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Urban green spaces in transition: Planning and urban social-ecological resilience in the Frankfurt Rhine-Main region

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von Pinar Dörder

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Zweitgutachter: Prof. Dr.-Ing. Hans-Joachim Linke

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Verfassererklärung

Ich versichere hiermit, dass die vorliegende Dissertation “Urban green spaces in transition: Planning and urban social-ecological resilience in the Frankfurt Rhein-Main region” – soweit nicht anders gekennzeichnet – das Ergebnis meiner eigenständigen Arbeit ist und von mir an keiner anderen Hochschule und zu keinem anderen Zeitpunkt vorgelegt wurde.

Heppenheim,	*20. März 2022*	P. Dürder
Ort	Datum	Unterschrift

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Heppenheim, Christmas Eve 2021

To my Mimi,

who helped me find joy in this life.

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Abstract

This study emphasizes the significance of urban green spaces in the fast growing middle-sized towns in the Frankfurt Rhine-Main region in Germany and investigates the transitions these spaces are currently undergoing. As the local impacts of a changing climate are now more severe and frequent, the role of urban green spaces in local climate regulation is becoming increasingly important. At the same time, the current settlement growth pressure in growing regions reached unprecedented levels, and '*inner before outer development'* is a resourceful strategy to enable settlement growth by mobilizing inner area potentials before resorting to the outer.

Though this is, in fact, a land-use conflict: Are green spaces spatial reserves for inner development, or are they natural resources for climate adaptation, biodiversity, and recreation, or can they be both? Inner development, particularly within the framework of the accelerated procedures of the Building Code and the minimum density values specified by the Hessian State Development Plan, is likely to bring higher levels of soil sealing in the already existing built-up areas, where green spaces are needed the most. This would be an unfavorable outcome for a well-functioning green infrastructure that is ideally interconnected, evenly distributed, and serving each individual equally. For the studied case, the fastest growing middle-sized towns in the region are investigated to understand the extent and the implications of this transition.

The study therefore benefits from urban governance and growth literature on one hand and the landscape ecology literature on the other. Two lines of inquiry guide the research: (i) understanding the phenomenon of resource conflict by exploring the extent to which urban growth impacts urban green spaces, and (ii) understanding the context of resource conflict by explaining how planning processes, its institutions and governance accompany urban growth. The research shows that social-ecological systems thinking can be the basis for an empirical investigation of urban green spaces through a replicable methodology. This is promising for the planning practice given the limitations in operationalizing the abstract goals such as sustainability or resilience.

The results are relevant for three main issues. First, the empirical parts of this study function as a social-ecological reading of the German spatial planning system. It is found that the region, as an administrational level and a planning scale, steers the inevitable contradictions between the supralocal and local planning through certain predetermined flexibilities. Second, it is found that the protection, provision, and maintenance of green spaces with high social and ecological value are highly vulnerable to institutional capacities. Finally, the spatial analysis of green space parameters and their social and ecological value proves beneficial for the development of a citywide green concept for the towns undergoing transitions. A certain level of both expansion and density is indeed needed for efficiently and effectively functioning urban areas. This research shows that despite inevitable tradeoffs, systematic approaches can help detect the potential for resourceful settlement growth.

Zusammenfassung

Diese Studie befasst sich mit der Bedeutung städtischer Grünflächen in schnell wachsenden Mittelstädten der Region Frankfurt Rhein-Main und untersucht die Transformationen, die diese Flächen derzeit durchmachen. Da lokale Extrema, verursacht durch den Klimawandel, immer stärker und häufiger auftreten, wird die Rolle von städtischen Grünflächen in der Klimaanpassung immer wichtiger. Gleichzeitig hat der aktuelle Siedlungswachstumsdruck ein noch nie dagewesenes Ausmaß erreicht. Hierbei soll die Strategie ‚Innen- vor Außenentwicklung' ein Siedlungswachstum ermöglichen, indem Innenflächenpotenziale erschlossen werden, bevor auf Außenflächen zurückgegriffen wird.

Es handelt sich hierbei um eine Flächenkonkurrenz: Sind Grünflächen räumliche Reserven für die Innenentwicklung, natürliche Ressourcen für Klimaanpassung, oder können sie beides sein? Die Innenentwicklung, insbesondere im Rahmen der beschleunigten Verfahren des Baugesetzbuches und der Mindestdichtewerte des Landesentwicklungsplanes, wird voraussichtlich zu einer höheren Bodenversiegelung im innerstädtischen Bereich führen. Dies wäre ein ungünstiges Ergebnis für eine gut funktionierende grüne Infrastruktur, die idealerweise verbunden, vernetzt und gleichmäßig verteilt ist. In dieser Studie werden die am schnellsten wachsenden, mittelgroßen Städte in der Region untersucht, um das Ausmaß und die Auswirkungen dieses Übergangs zu definieren.

Die Studie nutzt daher die Literatur zu urbaner Governance, Stadtwachstum und Landschaftsökologie. Zwei Gedanken leiten das Forschungsvorhaben: (i) das Phänomen des Ressourcenkonflikts durch die Untersuchung des Ausmaßes zu verstehen, in dem städtisches Wachstum städtische Grünflächen beeinflusst, und (ii) den Kontext des Ressourcenkonflikts dadurch zu erklären, wie Planungsprozesse, Planungsinstitutionen und Governance das Wachstum begleiten. Die Forschung zeigt, dass sozial-ökologisches Systemdenken, als Grundlage für eine empirische Untersuchung von städtischen Grünflächen, eine reproduzierbare Methodik sein kann. Dies ist vielversprechend für die Planungspraxis, angesichts der Grenzen bei der Operationalisierung abstrakter Ziele wie Nachhaltigkeit oder Resilienz.

Die Ergebnisse sind für drei Hauptthemen relevant. Erstens fungiert der empirische Teil dieser Studie als eine sozial-ökologische Lesart des deutschen Raumplanungssystems. Es wird festgestellt, dass die Region als Verwaltungsebene und Planungsmaßstab die unvermeidlichen Widersprüche zwischen überörtlicher und örtlicher Planung durch bestimmte vorgegebene Flexibilität steuert. Zweitens wird festgestellt, dass der Schutz, die Bereitstellung und die Pflege von Grünflächen mit hohem sozialem und ökologischem Wert von den institutionellen Kapazitäten abhängen. Schließlich erweist sich die räumliche Analyse von Grünflächenparametern und deren sozialem und ökologischem Wert als vorteilhaft für die Entwicklung eines gesamtstädtischen Grünkonzepts für die Städte im Wandel. In der Tat ist ein gewisses Maß an Innen- als auch Außenentwicklung für effizient und effektiv funktionierende städtische Gebiete erforderlich. Die Untersuchung zeigt, dass trotz unvermeidlicher Kompromisse, systematische Ansätze das Potenzial für ressourcenschonendes Siedlungswachstum ermöglichen können.

1. Introduction

1.1. Background

This research emphasizes the significance of urban green spaces in the planning discipline and their contribution to resilience through the studied case, the Frankfurt Rhine-Main region. In the face of ongoing urban growth driven by the peak demand for settlement development, ensuring sustainable urban planning practices is necessary. Considering the contributions of urban green spaces to local climate regulation, recreation, and biodiversity, improving and sustaining their social and ecological values, especially during times of inevitable transitions, is essential.

Over the last 50 years human activities have been altering the environment more extensively and rapidly with devastating environmental impacts attributed to cities (Grimm et al., 2008). Growing evidence shows that the functioning of urban systems is dependent on the environmental benefits provided by urban green spaces. How urban growth takes place influences the quality and quantity of urban green spaces and their benefits to a great extent: *growing in* (inner development) can take place at the expense of vegetation cover within an urban area; whereas *growing out* (outer development) can cause a significant loss of vegetation cover around an urban area. Outer development in the form of sprawl indicates an urban form that is to be avoided and connotes not only a massive loss of natural environment but also an increase in car dependency, greenhouse gas emissions, air pollution, infrastructure investment, operation, and maintenance costs, and social segregation. Therefore, compact urban form with higher density receives recognition as a key response against urban sprawl (Davern, Farrar, Kendal, & Giles-Corti, 2017; Olofsdotter et al., 2012).

The ideal of compact urban form is however not unproblematic: Inner development in the form of densification is often associated with increased impervious surfaces and decreased vegetation cover in already existing settlement areas. The loss of vegetation cover is associated with more intense local impacts of climate change and less room for recreation and biodiversity. For instance, urban heat island effect occurs when cities have higher temperatures than their rural surroundings due to high soil sealing proportions. Although urban heat island has negligible effect on global climate, temperature rise due to urban heat island in urban areas was shown to exceed the predicted rise in global temperature (Grimm et al., 2008). Numerous studies thus far have shown that urban green spaces moderate extreme heat in their surroundings by their cooling capacity (Davern, Farrar, Kendal, & Giles-Corti, 2017). A high degree of built-up density is also associated with the blocking of wind corridors and their cooling effect on the built environment. Increased sealed surfaces bring

about water-related hazards, too, as they alter the natural hydrological processes and increase the risk and damage of flooding. Drought, on the other hand, might not be directly physically experienced by urban dwellers, but has massive interruptive consequences on processes such as agricultural provision.

Considering the increased frequency, randomness, and severity of main urban hazards (floods, droughts, and heatwaves) the role of urban green spaces in climate adaptation becomes increasingly important. Additionally, inner-city urban green spaces have various other functions, including but not limited to recreation and biodiversity, and have to be protected. At the same time, due to the growing housing demand in urban areas, providing denser settlements in inner-city areas can be a resourceful strategy against sprawl. In this regard, urban green spaces can fulfill two distinct roles: on the one hand as multifunctional natural resources for climate adaptation, recreation, and biodiversity, and on the other as spatial reserves for settlement development. These competing roles of space is becoming a major challenge in many growing metropolitan regions in the world. The Frankfurt Rhine-Main region, with its peak rates of housing demand and increased risk of urban climate hazards, is no exception to this trend.

1.2. Setting the context

It is expected that the population of the Frankfurt Rhine-Main region will continue to increase. The population of the conurbation is expected to increase by 7,1 per cent until 2030, representing an influx of around 165.000 inhabitants. This corresponds to a housing supply that should reach approximately 230.000 dwellings (Regionalverband FrankfurtRheinMain, 2018), meaning that during the 2014-2030 period 10.900 dwellings should be provided yearly. Compared to the provision rate in the 2010-2014 period—approximately 6.500 dwellings per year (Regionalverband FrankfurtRheinMain, 2016c)—what becomes apparent is that today's housing provision strategies need to adequately respond to the demand.

National planning principles in Germany prioritize strategies against sprawl by reducing daily open land consumption from 113 hectares to 30 hectares by 2020 and by protecting natural environment through *inner before outer development* (*Innen- vor Außenentwicklung*), which urges local and supralocal institutions to take necessary measures to protect natural environment and to adjust settlement growth strategies accordingly (The Federal Government, 2002). Since this goal could not be reached by 2020, it is prolonged till 2030.

The role played by the regional-level planning in mediating the local-level and supralocal-level goals (e.g. settlement provision while not taking up open land) is quite significant: Regional plans safeguard that the supralocal goals are realized in towns and municipalities,

while remaining flexible and responsive to the changes and requirements coming from the local-scale. In the example of the studied case, the District Authority of South Hesse and the Regional Association Frankfurt Rhine-Main jointly develop land-use plans and concepts for the Frankfurt Rhine-Main conurbation. These institutions are in charge of creating regional-scale concepts to address current challenges through enabling vertical and horizontal dialogue and bridging federal and local levels of administration. For instance, the District Authority of South Hesse published the Regional Development Concept (*Regionalentwicklungskonzept*) which addresses settlement development, transportation infrastructure, industry and logistics (Regierungspräsidium Darmstadt, 2019). Prior to that, the Regional Association Frankfurt Rhine-Main drafted a Settlement Development Concept (*Siedlungsentwicklungskonzept*) for the residential settlement demand in the conurbation area (Regionalverband FrankfurtRheinMain, 2016a).

According to these investigations, the housing provision potential of the conurbation could potentially reach 220.000 new dwellings, 183.000 of which being located at the agglomeration area (*Verdichtungsraum*) and 37.000 at the regulatory (*Ordnungsraum*) and rural areas (*Ländlicher Raum*). Ideally, 106.000 of the overall potential could be provided through inner development, another 100.000 through new development on open land, and the remaining 14.000 through mixed-use development

Figure 1.1). According to the survey conducted with the member municipalities of the Regional Association in 2017, 38 per cent of the areas that are assigned for new development in the land-use plans cannot be mobilized due to constraints related to land ownership problems, high provision, operation, and maintenance costs of social and technical infrastructure, lack of political will, and environmental concerns (Regionalverband FrankfurtRheinMain, 2018).

In 2016, in line with the recent population prognosis, the feasibility studies for housing provision focused on prioritizing the 1.000-meter radius around train stations in towns that make up the well-connected agglomeration area in the conurbation. By prioritizing these spatial focus areas, inactive inner (and outer) development areas for residential development could be mobilized to reach the anticipated levels of new housing demand and respond to the backlogging demand.

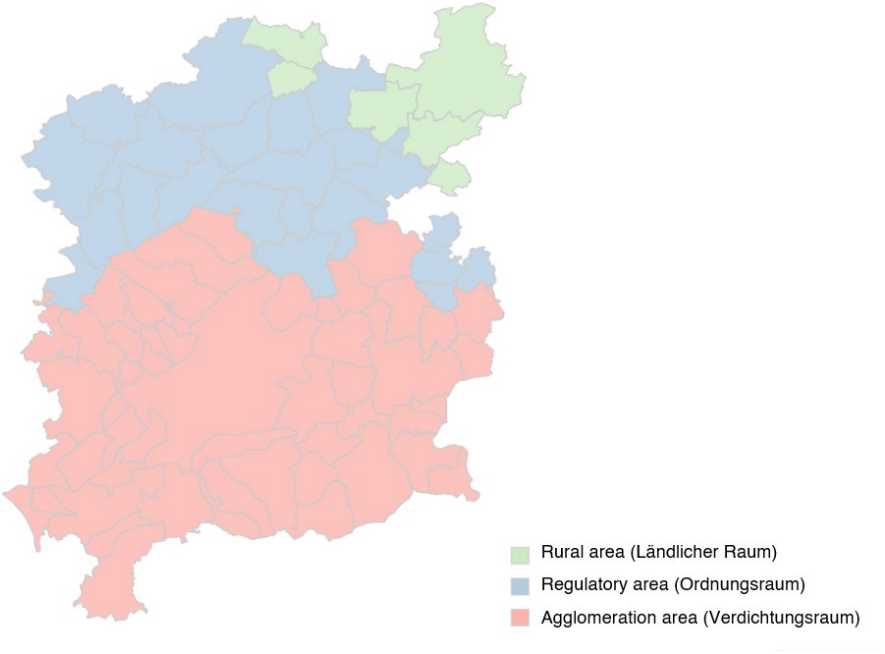


Figure 1.1: Rural, regulatory, and agglomeration areas in the Frankfurt Rhine-Main conurbation (adapted and translated from Regionalverband FrankfurtRheinMain, n.d.).

On the one hand, inner development within a 1.000-meter radius around a train station has certain advantages as it provides more efficient use of existing built environment and its services and, therefore, encourages the use of public transportation and reduces car dependency since 1.000 meters is a walkable and bikeable distance. However, it inevitably prioritizes the use of inner-city spatial reserves and resources more intensively in favor of denser settlements and might cause unfavorable conditions for the quality and amount of urban green spaces located within the catchment area determined by the 1.000-meter distance. On the other hand, developing the outer land can be less complicated provided that no political, environmental, and ownership-related issues restrict the development processes. However, it results in more open land take with no exception due to an extension of the urbanized area over agricultural land or greenfield that is adjacent to the existing settlement, which is often agreed to be an “unsustainable” practice.

1.2.1. Problem statement

Similar to many other growing metropolitan regions, the towns and cities in the Frankfurt Rhine-Main region are under tremendous pressure for providing living, working, and recreational spaces as well as space for infrastructures. Furthermore, the stable regional economy attracts domestic and international migration. Associated housing demand is acknowledged as one of the main drivers of recent transformations and opens up the debates on how settlement growth should take place in towns and cities that are facing growth pressure. With regards to inner-city urban green spaces, this manifests itself as an

urban land-use conflict among various potential uses for space, which represents a resource conflict.

From the viewpoint of the climate regulatory, recreational, and biodiversity functions of urban green spaces, settlement growth in the form of dense inner development in its entirety can be as socially and ecologically problematic as settlement growth in the form of sprawling outer development in its entirety. From the viewpoint of urban social-ecological resilience, protecting the green within a city is not less important than protecting the green around a city. Based on that, this research observes the urban green spaces of the Frankfurt Rhine-Main region both as spatial reserves and natural resources and problematizes the impacts of current pace of settlement growth. Institutional arrangements, governance conditions, and their impact on the urban green space quality and amount within the planning processes in the context of a growing European metropolitan region are the central concerns of this research.

1.2.2. Research aims, objectives, questions, hypothesis

Since the last several decades, scholarly debates within various bodies of literature (among others urban planning, urban development, urban governance, urban ecology, sustainability, resilience) have been elaborating on the issues on urban form and its impacts on the functioning of the city. A recent review focusing on densification as an urban growth strategy to counterbalance sprawl found that green space provision and protection especially during densification could not be easily realized (Haaland & van den Bosch, 2015). A recent federal-level policy, the dual inner development (*doppelte Innenentwicklung*), addresses this and proposes a ranking methodology for potential spatial reserves that could be used in favor of densification, which is done in parallel to a qualitative improvement of green spaces (Böhm et al., 2016). But the potential of these spatial reserves is not limitless and whether an increase in urban green space quality can offset the decrease in urban green space quantity remain to a large extent unknown (Haaland & van den Bosch, 2015).

The state-of-the-art of the relevant debates is already quite advanced. This research is a contribution to the state-of-the art in that it (i) does not limit the debate to densification but rather takes it as a real-life phenomenon and a point of departure; (ii) aims to understand the spatial/natural resource conflict through an investigation of urban green spaces as social-ecological systems; (iii) focuses on the urban growth-related challenges of several representative middle-sized towns that are in close vicinity to the metropolitan city; and (iv) combines a quantifiable spatial analysis of land-use/land-cover change with qualitative analyses of in-depth interviews to capture a more complete picture of the current planning processes.

This research observes the middle-sized towns in the Frankfurt Rhine-Main region with the highest increase in population, housing stock, and residential/mixed land-use. The main goal of the study is to explore the extent and the ways in which the current urban growth impacts green spaces and explain the ways in which planning processes are responding to this. Urban green spaces are approached as spatial reserves for growth as well as natural resources of social and ecological value. Based on that, the breakdown of the research aims, questions and objectives are as follows:

Research aim 1: To understand the *phenomenon of resource conflict* and its manifestation as an urban land-use conflict in urban green spaces.

Research question 1: To what extent does recent settlement growth impact the quality and quantity of urban green spaces?

