspired apartments	Size [ha]	Potential within RFNP-draft (status 2008)	Development status	Re-use	Display with RFNP-draft (status 2008)	Comment
Altendorf	Buschhauser Str. / Sterkrader Str.	Buschhauser Str.	110 (Single Family Homes)	4.47	Preparatory	Infill	Yes	Housing Area	Brownfield within "Krupp-Gürtel"
Bochold	Kesselstr.	Kesselstr.	66 (Single Family Homes)	2.59	Preparatory	Infill	Partially	Housing Area	Planned development of a currently used area for gardening purposes
Altenessen-Süd	Altenessener Str. / Kaiser-Wilhelm-Park	Palmbuschweg/Altenessener Str.	60 (Single Family Homes)	1.64	Binding	Infill	Yes	Housing Area	Binding land use plan 3ha, displayed as gap between buildings, no RFNP-potential any more
Altenessen-Süd	Palmbuschweg / Milchhof	Palmbuschweg/Altenessener Str.	140 Single Family Homes & Multi Storey Houses	3.15	Preparatory	Infill	Yes	Housing Area	Housing area of former industrial premise incl. nursing home
Stoppenberg	Im Natt	Im Natt	80 (Single Family Homes)	3.8	Preparatory	Greenfield	No	Housing Area	Planned development of a succession area in ex-change with neighboring area

Table a1 Housing sites and detailed information on legal state and measurements of settlement-development

District	Housing site	Name Buffer	Number of aspired apartments	Size [ha]	Potential within RFNP-draft (status 2008)	Develop-ment status	Re-use	Display with RFNP-draft (status 2008)	Comment
Katernberg	Röckenstr. / Bonnekampstr.	Zollverein/ Röckenstrasse	50 (Single Family Homes)	1.96		Green-field	No	Housing Area	Covered with houses until 2010, no RFNP-potential any more
Katernberg	Zollverein X (comprising 4 parts > a, b, c and d)	Zollverein/ Röckenstrasse	70 (Single Family Homes)	2.94	Binding	Infill	Partially	Housing Area	Re-densification
Horst	Breloher Steig (North)	Breloher Steig (North/South)	130 (Single Family Homes)	6.1	Preparatory	Infill	Yes	Housing Area	Housing area according to "Strukturkonzept Horst", currently partial commercial use
Horst	Breloher Steig (South)	Breloher Steig (North/South)	170 (Single Family Homes)	3.7		Infill	Yes	Housing Area	Development of binding land use plan, Covered with buildings until 2010, former commercial use
Byfang	Settlement Expansion Byfang (comprising 4 parts > a, b, c and d)	Settlement Expansion Byfang	60 (Single Family Homes)	7.24	Preparatory	Green-field	No	Housing Area	Housing area according to "Strukturkonzept Byfang", not in accordance to final version of the RFNP

Table a1 Housing sites and detailed information on legal state and measurements of settlement-development

District	Housing site	Name Buffer	Number of aspired apartments	Size [ha]	Potential within RFNP-draft (status 2008)	Development status	Re-use	Display with RFNP-draft (status 2008)	Comment
Heisingen	Duvenkamp / Hemsingskotten	Duvenkamp/Hemsingkotten	60 (Single Family Homes)	3.27	Binding	Infill	Partially	Housing Area	Current real estate management
Heidhausen	Barkhovenallee / Jacobsallee (comprising 2 parts > a, b)	Grüne Harfe/Barkhovenallee	45 (Single Family Homes)	1.97	Preparatory	Greenfield	No	Housing Area	Partially farmland or greenland
Heidhausen	Grüne Harfe	Grüne Harfe/Barkhovenallee	200 (Single Family Homes)	8.15	Preparatory	Greenfield	No	Housing Area	Partially farmland
Heidhausen	Honnschaftenstr. / Friedrich-Küpper-Weg	Grüne Harfe/Barkhovenallee	Undefined (Single Family Homes)	1.46		Infill	Partially	Housing Area	Developed, no RFNP-potential
Kettwig	Ringstr. / Bachstr.	Ringstr./Promenadenweg	140 (Multi Storey houses)	5.51	Preparatory	Infill	Yes	Housing Area	Partial commercial use,
Kettwig	Promenadenweg / Güterstr.	Ringstr./Promenadenweg	130 (Single Family Homes)	5.40		Infill	Yes	Housing Area	developed until 2010, no RFNP-potential

Table a1 Housing sites and detailed information on legal state and measurements of settlement-development

District	Housing site	Name Buffer	Number of aspired apartments	Size [ha]	Potential within RFNP-draft (status 2008)	Development status	Re-use	Display with RFNP-draft (status 2008)	Comment
Kettwig	Schmachtenbergstr.	Schmachtenbergstr.	53 (Single Family Homes)	2.4	Preparatory	Green-field	No	Housing Area	Partially farmland

Table a2 Step1: Indicator set assessing Quality of Place

Quality of Place	Indicator	Dataset	Source	Character/ Scale	Units	Increment Values/ Suitability	Formula
Ecological	Climate Regulation	Cadastral Data (Automatisierte Liegenschaftskarte) (2007)	Provided by: Office of Geoinformation , Measurement and Cadastre, City of Essen/ Amt für Geoinformation , Vermessung und Kataster der Stadt Essen	quantitative/ ordinal	none	<p>1=(site suitable): 0-2 = low performance 2=(site partially suitable): 0-3 = medium performance 3=(unsuitable): 3-4= high performance</p> <p><i>Own classification referring to the approach of Singer 1995</i></p>	$R_{sqr} = \sum_{sqr} \frac{S_{lu_cd_sqr}}{100\%} * AR_{lu_cd}$ <p>sqr= related to 500x500 raster cell lu= land use class cd= cadastral s= share [%] A = attribute R= Climate Regulation</p>
	Biotope Quality	Cadastral Data (Automatisierte Liegenschaftskarte) (2007)	Provided by: Office of Geoinformation , Measurement and Cadastre, City of Essen/ Amt für Geoinformation , Vermessung und Kataster der Stadt Essen	quantitative/ ordinal	none	<p>1=(site suitable): 0-2 = low performance 2=(site partially suitable): 0-3 = medium performance 3=(unsuitable): 3-4= high performance</p> <p><i>Own classification referring to the approach of Singer 1995</i></p>	$B_{sqr} = \sum_b \frac{S_{lu_cd_sqr}}{100\%} * ABQ_{lu_cd}$ <p>sqr= related to 500x500 raster cell lu= land use class cd= cadastral s= share [%] A = attribute BQ= Biotope Quality</p>
	Seepage	Soil Map of North Rhine-Westphalia/ Bodenkarte NRW 1:50.000 (2006)	Geological Survey NRW (© Geowissenschaftliche Daten: Geologischer Dienst NRW, Krefeld, 136/2006)	quantitative/ ordinal	cm/d	<p>1=(site suitable):> 100cm/d= high performance 2=(site partially suitable):40-100 cm/d, medium performance 3=(unsuitable):< 40 cm/d =low performance</p> <p><i>Own classification referring to DIN 18130</i></p>	
	Isolation/ use of biotope structures	Linfos-database/ Fachinformationssystem Linfos (2007)	Provided by: State Office of the Environment, Landscape and Consumer Protection of NRW/ Landesamt für Natur, Umwelt und Verbrauchers	qualitative	none	<p>1=(site suitable): site not located within biotope structures 2=(site partially suitable): site partially located within biotope structures 3=(unsuitable): site located within biotope structures</p> <p><i>Own classification</i></p>	

Table a2 Step1: Indicator set assessing Quality of Place

Quality of Place	Indicator	Dataset	Source	Character/ Scale	Units	Increment Values/ Suitability	Formula
			chutz Nordrhein-Westfalen (LANUV)				
	Sealing Rate	Cadastral Data (Automatisierte Liegenschaftskarte) (2007)	Provided by: Office of Geoinformation, Measurement and Cadastre, City of Essen/ Amt für Geoinformation, Vermessung und Kataster der Stadt Essen	quantitative/ ordinal	%	<p>1=(site suitable): sealing rate below 80%</p> <p>2=(site partially suitable): sealing rate partially above 80 %</p> <p>3=(unsuitable): sealing rate above 80%</p> <p><i>Own classification referring City of Essen 2002</i></p>	$S_{sqr} = \sum_b \frac{S_{lu_cd_sqr}}{100\%} * A S_{lu_cd}$ <p>sqr= related to 500x500 raster cell lu= land use class cd= cadastral s= share [%] A = attribute S=Sealing Rate</p>
	Protected Areas	Linfos-database/ Fachinformationssystem Linfos (2007)	State Office of the Environment, Landscape and Consumer Protection of NRW (LANUV)/ Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)	qualitative	none	<p>1=(site suitable): site not located within protection areas or buffers</p> <p>2=(site partially suitable): site partially located within protection areas or 250m-buffer or entirely within 500m-buffer</p> <p>3=(unsuitable): site located within protection area or 250m-buffer</p> <p><i>Own classification referring to the approach of GENELETTI ET AL. 2007</i></p>	
	Soil Quality/ Yield stability	Soil Map of North Rhine-Westphalia/ Bodenkarte NRW 1:50.000 (2006)	Geological Survey NRW (© Geowissenschaftliche Daten: Geologischer Dienst NRW, Krefeld, 136/2006)	quantitative	“Bodenwertzahl” (0-100)	<p>1=(site suitable): soil quality < 55</p> <p>2=(site partially suitable): soil quality 55 up to 75</p> <p>3=(unsuitable): soil quality > 75</p> <p><i>Own classification referring to “Bodenkundliche Kartieranleitung” (AG BODEN 1994)</i></p>	

Table a2 Step1: Indicator set assessing Quality of Place

Quality of Place	Indicator	Dataset	Source	Character/ Scale	Units	Increment Values/ Suitability	Formula
	Flood risk	Digital map of flood-affected areas ("Hochwassergefährdete Bereiche in NRW") (2003)	State Office of the Environment, Landscape and Consumer Protection of NRW/ Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)	qualitative	none	<p>1=(site suitable): location of site outside flood areas</p> <p>2=(site partially suitable): location of site partially within flood areas</p> <p>3=(unsuitable): location of site within flood areas</p> <p><i>Own classification</i></p>	
Social	Playgrounds	Cadastral playground-database (City of Essen 2004),	City of Essen, Grün und Gruga (Department of Green Management)	quantitative	m (including a walking distance coefficient of 1,2)	<p>1=(site suitable): location within 750m-buffer</p> <p>2=(site partially suitable): location of site partially outside 750m- buffer</p> <p>3=(unsuitable): location of site outside 750m-buffer</p> <p><i>Own classification referring to DIN 18034, Krappweis, City of Fellbach 2008</i></p>	
	Local supply	"Masterplan Einzelhandel" City of Essen (2006)	City of Essen, Department 61	quantitative	m (including a walking distance coefficient of 1,2)	<p>1=(site suitable): location within 500m-buffer</p> <p>2=(site partially suitable): location of site partially outside 500m- buffer</p> <p>3=(unsuitable): location of site outside 500m-buffer</p> <p><i>Own classification referring to Masterplan of City of Essen 2006</i></p>	
	Primary Schools	Concept of educational development (City of Essen, 2000/2001) and document 0423 (2. Step of primary-school concept 2006)	City of Essen	quantitative	m (including a walking distance	<p>1=(site suitable): location within 2000m-buffer</p> <p>2=(site partially suitable): location of site partially outside 2000m- buffer</p> <p>3=(unsuitable): location of site outside 2000m- buffer</p>	

Table a2 Step1: Indicator set assessing Quality of Place

Quality of Place	Indicator	Dataset	Source	Character/ Scale	Units	Increment Values/ Suitability	Formula
					e coefficient of 1,2)	<i>Own classification referring to the decree of travel costs for pupils of NRW(2009)</i>	
	Kindergartens	Cadastral Data/ Automatisierte Liegenschaftskarte (2007) & Supply-information (www.essen.de/kitas)	Provided by: Office of Geoinformation , Measurement and Cadastre, City of Essen/ Amt für Geoinformation , Vermessung und Kataster der Stadt Essen	quantitative/ ordinal	m (including a walking – distance coefficient of 1,2)	1=(site suitable): location within 500m- buffer 2=(site partially suitable): location of site partially outside 500m- buffer 3=(unsuitable): location of site outside 500m- buffer <i>Own classification referring to the approach of Schöning & Borchard, 1992</i>	
	Distance to Public Transport	Public Transport Survey (City of Essen, www.essen.de)	City of Essen	quantitative	m (including a walking – distance coefficient of 1,2)	<i>Bus</i> 1=(site suitable): location within 300m- buffer 2=(site partially suitable): location of site partially outside 300m- buffer 3=(unsuitable): location of site outside 300m- buffer <i>Subway</i> 1=(site suitable): location within 1000m- buffer 2=(site partially suitable): location of site partially outside 1000m- buffer 3=(unsuitable): location of site outside 1000m- buffer <i>Train</i> 1=(site suitable): location within 2000m- buffer 2=(site partially suitable): location of site partially outside 2000m- buffer 3=(unsuitable): location of site outside 2000m- buffer <i>Own classification referring to the approach of Schöning & Borchard, 1992, VöV 1981, RAK 2009</i>	

Table a2 Step1: Indicator set assessing Quality of Place

Quality of Place	Indicator	Dataset	Source	Character/ Scale	Units	Increment Values/ Suitability	Formula
	Noise	Noise screening/ Geräuschscreening NRW (2002)	State Office of the Environment, Landscape and Consumer Protection of NRW/ Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV)		Decibel (dB)	<p><i>Daytime</i></p> <p>1=(site suitable): noise level <= 60 dB 2=(site partially suitable): noise level partially > 60 dB 3=(unsuitable): noise level > 60 dB</p> <p><i>Nighttime</i></p> <p>1=(site suitable): noise level <= 45dB 2=(site partially suitable): noise level partially >45dB 3=(unsuitable): noise level > 45dB</p> <p><i>Own classification referring to the „Technische Anleitung zum Schutz gegen Lärm“ (1998)</i></p>	
	Distance to recreational areas	Cadastral Data/ Automatisierte Liegenschaftskarte (2007)	Provided by: Office of Geoinformation, Measurement and Cadastre, City of Essen/ Amt für Geoinformation, Vermessung und Kataster der Stadt Essen	quantitative	m (including a walking distance coefficient of 1,2)	<p>1=(site suitable): location within 500m-buffer and size of >0,5ha 2=(site partially suitable): location of site partially outside 500m- buffer and size of > 0,5ha 3=(unsuitable): location of site outside 500m-buffer and size of > 0,5ha</p> <p><i>Own classification referring to City of Leipzig (2004)</i></p>	
	Suspected contamination	Cadastral data of suspected contaminations (2007)	City of Essen, Environmental Agency/ Umweltamt der Stadt Essen	qualitative	none	<p>1=(site suitable): site located outside contaminated area 2=(site partially suitable): site located partially within contaminated area 3=(unsuitable): site located within contaminated areas</p> <p><i>Own classification</i></p>	

Tab. a3 Concept of QoL-determinants and associated UES according to SCHETKE ET AL.*

Concept of “Quality of Life” - determinants (e.g. PRIEGO ET AL 2008, BURGESS ET AL. 1988; MEA 2003, 2005, URGE-research team 2001- 2004)	Associated Ecosystem Services (COSTANZA ET AL., 1997, DE GROOT ET AL., 2002, CHAN ET AL., 2006, NORBERG, 1999)	Social functions, amenities, values (SCHETKE ET AL.*, MEA 2003, 2005; DE GROOT ET AL. 2002 ; URGE-RESEARCH TEAM 2001-2004)	Ecosystem Functions (definition see COSTANZA ET AL., 1997, DE GROOT ET AL. 2002, CHAN ET AL. 2006, NORBERG 1999)	Indicators (adopted from SCHETKE & HAASE 2008; PRIEGO ET AL. 2008; URGE-RESEARCH TEAM 2001-2004; CHAN ET AL. 2006)	Level of noticeable impact (spatial scale)	Qualitative or quantitative (method of assessment)	Shrinkage + function fulfillment increases - function fulfillment decreases	Growth + function fulfillment increases - function fulfillment decreases
Recreation	Recreation	Compensation of lack of private green	Soften and buffer the built environment (Providing opportunities for recreation)	Quant: LAI, amount of natural and semi-natural habitats	local	qualitative/ quantitative	+/-	-
		Executing leisure activities	Providing opportunities for recreation	Quant: Size of green spaces within different distances to apartment, total size of green per resident	Local, relation to green structural types relevant for recreation	quantitative	+	-
	Refugio	Feeling of naturalness, recreation, Accessibility	Habitat for resident and transient population	Quant: Distance between green spaces, isolation, LAI, amount of natural and semi-natural habitats	local	quantitative	+	-
		Privacy	Naturalness, carrying capacity	Quant: Capacity of green space , green space per resident	local	quantitative	+	-
Regulation and Environmental Health	Water regulation	Feeling of naturalness, temperature regulation	Seeping rate, surface runoff, evapotranspiration	Quant: Sealing rate (+ seeping rate, surface runoff, evapotranspiration)	Local/ general	quantitative	+	-
	Refugio	Feeling of naturalness, anthropogenic influence	Habitat function of soil	Quant: Sealing rate	Local/ general	quantitative	+	-
	Noise reduction	Recreation, comfort	Regulative function	Quant: LAI, isolation/ connectedness	Local/ general	quantitative	+/-	-
	Reduction of pollutants	Recreation, comfort, personal health	Provision of healthy living conditions	Quant: LAI, isolation/ connectedness, share of green areas/ total area	Local/ general	quantitative/ qualitative	+/-	-