- **Objective 1.1**: To analyze the recent population growth and construction activity to find out the fastest growing middle-sized towns in the conurbation.
- **Objective 1.2**: To demonstrate whether this pace of growth is reflected in land-use change in the spatial focus area.
- **Objective 1.3**: To analyze urban green spaces in selected case study towns in terms of amount, distribution, connectivity, proximity within the spatial focus area.
- **Objective 1.4**: To document the current status of urban green spaces in the studied towns with a focus on their social and ecological value.

Expected results: (i) Case study selection on the basis of the population and housing stock increase in the middle-sized towns; (ii) the quantified change in the amount of urban green spaces in the spatial focus area; (iii) the mapping and illustration of green space parameters in the focus areas of the studied towns.

Research aim 2: To understand the *context of resource conflict* within institutional arrangements and governance conditions.

Research question 2: In what ways are the governance conditions supportive for or restrictive to urban social-ecological resilience?[1]

- **Objective 2.1**: To analyze the implications of recent urban growth (e.g. implications of population and economic growth, settlement growth, inner development, esp. densification and outer development).
- **Objective 2.2**: To investigate settlement growth and its implications with a focus on urban green spaces.

[1] The formulation of the second research question is inspired by the line of thought in Bressers & Bressers, 2016.

- **Objective 2.3**: To propose approaches as to what practices should be kept as it is and what can be improved.

Expected results: (i) An overview of the institutional arrangements and resultant governance conditions within the planning practice; (ii) the indication of the ways in which the provision and protection of urban green spaces are supported or restricted.

The research tests the following hypothesis: *"If and when governance conditions are supportive for and not restrictive to social-ecological resilience, settlement growth in the middle-sized towns of the region can take place without negative impacts on the quality and quantity of urban green spaces."*

1.3. Conceptual framework

The planning practice strives to find a balance, an optimum, with tools at its disposal (e.g. the compensation measures of the Federal Building Code). Land-use management is also a tool in planning that operates in a cross-scale and cross-sectoral manner with its binding and non-binding components. The complexity of its aspects might be challenging, but it is designed to facilitate sustainable growth through resourceful land-use.

However, it is questionable whether such a balance could ever be reached and if at all sustained, because urban areas are dynamic, open systems with complexity and uncertainty. Although the ideal of reaching and sustaining the best possible urban system is very inspirational, it is necessary to acknowledge the likelihood of a short lifespan of an optimal and balanced state, given the openness, complexity, and uncertainty of urban systems. For the purposes of this research, towns and cities, as well as their urban green spaces, are acknowledged as social-ecological systems. From the viewpoint of urban social-ecological resilience, the research brings together (i) urban land-use conflict as a resource conflict resulting from the settlement growth priority and the environmental protection priority and (ii) debates in planning discipline with regards to institutional settings and governance conditions. The established conceptual framework lays a context-specific foundation to enable a comprehensive analysis of the current situation with the overarching goal to inform future interventions.

1.3.1. Point of departure: urban land-use conflict

In this study, building on Campbell's generic conceptualization of planner's triangle of priorities and conflicts in sustainable planning, the urban land-use conflict located between economic growth (that is related to settlement growth) and environmental protection represents the *resource conflict* between *economic development* and *environmental protection* priorities (Figure 1.2) (Campbell, 1996a).

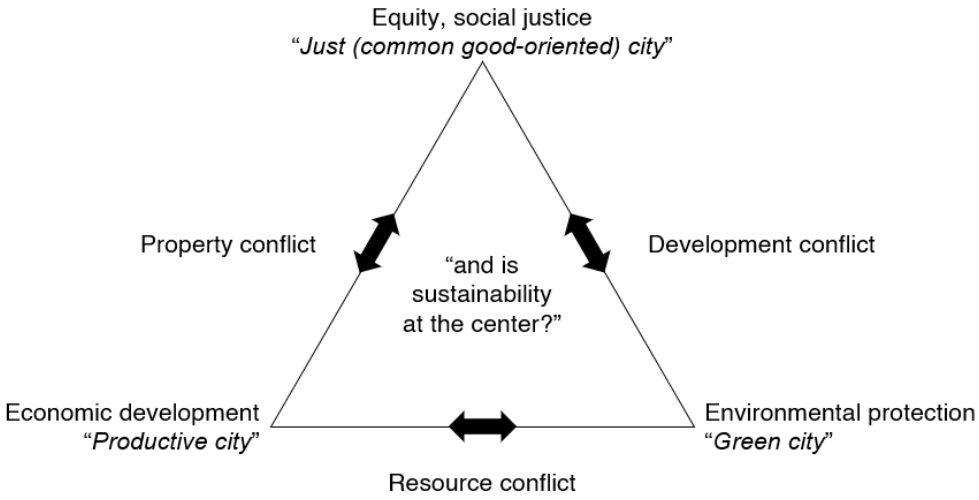


Figure 1.2: The triangle of conflicting goals for planning and the three associated conflicts. "And is sustainability at the center?" (as in original). Planners define themselves, implicitly, by where they stand on the triangle (adapted from Campbell, 1996).2

Urban green spaces as social-ecological systems refer to spatial reserves for settlement growth, which is linked to *economic development* and also to natural resources for climate adaptation, which is further linked to *environmental protection*. Therefore, the urban land-use conflict between these two priorities fully align with the *resource conflict*. It weakens this strong conceptualization if the focus is only on one of its components and the rest remains untouched. Equity and social justice aspects (and also the property and development conflicts) are therefore not excluded from the investigation.

1.3.2. Point of entry: economic development

The most of the world's population and economic activity is concentrated at urban areas. The common opinion is that the population increase is a function of production, innovation, and infrastructures that are determining spatial patterns (Boone & Modarres, 2006). Although it seems to be a simple causation, the correlation between the population increase and urbanization is rather complex, and one can become both the driver and the consequence of the other. This appears in the discussion of urbanized city-regions globally as they are both in cooperation and competition with one another. Global city-regions typically have high dependency on the resources in their surroundings. Against this backdrop, it is important to observe urban green spaces as one of the resources on which the functioning of city-regions depend on. Therefore, the economic development priority is one of the points of entry into

[2] The term "growing cities" referring to the economic development priority is replaced with "productive city" following the transitions in the debates in the last 25 decades. "Productive city" appears in the New Leipzig Charter (Europäische Kommission, 2020). For the purposes of coherence, "Just (common good-oriented) city" and "Green city" replaced the originals used by Campbell (just cities and green cities respectively).

the discussion of the resource conflict. This includes insights from the planning practice, governance, and institutions, with a focus on urban green spaces.

Arguably, the most important urban green space structure in the Frankfurt Rhine-Main region is the Frankfurt Greenbelt and its extension into the other towns in the region, the Regionalpark. The Greenbelt and the Regionalpark are important ecological systems of the region, but they also fulfil the function of being a spatial growth control mechanism. Despite their size, the Greenbelt and the Regionalpark systems do not have to be approached differently to inner-city natural resources. This line of thought of "interconnectedness" of green structures aligns with the argument that cities (also regions) can be considered as human-dominated ecosystems rather than places where the nature ends, with the central concern being *"who produces what kind of social-ecological configurations for whom"* (Heynen, Kaika, et al., 2006). For this reason, it is important to investigate the institutional settings and resultant governance conditions.

1.3.3. Point of entry: environmental protection

Equally important is the environmental protection priority in planning, which is the second entry point into the conceptual debates in this research. Urban green spaces are places of social and ecological value with countless vital functions. To name a few, their recreational function for the wellbeing of humans, their contribution to biodiversity through the habitat function, and their contribution to local climate regulation are vital functions. The consequences of a changing climate at the local level (most commonly the increase in the frequency, randomness, and intensity of floods, droughts, and heatwaves) are aggravated by urbanization. This also means that urban areas are now suffering more often and more intensely from these outcomes. Since the functioning of urban systems depends on the natural environment, the ways to ensure that this dependence is a healthy dependence (Campbell, 1996) calls for careful consideration. Managing this dependency inherently calls for interdisciplinary approaches, which requires the debates in landscape ecology to be incorporated into planning discipline.

What environmental protection means within the ecological subsystem and how it can be achieved through the means of planning cannot be explored without revisiting our understanding of green infrastructures, ecosystem services, nature-based solutions, and ecosystem-based adaptation. These key concepts pave the way to the spatial analysis of green spaces in the following parts of this research.

1.3.4. Paths merging: social-ecological systems thinking

Resilience is fundamentally a social-ecological system property and refers to the amount of change a system can undergo without shifting into different system states, structures or functions. It can be defined as the ability of a system to *"absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks"* (Walker et al., 2004 as cited in Folke et al., 2010). Based on this, a resilient city can be defined as an urban system which has the capacities to absorb a range of disturbances and still retain its basic function and structure (Girardet, 2018).

The urban system can be approached as a social-ecological system that is made up of integrated social and ecological components and their cross-scale interactions. From this perspective, understanding how the social components behave is equally important as understanding the behavior of ecological components (Section 2.2. provides a more detailed look into how the resilience thinking evolved) (Figure 1.3).

As a moving target, resilience has already been explored extensively. It was questioned within the urban resilience debates whether resilience is an idealized state to reach to, or it is rather to be understood as the ability to keep retaining the functions in the presence of any disturbance ranging from slight hazards to devastating disasters. What could be further explored is an approach that recognizes urban land-use conflict as a point of departure and acknowledges both the environmental protection and economic development priorities as equally important points of entry. In this respect, the social-ecological systems thinking can be a foundation in order to further the debate conceptually and empirically.

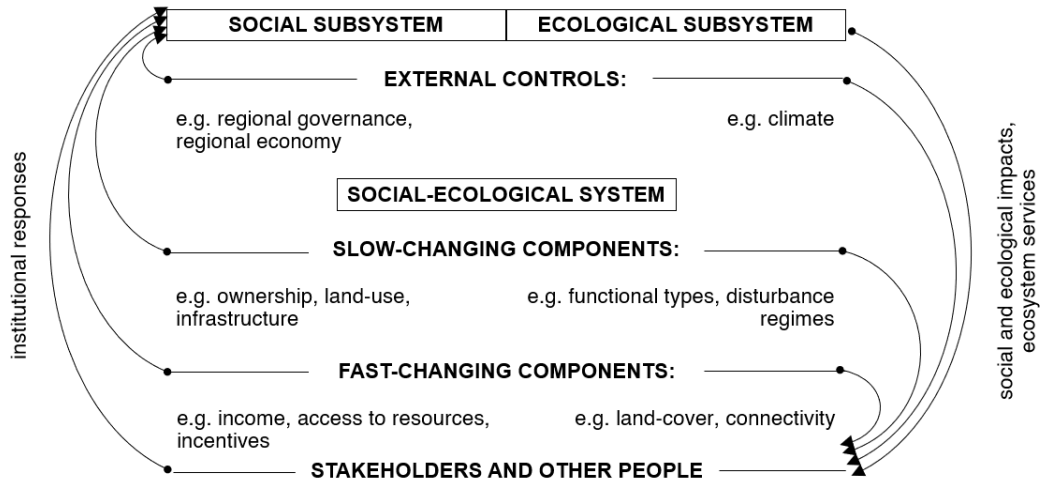


Figure 1.3: Model of integrated social-ecological system (adapted from The Resilience Alliance, 2010).

1.4. Methodological approach

1.4.1. Summary of methodological framework

This research addresses the impacts of urban growth on urban social-ecological resilience by investigating the settlement development dynamics in the fastest growing middle-sized towns in the Frankfurt Rhine-Main region, with a focus on urban green spaces. As an interdisciplinary field of inquiry, the contour of the overall investigation is determined by planning processes. The research thereby uses quantitative and qualitative data, both for the spatial analysis of land-use change and the qualitative analysis of planning processes. A convergent mixed methods design is used in which qualitative and quantitative data are collected in parallel, analyzed separately, and then merged in interpretation (Creswell, 2013). Both procedures have an equal weight and they act complementarily in addressing the main research problem.

1.4.2. Case study region, case study towns

This research is inspired by a researchable problem and investigates a real-life phenomenon occurring in a specific context. The research questions are concerned with the interactions of social subsystem and ecological subsystem in the Frankfurt Rhine-Main region. Therefore, it is a sensible research strategy to approach these correlations among urban growth, urban green spaces, and urban social-ecological resilience through inquiries that are explorative (how are the green spaces impacted?) and explanatory (in what ways are governance conditions supportive or restrictive?).

Table 1.1:The list of selected case study towns in the Frankfurt Rhine-Main region.

County (*Kreis*)	**Town (*Kommune*)**	**Population (current)**	**Population increase 2011-18, relative (%)**
Main-Kinzig-Kreis	Maintal	39.298	9,10
Kreis Groß-Gerau	Rüsselsheim am Main	65.440	10,34
Hochtaunuskreis	Bad Homburg v.d. Höhe	54.248	5,08
Landkreis Offenbach	Langen	37.902	7,36
Main-Taunus-Kreis	Hattersheim am Main	27.590	10,96
Wetteraukreis	Bad Vilbel	33.990	7,32
Regional increase for reference			**8,80**

In the selection of case study towns, the administrative structure of the region is taken into consideration. Each of the six counties (*Landkreis, Kreis*) of the region are represented by one middle-size case study town that is located at the agglomeration area in the conurbation, where both inner and outer development is anticipated to be the highest (Table 1.1). For each case study town, the area outlined by a radius of 1.000 meters around the train station determines the spatial focus area for the analysis of green space parameters. Through

regional concepts, spatial focus areas are prioritized for mobilizing available spaces for development.

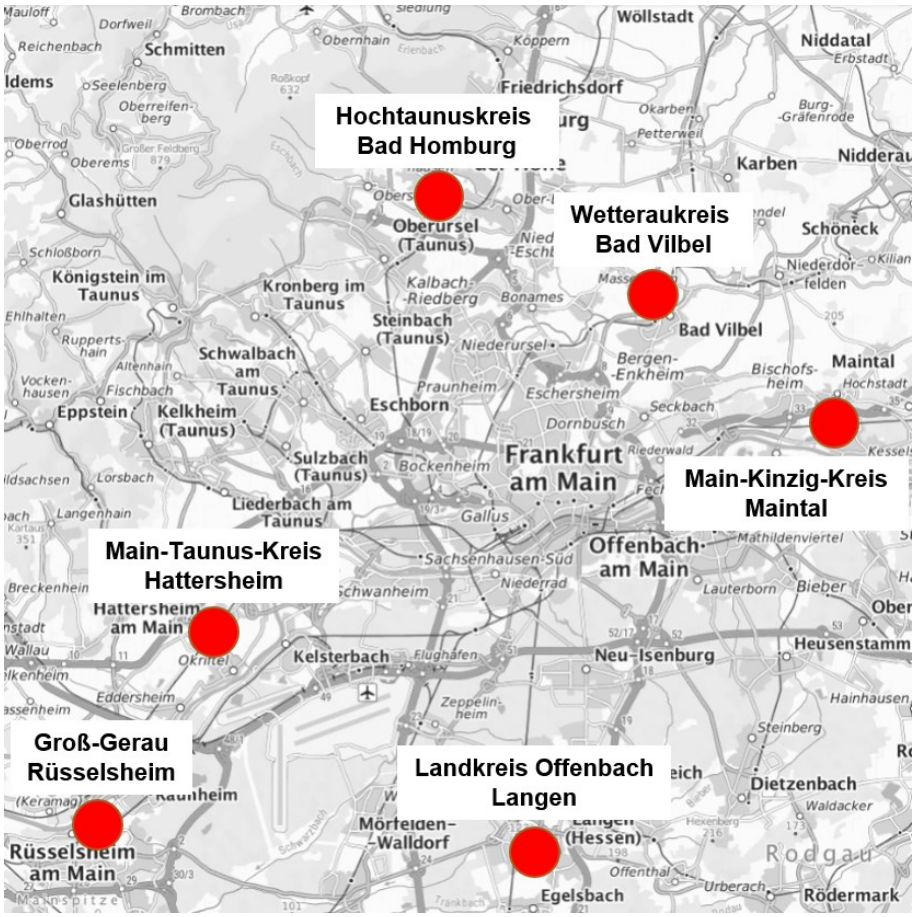


Figure 1.4: The selected case study towns in the Frankfurt Rhine-Main region (own illustration).

1.4.3. Data collection, analysis, interpretation

As formulated by the research questions, this study aims to find out (i) the extent to which recent settlement growth impacts the quality and quantity of urban green spaces and (ii) the ways in which governance conditions are supportive for or restrictive to urban social-ecological resilience for the case study towns.

The first line of inquiry corresponds to the *ecological subsystem* point of entry into the social-ecological systems thinking and is concerned with environmental protection priorities for urban green spaces (Section 2.4). In addition to a before/after comparison of the built environment, this part of the investigation is based on a spatial analysis of the land-cover data for the following green space parameters (European Environment Agency, 2006):

- Amount: The share of vegetation cover and recreational green cover is determined by percentage cover.

- Distribution: The evenness of recreational green space distribution is determined via edge density (m/ha), the ratio of the length of the green space perimeter to the area of the spatial focus area. Higher the ratio, higher the evenness of distribution.
- Connectivity: The percentage of vegetation cover that is connected.
- Proximity: The percentage of settlements that are located within the catchment areas of recreational green spaces.

The spatial analysis is complemented by visits to the spatial focus area of each case study town to conduct field observations onsite. Each green space is photographed, and its social and ecological value is documented through the application of a set of social value—particularly for recreational function and quality of stay—and ecological value—particularly for climate and habitat function—criteria. Social and ecological values are also spatially analyzed and cartographically presented. The goal is to demonstrate sensitive spots where further soil sealing should be restricted and locations that are available for settlement development. Equally important, the *social subsystem* point of entry into the social-ecological systems thinking which is concerned with the impacts of economic growth priorities on urban green spaces (Section 2.3). This part of the investigation is based on a qualitative analysis of the semi-structured interviews with the planning experts from the municipalities of the selected case study towns, regional institutions (the Regional Association Frankfurt Rhine-Main, the District Authority Darmstadt) and the private architecture and urban planning company that is commissioned to develop a regional development concept for South Hesse (Albert Speer and Partners, hereafter AS+P) (data collection and analysis in Chapter 4).

1.5. Significance of the study for audiences

This study aims to go beyond the inner and outer development and compact/sprawl dichotomy to allow for a broader understanding of urban transformations. It suggests that although our conventional planning practices do have the tools to address today's highly complex, unprecedented urban challenges, the rigid and deterministic institutional structures tend to limit the benefits of putting these tools in use. For instance, the concepts related to resilience (e.g. complexity, adaptivity, transformability, uncertainty) could prove useful, but cannot be readily introduced in the planning practices and thus remain as intellectual exercise only. An exception could be the social-ecological systems thinking: It can provide a more structured starting point especially for urban green spaces.

A study of urban green spaces from the perspective of urban social-ecological resilience is important for several reasons. First, the study contributes to the scholarly research and literature by assigning urban green spaces an intermediary role in understanding the impacts of urban growth on urban resilience. Second, it brings together the concepts of urban land-use conflict, economic growth, and environmental protection. Third, it reframes the role of

resilience and social-ecological systems thinking in planning discipline by suggesting that striving for resilience is an integral part of planning processes than an end destination to reach to.

Perhaps more importantly, this research is inspired by first-hand observations of multiple challenges in planning practice in the studied context. The ultimate purpose of the study is therefore to be beneficial for planning practice through a scientific investigation of the highly topical debates around urban growth and green spaces. While searching for answers to the research questions, the research brings new questions that can be of interest to planning scholars for further research and reveals several points that could be beneficial to consider within policy- and decision-making procedures.

1.6. Thesis structure

This chapter gives an outline for the entire study. It does so by introducing the reasons for undertaking the research and presenting the research questions, aims, and objectives. It also summarizes the conceptual models and the methodology, including the expected results and contributions to the field. Chapter 2 reviews the literature and builds on to the scholarly debates in the field. It focuses on the resource conflict as a point of departure, introduces the idea of urban green spaces being urban social-ecological systems, and investigates the social subsystem (institutions, governance, planning) and ecological subsystem (green spaces, landscape ecology) within the field of planning. Chapter 3 provides the justification for the research design. It explains the methods for data collection, analysis, and interpretation in detail on the basis of the research aims and objectives. Following that, Chapter 4 first examines the Frankfurt Rhine-Main region within planning practices and institutional frameworks as the holistic case and then outlines how the case studies are selected. After that, selected case study towns are investigated qualitatively with regards to planning, institutions, and governance, followed by a spatial analysis of its green spaces with regards to green space parameters. Chapter 5 analyzes the results of the investigations and factually presents the outcomes followed by the results of the qualitative and spatial analysis for the selected case study towns. The output of this analysis is a comparative overview both for the qualitative and spatial analyses. The results are discussed in Chapter 6 with reference to the most important concepts covered in the literature review and the research questions, aims, and the main hypothesis. The discussions chapter gives an overview of new themes emerging from the data and lists the identified limitations of the study. Finally, Chapter 7 provides an executive summary of the research, summarizes the most important contributions of this study, and addresses potential further research, policy- and decision-making directions.

2. Conceptual and theoretical considerations

In this chapter, previous studies with the potential to inform the concept, content, and context of this research are systematically reviewed. Based on this review, the research design is established. The reviewed scholarly literature and policy documents are compiled and thematically grouped between December 2018 and March 2019 based on systematic searches in major scientific databases and the University and State Library of Darmstadt University of Technology. An additional search and sort phase took place in Toronto at the York University's library between September and October 2019. The search is based on the keyword-directed inquiries both in English and German languages with various combinations of urban green spaces; urban land-use conflict; densification; inner (infill) development; sprawl; (regional) economic growth; (regional) governance; environmental protection; climate change adaptation; landscape ecology; urban resilience; urban social-ecological systems. The output is then narrowed down by a category filter (among others architecture, urban planning, urban development, urban studies, landscape ecology, urban ecology) and document type filter (articles, books, book sections, proceedings, policy documents). Among these, 129 documents inform the literature review. The systematic selection and review of relevant key literature helps develop the conceptual framework and supports the development of the methodological framework that guides the empirical parts of this study.

2.1. (Urban) land as a (scarce) resource

As hubs of knowledge and innovation, urban areas are where most of the global population and economic activity is concentrated. As dynamic systems of constant change, contemporary urban areas face massive challenges to an extent that humans and nonhuman components are exposed to unprecedented risks and hazards. This calls for an improvement in conventional responses.

Activating spaces to accommodate the increasing urban population is one of the most important interventions in the built and natural environment and also one of the main tasks of planning practices. In order to provide housing, workspace, and infrastructure, spatial reserves within already existing built environment can be considered available spots for activating spaces. These spatial reserves include urban green spaces often with multiple uses and functions. In the face of settlement growth pressure, inner-city green spaces can serve as spatial reserves to meet the housing demand while limiting the need for greenfield development. At the same time, in the face of increased randomness, intensity, and frequency of main urban hazards—floods, droughts, heatwaves—inner-city green spaces as natural resources are important components of climate change adaptation given their cooling

capacity and their contribution to the natural hydrological cycles. Depending on their social and ecological value, these spaces also provide recreational functions and support habitat functions and biodiversity. In this regard, their overall value within the built environment for human and nonhuman components of nature becomes increasingly important.

This section of the review acknowledges urban land as a scarce resource and looks at the resource conflict between two priorities: urban growth (in terms of both economic and settlement development) and environmental protection. The first subsection focuses on the urban land-use conflict as a resource conflict and lays the foundation for the conceptual framework. Following that, a brief look into the sustainable urban form and alternative approaches to *compact versus dispersed* discussions addresses some of the important insights from old and new critiques on urban form and processes.

2.1.1. Competing for urban land: resource conflict

Population growth and economic growth are the two main drivers of land take and soil sealing (Naumann et al., 2018); whereby population growth can be seen as a consequence of economic productivity and its distributive infrastructures (Boone & Modarres, 2006). Population increase may then bring further progress to economic conditions, which is expected to attract more population in return. This correlation is associated with an increased demand for living and working space which requires settlement provision with adequate social (e.g. schools, daycare centers, basic services) and technical (e.g. public transportation, road networks, waste disposal) infrastructure. The pressure for residential and industrial or commercial settlement development may be so strong, that municipal-level economic competition and land speculation may cause a prioritization of economic development over environmental concerns (Naumann et al., 2018, p. 97).

Almost 25 years ago, *Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development* (Campbell, 1996b) invited planners to rethink planning as an urban growth management tool, first by acknowledging the inherent conflicts among sustainable planning goals in adequately addressing and resolving contemporary urban challenges. Despite the refinement of terminologies and changing debates in the past 25 years, the model is still relevant to current urban sustainability discussions. Campbell (1996) builds a generic framework that outlines the relationships among the three main goals in planning (economic development, environmental protection, and equity and social justice) and three associated conflicts (resource conflict, development conflict, property conflict). It is argued that the three priorities are essential components of planning discipline, and so are the three conflicts among them. In an ideal situation, planners would be able to take a

position at the very center of the triangle with equal distance to all priorities and conflicts, and only then could they initiate the *ideal* of sustainable planning (Campbell, 1996).

First, the property conflict between social justice and economic growth priorities arises from the conflicting claims by social interventions and private sector on property, e.g. public good and private interest. Second, the development conflict between social justice and environmental protection priorities arises from the tension that in order to provide the lowest income communities with jobs, environmental protection principles are usually given up. Finally, the resource conflict occurs as the *Ur-Konflikt*, (1996, p. 299) taking place between economic growth and environmental protection priorities. The resource conflict is intimately related to equity and social justice, as the tension between economic utility of resources in the society and the conservation of resources for present and future cannot be considered separately from the outcomes of these priorities on societies.

Both economic and ecological systems need an interconnected critical mass of land to be sustainable, but *"the continuity of one system invariably fragments the continuity of the other"* (1996, p. 307). Resource conflict is therefore evident in land-use, as land-use is almost always a tradeoff between social, economic, and environmental goals, a result of decisions that are irreversible, long-term commitments (European Environment Agency, 2015). Land-use decisions shape how the natural and built environment is configured and reconfigured, determines where economic activity takes place and how communities develop. Because of this, drivers and consequences of, and control over, land-use decisions are societal matters (Goetz et al., 2004).

At this point, it is important to revisit the terms land-use and land-cover. Land-use is defined as the purpose and intent assigned to land and land-cover refers to the physical characteristics and attributes of Earth's surface, determined by land-use to a large extent humans (Bockstael & Irwin, 2000; Lambin et al., 2001). Land-use and land-cover are both directly assigned by human activities (Alberti et al., 2003). As a long-term decision that impairs the ecosystem, urbanization is found to be one of the major drivers of land-use and land-cover change (Lambin et al., 2001).

Although urban areas cover only three per cent of Earth's land surface (Grimm et al., 2008), this does not represent the overall consequences of extreme urbanization, as the percentage alone does not take the ecological footprint question into account. Ecological footprints of an urbanized area in the developed world expand over several hundred times of the actual surface it covers (Gago et al., 2013; Grimm et al., 2008) (Figure 2.1).

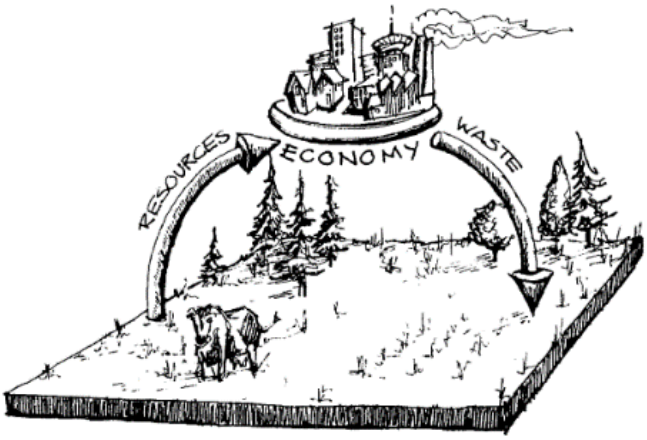


Figure 2.1: The footprint question asks how large a pasture is necessary for an urbanized area to function (original from Rees & Wackernager, 1996, p. 228).

2.1.2. Compact versus dispersed

> *"When you are densifying an area that is already dense, there is a question as to whether the existing infrastructure can cope . . . if done well, higher density does not necessarily decrease livability, [it] can be acceptable for residents as long as these developments also provide for new treed parks and urban greenery; but a well-used park a drive away cannot be suitable for new green space." (S. Lehmann, 2017, p. 327)*

This subsection looks into the dichotomy between compact and dispersed urban form from the perspective of land-use conflict. Based on the discussions on globally driven urbanization and its consequences on land-use and land-cover change, dense, compact cities can be seen as a growth management approach. The traditional scholarly work on urban land-use conflict tends to focus on sprawl and the peri-urban and rural land take as a consequence of settlement expansion. From the perspective of climate change adaptation, recreation and biodiversity in cities, transferring the resource conflict debate to the processes of inner development (and densification) will be necessary.[3]

Sprawl can be defined as *"the physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas […] 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"* (European Environment Agency (EEA), 2006, p. 6), or alternatively as *"uncontrolled expansion of urban development characterized by low density, segregated land-use and insufficient infrastructure provision over undeveloped land"* (OECD, 2012, p. 16). In Europe, urban development in the form of sprawl first appeared after the Second

[3] Inner development refers to infill development. Due to the wide use of the terms Innenentwicklung and Außenentwicklung in the German language, throughout this study the terms inner development and outer development are used.

World War. In response to the economic and population growth, settlement growth promoted a spatially expansive model. More expansion necessitated more social and technical infrastructure provision, which resulted in progressively more sprawl (Olofsdotter et al., 2012). Additionally, the urban expansion rate outpaced urban population increase rate and if the trend continues, until 2030 global urban land-cover triples while urban population doubles (Elmqvist et al., 2013). Additionally, sprawl is to be avoided not only because it fragments landscapes and causes significant loss of natural environment, but also because it requires high costs for the provision, operation, and maintenance of social and technical infrastructure, creates an irreversible car dependency, and triggers social segregation (Alberti et al., 2003). Therefore, compact urban form with higher density receives recognition as a response to sprawl (Davern, Farrar, Kendal, & Giles-corti, 2017; Olofsdotter et al., 2012)

Compact city is defined as the *"spatial urban form characterized by 'compactness'"* (OECD, 2012, p. 15), or alternatively as *"cities with higher densities to promote better accessibility, lower infrastructure cost, more efficient use of urban services, preserved land resources, lower cost of economic transactions, and social integration"* (Olofsdotter et al., 2012). Ideally, urban growth that promotes compact city safeguards a resourceful, efficient use of natural resources and infrastructure (Blanco et al., 2011). The compact city is expected to provide new and affordable housing options both with architectural and market diversity (rental, sale, or social), contributing to the development of a dynamic community and local economy, greening opportunities, and cultural and economic diversity (Newman, 2017). Compactness is relied on for a mobility system of shorter distances and less motorized traffic, made available by a connected urban fabric (Newman, 2017; Reißmann & Buchert, 2018). Therefore, it causes less greenhouse gas emissions change and thus contributes to global climate change mitigation efforts. Similarly, from the perspective of health-promoting urban planning and design, compact cities encourage more walking and cycling due to closer distances, while increasing the efficiency of public transportation (Boone & Modarres, 2006).

Although high density and compactness are often used interchangeably, densification is rather understood as the process by which compactness is strived for (Byrne & Sipe, 2010). In planning, density as a measurement may refer to the number of inhabitants (i.e. population density), the number of households (i.e. residential density, which is the most practical indicator in planning discipline), floor area ratio, or the number of dwellings in a given unit area (S. Lehmann, 2017). There is also the term *perceived density*, which is not to be quantified but can be understood as *"a dense built environment that provides proximity to various functionalities of the city"* (Swedish National Board of Housing, 2017, p. 6). Perceived density as an indicator may prevent densification to impair the character of already existing built environment, including but not limited to its open spaces.

Despite its tangible benefits to limit ineffective land-use, overcrowding, traffic, and environmental problems were found evident in some compact cities (Neuman, 2005). The existing infrastructure might not keep up with the pace of the population increase introduced by compactness (mostly evident in public transportation) (Reißmann & Buchert, 2018) and road networks as the stationary and flowing traffic increases. As far as the drivers of inner-city densification are concerned, the environmental arguments favoring high densities may be positioned in defense of projects or initiatives of political or profit-oriented agendas (Charmes & Keil, 2015).

In search of an optimal degree of compactness and an indicator for an ideal residential density, Lehmann (2017) experimented with various spatial configurations of 75 dwellings per hectare and concluded that planners and designers need a better understanding of the implications of each of these decisions (Figure 2.2). Lehmann's study consolidates the view that one cannot simply adopt one single indicator for residential density, as it requires other relevant economic, social, and environmental attributes that should not be neglected (Yoo et al., 2017). This variety in design is not to be understood that the resultant settlement typologies are unimportant. On the contrary, the morphology has always had various social and political implications (Charmes & Keil, 2015).

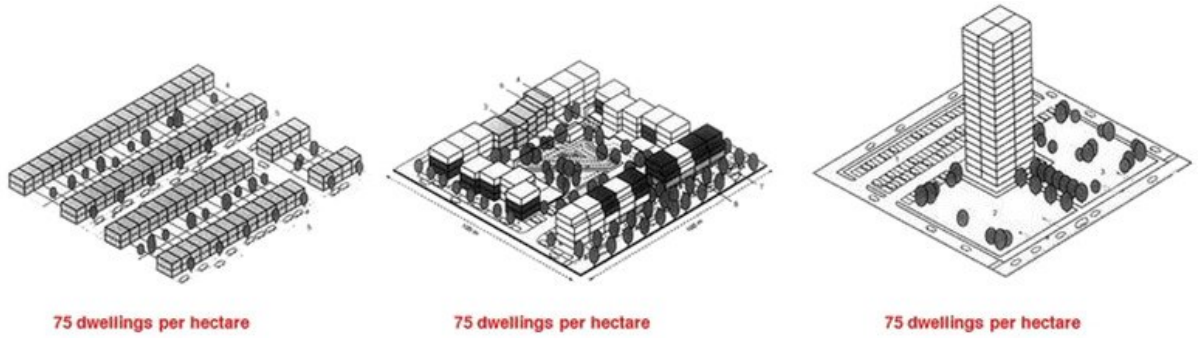


Figure 2.2: A certain residential density value can be reached in various ways, e.g. row houses (left), perimeter block (middle), or high-rise (right). Planners should use visualization technologies to better predict the consequences of their decisions (original from Lehmann, 2017).

Lehmann's model demonstrates one way of approaching the phenomenon but might not yield any benefits from the viewpoint of urban systems. An approach that includes further fundamental aspects in the density debate is the "Netzstadt," a method and strategy that is designed to guide the re-development and re-constructing the contemporary city while supporting self-sufficiency and remaining respectful to key resources. It is not a single model solution and it rather follows a set of criteria that is ideally fair to the local characteristics (Oswald, Baccini & Michaeli, 2003). According to this model, urban systems are made up of (i) nodes, which are high-density areas of people, goods, and information; (ii) connections, which enable the flows of people, goods, and information; (iii) borders, which are spatial,

temporal or organizational boundaries of urban systems. The model takes the densities of people, workplaces, services, and institutions as physiological indicators (Oswald, Baccini & Michaeli, 2003). With that it also verifies that approaches to indicate physiological density do not necessarily have to be based on built-up residential density.

Regarding the urban green, the limits to the compatibility between denser settlements and greener settlements was already discussed extensively within the sustainable urban form debates. Compact cities were found to have major challenges regarding provision and protection of urban green spaces during densification processes (Dallimer et al., 2011; Haaland & van den Bosch, 2015). It is argued that although the compact city approach is a key response to urban sprawl, provision and protection of urban green spaces[4] during densification remains a major challenge. Additional challenges with strong relevance to institutional constrains in planning include social inequalities in terms of access to urban green space, consideration of resident perspectives, reduced recreational value and increased compensation travels,[5] biodiversity loss (Haaland & van den Bosch, 2015, p. 763).

Urban green spaces are often multifunctional spaces with social (e.g. sports, leisure, recreation) and ecological (e.g. contribution to biodiversity) values. Additionally, urban green spaces help manage the outcomes of local climate hazards (floods, droughts, heatwaves) due to their cooling effect and contribution to closing up the natural water cycles. But since compactness is associated with increased impervious surfaces and decreased vegetation cover, higher densities might impair the functionalities of green spaces. Although compact cities are anticipated to contribute to less automobilized travel and consequently to less greenhouse gas emissions and peripheral green space protection, all this might take place at the expense of impaired functions at the inner cities, with potentially negative impacts on the local climate (Reißmann & Buchert, 2018).

Particularly for inner-city green spaces, it is important to consider how planning can become more supportive while implementing counter-sprawl measures, while in some cases the loss of private green space during densification is not adequately compensated by public green space provision and there is also more research needed to understand whether loss of green space quantity can be offset by improved green space quality (Haaland & van den Bosch, 2015). The question that remains unanswered is concerned with the quality of life and human

[4] Following Kabisch & Haase (2013, p. 113), urban green space in this research refers to “any vegetation found in the urban environment, including parks, open spaces, residential gardens, or street trees” and when relevant water bodies.

[5] As a consequence of densification, residents might have to travel to green spaces that are located outside of their neighbourhood, increasing dependency on the remaining recreational green spaces (Haaland & van den Bosch, 2015; Peschardt et al., 2012).

wellbeing: *"at what point do cities become too dense?"* (Naumann et al., 2018, p. 111). Without sufficiently addressing the drivers and consequences of growth-driven decisions, there seems to be a limit to what planning discipline can achieve.