Tab. a3 Concept of QoL-determinants and associated UES according to SCHETKE ET AL.*

Concept of “Quality of Life” - determinants (e.g. PRIEGO ET AL 2008, BURGESS ET AL. 1988; MEA 2003, 2005, URGE-research team 2001- 2004)	Associated Ecosystem Services (COSTANZA ET AL., 1997, DE GROOT ET AL., 2002, CHAN ET AL., 2006, NORBERG, 1999)	Social functions, amenities, values (SCHETKE ET AL.*, MEA 2003, 2005; DE GROOT ET AL. 2002 ; URGE-RESEARCH TEAM 2001-2004)	Ecosystem Functions (definition see COSTANZA ET AL., 1997, DE GROOT ET AL. 2002, CHAN ET AL. 2006, NORBERG 1999)	Indicators (adopted from SCHETKE & HAASE 2008; PRIEGO ET AL. 2008; URGE-RESEARCH TEAM 2001-2004; CHAN ET AL. 2006)	Level of noticeable impact (spatial scale)	Qualitative or quantitative (method of assessment)	Shrinkage + function fulfillment increases - function fulfillment decreases	Growth + function fulfillment increases - function fulfillment decreases
	Habitat	Feeling of naturalness/heterogeneous green spaces	Species richness	Quant: LAI, SHDI Qual: meaning of nature	Local, dependent on single green structure types	quantitative/ qualitative	+/-	-
	Climate regulation	Feeling of naturalness, comfort	Provision of favorable living conditions	Quant: LAI, size of green space, isolation of green spaces (stepping stones)	local	quantitative	+/-	-
Social Cohesion, Community and local identity	Cultural values, spiritual and historic information	Privacy, Identity, psychological benefits	Consolidation of a community Compensation of lack of private green in poorer areas	Quant: Size of green spaces within different distances to apartment Qual: daily recreational needs, free time activities, age, employment situation, level of education	local	quantitative, qualitative	-	+/-
	Impact on local societies, information function	Interaction of different social groups, civic participation, attractiveness of a place	Provision of meeting facilities, design of the public domain	Quant: LAI, green inventory Qual.: meaning of nature, protection of nature, investment in nature, participation in protecting nature	Local	quantitative, qualitative	+/-	-
	Habitat, species richness	Community/ acquaintance (ethnic)	Sensibility, memories	Qual: valuation of green spaces, perception, duration of occupancy there	Local, related to single green structure types	qualitative	+/-	-

Table a4: Step2: Formulas of Indicators on QoL & UFS

Indicator	Formula	Formula Symbol	Indices	Units
Climate Regulation	<p>A</p> $R_b = \sum_b \frac{S_{lu_cd,b}}{100\%} * AR_{lu_cd}$	<p>R = Climate Regulation s = share (%) AR = Attributes Climate Regulation according to SINGER 1995</p>	<p>b = referring to buffer-extends lu= land use class cd = cadastral data (ALK)</p>	None
Biotope Quality	<p>A1</p> $Bq_b = \sum_b \frac{S_{lu_cd,b}}{100\%} * ABq_{lu_cd}$	<p>Bq = Biotope Quality s = share (%) ABq = Attributes Biotope Quality according to SINGER 1995</p>	<p>b = referring to buffer-extends lu= land use class cd = cadastral data (ALK)</p>	none
Sealing Rate	<p>B</p> $S_b = \sum_b \frac{S_{lu_cd,b}}{100\%} * AS_{lu_cd}$	<p>S = Sealing Rate s = share (%) AS = Attributes Sealing Rate according to SINGER 1995</p>	<p>b = referring to buffer-extends lu= land use class cd = cadastral data (ALK)</p>	%
Seeping Rate, Surface-Runoff, Evapotranspiration	<p>C</p> $Sp_b = \sum_b \frac{S_{lu_RNK,b}}{100\%} * ASP_{lu_RNK}$ $Sr_b = \sum_b \frac{S_{lu_RNK,b}}{100\%} * ASr_{lu_RNK}$ $Etp_b = \sum_b \frac{S_{lu_RNK,b}}{100\%} * AETp_{lu_RNK}$ <p>D</p> $stSp_i = \mu_{i(n=10)} \left(\sum_s \frac{S_{lu_RNK_s}}{100\%} * ASP_{lu_RNK} \right)$ $stSr_i = \mu_{i(n=10)} \left(\sum_s \frac{S_{lu_RNK_s}}{100\%} * ASr_{lu_RNK} \right)$ $stEtp_i = \mu_{i(n=10)} \left(\sum_s \frac{S_{lu_RNK_s}}{100\%} * AETp_{lu_RNK} \right)$	<p>Sp = Seeping Rate (% of precipitation) Sr = Surface Runoff (% of precipitation) Etp = Evapotranspiration (% of precipitation) s = share (%) ASp, ASr, AETp = Attributes Seeping Rate, Surface Runoff, Evapotranspiration according to UMWELTATLAS BERLIN (2007) stSp, stASp, stEtp = standard values of seeping rate, surface runoff, evapotranspiration according to housing type, $\mu_{i(n=10)}$ = average of individual weighted mean reference values of each reference site (n=10)</p>	<p>b = referring to buffer-extends lu_RNK= land use class of land use mapping of RVR (<i>RNK=Realnutzungskartierung</i>) i = housing type lu_RNK_site = hydrological attributes based on standard-calculation according to RNK-classification at test sites (see 10 test sites for each housing type) s = site</p>	% of precipitation

Table a4: Step2: Formulas of indicators on QoL & UES

Indicator	Formula	Formula Symbol	Indices	Units
Total, Public and private green provision per resident	<p>E</p> $Re_{b,sq} = F_{cb,b} / \left(\frac{F_{cb,dr}}{Re_{dr}} \right)$ <p>E1</p> $st_s_prg_i[\%] = \mu_{i(n=10)}(s_{s,pgreen_{gbl_i}})[\%]$ <p>E2_1</p> $plg_{b,scen} [m^2] = plg_{b,sq} [m^2] - gbl [m^2]$ <p>E2_2</p> $prg_{b,scen} [m^2] = prg_{b,sq} [m^2] + ((st_s_prg_i[\%] * gbl [m^2])/100\%)$ <p>F</p> $Re_{b,scen} = Re_{b,sq} + gbl * hd_i * oc$ <p>F1_1</p> $plg_{b,sq}/Re_{b,sq} [m^2] = plg_{b,sq}/Re_{b,sq}$ <p>F1_2</p> $prg_{b,sq}/Re_{b,sq} [m^2] = prg_{b,sq}/Re_{b,sq}$ <p>F2_1</p> $plg_{b,scen}/Re_{b,scen} [m^2] = plg_{b,scen}/Re_{b,scen}$ <p>F2_2</p> $prg_{b,scen}/Re_{b,scen} [m^2] = prg_{b,scen}/Re_{b,scen}$	<p>Re = Residents</p> <p>F = building area (m²)</p> <p>st_s_prg= standard of private green share per housing type [%]</p> <p>μ = average of individual shares of private green per gross building land of each reference site (n=10)</p> <p>s= share [%]</p> <p>gbl = gross building land (m²)</p> <p>plg = share of public green [m²]</p> <p>prg =share of private green [m²]</p> <p>hd = housing density (apartments/ ha) (see fig.20)</p> <p>oc = occupancy rate (residents/ apartment) =1.94</p>	<p>sq = status quo</p> <p>cb = deriving from cadastral data</p> <p>dr = individual district reference</p> <p>i = housing type</p> <p>pgreen_i= private green per housing type</p> <p>green_gbl_i(n=10) =private green per gross building land according to housing type (n=10)</p> <p>scen = scenarios 1-3</p> <p>s =site</p> <p>b = referring to buffer-extends</p>	m ² /resident

Table a4: Step2: Formulas of indicators on QoL & UES

Indicator	Formula	Formula Symbol	Indices	Units
Ratio Private / Public Green	<p>F3</p> $r = s_{pg,sq,scen} [m^2] / s_{plg,sq,scen} [m^2]$	<p>R = ratio S= share [m²]</p>	<p>pg = private green plg= public green scen = scenarios 1-3 sq = status quo</p>	none
Park Area/ Resident	<p>G</p> $Re_{b,sq} = F_{cb,b} / \left(\frac{F_{cb,dr}}{Re_{dr}} \right)$ <p>H</p> $Re_{b,scen} = Re_{b,sq} + gbl * hd_i * oc$ <p>I</p> $pa_{b,sq} = \frac{pa_b}{Re_{b,sq}} [m^2]$ <p>J</p> $pa_{b,scen} = \frac{pa_b}{Re_{b,scen}} [m^2]$	<p>Re = Residents F = building area (m²) gbl = gross building land (ha) hd = housing density (apartments/ ha) (see fig.20) oc = occupancy rate (residents/ apartment) =1.94 pa = park area [m²]</p>	<p>sq = status quo cb = deriving from cadastral data referring to buffer extensions dr = individual district reference i = housing type b = referring to buffer extends</p>	m ² /residen t

Table a5 Standard values assigned to each housing site according to scenarios for IA on QoL and UES

Indicators	Housing Types	Scenario 1	Scenario 2	Scenario 3	Source	Value Width/ Unit	Spatial Reference
Climate Regulation	Single Family Homes	2	2	1	Singer (1995)	0 = very low performance 4 = very high performance	ALK (sheet 21 = land use classification of single lots)
	Multistory Houses	1	1	1	s.a.	s.a.	s.a.
Biotope Quality	Single Family Homes	2	2	1	Singer (1995)	0 = very low performance 4 = very high performance	s.a.
	Multistory Houses	1	1	1	s.a.	s.a.	s.a.
Sealing Rate	Single Family Homes	40	45	55	Singer (1995)	%	s.a.
	Multistory Houses	55	55	70	s.a.	%	s.a.
Seeping Rate	Single Family Homes (north/south)	33.63/34.68	32.92/33.22	34.60/35.02	Berliner Umweltatlas & standard calculations (see tab. a4)	% of precipitation	Land use mapping of Regional Association Ruhr (RVR)
	Multistory Houses	33.08	23.98	22.93	s.a.	% of precipitation	Land use mapping of Regional Association Ruhr (RVR)
Surface Run-off	Single Family Homes (north/south)	15.01/14.12	12.61/13.94	16.48/15.70	s.a.	% of precipitation	Land use mapping of Regional Association Ruhr (RVR)
	Multistory Houses	18.50	37.97	41.35	s.a.	% of precipitation	Land use mapping of Regional Association Ruhr (RVR)
Evapotranspiration	Single Family Homes (north/south)	51.80/51.72	54.74/53.17	49.63/49.87	s.a.	% of precipitation	Land use mapping of Regional Association Ruhr (RVR)
	Multistory Houses	48.84	38.77	36.39	s.a.	% of precipitation	Land use mapping of Regional Association Ruhr (RVR)
Private Green <small>(no differentiation to public green executed as an increase of public green cannot be estimated; it is assumed that only private green increases)</small>	Single Family Homes (north/south)	63.62/70.10	66.24/67.65	53.48/53.82	Green mapping (compare ch. 3.3.2.3.1. & standard calculation, compare tab. A4)	% of gross building land	Land use mapping of Regional Association Ruhr (RVR) & ALK (sheet 21 = land use classification of single lots)

Continuation of Table a5

Indicators	Housing Types	Scenario 1	Scenario 2	Scenario 3	Source	Value Width/ Unit	Spatial Reference
	Multistorey Houses	60.13	55.49	32.57	s.a.	% of gross building land	Land use mapping of Regional Association Ruhr (RVR) & ALK (sheet 21 = land use classification of single lots)
Public Green	Single Family Homes	0	0	0	s.a.	% of gross building land	Land use mapping of Regional Association Ruhr (RVR) & ALK (sheet 21 = land use classification of single lots)
	Multistorey Houses	0	0	0	s.a.	% of gross building land	Land use mapping of Regional Association Ruhr (RVR) & ALK (sheet 21 = land use classification of single lots)
Ratio Private Green / Public Green	Single Family Homes	Individually calculated	Individually calculated	Individually calculated	s.a.		Land use mapping of Regional Association Ruhr (RVR) & ALK (sheet 21 = land use classification of single lots)
	Multistorey Houses	Individually calculated	Individually calculated	Individually calculated	s.a.		Land use mapping of Regional Association Ruhr (RVR) & ALK (sheet 21 = land use classification of single lots)
Park Area/ resident (no additional public park assumed within scenarios)	Single Family Homes	0	0	0	s.a.		ALK (sheet 21 = land use classification of single lots)

Indicators	Housing Types	Scenario 1	Scenario 2	Scenario 3	Source	Value Width/ Unit	Spatial Reference
	Multistory Houses	0	0	0	s.a.		ALK (sheet 21 = land use classification of single lots)

Table a5a Equations of demographic characteristics

Youth Rate	YouthRate _{dr} = $\frac{\sum > 65 \text{ years}}{\sum > 18 < 65}$ dr= district
Elderly Rate	ElderlyRate _{dr} = $\frac{\sum < 18 \text{ years}}{\sum > 18 < 65 \text{ years}}$ dr= district

Table a6 Performance of QoL/UES indicators assessing recreational benefits of urban green (Source: Schetke 2009)

	Climate Regulation	Deviation from status quo (%)	Biotope Quality	Deviation from status quo (%)
CTV_{City}	2.14		1.65	
(I) Palmbuschweg/Altenessener Str.				
CTV _{neighborhood(1000m)}	1.79		1.43	
Status Quo	1.80	0.00	1.46	0.00
Scenario 1	1.83	1.86	1.50	2.71
Scenario 2	1.80	0.02	1.47	0.44
Scenario 3	1.79	-0.66	1.45	-0.40
(I) Kesselstr.				
CTV _{neighborhood(1000m)}	1.55		1.30	
Status Quo	1.66	0.00	1.37	0.00
Scenario 1	1.63	-1.64	1.37	0.04
Scenario 2	1.63	-1.64	1.37	0.04
Scenario 3	1.60	-3.50	1.34	-2.21
(S) Settlement Expansion Byfang				
CTV _{neighborhood(1000m)}	2.44		1.84	
Status Quo	2.48	0.00	1.85	0.00
Scenario 1	2.45	-0.85	1.86	0.47
Scenario 2	2.45	-0.85	1.86	0.47
Scenario 3	2.41	-2.49	1.82	-1.72
(S) Auf'm Gartenstück/ Östl. Humboldtstr.				
CTV _{neighborhood(1000m)}	2.01		1.65	
Status Quo	2.08	0.00	1.49	0.00
Scenario 1	2.04	-1.93	1.52	1.94
Scenario 2	2.04	-1.93	1.52	1.94
Scenario 3	1.99	-4.18	1.47	-1.19
(I/S) Grüne Harfe/Barkhovenallee				
CTV _{neighborhood(1000m)}	2.44		1.79	
Status Quo	2.40	0.00	1.68	0.00
Scenario 1	2.35	-2.31	1.72	2.04
Scenario 2	2.35	-2.31	1.72	2.04
Scenario 3	2.29	-4.77	1.66	-1.48
(I) Duvenkamp/ Hemsingkotten				
CTV _{neighborhood(1000m)}	2.62		2.48	
Status Quo	2.54	0.00	2.50	0.00
Scenario 1	2.53	-0.62	2.51	0.14
Scenario 2	2.53	-0.62	2.51	0.14
Scenario 3	2.49	-2.00	2.47	-1.26
(I) Breloher Steig (North/South)				
CTV _{neighborhood(1000m)}	1.91		1.44	
Status Quo	1.78	0.00	1.58	0.00
Scenario 1	1.84	3.06	1.64	3.78
Scenario 2	1.84	3.06	1.64	3.78
Scenario 3	1.77	-0.66	1.58	-0.40