2.1.3. Moving beyond urban form

> *"… open and dynamic systems like the city, subject to human will and caprice as well as the furies and salves of nature, can ever be in equilibrium? Instead, history records the flows of unending change. The human struggle to cope with these changes is the urban process." (Neuman, 2005, p. 19)*

Both in the scholarly and policy literature, many studies argue that the compact urban form is the most sustainable urban form, while many others argue that it is not, and there is empirical evidence for both. Yet, there is a third position which agrees that sprawl is not a sustainable urban form, but just because compact urban form is perceived as the opposite of sprawl, it does not necessarily mean that it is with no exception sustainable. This perspective suggests that the question of either compact or sprawl might be incomplete: Focusing exclusively on urban form is counterproductive and can be misleading in addressing today's highly complex and context-dependent societal and ecological challenges. As the models from old, preindustrial European towns[6] keep inspiring us as the ideal sustainable urban form, today's complexities require solutions beyond that (Neuman, 2005). In preindustrial times, communities had no alternative but be sustainable, because the feedback mechanisms were too short-term. If our ancestors destroyed vegetation, they would die out; whereas today, the scope of our alterations on nature is so extensive that we do not necessarily suffer the consequences (Campbell, 1996).

Safeguarding urban green space functions—including but not limited to recreational, biodiversity, and local climate regulation—require alternatives to promote dense settlement, for instance, by adding floors on existing buildings, brownfield development,[7] refunctioning of built-up areas with no current use, conversion of old or defunct industrial, military, or infrastructure areas (e.g. railways), or, ideally, a combination of these.[8] However, the root

[6] A typical medieval European city had a morphology of historical origins, with dwellings alongside streets and market functions alongside major roads and at squares. Often this can be observed in contemporary European cities (Boone & Modarres, 2006).

[7] Brownfield development is described as the "development of abandoned brownfield sites, often located near urban centers and occupying a considerable part of urban built-up areas, so as to revitalize and make better use of existing infrastructure and the potential of the sites" and greenfield development is defined as "new development in greenfield areas, typically located at urban fringes with both urban and rural land use" (OECD, 2012, p. 15).

[8] A recent study found that through addition of floors on existing buildings (i.e. vertical densification, Aufstockung), potentially 1,1 million additional housing units can be provided throughout Germany

causes of conflicts as in the example of compact versus sprawl are rarely only spatial, and only a *spatial fix* could hardly ever resolve them (Campbell, 1996, p. 13), because technical, legal, and political aspects may delay or hinder the realization of inner development alternatives. For this reason, it is beneficial to have an understanding of these aspects, which is in planning practice facilitated by land-use planning, a substantial tool at planner's disposal to manage processes (Campbell, 1996). It promotes creative technical, architectural, and institutional solutions for the land's use and its design. For instance, land-use plans can be managed in a way that it helps working with alternative policy directions for smaller but effective interventions to the built environment.

Reducing the resource conflict discussion to economic growth and environmental protection would miss the third issue, social justice and equity. In essence, what social justice and equity strives for is the just distribution of costs and benefits of economic wellbeing and environmental protection.[9] In the context of urban green spaces, this can be interpreted as ensuring a just distribution of costs and benefits of prioritizing—economic, settlement, urban, regional—growth or prioritizing environmental protection. A past study examined the validity of the claim that denser cities promote social equity and found that although cities that support social equity tend to have higher densities, they offer equal access to a less amount of facilities, including green facilities (Burton, 2000). Another study looked at the spatially uneven distribution of urban trees and proved a statistically positive correlation between income levels with tree cover percentage in relation to race and ethnicity (Heynen, Perkins, et al., 2006). A further study observed that the access to public urban green spaces varies among societal sectors (Barbosa et al., 2007). Paradoxically, inequalities may also result from green space investments. *Green gentrification* occurs when urban greening projects make older, low-income, or industrial settlements more livable but at the same time drastically alter housing opportunities that supports lower income groups (Wolch et al., 2014). According to this study, there is empirical evidence that based on socio-demographic differences inhabitants benefit disproportionally from urban green spaces, while greening disadvantaged areas may result in inflating property prices and trigger displacement.

The protection and provision of green spaces require thorough considerations to resolve socio-spatial imbalances. The density and urban green spaces debates indicate that it is a challenge to ensure social justice and equity and this is particularly the case for the uneven

(Tichelmann, 2016). A far higher potential is conceivable through a combination of densification alternatives (Reißmann & Buchert, 2018).

[9] The terminology used by the New Leipzig Charter, "common good-oriented city," successfully captures the meaning.

distribution of urban green spaces which causes only some settlements to be situated in close proximity to green spaces (Haaland & van den Bosch, 2015). In line with all these, it can be concluded that the search for environmental justice, "*the pursuit of a fair and equitable distribution of these amenities, so that no single group bears a disproportionate burden,"* is a central concern that seems to be evident in any resource conflict (Boone & Modarres, 2006, p. xiii).

2.2. Rethinking resilience thinking

Central to the literature review is the resource conflict that is evident in environmental protection and economic growth priorities. The main goal is to critically explore the importance of (sustainable) processes without overlooking debates on (sustainable) form and emphasize that a confrontational debate is necessary. This section brings the debate one step further and introduces the concepts from social-ecological systems and resilience thinking. Urban areas, as well as their green spaces, are acknowledged as social-ecological systems. This framing gives a direction to the discussions that follow in this section.

The existing urban resilience literature has informed various disciplines, and therefore, has a quite fragmented structure with different starting points (Chelleri, 2012). A recent study found that the term urban resilience is inconsistently defined and underdeveloped despite its theoretical richness (Meerow et al., 2016) and mostly cited as *"the degree to which cities tolerate alteration before reorganizing around a new set of structures and processes"* (Alberti et al., 2003, p. 1170). The study systematically reviewed the definitions of urban resilience and suggested the following definition: *"the ability of an urban system—and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity"* (Meerow et al., 2016, p. 39).

2.2.1. Unpacking embedded social-ecological systems thinking

Sustainability and resilience

The urban form-urban process debate in sustainability and planning debates is not new. Still, it introduces a new dimension to observe the resource conflict from the perspective of urban green spaces and to give the social-ecological systems a central role in doing that. Against this backdrop, the economic development end of the resource conflict represents the social subsystem with all its components such as institutions, individuals, politics, and economy. Likewise, the environmental protection end of the resource conflict represents the ecological subsystem including ecology, climate adaptation, and land-use (Figure 2.3). This suggests that the social-ecological systems thinking is in fact already embedded in planning, with its direct references to priorities and conflicts in Campbell's (1996) conceptualization. In order

for this line of thinking to provide alternative ways to capturing the sustainable form-sustainable process debates, it can be beneficial to refer to the social-ecological system properties such as complexity, uncertainty, adaptability and responses such as resistance, adaptation, and transformation with reference to urban green spaces and planning discipline.

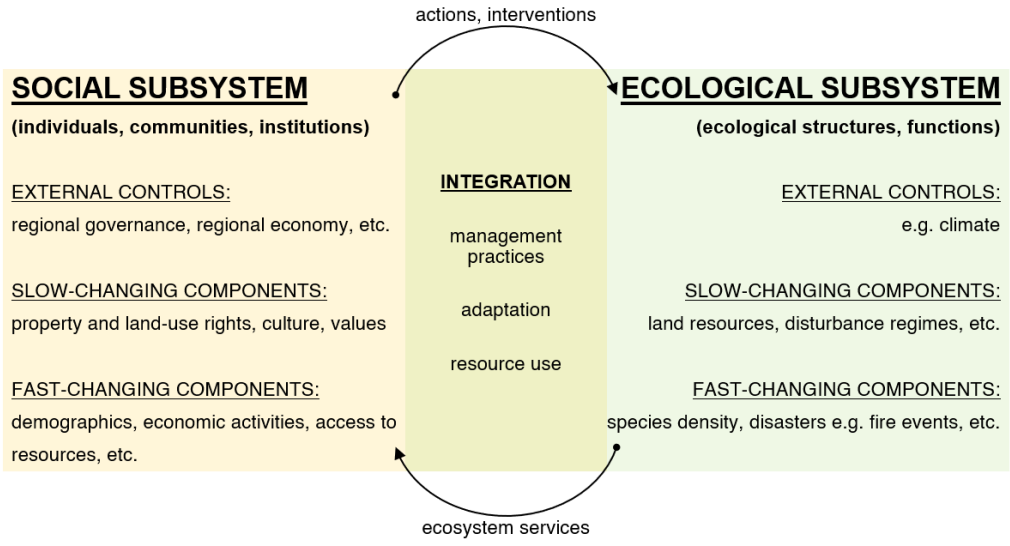


Figure 2.3: The social-ecological systems model is embedded in the conceptual model of priorities and conflicts in sustainable planning (adapted from The Resilience Alliance, 2010; Virapongse et al., 2016).

The global Sustainable Development Goals by the UNHABITAT have so far communicated the core issues in global sustainability and proposed the ways in which these can be measured in a systematic way with targets and indicators in order to promote global inter- and transdisciplinary action. The context, concept, and content of this research is closely related to the Sustainable Development Goal 11: *"Sustainable Cities and Communities: Make cities inclusive, safe, resilient and sustainable"* (United Nations, 2016).

As independent but complementary concepts, *sustainability* and *resilience* in planning represent positive visions of human well-being and quality of life. While both terms are highly contested and represent an ideal state to reach to, sustainability is regarded more as a normative concept as its arguments are concentrated around how the relationship between man and nature is supposed to be (Derissen et al., 2011). Within this distinction, it is argued that resilience challenges the balanced ideal of sustainability by embracing non-equilibrium states between social and ecological components of systems (Ahern, 2013). However, this does not free the resilience thinking from pointing to another system state that keeps functioning in unbalanced conditions. The shift from *sustainable urban form* to *resilient urban system* is accompanied by a shift from fail-safe (sustainability ideal) to safe-fail (resiliency ideal) approaches (Ahern, 2011). These discussions introduce rich and inspirational debates

to advance our understanding of urban systems, but in planning theory and policy their operationalization faces certain limits.

At this point, it is beneficial to briefly revisit how the definitions of resilience evolved. The definition of *engineering resilience*, *"the ability of a system to return to an equilibrium state after a temporary disturbance"* (Holling, 1973, p. 14) emphasizes the capacity of a system to resist the disturbances, bounce back, and return to its original state. This behavior is however not always favorable, as the original state is what caused the system's disturbances at the first place (Eraydin, 2012). Additionally, if the goal is to sustain the initial state regardless of circumstances, it would be inevitable to build and maintain costly technical systems with limited added value. Following that, *ecological resilience* is defined as *"the magnitude of the disturbance that can be absorbed before the system changes its structure"* (Holling, 1996, p. 33). Likewise, this definition emphasizes the capacity of a system to bounce forward to reach a new stable state. As both engineering and ecological resilience assume that there is an equilibrium state to return or reach to, these approaches are criticized for being too mechanical to be mainstreamed in planning discipline (Davoudi et al., 2012). Eventually, *evolutionary, i.e. social-ecological, resilience* is argued to be a closer fit: it is defined as the ability of complex systems to change, adapt, and transform while undergoing change (Folke et al., 2010).[10]

City as a social-ecological system

> *"Despite formidable obstacles, the social-ecological approach is laudable, as it pulls ecologists away from the typical characterization of humans solely as 'disturbers' and pulls social scientists away from the notion that human beings (and their cities) are driven solely by culture and divorced from ecological processes."*
> *(Boone & Modarres, 2006, p. xxi)*

A social-ecological system is defined as *"an integrated system of ecosystems and human societies with reciprocal feedbacks and interdependence"* (The Resilience Alliance, 2010, p. 52). It is a complex and adaptive system of humans and nature in which adaptability and transformability are prerequisites for its resilience (Folke et al., 2010), and resilience is the key to its sustainability (Walker & Salt, 2006). Adaptability is the capacity of a system to adjust its responses in accordance with external and internal changes without changing

[10] To give a more contemporary and practice-oriented example, it can also be defined as "the capacity of individuals, communities, institutions, businesses, and systems to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience … Resilience is about learning to live with the spectrum of risks that exist at the interface between people, the economy, and the environment" (World Bank, 2018a, p. 9). Here, the capacities of social components (individuals, communities, institutions, etc.) weigh heavier than the capacities of the ecological components to sustain their functions, even—or especially—when disruptions are present.

trajectory; whereas transformability is the capacity of a system to change its current trajectory to reformulate itself when ecological, economic, or social conditions make the existing system untenable (Folke et al., 2010). Both adaptive and transformative capacities are positive features, because when well-managed, transformation in response to disruptions at smaller scales resonates at larger scales. This feature is what might turn crises as opportunities.

The integration of social-ecological systems into planning is based on the underlying premise that cities are in fact social-ecological systems. Moreover, cities are considered human-dominated ecosystems in explaining the interactions between their social and ecological processes (Alberti et al., 2003), instead of places where nature ends (Heynen, Kaika, et al., 2006). Cities are where human-nature interactions are closely coupled (du Plessis, 2008) and should be studied as social-ecological systems (Grove et al., 2015).

This line of thought acknowledges cities, as well as their green spaces, as social-ecological systems. Urban areas are, therefore, multi-scalar systems of constant change, with a degree of uncertainty. Urban areas are also complex (due to the interrelations and interdependencies between their social and ecological subsystems, operating at multiple scales) and adaptive (as the system configures and reconfigures itself based on the internal and external changes) systems. The definition of urban areas as social-ecological systems can guide an alternative trajectory in planning in addressing human-nature interactions. Resilience is, in simplistic terms, the study of how a social-ecological system behaves while undergoing change. Based on that, the social-ecological systems thinking can fulfill a functional role to introduce resilience in planning.

2.2.2. Destination resilience?

> *"At the heart of resilience thinking is a very simple notion—things change—and to ignore or resist this change is to increase our vulnerability and forego emerging opportunities. In so doing, we limit our options." (Walker & Salt, 2006, p. 9)*

Planning, as a young discipline, borrows and adopts concepts from other disciplines, and resilience is no exception (Davoudi et al., 2012). However, at its current state, the resilience concept does not offer its full potential in planning as it is not yet readily operational (Davoudi et al., 2012; Pizzo, 2015). As Davoudi et al. argue, how ecological subsystem includes human-nature interactions does not necessarily correspond to the human-nature interactions in social subsystem. Only when some key mismatches between social and ecological domains are translated into planning discipline can resilience become operational. The key points which require resolution are specified as follows (2012, p. 305):

- Self-organization: higher adaptive and transformative capacity both in ecological and social systems, not a substitute for good governance.
- In ecology, the desired outcome of resilience is sustainability, but in social domain desired outcomes are based on normative judgements.
- In ecology, system's boundaries can be defined (resilience of what to what). In social systems some groups might end up excluded.
- In ecology, there are no winners or losers (resilience for whom). In social systems some people gain while others lose.

In response to the absence of translation, there are several key principles to be adopted in planning (Alberti, 2016):

- Complexity: create and maintain diverse development patterns that support diverse human and ecosystem functions.
- Resilience: focus on maintaining self-organization and increasing the capacity to adapt instead of aiming to control change and to reduce uncertainty.
- Uncertainty: expand the ability to consider uncertainty and surprise by designing strategies that incorporate uncertainties and are robust to the most divergent plausible futures.
- Adaptation: create options for learning through experimentation, and opportunities to adapt through flexible policies and strategies that mimic the diversity of environmental and human communities.
- Transformation: expand capacity for change through transformative learning by challenging assumptions and actively reconfiguring problems.

With these key principles, the embeddedness of social-ecological systems thinking in planning can be a key point in addressing resource conflict and its implications. It is, however, not necessary to fix resilience as a destination to reach to or a precondition to reap the benefits of introducing this line of thought into planning. Being able to work with system attributes such as complexity, adaptability, and uncertainty and system behaviors such as adaptation and transformation in planning discipline is, therefore, not unrealistic. Aiming at a state of resilience, instead of aiming at finding ways to efficiently and effectively operationalizing these concepts in planning, could lead to fixed outcomes without offering the possibility of different, *resilient* trajectories.

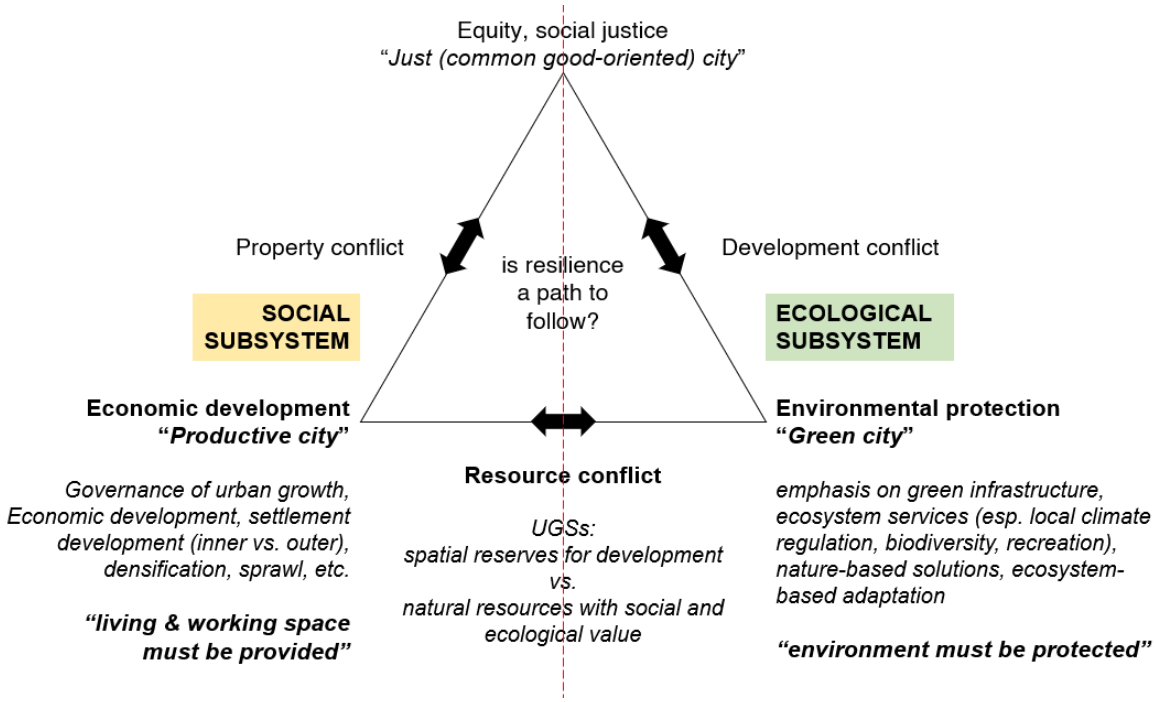


Figure 2.4: Can resilience be a trajectory for sustainable planning? (adapted from Campbell, 1996).

The contemporary global policy direction in the field of urban resilience often approaches resilience as a localized quality to reach to (MacKinnon & Derickson, 2013). In this study, however, normative approaches to how to make a city resilient are of little importance. Resilience is included in the debate because of its strong conceptual and theoretical links to social-ecological systems thinking on the grounds that it will also guide the empirical parts of this study. Therefore, it is a deliberate choice to approach resilience as a means than an end destination to reach to.

To conclude, while international policy directions address certain urban trends, e.g. in response to, recovery and protection from, and preparedness for climate-related disasters through the resilience concept, the likelihood and the extent to which these policies can provide solutions by, e.g. making a city resilient, remains a question mark. It is often the case especially in the Global South context that in the aftermath of international policy implementation at local scales, in the absence of human and financial resources, the progress in the long run is impaired. This is, in fact, a costly outcome of approaching resiliency as a state to reach to, instead of unpacking the potentials of social-ecological system thinking.

2.3. Social subsystem

2.3.1. Region: the scale at which things work[11]

Urban resources are vital for the functioning of metropolitan regions (among others Graham & Marvin, 2001). The impact of globalization (i.e. the worldwide interconnectedness of places and people through the capital and information flows (Lambin et al., 2001)) has become increasingly apparent in the regional-scale actions taken toward regional economic growth. The urge to belong to global city networks (i.e. a global economic ranking network of city-regions that are interconnected and in competition) influence urban processes (Neuman & Hull, 2013).

Studies looking at the state of understanding on global trends agree that urbanization is one of the major drivers of land-use change (among others Lambin et al., 2001; Alberti et al., 2003) and that massive changes in urban land-use and land-cover often overlap with new practices motivated by regional incorporation into the socio-economic network that operates at a global scale (Lambin et al., 2001). Global city-regions are spatial concentrations of where people live and work. They are interconnected within and among themselves and are in competition among themselves (Brenner & Keil, 2014). While their functioning relies on well-functioning infrastructures and abundance of key resources, the question of social justice and equity may not surface while economic motivations drive the land-use decisions (Sassen, 2005).

This is argued to materialize in the city-regions where central business districts are in good conditions and the poverty is not as visible in comparison to urban peripheries. This is shown to be an inevitable outcome if and when economic prosperity is the primary motivation and outweighs the equity motivation. There emerges a pattern at the urban form-process divide: First, as economic activities cluster at the cores, this affects land-use through speculative real estate. Second, small to medium size agglomerations become backyards for headquarters at bigger city cores as they provide more affordable office spaces, bringing daily commuting into the debate. Third, gentrification takes place in inner-city areas where the *headquarter economy* is developing (Brenner & Keil, 2014, p. 8).

What Sassen and Brenner & Keil explain relates to the question of how scarce urban land resources are used and what trends there are concerning the global city-regions (Sassen, 2005; Brenner & Keil, 2014). Also, in line with the fact that the economic shift from the industrial capitalist city—which needed vast production spaces outside of city cores—to the post-industrial city—which requires office spaces at city cores—globalization entails

[11] Inspired by Newman (2018).

significant urban restructuring (Olofsdotter et al., 2012), and it can be confirmed with certainty that urban transformations are by no means freed from such global pressures (Eraydin, 2012).

Despite institutional arrangements and spatial patterns indicating clear levels and scales, cities are not to be perceived as isolated, stand-alone entities emerging and existing within their administrative borders. Their functionalities reach far beyond their boundaries (European Environment Agency, 2006). In the context of globalization, today's cities are more dependent on the natural resources to continuously provide for their populations and economic activity. They are thus forming urbanized regions of global economy, creating cities that are both urban and rural, making the traditional categorizations of urban form no more plausible (Olofsdotter et al., 2012) (further elaborations on in-between city in Section 2.6.1.). Consequently, *region* is a significant scale at which tangible (e.g. infrastructure) and intangible (e.g. governance) systems function and that *"serve as the scale and medium of societal differentiation in a competitive neoliberalizing economy"* (Keil, 2011, p. 2497). A challenge for global regions is that they have to establish uninterrupted outward-oriented strategies for international cooperation (Heinelt et al., 2011); whereas they also have to turn their attention inward for a functional coherence that is a precondition for competitiveness (Heinelt et al. 2011; Keil 2011).

2.3.2. Governance in the context of resilience

In this research, the governance concept relates closely to the *"forms of regional organization"* (Hudson, 2010, p. 17) and is therefore addressed as a concept within the social subsystem and regional scale discussions. Governance as a concept emerged in political sciences and is adopted by other disciplines including planning (Buizer et al., 2015). Governance can be defined as *"an intended activity undertaken by one or more actors seeking to shape, regulate or attempt to control human behavior in order to achieve a desired collective end"* (van der Heijden, 2014). Governance either builds bridges or barriers and is either supportive for or restrictive to a well-functioning social-ecological system (Bressers & Bressers, 2016).

Governance describes a fundamentally informal form of self-management. It links different traditional social system components (politics, institutions, civil society, etc.) and brings all actors together, so that components and actors can cooperate and find frameworks to manage responsibilities and challenges through self-binding decisions (BMVBS Bundesministerium für Verkehr Bau und Stadtentwicklung, 2007). The shift from government to governance occurred as government and its institutions are no longer the only decision-makers, which opened up processes for a direct influence of other involved (e.g. private,

political) actors (Harvey, 1989). This procedural shift is accompanied by a shift from power *to* than power *over* (Keil, 2011, p. 2496, italics original).

The increased opportunities to bring together traditional and innovative approaches with technological and behavioral changes can be seen as an advantage in terms of resilience and sustainability (van der Heijden, 2014). Understanding governance is therefore fundamental for understanding social-ecological system (Resilience Alliance, 2010). In line with that, adaptability is seen as an important feature of governance. Adaptive governance is defined as *"the institutional and political frameworks designed to adapt to changing relationships between society and ecosystems in ways that sustain ecosystem services"* (Resilience Alliance, 2010, p. 51). Thereby adaptive governance of social-ecological systems is supposed to better counteract social and ecological injustice which usually results from exclusion and rushed land-use decisions. Adaptive governance can guide the transitioning from (Resilience Alliance, 2010):

- rigid to flexible (from the rigid nature of levels and scales of administration to the flexible nature of introducing informal processes),
- exclusive to inclusive (from involving only several actors into decision-making processes and silo approaches to involving all stakeholders from residents to non-governmental organizations),
- uniform to diverse (from taking only specific interests to all relevant interests into account), and
- conventional to innovative (from remaining in the status quo which may have caused the problems at the first place to creating time and space for finding new solutions).

The anticipated outcomes of adaptive governance approaches in system management are (i) to build knowledge and understanding of resource and ecosystem dynamics, (ii) to feed ecological knowledge into adaptive management practices, (iii) to support flexible institutions and multilevel governance systems, (iv) to deal with external perturbations, uncertainty, and surprise (Folke et al., 2005). However, drawbacks of adaptive and flexible governance approaches are found evident when these approaches are adopted in instable institutional and organizational environments (Metzger et al., 2021). These approaches are monitoring-intensive and demanding processes which require optimal institutional capacities to ensure stability in the management of uncertainties (Metzger et al., 2021). This evidence underlines the importance of institutions, their capacities, and their arrangements. Based on that, it can be argued that institutional arrangements shape governance conditions, which affect resilience (Huck, 2020) (Figure 2.5).

Institutional arrangements	→ shape →	Governance (strategies to enhance resilience)	→ affect →	(Urban and infrastructure) resilience
Formal institutions (e.g. laws, rules, regulations, standards)		Knowledge co-production		Capacities to resist shocks and stresses
		Network management		Capacities to absorb and recover from them
Informal institutions (e.g. work routines, traditions, knowledge systems)		Enhancing connectivity		Capacities to adapt and transform over time
		Mainstreaming		

Figure 2.5: Institutions shape governance, governance affects resilience (adapted from Huck, 2020, p. 20).

Some strategies for achieving this stability in the context of urban and infrastructure resilience were already defined as follows (Huck, 2020):

- Knowledge co-production: This aspect investigates how knowledge production takes place when different communities deal with similar resilience problems and how this shapes governance and policymaking practices. Scholars supported the idea of co-production of knowledge, so that the learning of urban and infrastructure resilience can be improved beyond disciplinary and administrative borders. This can bridge the silos and can help set common goals and shared responsibilities.
- Network management: The strategic network management looks into the key conditions required for enhancing resilience. This is deemed important for bringing relevant actors in decision-making processes, to mediate actual and perceived conflicts of interest, to coordinate individual actors, and to give a direction to the measures to strengthen resiliency.
- Enhancing connectivity: Institutional connectivity is concerned with the improvement of the vertical, horizontal, and interdisciplinary cooperation and coordination of relevant actors to move beyond silos and constraints in decision-making. This aspect is particularly important for infrastructures, because their management succeeds through multiple political fields with disruptions beyond disciplinary and administrative borders.
- Mainstreaming: Mainstreaming refers to the necessity to integrate the goals of resilience in the existing disciplinary policy and decision-making practices. It acknowledges resilience as a key goal for interdisciplinary policy-making. It is understood as a contribution to the interdisciplinary synergies toward resource-efficient and effective strategy, including the budget.

2.3.3. Planning and urban green spaces

Planning at the regional scale brings together numerous aspects of spatial planning. Integrated urban development is an aspect that the former Leipzig Charter also referred to as a *"simultaneous and fair consideration of interests and concerns that are of relevance to the development of cities"* (European Commission, 2007, p. 2). For instance, the transit-oriented

development concept is an output of such cross-cutting considerations.[12] Similarly, strategic plans at regional scale allow for holistic approaches to urban challenges (Jim, 2013). As far as the green spaces within integrated urban development are concerned, a regional approach to growth management proves necessary, if cross-cutting strategies such as greenbelts and green fingers are to be implemented (Jim, 2013). Urban and regional green spaces have been an essential component of planning especially in the context of growth management. Boone and Modarres introduced the following main concepts and approaches of urban green spaces planning with relevance to regional scale (2006, p. 170):

- Greenways, green fingers: Since it is not always possible to provide large parks in the dense urban cores due to the high demand for land for other uses, a strategy could be to provide green corridors from urban periphery to core. These green corridors can bring some limited added benefits, e.g. abandoned railways in deindustrialized towns can help establish walking and cycling routes connecting urban cores with peripheries. Greenways also interconnect neighboring communities through trails, but access can be uneven, disproportionately high or low for one community compared to the other.
- Brownfields: As remainders of industrial era, brownfields are abandoned, avoided properties often with contamination risk, causing interruptions in the urban fabric and consequently inefficiencies in infrastructure and land-use systems. Redeveloping brownfields improves environmental conditions by eliminating contamination and with a more resourceful use of inner-city land. Brownfields could be considered both for industrial/commercial and residential redevelopment.
- Greenbelts: The conceptual roots of physical limitation to settlement growth can be traced back to the walls of early cities where the distances were determined by muscular capacities of humans and animals. A greenbelt is a continuous natural environment and an effective way to limit settlement growth, providing the benefits of multifunctional green spaces (as in Wei, 2017). One drawback of greenbelts could be the leapfrog development beyond the belt, especially when predominantly residential settlements are emerging in comparison to workplaces, which would indicate increased commuting. Another concern puts social justice and equity in question: Who benefits from the amenities of greenbelts?
- Smart growth: Smart growth promotes taking advantage of and reaping benefits of existing neighborhoods, existing infrastructure and preserving greenfield sites. When greenbelt restrictions are considered too strict, technical and political agendas urge private sector to develop more compact urban settings. This approach tries to combine more brownfield and less greenfield development with reduced commuting times. This can be considered an attempt to balance the interests of investors when

[12] Transit-oriented development: Urban development designed to maximize access to mass-transit systems, often with a center with public transit station, high-density, mixed-use settlements with gradually density toward peripheries (OECD, 2012, p. 16).

the restrictions are "too strict" and the environmentalist viewpoint that the protective regulations are too weak.[13]

Building up on the foundation formed by the above components with regional relevance (i.e. greenways, brownfields, greenbelts, smart growth initiatives with the private sector), three main stages can be introduced in green space planning (Jim, 2013):

- Applying urban ecological principles (design and geometry of urban green spaces with a focus on their social and ecological functions),
- Protecting existing urban green space, and
- Providing more urban green space, especially in already dense built environment.

What remains unanswered is, how all this can be achieved in practice. A narrow interpretation of planning discipline might focus on planning as a technical tool and neglect its qualitative features (planning as an onsite process). Many studies in the field of planning analyzed green spaces only with a quantitative set of criteria and without quality criteria, creating weaknesses in explaining in what ways the state-of-the-art as well as the transitions in planning practice impacted green spaces (Haaland & van den Bosch, 2015). Certainly, several other studies attempted to bridge this gap and, for instance, looked into the consequences of new policies on urban green spaces (e.g. Gupta et al., 2012; Wilson & Hughes, 2011) in terms of how its quantitative and qualitative parameters are changing.

2.4. Ecological subsystem

2.4.1. Climate change adaptation

Aggravated by urbanization, the frequency, randomness, and intensity of the three main urban hazards—floods, droughts, and heatwaves—are increasing (among others Chen et al., 2016; Depietri et al., 2012; European Environment Agency, 2012). Floods damage buildings, open fields, and infrastructures with cascading impacts. Heatwaves reduce human wellbeing and public health and increase the risk of heat stroke. Droughts cause disruptions in agricultural production and affect many sectors. These impacts can be lessened through integrating adaptation strategies and actions into planning. Adaptation in this regard is defined as *"the ability of a system to adjust to climate change (including climate variability and*

[13] Boone & Modarres's list includes "New Urbanism" as the fifth approach. New urbanism aimed to remedy the ills of the lifestyle choices and their consequences: car dependency, lack of aesthetics due to suburban replicas and resultant placelessness. New urbanists proposed environmentally-friendly neighborhoods supporting walking and cycling with small plots and narrower streets, encouraging encounters and the feeling of community. However, new urbanists were criticized due to their very narrow focus, as they looked for control only through design which could only operate at smaller scales and be realized mostly as greenfield development. Given its limited relevance to contemporary urban green space debates, New Urbanism is excluded from the above list.

extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC, 2007, p. 869). In relation to previous concepts and discussions, Pelling (2011) approached adaptation as an intervention in the co-production of risk and development with three equally important and context-dependent visions of adaptation:

- Resilience: persistence in a changing environment,
- Transition: intermediary level within the established regime, and
- Transformation: deepest form of adaptation, reformative,

whereas the lack of adaptation in the interplay between risk and development is understood as a synonym for *vulnerability* (Pelling, 2011). In explaining why urban areas occupy a central position in the adaptation agenda, Pelling (2011) gives the following climate change-related reasons:

- Population growth takes place in urban areas and the twenty first century is and will be defined by continued urbanization and suburbanization (seconding Graham & Marvin, 2001). Local impacts will impact more and more people.
- Urbanization and suburbanization shape cities in such a way that it creates local climate phenomena, e.g. overheating and increased risk of flood.
- Cities, with their vulnerable populations of poor and elderly as well as their material and cultural assets, heavily rely on interconnected networked infrastructure which may be prone to failure when exposed to climate risks.

Adaptation efforts do not aim at avoiding or eliminating negative impacts through climate-proofing; instead it addresses reducing the severity of these impacts not only through physical but also through political, institutional, and even behavioral measures while making use of arising opportunities (Davies et al., 2015). Adaptation differs from mitigation in that it is not driven by an international motivation to slow down the climate change or reducing/zeroing carbon emissions. Climate change mitigation strategies have to rely on a number of factors. Emissions have increased by 45 per cent since the 1990s and by 5,8 per cent in 2010 alone (Carter et al., 2015) by which the main contributors are the urbanized areas of the developed world. At the same time, supranational commitment to mitigation strategies are showing very slow progress, but the Earth's capacity to naturally absorb emissions are reaching to a point of no return (Carter et al., 2015).

This is to justify that both adaptation and mitigation strategies are needed. These strategies are sometimes in harmony with each other, but in some cases, they are in conflict (Hamin & Gurran, 2009). For instance, while compact urban form ideal is in line with climate mitigation strategies since the aim is to reduce car dependency and consequently greenhouse gas emissions, leaving inner-cities with more green spaces and less dense would contribute to

adaptation efforts as pervious surfaces help reduce floods, eliminate droughts by closing up water cycles, and provide a cooling effect in cases of extreme heat. Within the conceptual scope of this study, the capacities of urban green spaces in climate adaptation weigh heavier.

Flood

In Europe, floods are the most important hazards in terms of economic loss (European Environment Agency, 2010). Floods in urban areas occur because of a number of manmade and natural factors, e.g. sealing pervious surfaces is a human modification on natural hydrologic systems, increasing surface runoff and cause a significant rise in flood risk. Because of that, impervious surface cover is taken as an environmental indicator (Arnold & Gibbons, 1996). Another related phenomenon is the urban stream syndrome. The main driver of urban stormwater runoff is the increase in impervious surfaces (Mcphearson et al., 2005), and it occurs when pollutants from buildings and roads combined with industrial contaminants are accumulated and funneled into streams. Hydrological models show that when impervious surface cover is above 10 per cent, streams already become polluted, which must be handled by treatment plants at high economic and energy costs (Boone & Modarres, 2006). When stormwater and wastewater infrastructure are not separated, as in the case of most European cities, this leakage creates pollution in the entire water system.

Urban green spaces, including small pocket parks (Green et al., 2016; Grimm et al., 2008), contribute significantly to natural hydrological cycles insofar as their quality is not decreased by poor land-use practices (Depietri et al. 2012). They absorb runoff water, and this also decreases the stress on the aging and mostly centralized water infrastructure in Europe (Green et al., 2016). In adaptation efforts, urban green spaces are the most important components in water-sensitive urban design.

Drought

Flood and drought, the hazards of too much and too little water, are not mutually exclusive and can happen simultaneously. Drought, unlike flood, is usually not directly visible in urban areas (Bressers & Bressers, 2016). It develops gradually and can be therefore difficult to identify (European Environment Agency, 2010). As a long-term (from several weeks to decades) below-average presence of water, drought has massive interruptions e.g. on agricultural supply and livelihood. Drought is caused by climate change and it differs from aridity (a feature of dry climate) and from water scarcity (a long-term water condition) (European Environment Agency, 2010).

Harvesting and reuse of water is an important measure in tackling drought. Related to consequences of soil sealing, rainwater should be kept where it falls, water infiltration should be enabled, permeability and wetlands should be regenerated where necessary (European Environment Agency, 2010). European water management has largely focused on meeting the increasing demand by increasing the supply. However, it is important to find ways to decrease the use, not only for households but also for industrial usage, by for instance efficient ways of water reuse and recycling. Considering the contribution of pervious surfaces to closing up the natural hydrological cycles, green spaces contribute indirectly to drought management.