Continuation of Table a6

	Climate Regulation	Deviation from status quo (%)	Biotope Quality	Deviation from status quo (%)
(I) Zollverein/ Röckenstrasse				
CTV _{neighborhood(1000m)}	1.84		1.57	
Status Quo	1.86	0.00	1.59	0.00
Scenario 1	1.84	-1.21	1.59	-0.01
Scenario 2	1.84	-1.21	1.59	-0.01
Scenario 3	1.81	-2.70	1.56	-1.75
(S) Schmachtenbergstr.				
CTV _{neighborhood(1000m)}	2.41		1.95	
Status Quo	2.32	0.00	2.03	0.00
Scenario 1	2.29	-1.35	2.06	1.21
Scenario 2	2.29	-1.35	2.06	1.21
Scenario 3	2.26	-2.70	2.03	-0.34
(I) Ringstr./Promenadenweg				
CTV _{neighborhood(1000m)}	2.41		1.95	
Status Quo	2.22	0.00	1.85	0.00
Scenario 1	2.24	0.74	1.88	1.31
Scenario 2	2.24	0.74	1.88	1.31
Scenario 3	2.21	-0.67	1.84	-0.39
(I) Buschhauser Str.				
CTV _{neighborhood(1000m)}	1.55		1.30	
Status Quo	1.39	0.00	1.25	0.00
Scenario 1	1.41	0.95	1.25	0.12
Scenario 2	1.41	0.95	1.25	0.12
Scenario 3	1.36	-2.14	1.21	-3.32
(I) Thurmfeld				
CTV _{neighborhood(1000m)} ^r	1.55		1.30	
Status Quo	1.60	0.00	1.34	0.00
Scenario 1	1.61	0.69	1.40	4.09
Scenario 2	1.61	0.69	1.40	4.09
Scenario 3	1.54	-3.51	1.33	-0.91
(I) Alfredstr./ Wittekindstr./ Henri-Dunant-Str.				
CTV _{neighborhood(1000m)}	1.82		1.47	
Status Quo	1.59	0.00	1.35	0.00
Scenario 1	1.54	-3.31	1.30	-4.12
Scenario 2	1.54	-3.31	1.30	-4.12
Scenario 3	1.53	-4.07	1.28	-5.00
(S) Im Natt				
CTV _{neighborhood(1000m)}	1.84		1.57	
Status Quo	2.04	0.00	1.78	0.00
Scenario 1	2.01	-1.23	1.72	-3.19
Scenario 2	2.01	-1.23	1.72	-3.19
Scenario 3	1.97	-3.13	1.69	-5.36

	Sealing Rate (%)	Deviation sealing rate compared to status quo	Surface Run-Off (% of precipitation)	Deviation of Surface Runoff compared to status quo (%)	Seeping Rate (% of precipitation)	Deviation of Seeping Rate compared to status quo (%)	Evapotranspiration (% of precipitation)	Deviation of Evapotranspiration compared to status quo (%)
CTV_{city}	34.59		19.08		26.03		55.02	
(I) Palmbuschweg/ Altenessener Str.								
CTV _{neighborhood(1000m)}	49.39		30.27		25.14		44.90	
Status Quo	52.40	0.00	31.20	0.00	25.32	0.00	43.77	0.00
Scenario 1	52.03	-0.71	29.87	-4.24	25.85	2.09	44.56	1.82
Scenario 2	52.24	-0.31	30.18	-3.25	25.65	1.33	44.45	1.56
Scenario 3	52.79	0.73	30.35	-2.71	25.68	1.43	44.27	1.14
(II) Kesselstr.								
CTV _{neighborhood(1000m)}	55.18		31.41		25.47		43.22	
Status Quo	47.64	0.00	26.13	0.00	26.27	0.00	47.90	0.00
Scenario 1	48.23	1.25	26.41	1.09	26.35	0.29	47.55	-0.73
Scenario 2	48.39	1.58	26.34	0.80	26.33	0.21	47.65	-0.54
Scenario 3	48.70	2.23	26.46	1.27	26.38	0.41	47.49	-0.87
(S) Settlement Expansion Byfang								
CTV _{neighborhood(1000m)}	22.78		8.83		26.57		64.60	
Status Quo	22.32	0.00	6.67	0.00	27.37	0.00	65.95	0.00
Scenario 1	23.17	3.82	6.88	3.21	27.71	1.21	65.43	-0.80
Scenario 2	23.38	4.73	6.87	3.10	27.65	1.00	65.48	-0.71
Scenario 3	23.79	6.56	6.95	4.18	27.72	1.26	65.35	-0.91
(S) Auf'm Gartenstück/ Östl. Humboldtstr.								
CTV _{neighborhood(1000m)}	33.34		14.46		29.06		56.67	
Status Quo	31.05	0.00	14.44	0.00	30.07	0.00	55.64	0.00
Scenario 1	33.91	9.21	14.71	1.89	30.54	1.55	54.93	-1.28
Scenario 2	34.14	9.97	14.70	1.82	30.46	1.28	55.00	-1.13
Scenario 3	34.61	11.47	14.80	2.48	30.56	1.61	54.83	-1.46

	Sealing Rate (%)	Deviation sealing rate compared to status quo	Surface Run-Off (% of precipitation)	Deviation of Surface Runoff compared to status quo (%)	Seeping Rate (% of precipitation)	Deviation of Seeping Rate compared to status quo (%)	Evapotranspiration (% of precipitation)	Deviation of Evapotranspiration compared to status quo (%)
(I/S) Grüne Harfe/Barkhovenallee								
CTV _{neighborhood(1000m)}	24.33		10.23		28.17		61.70	
Status Quo	25.62	0.00	9.76	0.00	29.81	0.00	60.52	0.00
Scenario 1	27.95	9.07	10.36	6.08	29.75	-0.23	60.02	-0.83
Scenario 2	28.24	10.22	10.35	5.99	29.67	-0.48	60.09	-0.70
Scenario 3	28.83	12.53	10.44	6.93	29.76	-0.17	59.92	-0.99
(I) Duvenkamp/Hemsingkotten								
CTV _{neighborhood(1000m)}	15.83		5.18		21.13		73.74	
Status Quo	14.69	0.00	5.44	0.00	21.85	0.00	72.75	0.00
Scenario 1	15.77	7.31	5.45	0.10	22.32	2.12	72.31	-0.61
Scenario 2	15.94	8.51	5.44	-0.02	22.27	1.88	72.36	-0.54
Scenario 3	16.29	10.90	5.50	1.12	22.33	2.18	72.24	-0.70
(I) Breloher Steig (North/South)								
CTV _{neighborhood(1000m)}	46.96		32.76		24.65		42.67	
Status Quo	49.21	0.00	22.99	0.00	26.96	0.00	50.10	0.00
Scenario 1	47.35	-3.78	21.31	-7.29	27.88	3.40	50.89	1.59
Scenario 2	47.69	-3.10	21.30	-7.34	27.78	3.03	51.00	1.79
Scenario 3	48.35	-1.75	21.42	-6.81	27.90	3.49	50.77	1.34
(I) Zollverein/Röckenstrasse								
CTV _{neighborhood(1000m)}	43.39		23.94		26.81		49.50	
Status Quo	41.79	0.00	24.84	0.00	27.47	0.00	47.91	0.00
Scenario 1	42.68	2.11	25.12	1.11	27.46	-0.05	47.68	-0.49
Scenario 2	42.82	2.44	25.05	0.84	27.44	-0.12	47.76	-0.32
Scenario 3	43.09	3.11	25.16	1.28	27.48	0.05	47.62	-0.61

	Sealing Rate (%)	Deviation sealing rate compared to status quo	Surface Run-Off (% of precipitation)	Deviation of Surface Runoff compared to status quo (%)	Seeping Rate (% of precipitation)	Deviation of Seeping Rate compared to status quo (%)	Evapotranspiration (% of precipitation)	Deviation of Evapotranspiration compared to status quo (%)
(S) Schmachtenbergstr.								
CTV _{neighborhood(1000m)}	26.51		12.94		25.36		61.88	
Status Quo	22.33	0.00	10.61	0.00	26.13	0.00	63.50	0.00
Scenario 1	23.63	5.83	10.90	2.67	26.12	-0.03	63.24	-0.41
Scenario 2	23.79	6.53	10.89	2.63	26.09	-0.18	63.28	-0.35
Scenario 3	24.10	7.94	10.94	3.07	26.13	0.01	63.19	-0.49
(I) Ringstr./ Promenadenweg								
CTV _{neighborhood(1000m)}	26.51		12.94		25.36		61.88	
Status Quo	34.31	0.00	18.50	0.00	21.31	0.00	60.35	0.00
Scenario 1	32.92	-4.06	17.32	-6.41	21.47	0.79	61.42	1.78
Scenario 2	33.07	-3.61	17.93	-3.08	21.14	-0.79	61.15	1.32
Scenario 3	33.87	-1.29	18.10	-2.20	21.16	-0.68	60.97	1.02
(I) Buschhauser Str.								
CTV _{neighborhood(1000m)}	55.18		31.41		25.47		43.22	
Status Quo	58.88	0.00	32.15	0.00	27.00	0.00	40.83	0.00
Scenario 1	58.42	-0.77	32.42	0.87	26.53	-1.73	41.08	0.60
Scenario 2	58.64	-0.41	32.32	0.55	26.50	-1.85	41.21	0.91
Scenario 3	59.07	0.33	32.49	1.06	26.57	-1.58	40.99	0.37
(I) Thurmfeld								
CTV _{neighborhood(1000m)}	55.18		31.41		25.47		43.22	
Status Quo	57.02	0.00	33.72	0.00	23.05	0.00	43.37	0.00
Scenario 1	56.18	-1.47	32.03	-5.00	23.79	3.19	44.35	2.26
Scenario 2	56.52	-0.88	31.86	-5.53	23.74	2.96	44.57	2.76
Scenario 3	57.19	0.30	32.14	-4.67	23.86	3.51	44.19	1.88

	Sealing Rate (%)	Deviation sealing rate compared to status quo	Surface Run-Off (% of precipitation)	Deviation of Surface Runoff compared to status quo (%)	Seeping Rate (% of precipitation)	Deviation of Seeping Rate compared to status quo (%)	Evapotranspiration (% of precipitation)	Deviation of Evapotranspiration compared to status quo (%)
(I) Alfredstr./ Wittekindstr./ Henri-Dunant-Str.								
CTV _{neighborhood(1000m)}	45.46		28.12		24.17		47.96	
Status Quo	52.57	0.00	32.66	0.00	24.32	0.00	43.19	0.00
Scenario 1	54.96	4.55	32.08	-1.80	24.60	1.12	43.52	0.78
Scenario 2	55.02	4.66	32.64	-0.07	24.31	-0.04	43.25	0.14
Scenario 3	55.58	5.71	32.76	0.29	24.31	-0.07	43.14	-0.11
(S) Im Natt								
CTV _{neighborhood(1000m)}	43.39		23.94		26.81		49.50	
Status Quo	38.10	0.00	19.67	0.00	27.12	0.00	53.53	0.00
Scenario 1	40.31	5.80	20.04	1.92	27.50	1.42	52.79	-1.39
Scenario 2	40.50	6.31	19.95	1.43	27.47	1.31	52.90	-1.17
Scenario 3	40.88	7.32	20.10	2.22	27.54	1.56	52.70	-1.56

	Residents (2007)	Total Green/Resident (m ²)	Private Green/Resident (m ²)	Semi-Public Green/Resident (m ²)	Public Green/Resident (m ²)	Ratio Private Green/Public Green per Resident	Park-Area/Resident (m ²)
CTV_{City}	580597	242.77	73.58	19.31	149.89	0.49	17.69
(I) Palmbuschweg/ Altenessener Str.							
Altenessen-Süd	26161.00						
CTV _{neighborhood(1000m)}	17805.02	110.86	66.77	7.85	36.24	1.84	21.70
Status Quo	6493.11	108.48	51.96	13.16	43.36	1.20	23.32
Scenario 1	6803.45	106.69	53.73	12.24	40.72	1.32	22.25
Scenario 2	6924.40	105.06	53.02	12.02	40.01	1.33	21.86
Scenario 3	7567.64	95.09	47.48	11.00	36.61	1.30	20.00
(I) Kesselstr.							
Bochold	18248.00						
CTV _{neighborhood(1000m)}	31659.27	126.63	55.00	31.45	40.18	1.37	10.16
Status Quo	4647.00	100.06	71.00	1.87	27.19	2.61	14.58
Scenario 1	4724.38	96.98	71.96	0.40	24.63	2.92	14.34
Scenario 2	4750.18	96.60	71.71	0.39	24.50	2.93	14.26
Scenario 3	4801.76	94.86	70.24	0.39	24.23	2.90	14.11
(S) Settlement Expansion Byfang							
Byfang	2139.00						
CTV _{neighborhood(1000m)}	4913.74	706.09	192.60	19.50	493.99	0.39	1.54
Status Quo	1769.92	848.08	232.37	17.44	598.27	0.39	3.72
Scenario 1	1980.67	752.64	219.05	13.84	519.75	0.42	3.32
Scenario 2	2050.92	726.00	210.68	13.37	501.95	0.42	3.21
Scenario 3	2191.42	674.88	192.61	12.51	469.76	0.41	3.00
(S) Auf'm Gartenstück/Östl. Humboldtstr.							
Fulerum	3339.00						
CTV _{neighborhood(1000m)}	10905.18	219.31	100.51	5.97	112.83	0.89	6.60
Status Quo	4603.17	242.65	103.71	5.90	133.04	0.78	4.63
Scenario 1	4723.07	233.24	110.88	4.70	117.67	0.94	4.51

Continuation of tab. a6

	Residents (2007)	Total Green/Resident (m ²)	Private Green/Resident (m ²)	Semi-Public Green/Resident (m ²)	Public Green/Resident (m ²)	Ratio Private Green/Public Green per Resident	Park-Area/Resident (m ²)
Scenario 2	4763.04	230.87	109.54	4.66	116.68	0.94	4.47
Scenario 3	4842.97	224.76	105.43	4.58	114.75	0.92	4.40
(I/S) Grüne Harfe/Barkhovenallee							
Heidhausen	6394.00						
CTV _{neighborhood(1000m)}	6873.43	544.59	159.20	33.19	352.20	0.45	15.23
Status Quo	3244.92	486.46	161.71	7.37	317.38	0.51	14.35
Scenario 1	3483.77	444.77	168.56	6.86	269.35	0.63	13.36
Scenario 2	3563.38	434.13	164.09	6.71	263.33	0.62	13.06
Scenario 3	3722.62	411.77	153.29	6.42	252.07	0.61	12.51
(I) Duvenkamp/Hemsingkotten							
Heisingen	12672.00						
CTV _{neighborhood(1000m)}	3567.64	665.81	146.20	9.37	510.23	0.29	3.41
Status Quo	1203.81	688.98	137.20	0.00	551.79	0.25	0.00
Scenario 1	1299.79	635.84	135.61	0.00	500.22	0.27	0.00
Scenario 2	1331.79	619.95	131.75	0.00	488.21	0.27	0.00
Scenario 3	1395.78	588.27	122.44	0.00	465.83	0.26	0.00
(I) Breloher Steig (Nord/Süd)							
Horst	10402.00						
CTV _{neighborhood(1000m)}	9256.07	276.50	79.20	26.29	171.00	0.46	21.08
Status Quo	4535.01	183.67	80.98	32.33	70.35	1.15	11.23
Scenario 1	4819.67	179.63	89.36	25.48	64.78	1.38	10.57
Scenario 2	4914.56	175.67	87.15	24.99	63.53	1.37	10.36
Scenario 3	5104.33	166.49	81.26	24.06	61.17	1.33	9.98
(I) Zollverein/Röckenstrasse							
Katernberg	23442.00						
CTV _{neighborhood(1000m)}	22460.38	167.06	80.19	15.37	71.50	1.12	21.03
Status Quo	9691.13	116.53	72.95	2.28	41.29	1.77	15.95
Scenario 1	9835.49	113.23	72.03	2.25	38.95	1.85	15.71