Heatwaves

Heatwaves are extreme events of sustained high temperatures with negative consequences not only on regional ecosystems and economies but also on human wellbeing. Heatwaves are the most important hazard in Europe in terms of increased fatalities (European Environment Agency, 2010). Urbanization is a factor that intensifies the impacts of heatwaves. Buildings and impervious surfaces absorb and re-emit the heat. Associated urban heat island effect occurs when urban areas have higher temperatures than their immediate rural surroundings especially at nights (Grimm et al., 2008, p. 758). It is found out that the magnitude of urban heat island effect at a local scale far exceeds global temperature rise. It warms urban areas by 3,5 to 4,5°C; whereas rural areas get warmer 1°C each decade (OECD, 2012). The degree of intensity of urban heat islands depends on factors such as dominant land-cover, city size, its relation to population size, and thermal-storage capacity of buildings. It is important to be aware of potential tradeoffs: If the vegetation cover at an arid climate is to be increased because of the increased urban heat island effect, might this mean that the natural flora of that place will be replaced with vegetation? Imbalances that might emerge from such alterations in the natural environment should be well-elaborated before they are implemented as solutions (OECD, 2012).

Many studies thus far have shown that urban green spaces moderate extreme heat in their surroundings by their cooling capacity (Davern, Farrar, Kendal, & Giles-corti, 2017), with an 80 to 140-meter offset (Gargiulo et al., 2016). It was also shown in a study which reviewed 40 previous studies that green areas are cooler than non-green areas (Bowler et al., 2010). This highlights the importance of public green spaces with unrestricted access for any inhabitant to benefit from it.

2.4.2. Biodiversity and recreation

Urban ecological subsystem plays an essential role as a habitat for plant and animal species. In line with international conventions, natural biodiversity reserves are no longer limited to

landscapes far from urban areas. Urban green spaces provide the habitat for increasingly rare species and this diversity is to be protected (Bundesinstitut für Bau- Stadt- und Raumforschung (BBSR), 2018). However, current pace of urbanization, settlement growth, and transport infrastructure, as well as the pollution associated with that, cause large sums of loss of open land and biodiversity. Connected and networked species-rich green spaces, as well as natural or near-natural sites and urban habitats, are to be protected for hosting and enhancing the biodiversity. This can be achieved, for instance, by interconnecting natural and near-natural sites in urban areas and greening large sealed surfaces (Mayer & Schröder, 2017, p. 9).

In addition to the climate adaptation and biodiversity functions, numerous previous studies referred to the contribution of green spaces to human physical and mental health (among others Tzoulas et al., 2007; Wolch et al., 2014). As places of contact with nature and social interaction, urban green spaces provide wellbeing benefits such as increased physical activity, recreation and restoration, and social interaction (as in Davoudi & Brooks, 2016). As Davoudi & Brooks argue, *"the materialization of many of these benefits depends on a number of factors such as: the availability (size and distance to where people live), accessibility (physical and socio-cultural), and quality (actual and perceived) of urban greenspace"* (2016, p. 31). This shows that the existence of urban green spaces in a given area does not guarantee that these green spaces are benefitting the individuals equally. The evenness of distribution, the level of upkeep and maintenance, and accessibility (public, semi-public, or private green spaces with conditional or unconditional access, e.g. also for various user groups) are decisive factors in determining the actual recreational benefit of such spaces.

However, the benefits of green spaces in terms of biodiversity and recreation are observed to be in conflict with each other. From the point of landscape architecture, the two functions are actually incompatible, as the latter invariably disturbs the former. When natural and near-natural sites of high biodiversity are open for visitors for recreation, a certain degree of emissions, pollution, and disturbance to the natural environment is to be expected (e.g. due to parking lots for visitors etc.) (Young et al., 2004). This is a remarkable conflict especially when the limits to multifunctionality are considered.

2.4.3. Key concepts in landscape ecology

"'Nature' is what city dwellers find beyond the city limits sign. The problem with this way of thinking is that it neglects the natural or nonhuman organisms that exist in cities, even in the densely built-up cores of urban areas […] the city / countryside, urban / rural, human / natural dichotomies are beginning to become

blurred in environmental science, but they still resonate in the minds of many."
(Boone & Modarres, 2006, p. xi)

In terms of action fields, policies promote unsealing, shaded parking lots, greened rail infrastructure, roadside green, pocket parks, green courtyards, water surfaces in public places as important measures. Given the multiplicity of aspects (e.g. technical, political, legal) and the variety of involved sectors (e.g. traffic and transport infrastructure, energy infrastructure, and increasingly digital infrastructure), following these policies can be quite a challenge. Regardless of procedural complexities and uncertainties, these strategies need to be translated into implementable measures (Davoudi et al., 2012). The positive aspect is that adaptation measures do not necessitate substantial changes in the existing planning system but mainstreaming these action plans in existing policy and decision-making structures should not be overlooked (Davoudi et al., 2012).

A way of achieving this could be to follow the guidance of landscape ecology, which has not yet been fully integrated into the planning discipline (Ahern, 2013). Applying ecological knowledge to cities has a rich history of development (du Plessis, 2008). As part of this evolving process, more and more approaches find the natural-unnatural divide in cities rather artificial and observe the built and natural environment as a whole, e.g. the switch from ecology *of* cities to ecology *in* cities (Grove et al., 2015, italics original). Grove et al. propose following principles at the interface of planning and ecology (2015, p. 2):

1. The ecology in and of cities looks at the entire metropolitan land-use and land-cover system, not just the rural green.
2. It embraces the spatiotemporal and scalar complexity of urban mosaic.
3. It integrates knowledge from the social and ecological sciences and highlights the need to integrate diverse disciplines within the abovementioned layers of complexity.
4. The overarching aim is to be useful both for decision-making and science.

In the context of this study, *green infrastructure*, *ecosystem services*, *nature-based solutions* and *ecosystem-based adaptation* are complementary concepts to one another in framing the benefits of urban green spaces as social-ecological systems and to address urban risks and hazards resulting from climate change within planning discipline. Perhaps more importantly, this approach is a balance between the dominance of the view that green spaces exist to "benefit" humans and other living things, and the view that green space in and of itself is also "life".

Despite several conceptual unclarities or difficulties in operationalization in planning, the green infrastructure, ecosystem services, nature-based solutions, and ecosystem-based adaptation concepts are promising in safeguarding biodiversity, recreation, climate

adaptation. The synergies between these concepts can be transformative and improve contemporary planning if mainstreamed into planning practices. It is to be noted that it is beyond the scope of this research to quantify ecosystem functions or come up with nature-based solutions on the basis of green infrastructures. The goal is rather to introduce some of the most topical concepts that inform how urban green spaces can be approached. This is based on the premise that the integratedness of landscape ecology and planning creates synergies.

Green infrastructure

Green infrastructure is *"an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations"* (Benedict & McMahon, 2002, p. 5). Complimentarily, an alternative definition puts emphasis on planning and defines green infrastructure as *"a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings"* (European Commission, 2013, p. 7). Ideally, green infrastructure is an interconnected system rather than a series of components in isolation (Benedict & McMahon, 2002). Similar to any other infrastructure, the major physical components of the green infrastructure are its nodes (e.g. parks, gardens) and connections (i.e. green corridors). As the *infrastructure* metaphor implies, connectivity is an important feature. From the user's perspective, connectivity favors quality of stay via walking and cycling. From the ecological perspective, connectivity promotes the habitat function and biodiversity, and better functioning of ecosystem services without interruption.

The green infrastructure concept originates as a sprawl controlling strategy and has a history of at least two decades. Its definition is well-established; however, different definitions highlight different aspects (e.g. ecosystems, planning, connectivity). Its use in urban context and application in planning are also well-established (Pauleit et al., 2017, p. 40).

Ecosystem services

In contrast to the challenges in its implementation on real-life cases, widely accepted definitions of ecosystem services are rather straightforward. According to Costanza et al., there are 17 ecosystem services (gas regulation, climate regulation, disturbance regulation, water regulation, water supply, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, pollination, biological control, refugia, food production, raw materials, genetic resources, recreation, cultural) which *"represent the benefits human populations derive, directly or indirectly, from ecosystem functions"* (1997, p. 253). Likewise, Millennium Ecosystem Assessment defines ecosystem services as *"the benefits people obtain*

from ecosystems" (Millennium Ecosystem Assessment, 2005, p. 40) and further develops the classification by Costanza et al. by grouping the ecosystem services into four basic categories: provisioning services (e.g. food, water, timber, and fiber); regulating services (e.g. disease, wastes, and water quality, including local climate regulation—i.e. the focus of this research); cultural services (recreational, aesthetic, and spiritual); and supporting services (soil formation, photosynthesis, and nutrient cycling) (Millennium Ecosystem Assessment, 2005; as in Pauleit et al., 2017).

Humans are fundamentally dependent on urban ecosystem quality, quantity, and diversity (Tzoulas et al., 2007). The most important sources of ecosystem services in urban areas are street trees, parks, forests, vegetation covers, wetlands, and streams (Depietri et al., 2012). Breuste et al. (2013) also point out that both small patches and more complex green areas are providers of ecosystem services. It is suggested that the ecosystem services approach can improve urban green space planning; however, this potential is impaired by poor land-use practices and drastic changes in land-cover combined with the impacts of climate change (Niemelä et al., 2010). Therefore, it would be beneficial to optimize institutional and governance systems for a better integration of ecosystem services concept into planning (McPhearson et al., 2015). Although ecosystem services in urban studies is still not quantifiable (Ahern et al., 2014), various analytical frameworks, e.g. of multifunctionalities, can prove beneficial (Wei, 2017).

The ecosystem services concept has a rich history of establishment and definition that are still debated. The concept is rooted in protection and biodiversity conservation and the current focus is also on biodiversity conservation. Their use in urban context is relatively new, and their application in planning is only partially established due to limitations in its operationalization (other concepts, e.g. green infrastructure and nature-based solutions could support operationalization) (Pauleit et al., 2017, p. 40).

Nature-based solutions

Costanza et al. (1997) classify 17 ecosystem services and de Groot et al. (2010) later investigate the challenges of integrating ecosystem services in planning and management by reclassifying them under 23 categories. Despite various categorization, classification, and regrouping, it is still discussed in what ways ecosystem services can be made operational in practice. A supportive concept, nature-based solutions, builds on the complexities of ecosystem services by perceiving these as resource-efficient solutions to societal challenges. It is defined as the *"actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"* (Cohen-Shacham et al., 2016, p. xii).

According to Faivre et al., nature-based solutions have the capacity to turn ecosystem services into innovative responses to *"optimize the synergies between nature, society and the economy"* (2017, p. 509). The ecosystem services concept is mostly a field of inquiry in scholarly literature; whereas nature-based solutions appears more often in policy literature.

Coupling the ecosystem services concept with nature-based solutions can create synergies. Nature-based solutions is a new concept and its definition is still under development. The concept is rooted in climate change problems and has a current focus on societal challenges. Given the aim to solve societal problems, the focus of nature-based solutions is the urban context. However, despite its *"action focus,"* its application in planning needs further development (Pauleit et al., 2017, p. 40).

Ecosystem-based adaptation

Ecosystem-based adaptation is essentially a subset of nature-based solutions (Pauleit et al., 2017) and focuses on making use of ecosystem services to help societies adapt to the adverse effects of climate change as part of an overall adaptation strategy (Secretariat of the Convention on Biological Diversity, 2009). Fundamentally, ecosystem-based adaptation is *"the sustainable management, conservation and restoration of ecosystems"* (Secretariat of the Convention on Biological Diversity, 2009, p. 6) with the intention to make use of *"the capacity of nature to buffer human communities against the adverse impacts of climate change through the sustainable delivery of ecosystems services"* (Munang et al., 2013, p. 68).

Given the increased severity of the impacts of climate change, scholars addressed the urgency for a *"closer attention to a broader spectrum of adaptation options"* (Munang et al., 2013, p. 67). Similar to the nature-based solutions concept, ecosystem-based adaptation is concerned with the root causes of risks, hazards, and damages. Disadvantaged societies and vulnerable populations are at the forefront while considering adaptive solutions that are based on ecosystems (similar discussions in e.g. Millennium Ecosystem Assessment, 2005; Munang et al., 2013).

Ecosystem-based adaptation is also a new concept with no consensus on its definition. As the name suggests, it stems from and currently focuses on climate change adaptation. Formerly its focus was on more agriculture and forests and less on urban. Its application in planning is not yet readily available (Pauleit et al., 2017, p. 40).

2.4.4. Qualitative and quantitative variables and indicators

The quantitative and qualitative variables and indicators usually include the amount (percentage cover), distribution (even or uneven distribution of green spaces in a given area), proximity (whether green spaces are closely located to where people live),

accessibility (whether green spaces are accessible physically and socio-culturally), connectivity (whether the vegetation cover is connected), and land-use and land-cover type (e.g. tree cover indicates higher quality than bare soil). In order to characterize green infrastructure at the city level in Europe through an interactive tool, European Environment Agency proposed two indicators: share of urban green areas and distribution of urban green areas (European Environment Agency, 2006). The share of urban green areas is the percentage amount of any vegetation cover in the city or the given area of examination in order to calculate how much green there is. However, measuring only the amount of or per capita green space is insufficient to understand other important spatial parameters such as distribution, connectivity, and proximity. Additionally, qualitative characteristics (e.g. maintenance, accessibility, quality of stay) of urban green spaces should also be observed.

In previous studies, the green space distribution and resultant proximity discussions play a central role in environmental justice debates (e.g. following Davoudi & Brooks (2016), evidence shows that residents of deprived neighborhoods are less likely to live near urban green spaces). Recently, the policy literature is also inclined toward setting nationwide standards to green space accessibility, one key example of which is the UK's Accessible Natural Greenspace Standards (Natural England, 2010 as in Davoudi & Brooks, 2016):

- At least 2 hectares in size, reachable in less than 300 m or 5-minute walk from home,
- 20 hectares in size, within 2 km from home,
- 100 hectares in size, within 5 km from home,
- 500 hectares in size, within 10 km from home,
- At least 1 hectare in size, Local Nature Reserve per 1.000 population.

In Germany, there are no nationwide green space accessibility indicators, but several scholars developed a set of proposed indicators (Grunewald et al., 2017; Richter et al., 2016). In a nationwide study, it was found that almost three quarter of the population in analyzed cities were living in 300 m linear and 500 m walking distance to green spaces that are larger than 1.000 m² and 700 m linear and 1.000 m walking distance to green spaces that are larger than 10.000 m². A mathematical result may indicate favorable green space distribution, but it could still be observed that disadvantaged populations might not be living in close proximity to high quality green spaces, which makes the distribution of quality also a primary aspect (Davoudi & Brooks, 2016). For this reason, some studies primarily involved the quality characteristics while studying urban vegetation. Gupta et al. (2012) aimed to objectively measure the greenness in a neighborhood and included the quality of the built environment in their analysis (parameters: proximity to green, height of structures, and built-up density as features of the built environment). Their approach took both built and natural environment into account.

2.5. A note on systems thinking

The review of the scholarly debates aimed to locate the phenomena within various theories and concepts, designating the resource conflict as a point of departure. Involving various discussions (e.g. sustainable urban form, resilience, governance, landscape ecology) proves useful to approach urban green spaces from a variety of perspectives and eliminates the risk of one-sidedness. Also, it allows for critical reflection.

Despite its methodological practicalities, the central role the social-ecological systems thinking plays does not indicate any separation of the *social* from the *ecological*. On the contrary, the long history (as Gandy (2015) puts it, the *ambiguous trajectory*) of intellectual richness in the debate of social-ecological (dis)juncture is fully respected. Scholars have sought to understand ecology in the context of growth-driven urbanization, both through clear distinctions between society and nature (what the social-ecological systems thinking may imply) and with approaches that emphasize social-ecological interdependencies in the production and reproduction of urban space (Gandy, 2015), e.g. urban metabolism, urban political ecology, cities as human-dominated ecosystems.

When the natural elements in an urban setting are studied, the urban is no more seen as a "purely *social* space," as Braun puts it (Braun, 2005, p. 635). The current urban scholarship does not see the city as an antonym to nature, nor does it insist on rural/urban or city/nature dualities. These dualities were already unsettled when cities were seen as the metabolic relationship between society and nature, addressing human and nonhuman ethical and political concerns. In urban studies, ecological concepts and biological metaphors (e.g. metabolism) have been used since the beginning of 1900s—when it was argued that there must be enough countryside in city to counteract its urban-ness, as these two were still seen as opposites—but including the "metabolized nature" in the debate is relatively new. As of 21st century, countryside and city are not approached as opposites. Today the wilderness areas, natural parks, protection areas are metropolitan natures that are metabolized, produced and reproduced, as commodities (Braun, 2005).

In addition to urban metabolism, another line of advancement has been the urban political ecology,[14] which furthers the understanding of production and reproduction of nature within and beyond urbanization. It is concerned with the uneven and contested character of social-ecological landscapes (Braun, 2005, p. 644), uneven access to resources, disadvantaged social groups, local/global context of environmental conflicts, and the role of state and nonstate institutions. Desfor & Keil (2004) looked into the root causes and the ways in which

[14] Urban political ecology is not a synonym for environmental justice, which is primarily concerned with the distribution of costs and benefits for parts of the society (as in Braun, 2005).

urban natures are being reshaped (through the examples of Toronto and Los Angeles). As the meaning and function of urban and regional economic activity outweigh that of nations and national institutions, the *urban* is the scale to explore the reshaping of nature. As the social and the ecological in the urban scope is not separated, a separation of the two while exploring the reshaping of nature is likely to be counterproductive.

2.6. Phenomenon contextualized: Frankfurt Rhine-Main

2.6.1. Frankfurt Rhine-Main in a nutshell

At this point, it is necessary to locate these discussions within the studied case, the Frankfurt Rhine-Main region. The city of Frankfurt am Main is known for being one of the smallest metropolitan cities in the world with its 753.000 inhabitants. The city is currently growing by 15.000 inhabitants per year (Keil, 2011; Reißmann & Buchert, 2018) and is home to high rates of international financial activity, thus given the nickname *Mainhattan* since its central business district resembles that of Manhattan. The metropolitan region of Frankfurt Rhine-Main is the third largest in Germany with a population of 5,8 million. The region is one of the few in Germany with continuous economic growth while undergoing transitions toward financial and service industries, urging for parallel transitions in governance and planning (Keil, 2011). The region has had high economic activity since its preindustrial times, and currently in its post-industrial era, it is home to production, commerce, and services. Both the Frankfurt city and the region performed relatively stable during the global financial crisis of 2008. A reason for this stability is claimed to be the diversity of economic activities and socio-demographic composition. In a reciprocal relationship, the region is currently attracting high rates of domestic and international migration mainly due to the shrinking cities and declining economies in some regions in Germany and Europe, influx of refugees and asylum seekers since 2015, and Brexit (Macdonald et al., 2020; Monstadt & Meilinger, 2020a), as Frankfurt is assumed to take over a significant portion of London's financial functions in the continental Europe. Given the highly interconnected public transportation networks, the region around the city of Frankfurt am Main remains attractive for newcomers (Reißmann & Buchert, 2018).