Continuation of tab. a6

	Residents (2007)	Total Green/Resident (m ²)	Private Green/Resident (m ²)	Semi-Public Green/Resident (m ²)	Public Green/Resident (m ²)	Ratio Private Green/Public Green per Resident	Park-Area/Resident (m ²)
Scenario 2	9883.61	112.81	71.81	2.24	38.76	1.85	15.64
Scenario 3	9979.84	111.09	70.49	2.22	38.38	1.84	15.49
(S) Schmachtenbergstr.							
Kettwig	17811.00						
CTV _{neighborhood(1000m)}	12449.74	392.34	111.81	32.40	248.13	0.45	12.09
Status Quo	1887.69	399.16	118.16	0.67	280.34	0.42	0.00
Scenario 1	1957.09	381.92	122.51	0.64	258.77	0.47	0.00
Scenario 2	1980.23	377.16	120.78	0.63	255.74	0.47	0.00
Scenario 3	2026.49	366.92	116.40	0.62	249.91	0.47	0.00
(I) Ringstr./Promenadenweg							
Kettwig	17811.00						
CTV _{neighborhood(1000m)}	12449.74	392.34	111.81	32.40	248.13	0.45	12.09
Status Quo	4838.57	188.87	72.92	17.83	98.11	0.74	4.68
Scenario 1	5315.55	175.72	79.60	7.95	88.18	0.90	4.26
Scenario 2	5495.94	169.25	76.28	7.68	85.28	0.89	4.12
Scenario 3	6020.03	151.18	66.31	7.02	77.86	0.85	3.76
(I) Buschhauser Str.							
Altendorf	20589.00						
CTV _{neighborhood(1000m)}	37448.27	107.05	46.50	26.58	33.97	1.37	8.59
Status Quo	4922.77	114.86	37.05	49.70	28.10	1.32	10.51
Scenario 1	5052.91	109.70	41.66	43.27	24.78	1.68	10.24
Scenario 2	5096.29	109.00	41.53	42.90	24.57	1.69	10.15
Scenario 3	5183.05	106.07	39.74	42.18	24.16	1.64	9.98
(I) Thurmfeld							
Nordviertel	7854.00						
CTV _{neighborhood(1000m)}	27070.93	148.09	64.33	36.78	46.99	1.37	11.88
Status Quo	2521.78	219.96	40.62	32.59	146.76	0.28	3.66
Scenario 1	2773.22	200.03	56.12	17.60	126.31	0.44	3.33
Scenario 2	2857.03	194.95	55.27	17.08	122.61	0.45	3.23

Continuation of tab. a6

	Residents (2007)	Total Green/Resident (m ²)	Private Green/Resident (m ²)	Semi-Public Green/Resident (m ²)	Public Green/Resident (m ²)	Ratio Private Green/Public Green per Resident	Park-Area/Resident (m ²)
Scenario 3	3024.65	180.51	48.56	16.13	115.81	0.42	3.05
(I) Alfredstr. / Wittekindstr. /Henri-Dunant- Str.							
Rüttenscheid	27932.00						
CTV _{neighborhood(1000m)}	29361.70	108.68	40.32	7.26	61.10	0.66	20.54
Status Quo	13070.49	82.21	37.16	5.00	40.06	0.93	9.41
Scenario 1	13617.68	78.67	40.73	3.38	34.56	1.18	9.03
Scenario 2	13830.32	77.14	39.79	3.33	34.03	1.17	8.89
Scenario 3	14618.54	71.46	36.12	3.15	32.19	1.12	8.41
(S) Im Natt							
Stoppenberg	16831.00						
CTV _{neighborhood(1000m)}	24315.68	154.31	74.07	14.19	66.05	1.12	19.42
Status Quo	3028.53	229.83	90.81	15.70	123.32	0.74	32.24
Scenario 1	3136.48	217.78	93.02	15.16	109.59	0.85	31.13
Scenario 2	3173.21	215.56	92.25	14.99	108.32	0.85	30.77
Scenario 3	3245.54	209.29	88.73	14.65	105.91	0.84	30.09

Continuation of tab. a6

	Deviation (%) of Private Green/Resident from Status Quo (500m)	Deviation (%) of Public Green/Resident from Status Quo (500m)	Deviation (%) of Total Green/Resident from Status Quo (500m)	Deviation (%) of Park-Area/Resident from Status Quo (500m)
(I) Palmbuschweg/Altenessener Str.				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	3.40	-6.09	-1.65	-4.56
Scenario 2	2.04	-7.73	-3.16	-6.23
Scenario 3	-8.63	-15.57	-12.35	-14.20
(I) Kesselstr.				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	1.35	-9.41	-3.07	-1.64
Scenario 2	1.00	-9.90	-3.45	-2.17
Scenario 3	-1.07	-10.87	-5.20	-3.22
(S) Settlement Expansion Byfang				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	-5.73	-13.12	-11.25	-10.64
Scenario 2	-9.33	-16.10	-14.40	-13.70
Scenario 3	-17.11	-21.48	-20.42	-19.23
(S) Auf'm Gartenstück/Östl. Humboldtstr.				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	6.91	-11.55	-3.88	-2.54
Scenario 2	5.62	-12.30	-4.86	-3.36
Scenario 3	1.66	-13.74	-7.37	-4.95
(I/S) Grüne Harfe/Barkhovenallee				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	4.24	-15.13	-8.57	-6.86
Scenario 2	1.47	-17.03	-10.76	-8.94
Scenario 3	-5.21	-20.58	-15.35	-12.83

Continuation of tab. a6

	Deviation (%) of Private Green/Resident from Status Quo (500m)	Deviation (%) of Public Green/Resident from Status Quo (500m)	Deviation (%) of Total Green/Resident from Status Quo (500m)	Deviation (%) of Park-Area/Resident from Status Quo (500m)
(I) Duvenkamp/ Hemsingkotten				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	-1.15	-9.34	-7.71	0
Scenario 2	-3.97	-11.52	-10.02	0
Scenario 3	-10.76	-15.58	-14.62	0
(I) Breloher Steig (Nord/Süd)				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	10.34	-7.92	-2.20	-5.91
Scenario 2	7.61	-9.69	-4.35	-7.72
Scenario 3	0.34	-13.05	-9.35	-11.15
(I) Zollverein/ Röckenstrasse				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	-1.26	-5.68	-2.83	-1.47
Scenario 2	-1.56	-6.13	-3.19	-1.95
Scenario 3	-3.38	-7.04	-4.67	-2.89
(S) Schmachtenbergstr.				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	3.68	-7.69	-4.32	0
Scenario 2	2.22	-8.77	-5.51	0
Scenario 3	-1.49	-10.86	-8.08	0
(I) Ringstr./Promenadenweg				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	9.16	-10.13	-6.96	-8.97
Scenario 2	4.61	-13.08	-10.39	-11.96
Scenario 3	-9.06	-20.64	-19.95	-19.63
(I) Buschhauser Str.				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	12.43	-11.82	-4.49	-2.58
Scenario 2	12.09	-12.57	-5.10	-3.40

Continuation of tab. a6

	Deviation (%) of Private Green/Resident from Status Quo (500m)	Deviation (%) of Public Green/Resident from Status Quo (500m)	Deviation (%) of Total Green/Resident from Status Quo (500m)	Deviation (%) of Park-Area/Resident from Status Quo (500m)
Scenario 3	7.24	-14.04	-7.65	-5.02
(I) Thurmfeld				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	38.17	-13.93	-9.06	-9.07
Scenario 2	36.07	-16.46	-11.37	-11.73
Scenario 3	19.56	-21.09	-17.94	-16.63
(I) Alfredstr. / Wittekindstr. /Henri-Dunant- Str.				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	9.63	-13.73	-4.31	-4.02
Scenario 2	7.09	-15.06	-6.17	-5.49
Scenario 3	-2.79	-19.64	-13.08	-10.59
(S) Im Natt				
Status Quo	0.00	0.00	0.00	0.00
Scenario 1	2.44	-11.13	-5.25	-3.44
Scenario 2	1.59	-12.16	-6.21	-4.56
Scenario 3	-2.29	-14.12	-8.94	-6.69

Continuation of tab. a6

Annex C

Annex C1 Theory

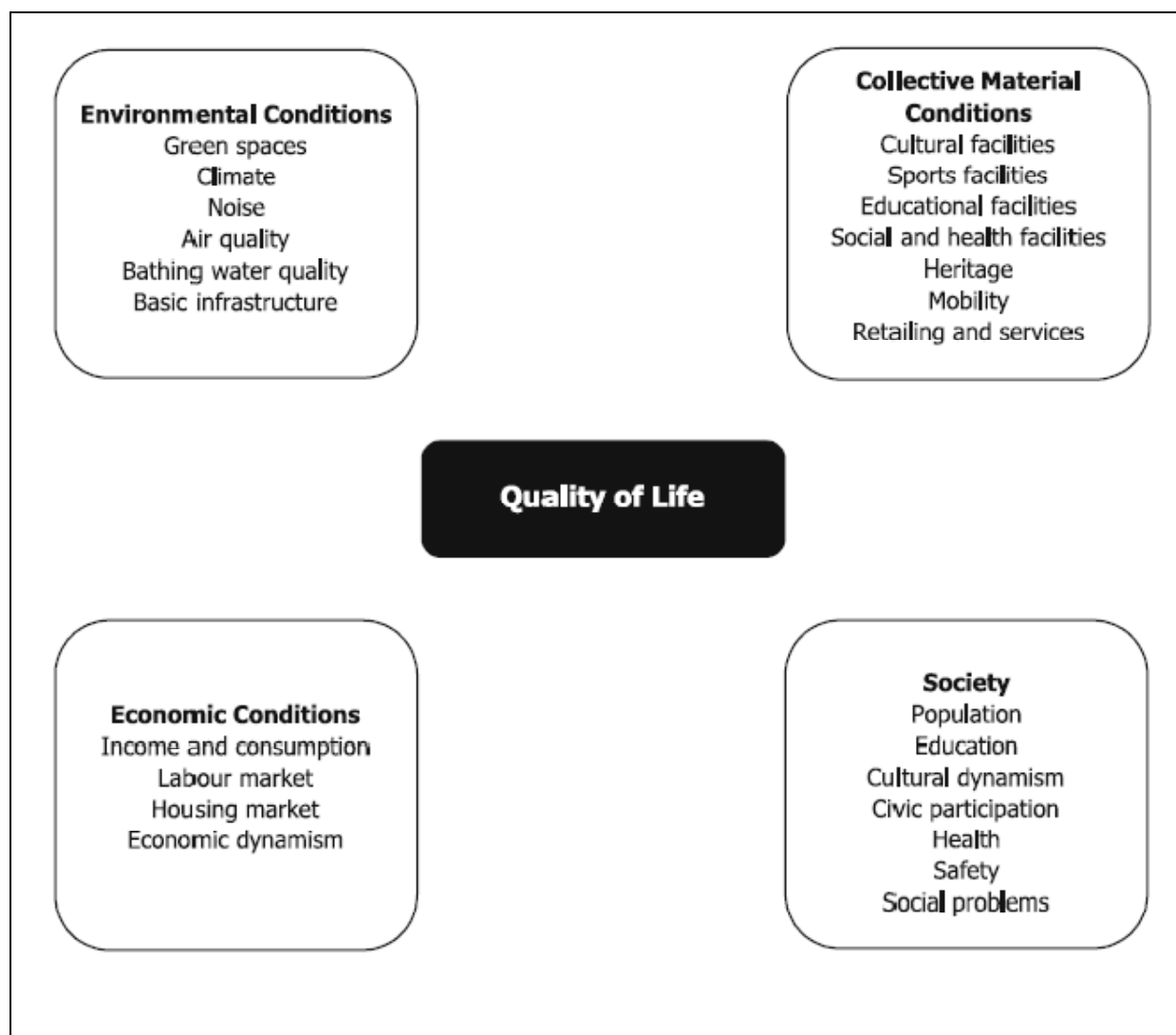


Figure c1 Fields and thematic areas of QoL according to Santos & Martins (2007, p. 415)

Annex C2: Methodology

Additional remarks on indicator-characteristics

Nominal indicators appear as “yes/no-indicators”. A typical example derives from the overlay of data-sets of protected areas and the potential housing sites and their position with respect to existing protected areas. To enable a more flexible and realistic analysis a third class has been implemented for those cases as a site only partially covers a protected area and therefore is not entirely unsuitable for enhancing a resource-protecting settlement growth. This kind of indicators can be found in both the ecological and social dimensions of sustainability.

Ordinal indicators of this assessment are quantitative in nature; their performance can be assigned to a distinct class and can be put in an order. Threshold values are deriving from the respective minimum and maximum values of the single data-sets or –if this is possible- from planning and scientific literature and are applied to the threefold classification normatively. An example of the ecological dimension is the biotope quality which can be assessed quantitatively according to the attribution- approach of Singer (1995). Threshold values for this indicator are deriving from this approach where a value- range from 0 (= very low performance) up to 4 (=very high performance) determines the width of all values being included in the calculation of the indicator-performance. As – in most cases- the location of a site cannot be assigned to one indicator value, the classification is defined by ranges of the respective indicator values (see tab. A2).

Another example is the calculation of potential housing sites within a defined distance of facilities of social infrastructure (see tab. a2). Here, threshold- values are exclusively deriving from scientific and planning literature. According to the position of the respective buffers it is possible to assess whether a potential housing site is located within the requested maximum distance of e.g. 500m (Example: distance to kindergarten), if it is only partially the case or a site is located entirely outside the requested maximum distance.

Annex C3: Procedure of the Green-Classification

Major information on property-conditions which also imply different degrees of accessibility of related green spaces can be derived from cadastral data. Still, the integrated cadastre-based green classification extended by the land use mapping of the Regional Association Ruhr has been necessary to analyze the green composition of the City of Essen according to the following reasons:

- Closer insight into the accessibility of green spaces: Cadastral data (ALK, layer 21) explicitly provide with information due to general property conditions but not on its usability. Whilst the land use class “detached house” clearly implies a private use of the green spaces the land use class “green space” does not give closer insight into its distinct use.
- Detection of new green classes: Cadastral data do not provide with the land use class “roadside greenery” which is one of the most obvious green types in the public domain but with the land use type “street”. Here a combination of cadastral data and the land use data provided by the RNK has been essential to newly define this green type.
- Detection of ecological valueless open space types: As e.g. the cadastral land use class “residential housing” implies open space structures such as courtyards/ residential greenery this has to be scrutinized as it is located with the RNK-type “pedestrian zone”.
- Detailed proof of industrial premises regarding their overall inventory and general green share and recreational value. As both land use classification define industrial premises and brownfields a clear distinction according to their usability or ecological benefit could be executed comparing all types of allocation of these land use class.

Qualitative uncertainty analysis

The green classification does not aim at a detailed description of functions, inventories and demarcation of green spaces within the City of Essen. It surely implies uncertainties due to the recreational values as a backup by aerial photos does not replace an on-site assessment. The more, it provides data on green provision which also include partially sealed surfaces.

Most insecurity regarding accessibility and structure occurred in mixed areas of commercial and residential functions in areas of multi-storey housing.

Still, clear results can be obtained from neighborhoods containing detached and semi-detached housing structures regarding the green composition facing property conditions and accessibility (Erreichbarkeit) can be obtained on district and city level.

A minor insecurity regarding the two different data sets in accordance with aerial photographs affects their original date. Having a closer look on e.g. fallow land –classes, it becomes clear that here

insecurities occur. Cadastral data are dating from 2007 whilst land use mapping of the Regional Association Ruhr and aerial photos are dating from 2005.

Annex C4: Detailed Description of the VB-DSS

The concept of the outlined VB-DSS provides a spatial MCA based on communally provided GIS-data and integrates two components: *Firstly*, a potential-analysis of socio-environmental framework-conditions determining the Quality of Place of future housing sites to promote a resource-preserving and sustainable settlement-development. *Secondly*, it provides a socio-environmental impact-assessment depending on varying housing-scenarios and housing densities using the target systems Quality of Life and Urban Ecosystem Services. The VB-DSS integrated both steps of the MCA into one user-interface using Visual Basic and MS EXCEL[®]. The following paragraphs will give an insight into the scheme of the VB-DSS and its working-steps.

The design of the user-interface follows the conception of the MCA and provides three different slides holding the QoP-analysis, the QoL/UES-impact-assessment and a summary of both. To use the outcomes of the VB-DSS all results will be transferred into a MS EXCEL[®]-dossier.

Note, that the user-interfaces stores data and conjoins them to one integrated analysis but does not calculate indicator-values or executes a GIS-analysis on its own. This has been executed in advance.

Figures c2 and c3 show the first slides of the MCA and its major steering elements. As the QoP-analysis is divided into ecological and social determinants, also the slider of the QoP-assessment of the VB-DSS is divided into two sub-sliders holding ecological and social indicators. The example below shows the ecological dimension of QoP-analysis. The left-hand column shows all defined indicators. The column "performance" enables an assignment of indicator-values deriving from communal data-sets due to the pre-defined threefold definition of increment values. The increment values of the indicators are predefined but refer to "rough" communal data. The column "weighting" provides individual weighting of each indicator due to altering stakeholders and users. During the assessment, the user is able to update the already assigned weightings (button "update and finish analysis") and to save the inputs at any time (button "Save").

The assessment of social indicators of QoP is executed analogically.

Slider: Quality of Place and sub-sliders holding ecological and social indicators

Confirmation of all inputs and output of the final rating

Indicator-column, information-button describing the meaning of the respective indicator

Input of indicator-values deriving from GIS-analysis

Deriving three-fold classification of increment-values to aggregate quantitative and qualitative indicators to one final rating

Indicator-weighting

Button to intermediately save inputs

Intermediate proof of open weights to assign and button to clear all assigned weights

Figure c2 Slider of QoP-assessment (author's draft)

Update & Finish Analysis

Save

Vacant Weights

Clear Weights

Figure c3 Slider of social indicators (author's draft)

The second major slider of the interface holds the socio-environmental impact-assessment following the target systems QoL and UES. The slide is divided into the three sub-sliders represent the three major tasks of urban green to enhance QoL and UES (see chapter 2) and hold the respective indicators (see fig. c4). Each of the sub-sliders provides the assignment of local threshold-values and of indicator-values according to varying housing densities represented within three housing-scenarios.

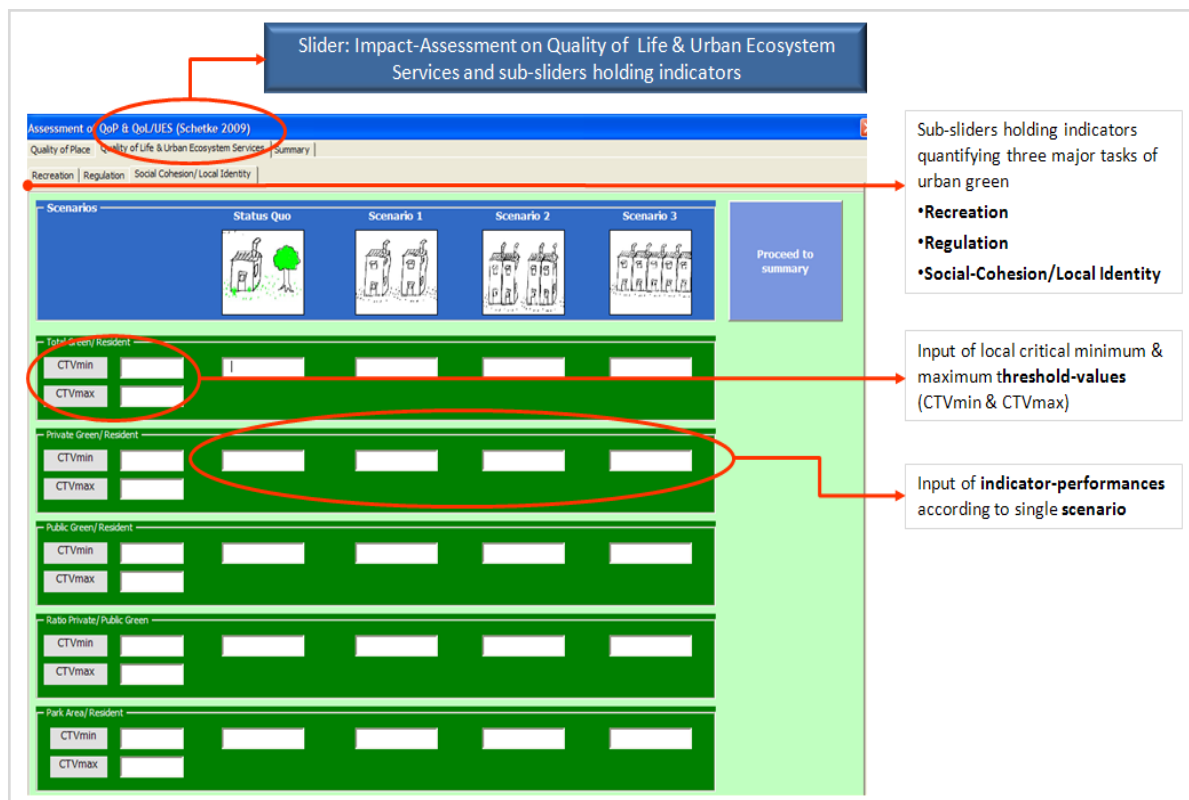


Figure c4 Design of the slider of socio-environmental impact-assessment (author's draft)

An individual weighting is not possible during the impact-assessment. Not a planner-oriented potential-analysis but a scientific and objective assessment of socio-environmental effects of settlement-development compared to status-quo-conditions and local standards is the major target of this step. Therefore, a weighting of indicators is considered as not compulsory.

The impact-assessment starts with the assignment of local threshold-values. These values have been calculated in advance and set the indicator-performances against local standards on e.g. city-level (CTV_{city}). The respective indicator-value – or its performance- is embedded into a range spanned by both threshold-values and assessed against them. Following that, we refer to CTV_{min} and CTV_{max} as the order of both threshold-values can differ.

Following that, the calculated values of the indicator-performance are to be inserted. The input starts at the slider "Recreation" which holds the respective indicators. It then proceeds to the slider "Regulation" and the following slider "Social Cohesion/local Identity". The user-interface and all operations are steered with a Visual Basic-syntax in the background (fig. c5)

```

Private Sub CommandButton5_Click()
MsgBox "Average Sealing rate; reference value (80%) as critical point according to climate analysis (City of Essen 2005)"
End Sub

Private Sub CommandButton6_Click()
MsgBox "Protected areas (nature protection and landscape convention area, $ 62-habitats, FFH-habitats)"
End Sub

Private Sub CommandButton7_Click()
MsgBox "soil quality/yield stability (Bodenwertzahl): > 75 = high; 75-55 = medium; <55 =low"
End Sub

Private Sub CommandButton8_Click()
MsgBox "Centennially Flood-affected areas and potential flooding area"
End Sub

Private Sub optBiotope1_Click()
Dim blnWert As Boolean
blnWert = Me.optBiotope1.Value
If blnWert = True Then [Ecology!C5] = 1
End Sub

Private Sub optBiotope2_Click()
Dim blnWert As Boolean
blnWert = Me.optBiotope2.Value
If blnWert = True Then [Ecology!C5] = 2
End Sub

Private Sub optBiotope3_Click()
Dim blnWert As Boolean
blnWert = Me.optBiotope3.Value
If blnWert = True Then [Ecology!C5] = 3
End Sub

Private Sub optBus1_Click()
Dim blnWert As Boolean
blnWert = Me.optBus1.Value
If blnWert = True Then [Social!C8] = 1
End Sub

```

Figurec5 Visual Basic-syntax of the VD-DSS (author’s draft)

The third step of the VB-DSS is represented by a summary of both potential-analysis (QoP) and impact-assessment (QoL/UES) of future housing-sites. The summary is qualitative in nature and provides verbal statements on both steps of the MCA (see fig. c6). The button “Finish Analysis and write Dossier” transmits all inserted indicator-values of both steps of the MCA from a MS EXCEL-worksheet into a final sheet and translates them into verbal statements.

Expanding this final step of the VB-DSS all inserted indicator-values of the QoP-analysis and a grafic overview of the impact-assessment are given in a dossier which is provided as a MS ECXEL-worksheet stored in the same xls-files as the VB-DSS itself (see fig.c7).

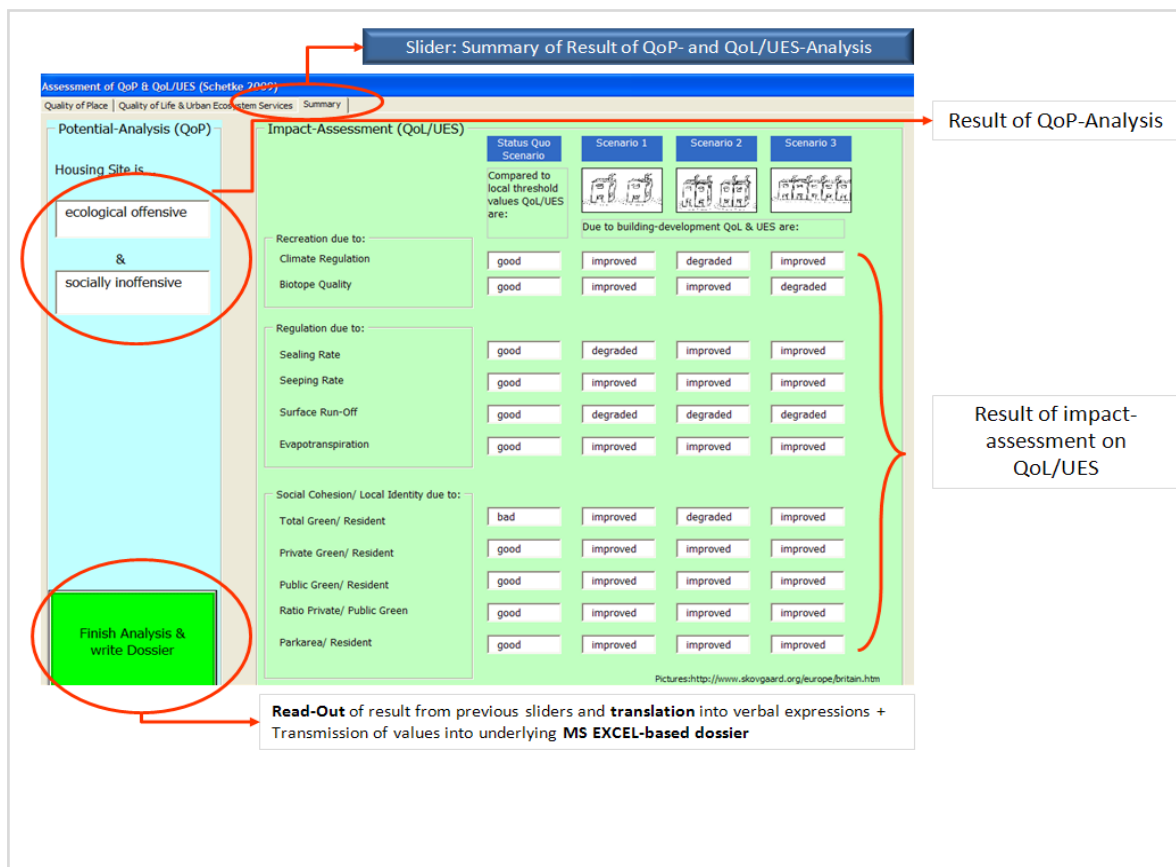


Figure c6 Summary of QoP-analysis and QoL/UES-assessment (author's draft)

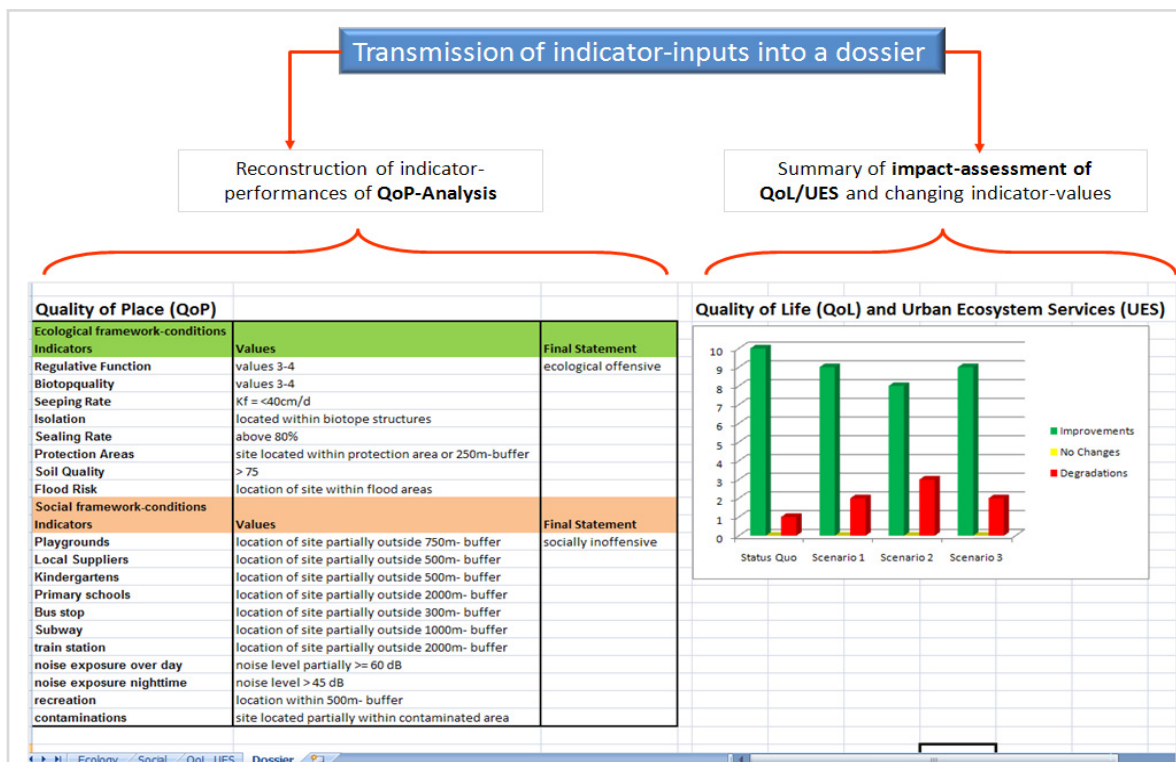


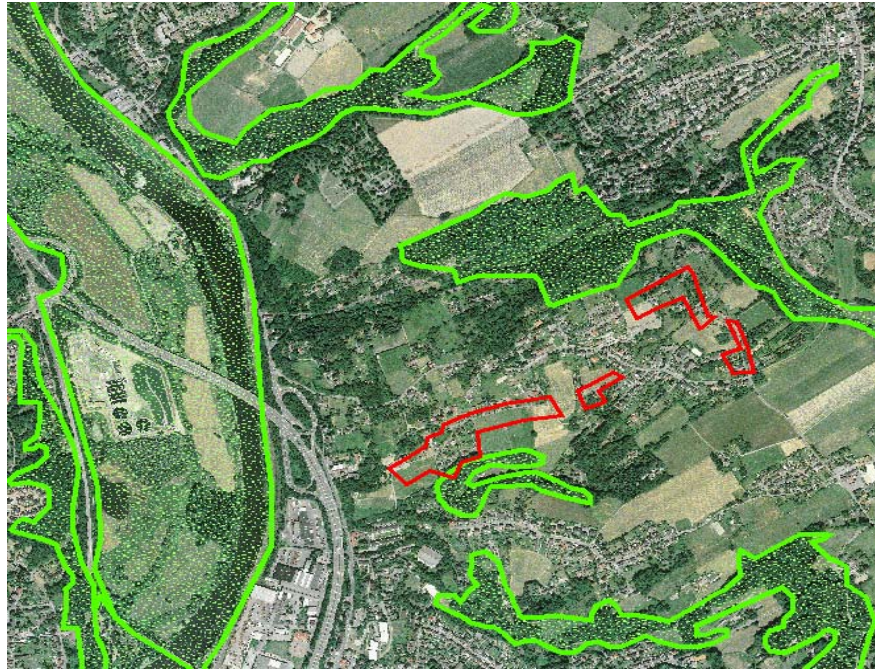
Figure c7 Dossier of the VB-DSS (author's draft)

Annex C5

Approach of SINGER on ecological performance of cadastral land use classes

The approach of SINGER (1995) has been developed to get more or less exact numbers about the ecological performance of valuable green and open spaces within a city. According to him „open areas“ are defined as unsealed and undeveloped areas. Due to the fact that cadastral land use data do not distinct between sealed and unsealed surfaces but only provides the category “buildings and associated open spaces” integrating both, the concept of SINGER has calculated mean values of open spaces shares according throughout cadastral land use classes and deduce according sealing rates. He assumes, that the respective share of open spaces of a land use class depends on its position within the settlement-structure itself. That means, that according to housing-densities associated high or low sealing rates can be found. According to these notions he defines five factors of ecological performance which depend on the association to land use classes, its densification and humanely modification: regulation, biotope quality, recreational potential, soil and water services.