A typical Zwischenstadt

The Frankfurt city-region is argued to be the most suburbanized city-region in Germany (Monstadt & Meilinger, 2020a), demonstrating a prime example to the debate of global networks and global city-region as well as to the concept of *in-between cities* (*Zwischenstadt*), which is a feature of the urban landscape configuration of city-regions. In-between cities are a continuum of built-up and open areas composed of connected nodes of centrality and technically manipulated, modified, and influenced forms of nature which continually strive for both the urban and rural ideals, in which the original nature is almost

completely “penetrated by artefacts,” and the city-nature contrast is dissolved (Sieverts, 2003, p. xiii). As the transport infrastructure and technologies have developed, the physical capabilities of humans and animals did not determine the spatial limits of cities and cities started growing into their surrounding countryside (Sieverts, 2003). This resulted in spatial structures that could neither be categorized as urban nor rural. This evolved into a two-way process, expansive urbanization coupled with selective densification, resulting in indiscernible blends of “urbanized landscape” and “landscaped city” patterns (Sieverts, 1998). Sieverts proposes five concepts as a framework for advancing the debates on the features of in-between cities, which are still profoundly relevant for the Frankfurt city and region:

- Urbanity: A tolerant, outward-looking attitude of city’s inhabitants to each other and to outsiders. Today, the meaning of urbanity is almost synonymous to density, given its importance in booming city tourism.
- Centrality: Traditionally-ordered and structured society and administration that is reflected in the distinction between a city’s core and periphery. As the city extends into its surrounding, centrality loses its meaning, so does the periphery, since there are now peripheral centers (explained below).
- Density: The main argument is that the only way to limit settlement expansion is compact development. The distinction between material (floor area per unit area), perceived (degree of spatial enclosure per unit area), and social (quantity and quality of social contacts per unit area) are crucial but often neglected.
- Mixed-use: Supporting the density argument, mixed-use is a means to minimize motorized traffic. Although contemporary spatial requirements of different uses do not comply with such flexibility in use, the widest possible mix should be aimed for.
- Ecology: All arguments on resource and energy consumption and waste production relate to urban ecology and rightfully become the overriding principle of urban development. Unless how industrial cities keep developing is restructured, the world’s ecosystem will fail.

Central Places Theory: then and now

The Central Places Theory (*System der zentralen Orte*) is a concept developed by Walter Christaller in 1933 to rank the size, number, and location of spatial structures and size patterns. It focuses on the provision of the population with livelihood, workspaces, and public and private goods and services based on the spatial categories of (Pahl-Weber & Henckel, 2008):

- Basic, lower-order or small centers supply basic daily needs in the immediate area,
- Middle-order centers meet more demanding needs in the intermediate area,
- Higher-order centers meet demanding, specialized needs in the extended catchment area.

The theory is based on the idea that the provision and consumption of goods and services can only cover a certain catchment area. For instance, a town with a specialized service (e.g. university) would be a higher-order center, and a town with basic services (e.g. groceries) would be a lower-order center. The providers have to consider an area of minimum distance to consumers in order to minimize logistics costs, which is decisive for the location choices of providers as well as customers (Terfrüchte & Flex, 2018). The system supports the spatial principle *decentralized concentration*, so that a decentralized settlement structure throughout the national territory can be maintained to function as efficient centers, without huge spatial disparities (Pahl-Weber & Henckel, 2008).

This ranking is still embedded in today's German spatial planning system as it assigns municipalities these categories and provides state and regional institutions with a guidance system. Since its inception, the hierarchy introduced by the Central Places Theory has provided some benefits, e.g. by ensuring basic and complex services in towns and cities, it concentrated settlement densities and limited sprawl (Borchers, 2020). But the central places system falls short of eliminating spatial disparities in contemporary cities. The emergence of in-between city and the more complex patterns of settlement structures appears to be the main reason why this happens (Pahl-Weber & Henckel, 2008). Currently the central place rankings do not consistently correspond to the actual status of towns and municipalities. On the contrary, it now has unintended negative impacts on the lower-ranking centers. For instance, attractiveness of conurbations may reduce the dynamism in towns with predominantly rural characteristics, causing higher rates of vacancies in residential and commercial settlements. In the context of Frankfurt Rhine-Main, this can be observed in the transformations in the Odenwald county in South Hesse, where *"each new dwelling in the conurbation means one more empty dwelling in the towns with rural character"* (Borchers, 2020).

2.6.2. Growth management

Legal frameworks (supralocal level)

National planning principles in Germany prioritize strategies against sprawl by reducing daily open land take from 113 hectares to 30 hectares by 2020 and by protecting natural environment through *inner before outer development* (*Innen- vor Außenentwicklung*) (The Federal Government, 2002). Since this goal could not be reached by 2020, it is prolonged till 2030. The Federal Building Code supports this with the simplified procedures for inner development (*vereinfachtes Verfahren*). As per Section 13, inner areas can be developed through simplified procedures (e.g. in certain cases without the requirement of environmental impact assessment), provided that the new development does not necessitate any alterations in the land-use plans. In effect since 2007 (Petzold, 2020), the accelerated

procedure (*beschleunigtes Verfahren*) described in the Section 13a of the Federal Building Code can be used for the purposes of reuse of areas and densification in the inner areas to counteract outer development. If the sealing area is less than 20.000 m², there may be exemptions from environmental impact assessment, and a coarse assessment suffices for sealing areas between 20.000 and 70.000 m², including shortcuts for public participation procedures.

More recently, the temporary[15] inclusion of outer areas in the accelerated procedures for housing development since 2017 through the special rule of Section 13b is often criticized for conflicting with the goal to promote inner development. The section is often used by smaller municipalities to enable outer area development for residential purposes up to 10.000 m² that is directly adjacent to the already built-up area, often without the obligation to follow the compensation measures or environmental impact assessment. A counterargument, however, states that the use of the section by smaller municipalities is not due to an absolute necessity, but due to rather uncomplicated processes that is often not the case with the regular processes. Additionally, it cannot be directly concluded that the outer development enabled by the Section 13b guarantees affordable housing with minimal land consumption (Petzold, 2020).

Technical approaches (local level)

The housing demand in the State of Hesse till 2040 is expected to reach 517.000 new dwellings, 367.000 of which is supposed to be located in the District of South Hesse (Hessisches Ministerium für Wirtschaft Energie Verkehr und Wohnen, 2020b). In order to address the increasing population in South Hesse, the Hessian Ministry of Economy initiated the housing project *Großer Frankfurter Bogen*. The goal is to provide 200.000 new housing units in more than 50 invited towns (of which 35 are already on board) that are reachable to Frankfurt central train station with suburban or regional trains in maximum 30 minutes (Figure 2.6). The State invests around 28 billion Euros in the initiative. A large portion of these resources is intended for sport areas, green areas, daycare centers, and social housing (Hessisches Ministerium für Wirtschaft Energie Verkehr und Wohnen, 2020b).

The pressure for settlement space makes large-scale supportive approaches a necessity; however, the initiative is criticized because it might intensify the negative outcomes of place ranking, as it is fundamentally based on a prioritization of well-connectedness to Frankfurt. This is likely to sharpen the divide between the conurbation and the towns with rural

[15] An argument favoring the recent extension of Section 13b of the Building Code addresses how the pandemic made moving to the peripheries to single-family houses became an attractive option for many (Erhardt, 2021).

characteristics, introducing another de-facto central places system, instead of, for instance, improving the public transportation connections of rural towns (Borchers, 2020).

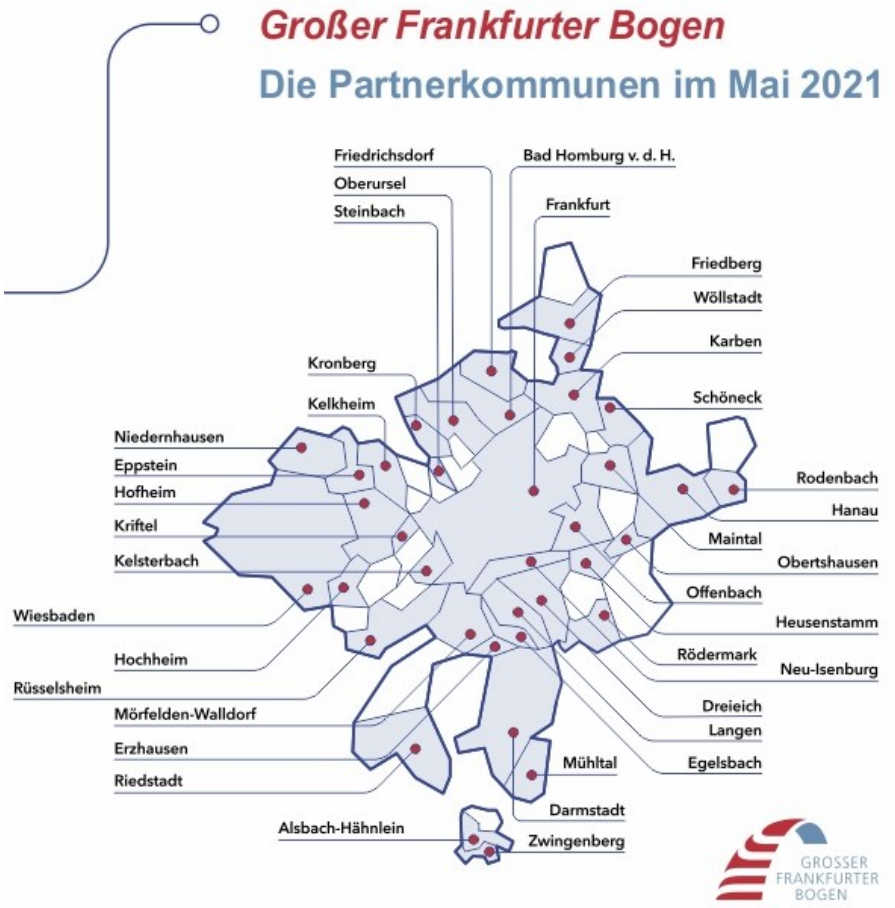


Figure 2.6: The partner municipalities of the Großer Frankfurter Bogen project (image credits: Hessisches Ministerium für Wirtschaft Energie Verkehr und Wohnen).

Given the focus on urban green spaces in this study, a fundamentally different growth management approach is the Frankfurt Greenbelt (Figure 2.7) and the Regionalpark RheinMain (Figure 2.8).[16] The Frankfurt Greenbelt is developed in 1991 with multiple goals (e.g. climate, regional identity, environmental protection, and the intention to limit sprawl). The Frankfurt Greenbelt is a case with certain governance complexities due to its multi-actor governance conditions emerging from its multifunctionality (Macdonald et al., 2020).

[16] In many ways, the Frankfurt Greenbelt and the Regionalpark Rhein-Main are a representation of the debates of metabolization of nature following the debates addressed in Section 2.5.1.

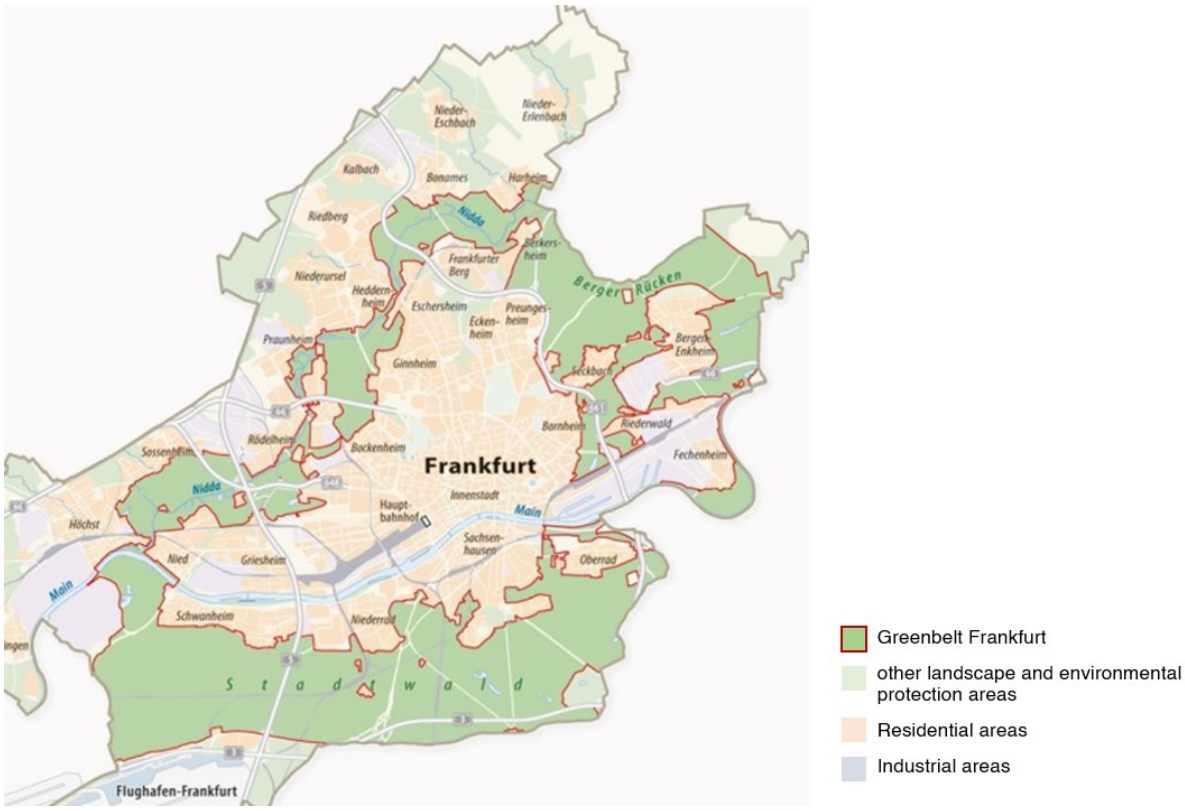


Figure 2.7: The Frankfurt Greenbelt (image credits: Frankfurter Allgemeine Zeitung, 2020).

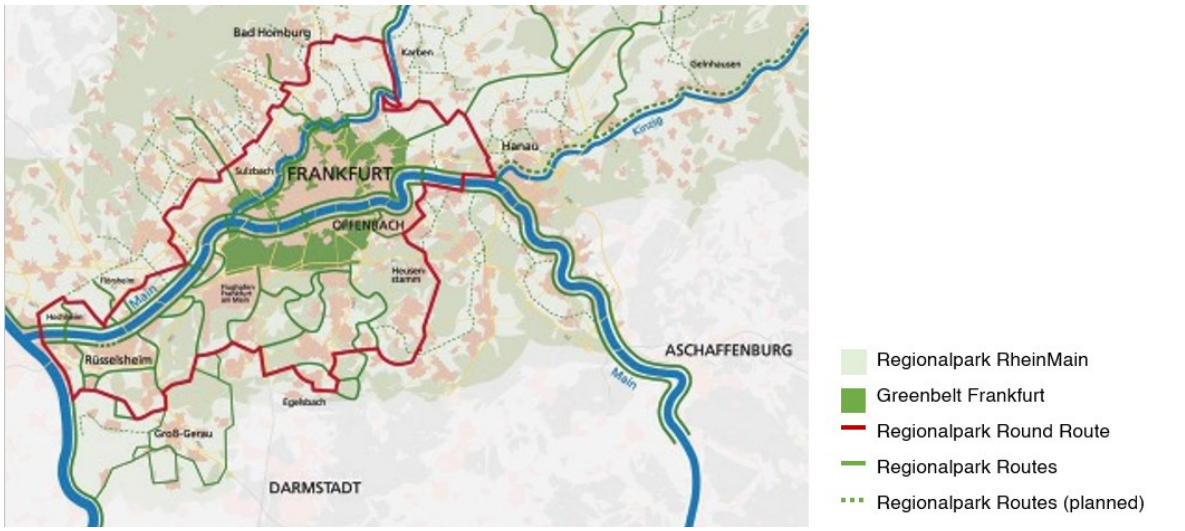


Figure 2.8: Regionalpark RheinMain, expanding from Frankfurt's greenbelt outwards (image credits: Regionalpark RheinMain).

Policy-practice divide: The need for supportive methodologies

Planning policies are often recognized as the link between planning theory and practice. Traditionally, planning policies emerge by interpreting theory, but this is not a one-way relationship, since new theories emerge based on planning practice. Policies are created at international and national levels, but it is the local level that implements them to adequately address the actual anticipations of citizens and other involved actors.

As far as the German spatial planning system and the urban green spaces are concerned, the policies produced by the Federal Agency of Nature Conservation (*Bundesamt für Naturschutz*) stand out as they directly relate to urban growth challenges, strategies, and potentials for implementation while safeguarding the quality and quantity of urban green spaces.[17] As a set of strategic recommendations for the federal- and state-level planning and for municipal planning practice, the dual inner development (*doppelte Innenentwicklung*) policy was published in 2016 (Böhm et al., 2016; Kühnau et al., 2017). Dual inner development means, making use of the spatial reserves in existing settlements in favor of construction, provided that urban green spaces are qualitatively improved. This protects not only the outer landscape from further open land take but also the ecological functions of urban green spaces. Therefore, the settlement space is qualified through the measures of open space development (Böhm et al., 2016, pp. 16, 17).

The policy introduces a methodology through the use of mainly geospatial data for inner development through a ranking of urban green spaces based on the following cross-functional criteria (Böhm et al., 2016, p. 199): green space size and form; location, connectivity, interconnectedness; existing vegetation cover; percentage of built and sealed surfaces; and anthropogenic limitations (e.g. noise, overuse, etc.). In addition to the significance of the observed green space for the neighborhood- and city-scale determined by land-use plans, other key functions (i.e. habitat function for plans and animals, climate regulatory function, water function, soil and groundwater function, and recreational and health function) are also evaluated. The resultant ranking of green spaces is expected to guide the municipalities to decide where to improve the green space qualities and where to promote inner development. The study concludes with recommendations for the state and federal governments (Böhm et al., 2016, p. 235, own translation):

- Make the strategy and its opportunities for development better known to municipal decision-makers,
- Look into the possibility for a separate funding program for the development of urban green spaces in inner development,
- Initiate a landscape planning and dual inner development campaign,
- Support the municipalities in the (initial) identification of inner development potential,
- Expand interdepartmental cooperation at the federal and state levels,

[17] Some important examples of recent policies relate to urban wastelands, multifunctional urban spaces, nature protection and landscape conservation in integrated urban development (specific themes are e.g. multifunctional land-use at urban peripheries; brownfields and the conflict of natural or building use; ways to establish nature experience in large cities; nature protection in integrated urban development; green infrastructure in urban space, principles, planning, and implementation, etc.).

- Examine the creation of a professional convention on uniform federal orientation values, recreational provision through urban green space, together with the municipal umbrella organizations and relevant professional associations, and
- Examine the transferability of the results to small and medium-sized cities.

Complementarily, Kühnau et al.'s work looks into the municipal practices and provides recommendations for the local-level, including but not limited to (2017, own translation):

- Understand inner development as a task for integrated planning, ensuring cooperation in the municipal administration,
- Determine guidelines, goals, and strategies together with politics,
- Capture the entire spatial potential including the nature, landscape, recreation,
- Integrative assessment, transparent weighing up of interests,
- Set site-specific goals for the urban green,
- Take the preliminary land-use plan as a reference point,
- Use funding programs and interventions, attract donors,
- Take upkeep costs into consideration and keeping them low, and
- Make processes open, transparent, and participatory.