Annex D



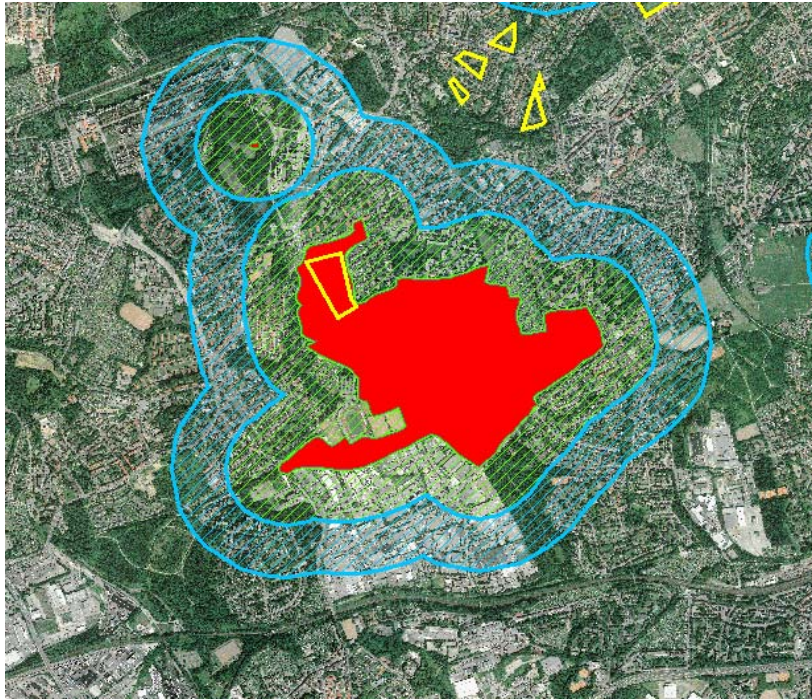
- Connected habitat structure
- Housing Sites





Source: 1. Linfos data-base (LANUV) 2007/*Fachinformationssystem Linfos (Stand 2007, Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen*; 2. Aerial Photographs (License-Nr. 37/ 2008 with permission of the Office of Geoinformation, Measurement and Cadastre City of Essen, 18.06.08)/ *Darstellung aus Lizenz-Nr. 37/2008 mit Genehmigung vom Amt für Geoinformation, Vermessung und Kataster der Stadt Essen vom 18.06.08*

Figure d1:
Indicator "Isolation/ use of biotope structures"

Adjustment of indicator-performance at housing-sites to increment values:

- 1**=(site suitable): site not located within biotope structures
- 2**=(site partially suitable): site partially located within biotope structures
- 3**=(unsuitable): site located within biotope structures



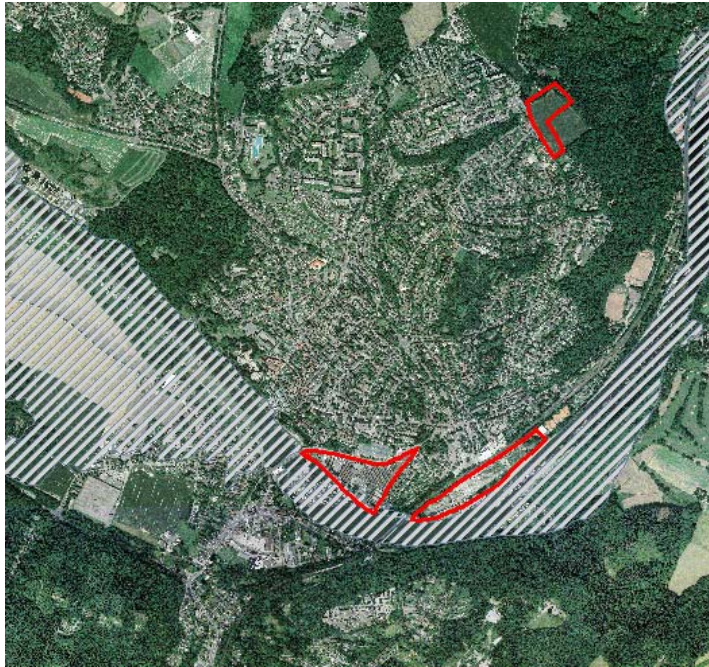
-  Housing-Site
-  Protected Area
-  250m-Buffer
-  500m-Buffer

Source: 1. Linfos data-base (LANUV) 2007/*Fachinformationssystem Linfos (Stand 2007, Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen*; 2. Aerial Photographs (License-Nr. 37/ 2008 with permission of the Office of Geoinformation, Measurement and Cadastre City of Essen, 18.06.08)/ *Darstellung aus Lizenz-Nr. 37/2008 mit Genehmigung vom Amt für Geoinformation, Vermessung und Kataster der Stadt Essen vom 18.06.08*

Figure d2:
Indicator "Protected Areas"

Adjustment of indicator-performance at housing-sites to increment values:

- 1**=(site suitable): site not located within protection areas or buffers
- 2**=(site partially suitable): site partially located within protection areas or 250m-buffer or entirely within 500m-buffer
- 3**=(unsuitable): site located within protection area or 250m-buffer



Flood Area
 Housing Sites

Source: 1. Digital Map of flood-affected areas of NRW (LANUV 2003)/Karte der hochwassergefährdeten Bereiche in NRW (Stand 2003); 2. Aerial Photographs (License-Nr. 37/ 2008 with permission of the Office of Geoinformation, Measurement and Cadastre City of Essen, 18.06.08)/ Darstellung aus Lizenz-Nr. 37/2008 mit Genehmigung vom Amt für Geoinformation, Vermessung und Kataster der Stadt Essen vom 18.06.08

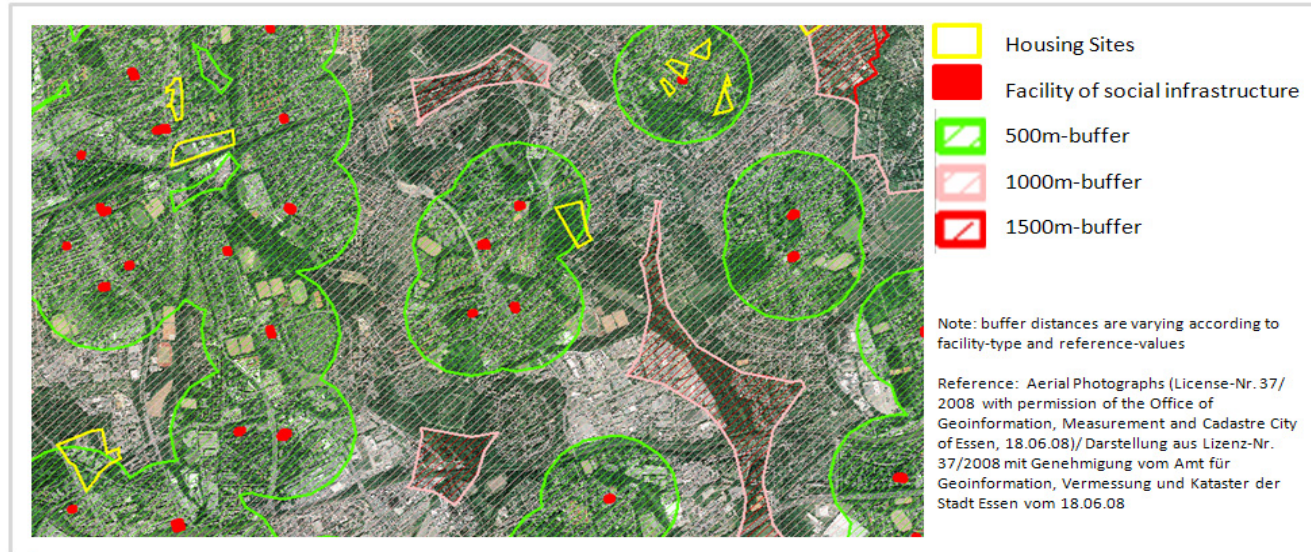
Adjustment of indicator-performance at housing-sites to increment values:

- 1**=(site suitable): location of site outside flood areas
- 2**=(site partially suitable): location of site partially within flood areas
- 3**=(unsuitable): location of site within flood areas

Figure d3

Indicator "Flood Risk"

Principle of buffer-analysis assessing the accessibility of facilities of social infrastructure



Adjustment of indicator-performance at housing-sites to increment values:



- 1=(site suitable): location within 500m- buffer
- 2=(site partially suitable): location of site partially outside 500m- buffer
- 3=(unsuitable): location of site outside 500m- buffer

Figure d4: Buffer analysis

Scheme applicable to indicators:

- Distance to playgrounds
- Distance to local suppliers
- Distance to primary schools
- Distance to kindergartens
- Distance to public transport facilities
- Distance to recreational areas



-  Housing Sites
-  Suspected Contamination

Reference: 1. Aerial Photographs (License-Nr. 37/ 2008 with permission of the Office of Geoinformation, Measurement and Cadastre City of Essen, 18.06.08)/ Darstellung aus Lizenz-Nr. 37/2008 mit Genehmigung vom Amt für Geoinformation, Vermessung und Kataster der Stadt Essen vom 18.06.08; 2. Cadastre of suspected contaminations(Environmental Agency City of Essen, received 2007)

Adjustment of indicator-performance at housing-sites to increment values:

- 1**=(site suitable): site located not within contaminated area
- 2**=(site partially suitable): site located partially within contaminated area
- 3**=(unsuitable): site located within contaminated areas

Figure d5:

Indicator "Suspected contamination"

Table d1 Cadastral land use classes used for indication of recreational areas

Land use number cadastral data	Land use type
4200	Meadows
4210	Park
4220	Playground
5940	Waterfront green
6220	traditional orchard
6300 & 6310	Gardens, allotments
6500	Moor
6700	Fruit Cultivation
6710	Fruit Trees
7100	Deciduous forest
7200	Coniferous forest
7300	Mixed forest
7400	Bosks
8100	Rivers
8200	Canals
8400	Creeks
8500	Graben
8600	Lakes
8650	Artificial lakes
8800	Ponds
9300	Historical areas
9330	Monuments

Annex Results

Tab. 1r Kolmogorov-Smirnov-Test of ecological QoP-indicators

Indicator	Asymptotic Significance
Regulative Function	0.001
Biotope Quality	-
Seeping Rate	0.001
Sealing Rate	-
Isolation	0.000
Protected Areas	0.020
Soil Quality	0.004
Flood Risk	-

n=31

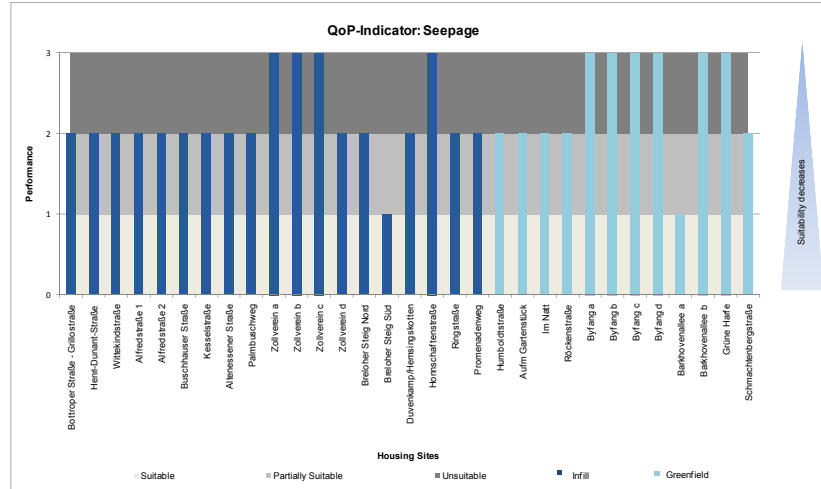
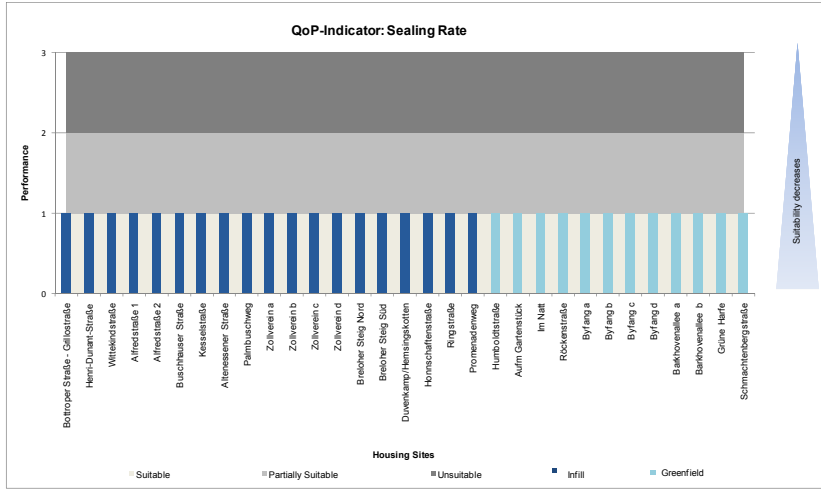
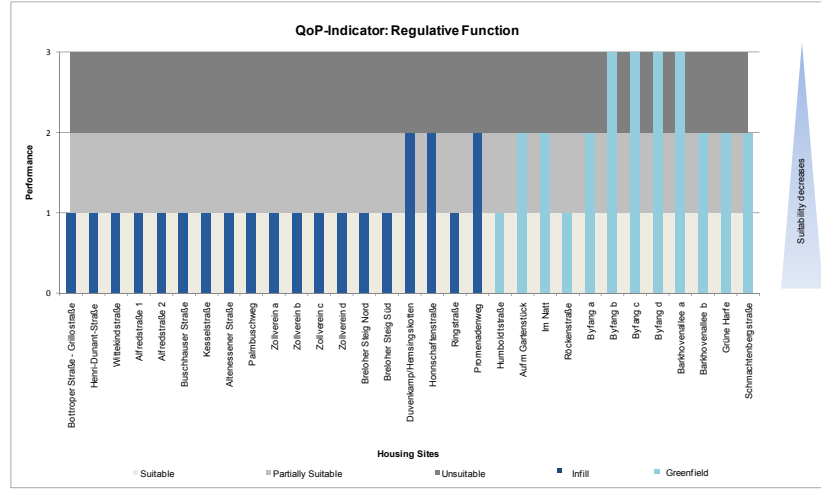
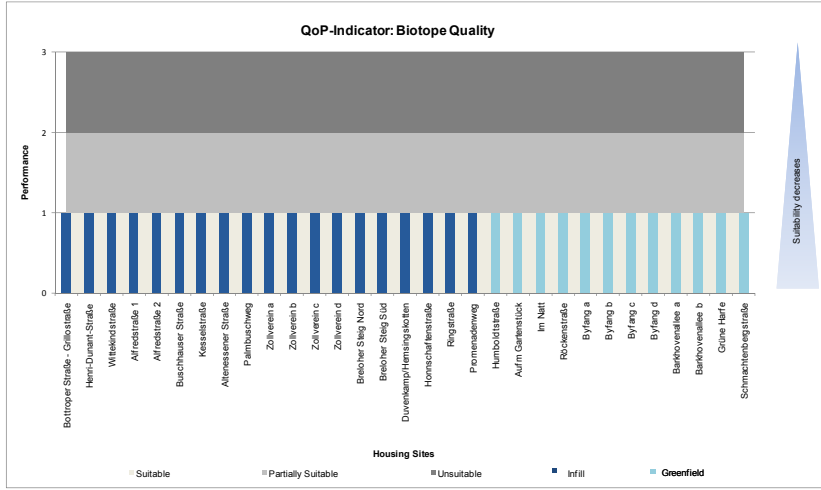


Fig. 1r Indicators of ecological QoP-assessment. Dark blue bars = sites of infill development, light blue bars = sites of greenfield development (own source)

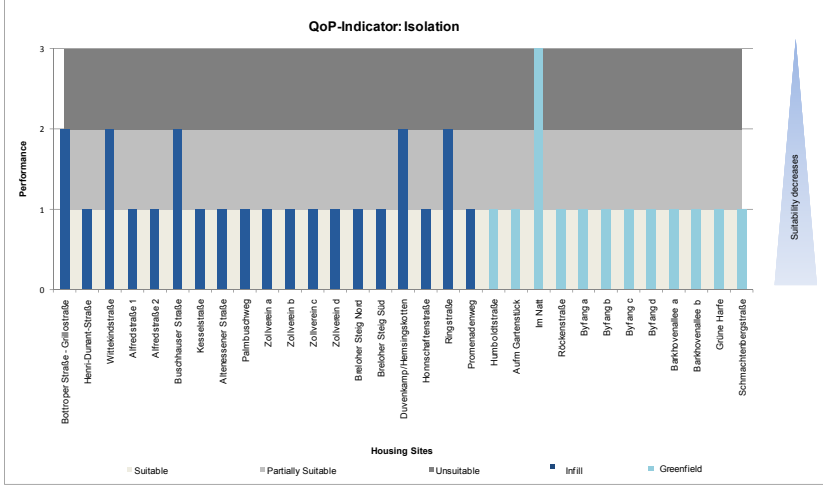
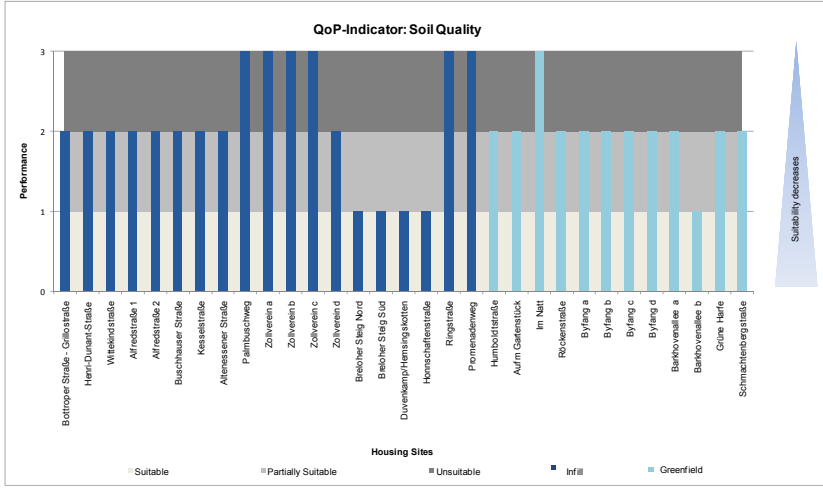
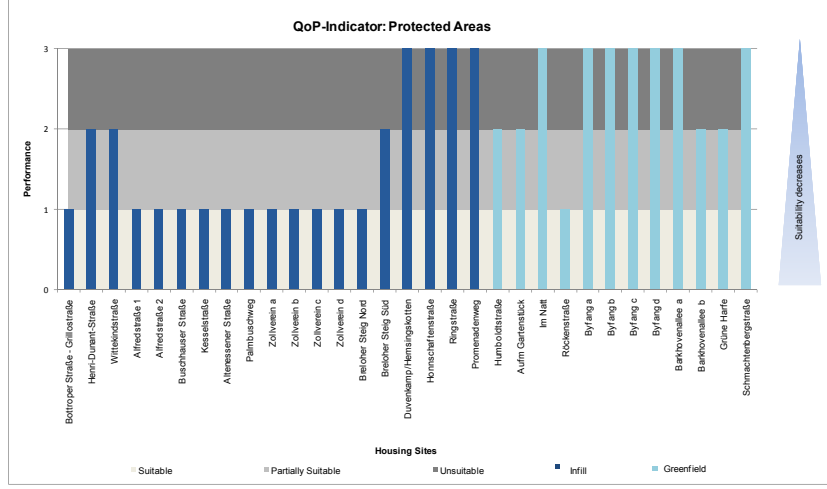
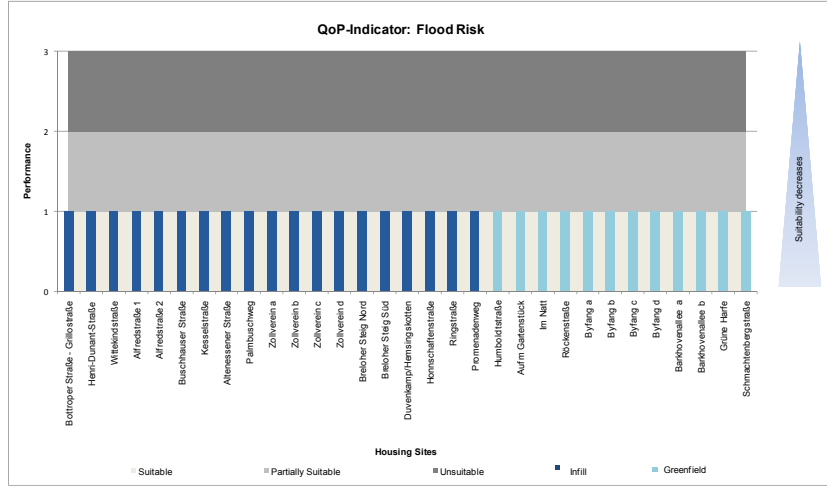


Fig. 14: Indicators of ecological QoP-assessment. Dark blue bars = sites of infill development, light blue bars = sites of greenfield development (own source)

Table 8r Kolmogorov-Smirnov-Test of social QoP-indicators (Source: Schetke 2009)

Indicator	Asymptotic Significance
Playgrounds	0.000
Local Suppliers	0.009
Primary Schools	0.000
Kindergartens	0.000
Bus-Stop	0.002
Subway	0.002
Train Stations	0.000
Noise Exposure (daytime)	0.000
Noise Exposure (nighttime)	0.080
Suspected Contamination	0.001
Accessibility of recreational areas	0.000

n=31

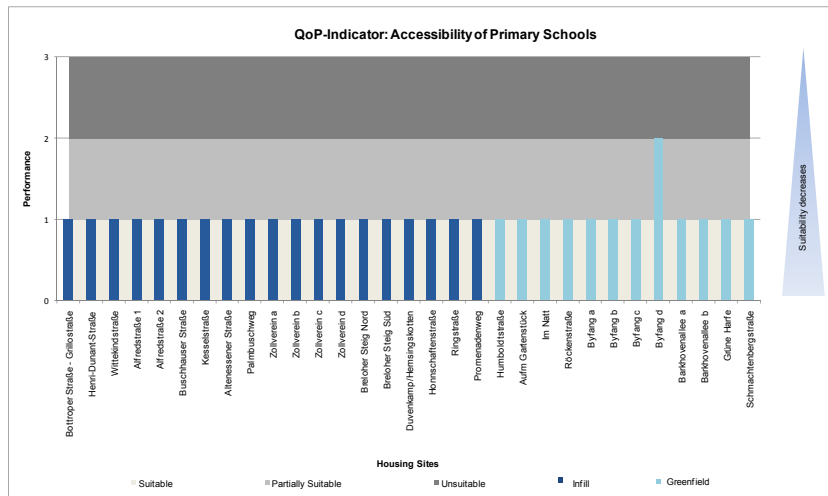
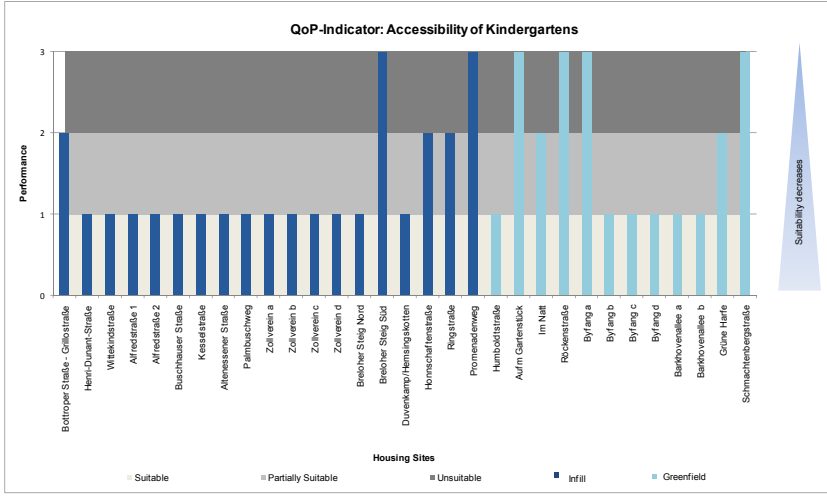
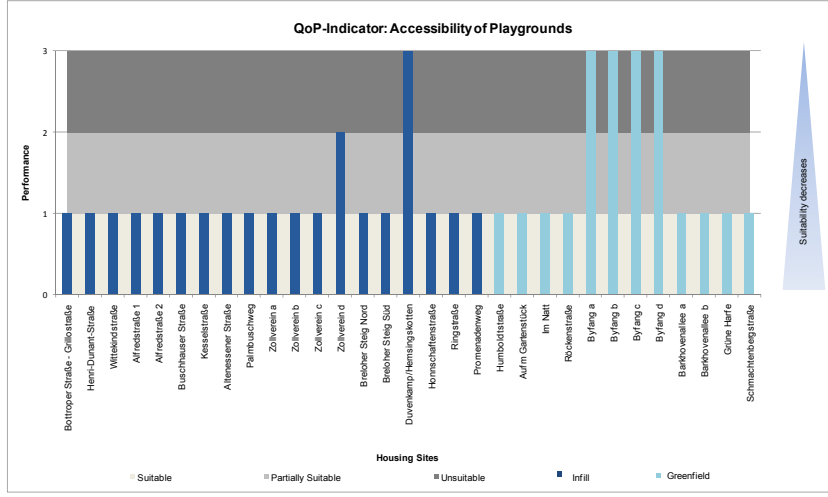
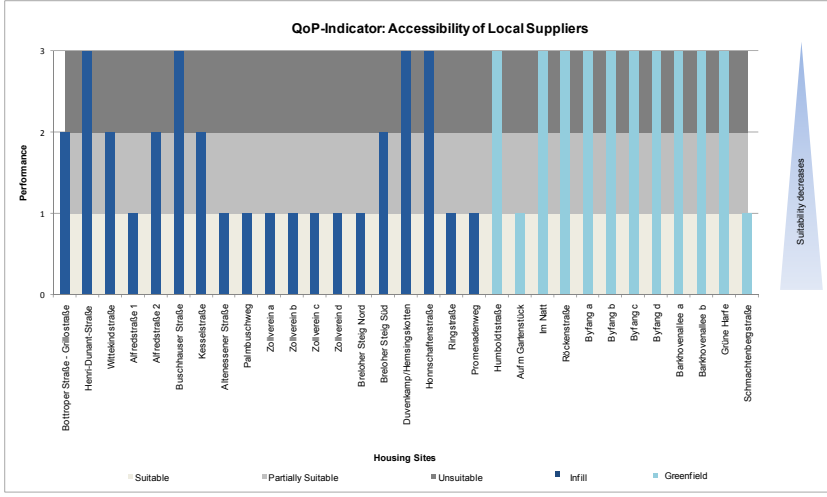
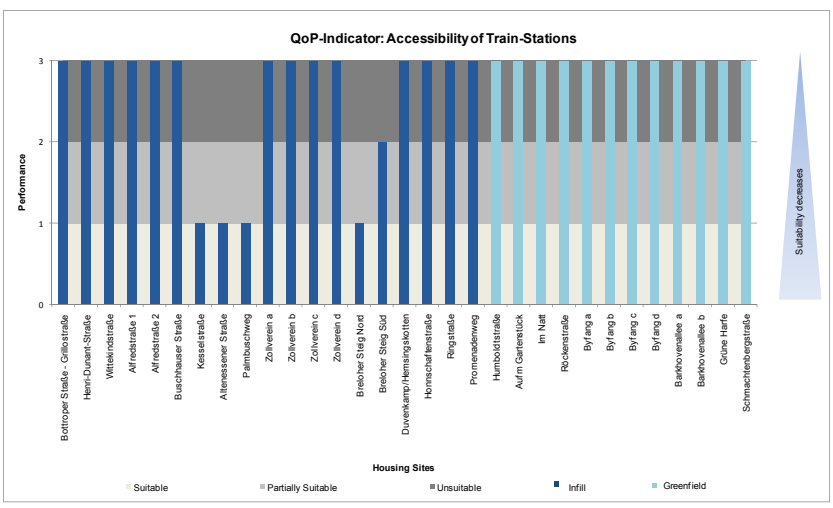
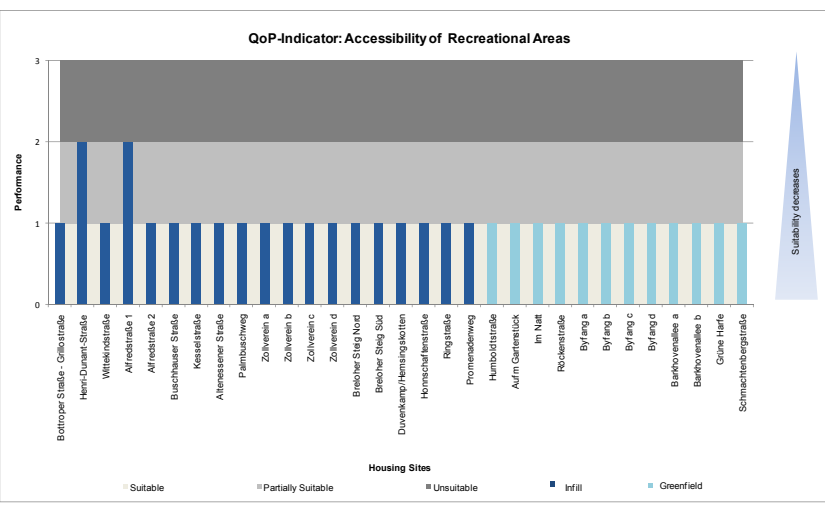
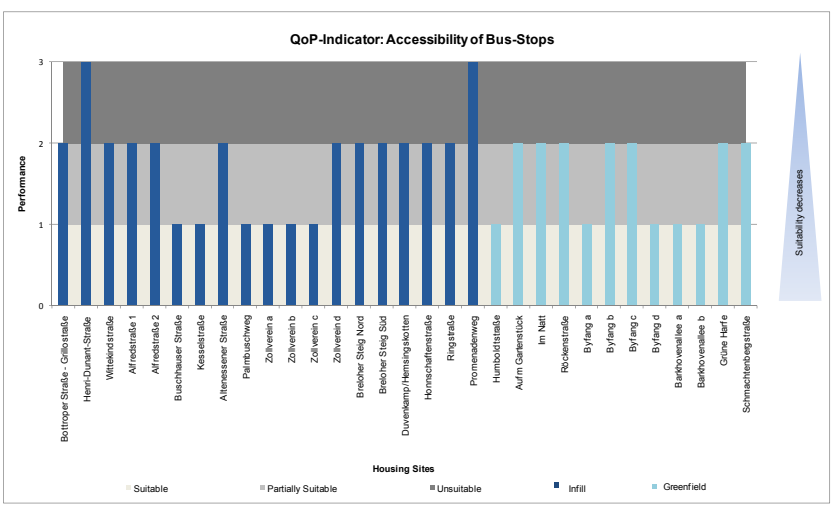
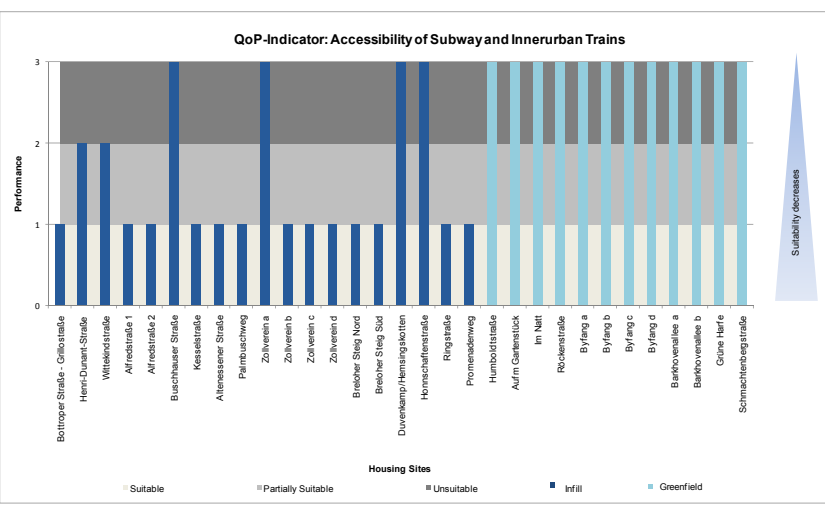


Fig. 2r Indicators of social QoP-assessment. Dark blue bars = sites of infill development, light blue bars = sites of greenfield development (own source)

Fig. 21 Indicators of social QoP-assessment. Dark blue bars = sites of infill development, light blue bars = sites of greenfield development (own source)



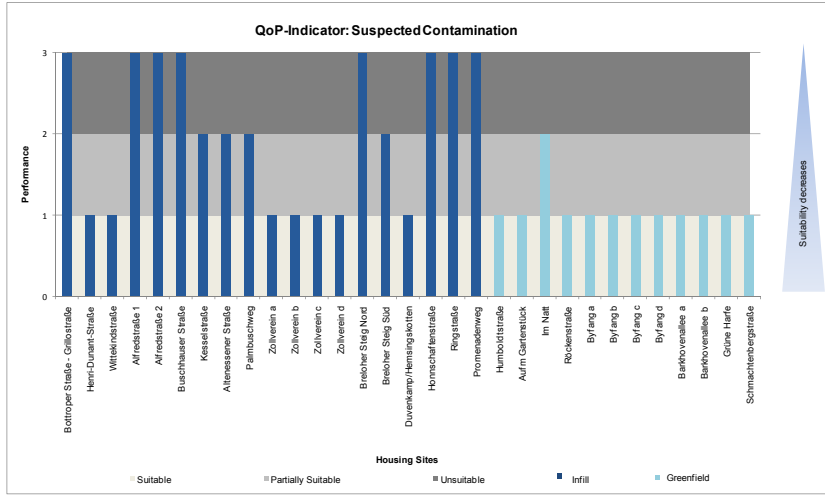
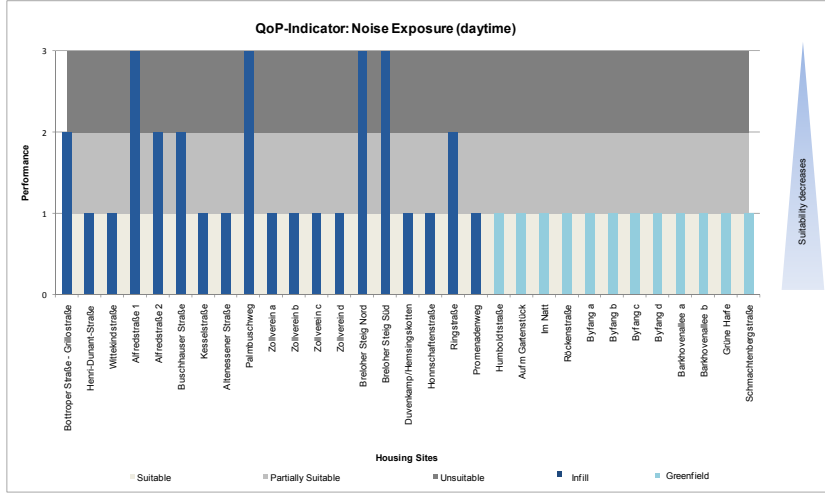
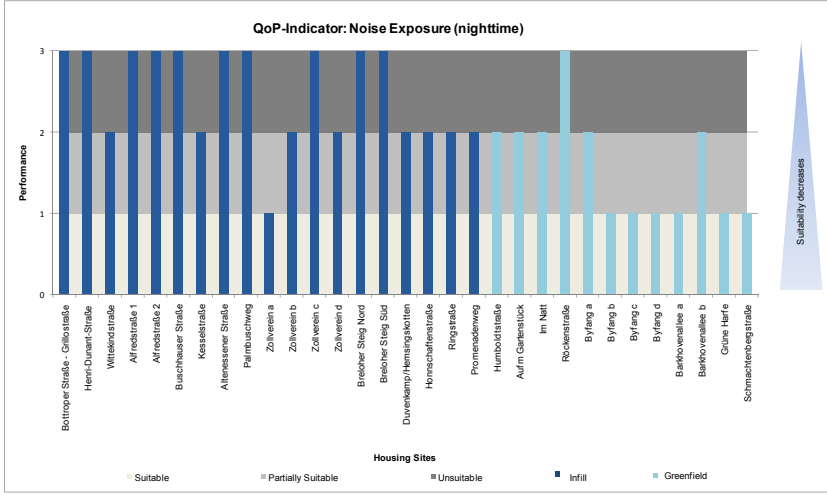


Fig.21 Indicators of social QoP-assessment. Dark blue bars = sites of infill development, light blue bars = sites of greenfield development (own source)

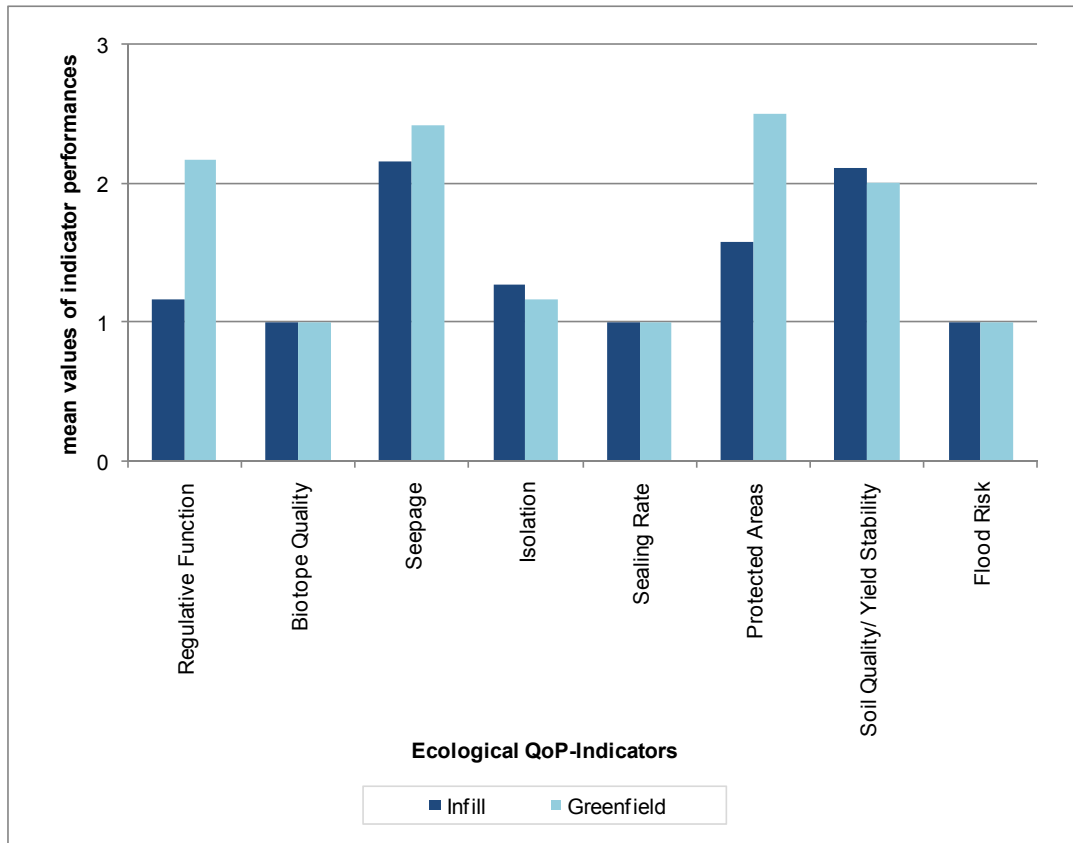


Figure 3r Mean values of performances of ecological QoP-indicators (own source)

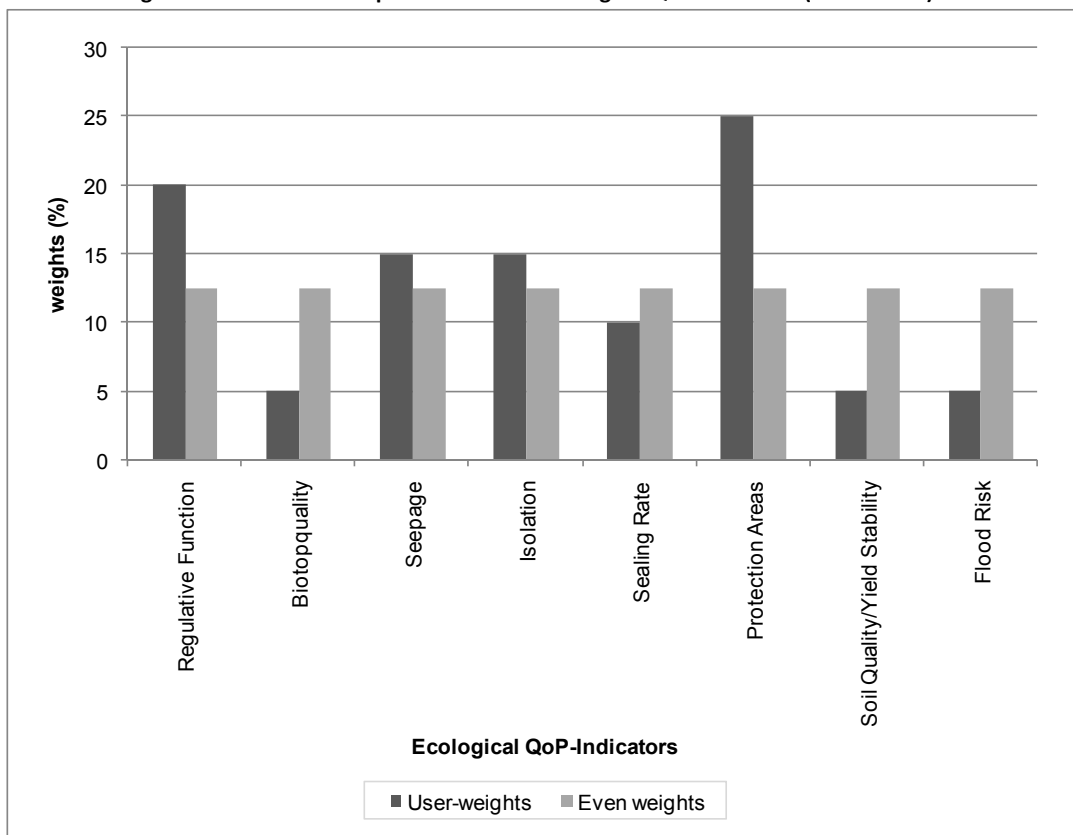


Figure 4r Indicator weights of ecological QoP-indicators (expert-weighted & equally weighted; own source)

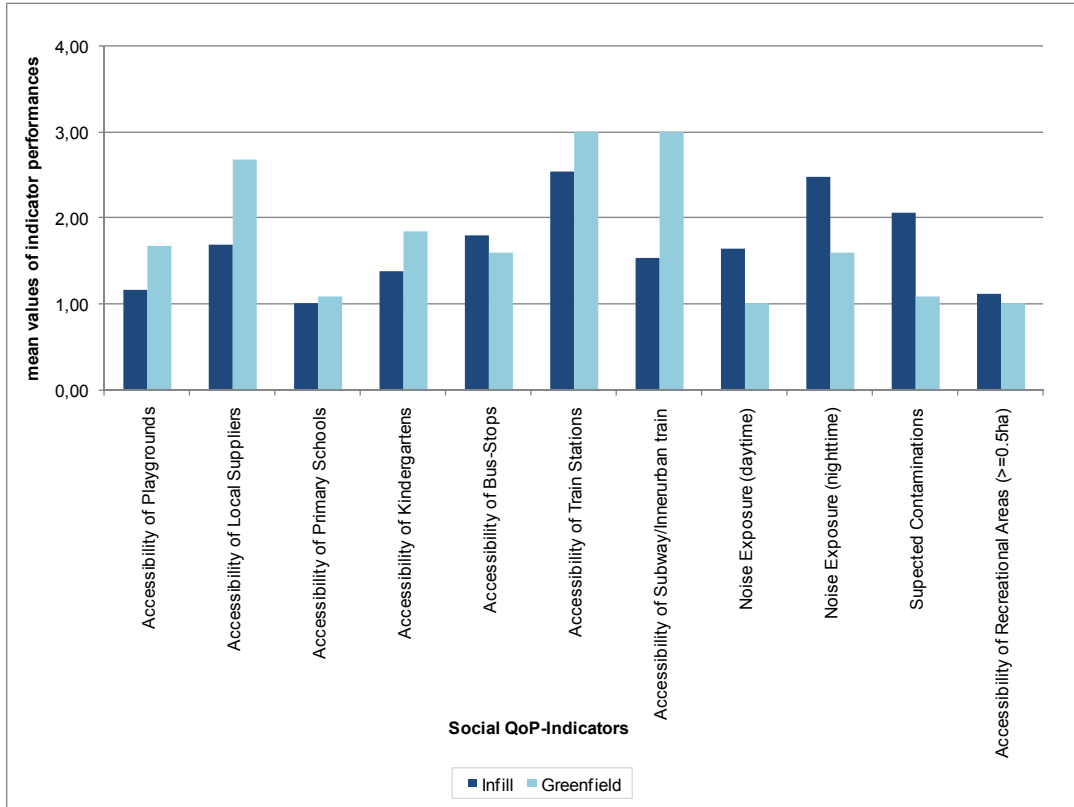


Figure 5r Mean values of performances of social QoP-indicators (own source)

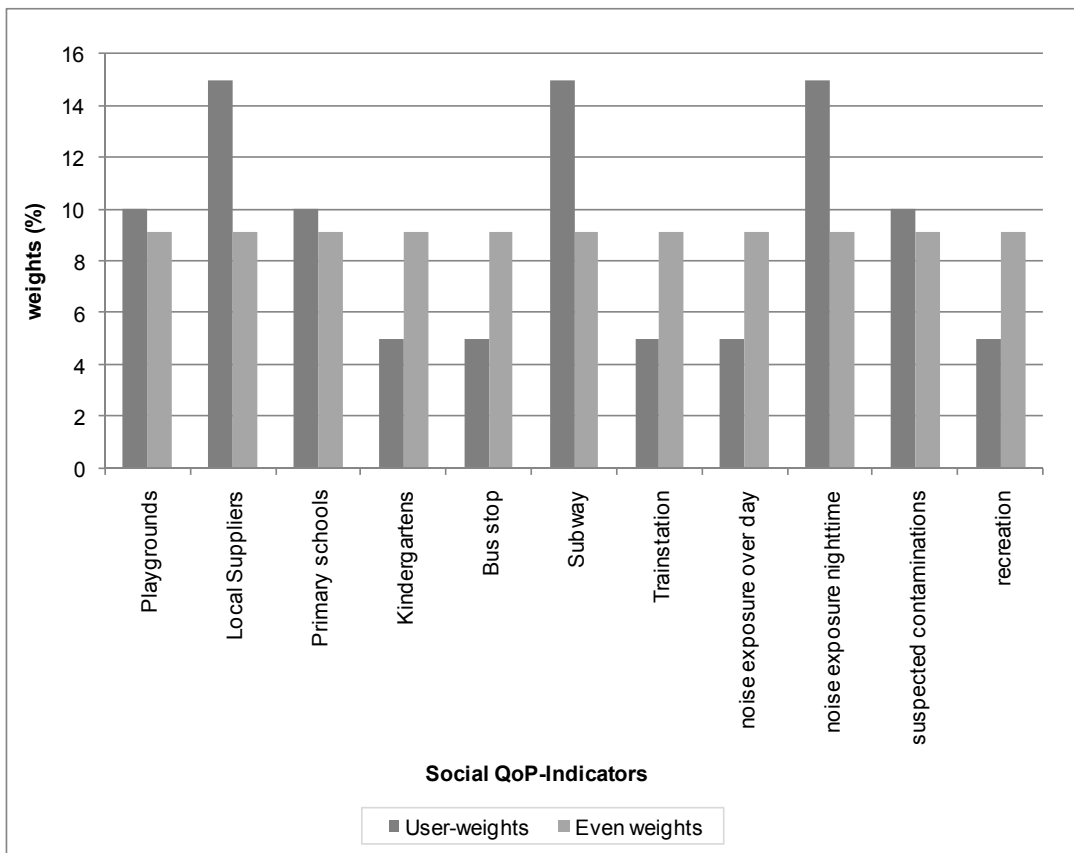


Figure 6r Indicator weights of social QoP-indicators (expert-weighted & equally weighted; own source)

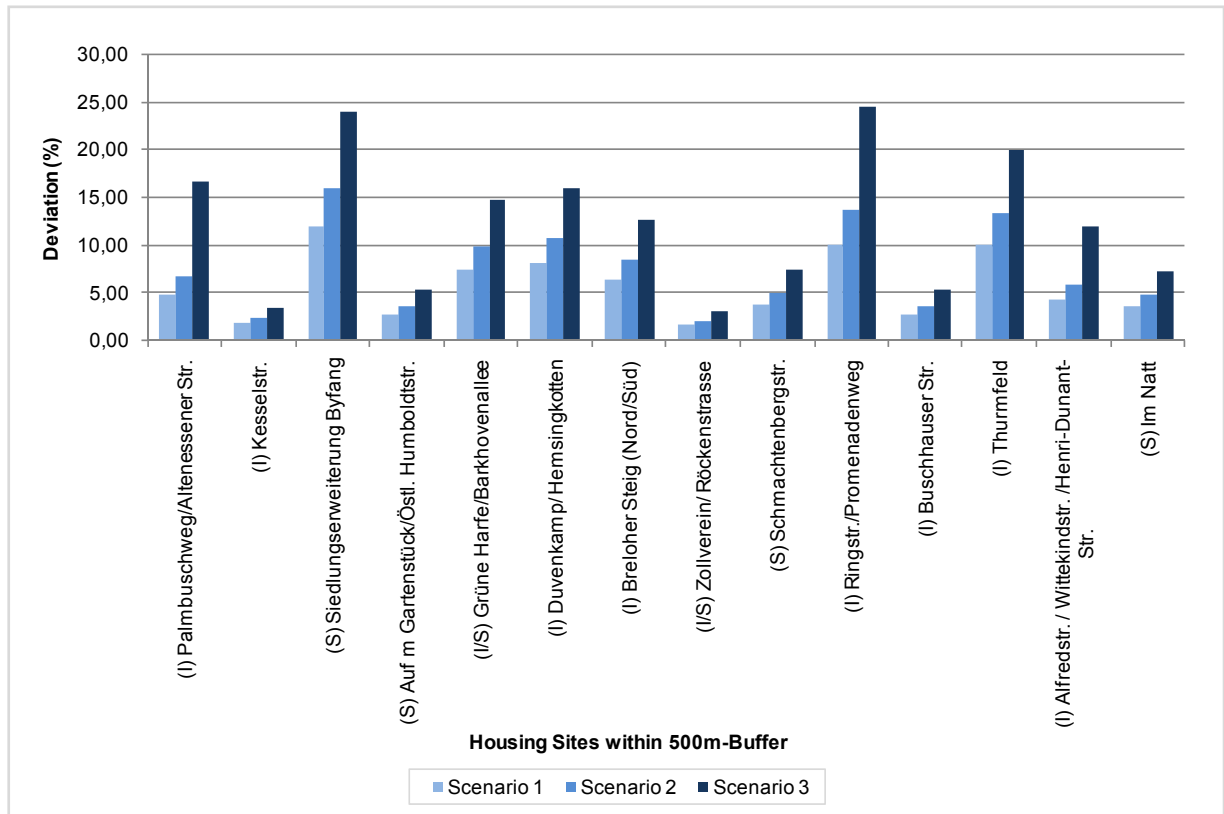


Figure 7r Deviation of residents of closer living surroundings from status quo (Source: Schetke)

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