It is noteworthy that these recommendations, both for the policy-producing federal and state governments and municipal administrations, are resulting from a detailed qualitative and quantitative research on municipal green space management, with a focus on the feasibility and potentials for dual inner development. Nevertheless, these recommendations are not specific to the dual inner development and can be generalized for improvements in green space management.

2.7. Summary

Based on the concept, content, and context discussed in this research, it can be suggested that protecting the green within a city is not less important than protecting the green around a city, and settlement growth in the form of outer development in its entirety can be as social-ecologically problematic as settlement growth in the form of inner development in its entirety.

This study acknowledges the urban land as a scarce resource and the urban land-use conflict as the point of departure and regional economic growth and environmental protection as points of entry into social-ecological systems thinking. Once the green space debate is situated within systems thinking, it makes sense to briefly revisit the main concepts in resilience. The aim is to go beyond the normative views on urban form when it comes to growth management and to allow for a broader understanding of urban processes accompanying the contemporary shaping and reshaping of the built and the natural environment.

It is suggested that resilience is an inherently available concept in planning and can prove useful, because what is at the core of resilience thinking, i.e. social-ecological systems, is in fact rooted in planning discipline. Whether or not this can help open up new ways of responding to known and unknown transitions will largely depend on its institutional operationalization.

The review of the literature therefore is a transition from the conceptual framework into a methodological framework and the roadmap for analyzing the land-use conflict in the studied context. It is of practical importance to provide an overview of the most important features of the region based on the previous discussions, e.g. in-between cities and central places, followed by a quick recap of the legal frameworks and spatial approaches to growth management. The importance of enabling policy implementation at the local-level is also emphasized.

3. Toward a methodological framework

Building on the conceptual and theoretical debates in the previous chapter, this chapter is a transition from the conceptual to the methodological framework and provides the roadmap to analyze the complex interactions among the components of the social and ecological subsystems. For the studied case, not only the Frankfurt city, but also the middle-sized towns in close proximity are facing the pressure for settlement provision. As a highly dynamic commuting region, these towns in the conurbation are likely to be buffering the housing demand pressure which is reflected in the increase in the recent construction activity, but they are also nearing the limits of their capacities. What are the consequences of these transitions on the quality and quantity of urban green spaces? How are the green spaces being produced and reproduced, with which social and ecological implications? What are the tools to manage settlement growth, and how effective are they? Guided by these questions, several fastest growing middle-sized towns in the conurbation are specified and their spatial focus area is spatially analyzed for green space parameters.[18] The case study towns are also analyzed qualitatively through the semi-structured interviews. This chapter describes the research design, research aims, hypothesis, as well as the data collection, analysis, and interpretation methods, complementary tools, and procedures and identifies the spatiotemporal scope.

3.1. Case study research

This research looks at the urban green spaces in the fastest growing middle-sized towns in the Frankfurt Rhine-Main region. In order to investigate this real-life phenomenon occurring in a specific context, case study method is employed (Yin, 2014). The empirical part of this study is conducted based on various qualitative and quantitative components. It follows explorative and explanatory approaches in parallel. The explorative approach stems from the first research question: *"To what extent does recent settlement growth impact the quality and quantity of urban green spaces?"* This research question is asking *how much* qualitative and quantitative change is going on. The explanatory approach stems from the second research question: *"In what ways are the governance conditions supportive for or restrictive to urban social-ecological resilience?"* This question is asking *how* the governance conditions are shaping and reshaping the social-ecological system. The research questions complement each other to construct the main hypothesis: *"if and when governance conditions are supportive for and not restrictive to social-ecological resilience, settlement growth in the middle-sized towns of the region can*

[18] This spatial scope is not intended for the qualitative part of the analysis and the interviews with the planning experts focused on the entire town and where relevant the region.

take place without negative impacts on the quality and quantity of urban green spaces." The hypothesis tests whether it is possible for urban green spaces to serve both as natural resources and spatial reserves in a balanced, optimal manner to contribute to the urban social-ecological resilience. It carries the assumption that the resource conflict can be resolved, tradeoffs can be evened out, and synergies can be enhanced (Figure 3.1).

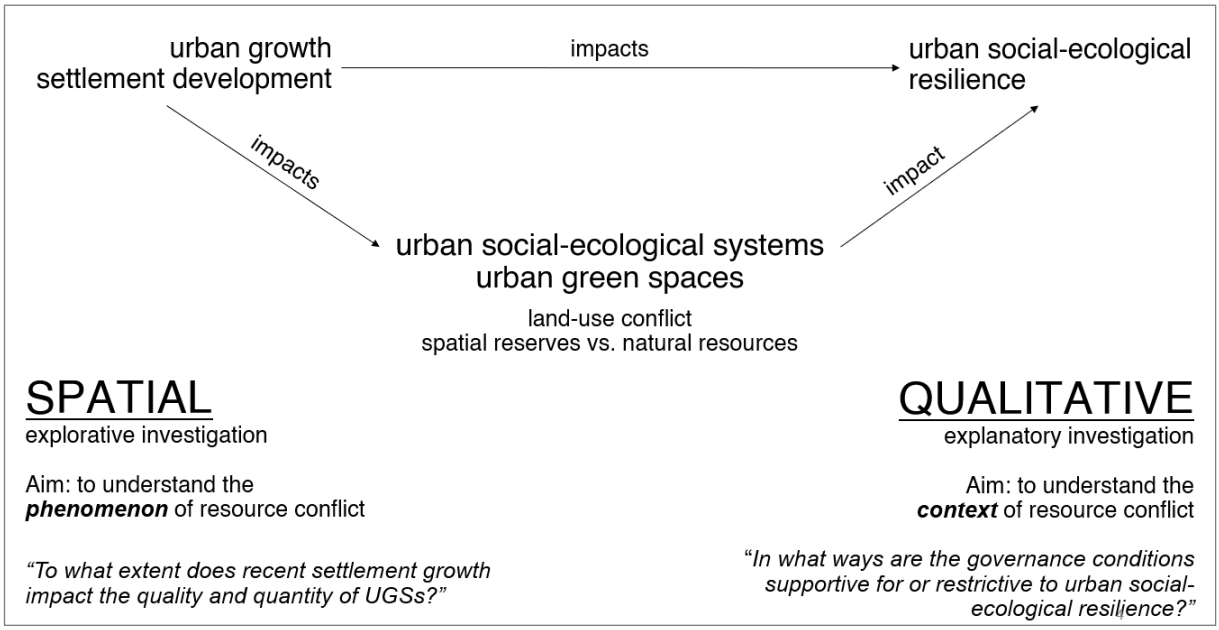


Figure 3.1: The methodological framework emerging from the conceptual model established in the previous chapter (own illustration).

This research calls for a hybrid design because it is concerned with a single case (i.e. the Frankfurt Rhine-Main region, the larger unit) and multiple cases (i.e. selected case study towns, the subunits). It is, therefore, a *holistic case study with embedded units* (Baxter & Jack, 2008). Attention is paid to not lose sight of the regional level in order to avoid scattered and differentiated conclusions.

3.2. Research design

An overview of the case study research design is provided by outlining each step in accordance with the research questions and aims. The study has predominantly a qualitative nature, but it makes use of specific quantitative data and methods especially for the spatial analysis. It is a mixed methods study, a single study embracing both qualitative and quantitative components (Yin, 2014).

3.2.1. Data collection

Quantitative data

Statistical data: In order to identify the fastest growing middle-sized towns in the region, it is necessary to take the demographic change as a reference, especially in terms of population

increase in the recent years. Since this study is concerned with the loss of vegetation cover, it is also important to point out whether an increase in the population is reflected in an increase in the construction activity. Therefore, population and housing stock datasets for each municipality is retrieved from the Regional Association's online statistics-viewer tool (Regionalverband FrankfurtRheinMain, n.n.).

Spatial data:

- **Land-use data**: To ensure a representative case study selection, it proved necessary to take the recent land-use change in the spatial focus area into consideration. This way the highest increase in population and housing stock is reflected in a positive change in the settlement land-use. Therefore, the Official Topographic-Cartographic Information System, GIS-based land-use data (*Amtliches Topographisch-Kartographisches Informationssystem, ATKIS*) is involved in the selection of the case study towns. The ATKIS land-use data is acquired following an official data usage agreement with the Regional Association Frankfurt Rhine-Main. The raw data includes the land-use data of all 24 middle-sized towns in the region for the period 2012 – 2019 (excluding 2014 and 2015 due to data unavailability) (received from the Regional Association on October 17, 2019). These shapefiles were operated on an educational account for ArcGIS ArcMap Version 10.1.7. Produced based on the German land-use management system (*Digitales Landschaftsmodell, DLM*), the ATKIS data is utilized to extract the actual use data (*tatsächliche Nutzung*) for the attributes that are provided in Appendix C (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV), 2018).
- **Land-cover data**: After the case studies are selected, the green space parameters of amount (percentage cover within the spatial focus area, square meter per person within town boundaries), distribution, connectivity, and proximity are spatially analyzed within the spatial focus areas of selected towns. This analysis is conducted on the basis of the land-cover data that is retrieved from OpenStreetMap.

After separating the yearly land-use/land-cover data into layers on ArcGIS ArcMap, the data is exported to Autodesk AutoCAD 2020 Student Version. The extracted data outputs from AutoCAD drawings were in the format of MS Excel spreadsheets, which enabled a systematic data reorganization and analysis. Due to imperfections in the raw data (duplicate objects and/or missing coverages), the verification of total area may not consistently equal to the area of a circle with a radius of 1.000 meters. However, these remain in the margin of error and do not require further alteration in the methods. The summaries can be found in Appendix G.

The catchment area defined by a 1.000-meter radius around a train station is representative of a well-connected area that already contains various functions (predominantly residential

and commercial, but also based on the characteristics of the town industrial and recreational areas, as well as services, education, and healthcare), ideally with the potential for further spatial development. That is why the individual bus stations are not included while determining the spatial focus area, unless a bus station is located at the central train station. Additionally, a previous review defined the 1.000-meter radius as an “acceptable” “pedestrian radius” (Pongprasert & Kubota, 2019), hence the anticipation for reduced car dependency.

Qualitative data

Field observations: In addition to the spatially analyzed green space parameters by using the land-cover data, in-person visits to the field add a systematic qualitative layer of observation. In-person field visits are the only way to detect any potential flaws in the land-cover data, e.g. areas that are indicated as green space turn out to be parking lots (this is discussed as a limitation in the upcoming chapters in detail). During the field visits, each green space in the spatial analysis is given an ID number, photographed, and its social and ecological values are documented. The entire documentation is then transferred to Excel and AutoCAD maps immediately. The field visits took place between September 26, 2020 – October 31, 2020 in the following order:

- Rüsselsheim: September 26, 2020
- Bad Homburg: October 17, 2020
- Maintal: October 31, 2020
- Hattersheim: October 24, 2020
- Langen: October 10, 2020
- Bad Vilbel: October 17, 2020

Semi-structured in-depth interviews: The interviews are conducted with planning experts from the municipal administration of the selected case study towns, in addition to interviews with one senior regional planning expert from the Regional Association Frankfurt Rhine-Main, one senior regional planning expert from the District Authority South Hesse in Darmstadt, one project leader from AS+P, the company commissioned to develop the Regional Development Concept (*Regionalentwicklungskonzept, REK*) for South Hesse. The goal is to enable data gathering from a variety of local and regional institutional actors. The interviews are structured based on several predetermined themes with open-ended questions and let new themes to emerge. The conducted interviews are as follows:

- Interview 1, 2020. Municipal Planning Official. Urban Planning Department, Maintal, July 1, 2020. Conducted and recorded via video call.
- Interview 2, 2020. Planning Expert. AS+P Albert Speer + Partner GmbH, Frankfurt, July 1, 2020. Conducted and recorded via video call.

- Interview 3, 2020. Municipal Planning Official. Urban Planning Department, Hattersheim am Main, July 9, 2020. Conducted and recorded via video call.
- Interview 4, 2020. Municipal Planning Official. Urban Planning Department, Bad Homburg vor der Höhe, July 16, 2020. Conducted and recorded via video call.
- Interview 5, 2020. Municipal Planning Official. Urban Planning Department, Rüsselsheim am Main, August 6, 2020. Conducted and recorded on device in person.
- Interview 6, 2020. Regional Planning Official. Regional Planning Department, Darmstadt, August 14, 2020. Conducted and recorded via telephone call.
- Interview 7, 2020. Regional Planning Official. Regional Planning Department, Frankfurt am Main, August 19, 2020. Conducted and recorded on device in person.
- Interview 8, 2020. Municipal Planning Official. Urban Planning Department, Langen, October 2, 2020. Conducted and recorded via telephone call.

An interview with the planning department of the town Bad Vilbel had to be excluded due to several rejections to the interview request. A summary of the data sources in line with the research aims and objectives is as follows (Table 3.1):

Table 3.1: An overview of the data sources in combination with the research aims and objectives.

Aim 1: To understand *the phenomenon of resource conflict* and its manifestation as an urban land-use conflict in urban green spaces:	**Associated data sources:**
Objective 1.1: To analyze the increase in the recent population and construction activity to identify the fastest growing middle-sized towns in the conurbation	**Statistical data**: Population increase; resultant increase in housing stock (Regionalverband FrankfurtRheinMain, n.d.)
Objective 1.2: To demonstrate whether this pace of growth is reflected in land-use change in the spatial focus area	**Spatial data**: Land-use data for geographic information system (privately gathered from Regionalverband FrankfurtRheinMain, October 2019)
Objective 1.3: To analyze urban green spaces in selected case study towns in terms of amount, distribution, connectivity, proximity within the spatial focus area	**Spatial data**: Land-cover data for geoinformation system (OpenStreetMap)
Objective 1.4: To document the current status of urban green spaces in the studied towns with a focus on their social and ecological value within the spatial focus area	**Field observations**: Social value criteria (Marcus & Francis, 1990) in combination with open space typology (Dettmar, 2018) (Appendix D), ecological value criteria (Gill, 2006; I. Lehmann et al., 2014)
Aim 2: To understand *the context of resource conflict* within institutional arrangements and governance conditions:	**Associated data sources:**
Objective 2.1: To analyze the implications of recent settlement growth (concerning both inner and outer development)	**Aerial images**: Spatial growth comparisons from 2006 (Regionalverband FrankfurtRheinMain, 2021) compared with up-to-date land-cover data (OpenStreetMap)
Objective 2.2: To investigate settlement growth	**Interviews**: Semi-structured in-depth interviews

and its implications with a focus on urban green spaces	with public and private actors
Objective 2.3: To propose approaches as to what practices should be kept as it is and what can be improved	Spatial data, field observations, aerial images, interviews

3.2.2. Data analysis

Given the variety of datasets and data sources used in this research, it is possible and necessary to observe the central matters from at least two different viewpoints, a process called triangulation (Flick et al., 2004). Throughout this research, it is intended to consistently crosscheck the statistical data, land-use data, land-cover data, interviews, aerial images, and the secondary data. All data are considered as part of a whole, not as isolated units. Following the same order as the previous subsection, the data analysis methods and tools are listed as follows:

Pre-analysis: case study selection

The percentage increase in population is calculated for all middle-sized towns for the years 2011 and 2018. Similarly, the percentage increase in construction activity (through the analysis of housing stock) is calculated for the years 2011 and 2019. The time frame for the analysis was set between years 2012 and 2019, because the acquired land-use data from the Regional Association was only available for this period.

In cases where the population and housing stock trends were not sufficient to identify the fastest growing town, the land-use change within the spatial focus is calculated. The land-use change is concerned primarily with the increase in the residential settlement area. If still indecisive, the increase in residential and mixed-use area in combination is taken as an indicator (the anticipation is that the increase in the mixed-use zones are predominantly for residential purposes) and calculated in terms of percentage increase for the years between 2012 and 2019.

Spatial analysis: green space parameters

For the spatial analysis of green space parameters, the land-cover data is used and the green space parameters (amount, distribution, connectivity, and proximity) are mapped for the spatial focus area of the selected case study towns by using ArcGIS and AutoCAD. These parameters are taken as variables of spatial configuration and they are evaluated according to the following indicators (primarily based on European Environment Agency, 2006):

- **Amount**: The entire percentage of vegetation cover as well as the green space cover only with sport, leisure, and recreational functions in the entire town and in the spatial

focus area. Several research and policy (Russo & Cirella, 2018) pointed out that each individual must be provided with a minimum of 9 m² of urban green space. However, since it is not possible to provide an exact number of inhabitants living in the spatial focus area determined in this study, calculating the amount of green space percentage cover serves comparative purposes only. For reference, the City of Frankfurt am Main has 50,6 per cent share of green space) (European Environmental Agency, 2017).

- **Distribution**: A high amount of green cover does not guarantee an even distribution of urban green spaces. The distribution of recreational green cover is decided by the indicator *edge density*, the total length of the green space edges divided by the total area of investigation (European Environment Agency, 2006). For reference, the City of Frankfurt am Main has an edge density of 18,02 meters per hectare (European Environmental Agency, 2017), which represents a moderately even distribution.
- **Connectivity**: Landscape connectivity is a significant indicator mainly for biodiversity and habitat functions. It can enhance biking and walking for recreation purposes. The connectivity of the entire vegetation cover in each spatial focus area is calculated and illustrated on AutoCAD. A grid system of hexagons with a 100-meter diameter is superimposed onto the spatial focus area. A sequential connectivity analysis of each hexagon patch is categorized as follows:
    - No connectivity: Not connected to any other patch
    - Very low connectivity: immediate neighbor to 1 hexagon
    - Low connectivity: immediate neighbor to 2 hexagons
    - Moderate-low connectivity: immediate neighbor to 3 hexagons
    - Moderate-high connectivity: immediate neighbor to 4 hexagons
    - High connectivity: immediate neighbor to 5 hexagons
    - Very high connectivity: immediate neighbor to 6 hexagons.

  There are various methods to indicate landscape connectivity. The method chosen in this study (following Rusche et al., 2019) provides simplicity in terms of classification while at the same time produces highly informative visualizations. Also, a grid of hexagons is superior to a grid of pixels in that it results in a lower error in diagonal measurements and eliminates the *corner dilemma*[19] of square grids (Rusche et al., 2019). The diameter of the hexagons is determined as 100 meters, because this is one of the indicator values of landscape connectivity in biodiversity research (Hejkal et al., 2017). The connectivity analysis can be replicated for other hexagon grid sizes (2 m, 44 m, and 1.000 m), but given the size of the spatial focus area, a 100 m grid system is found most appropriate.
- **Proximity**: Building on the distribution analysis, proximity is a parameter concerned with the catchment area of each recreational green space and how much of the settlements are located in the catchment area of at least one recreational green space. The catchment areas are determined by a 300 m linear distance (indicating approximately a 500 m path distance) to the edges of green spaces that are larger

[19] i.e. should squares connected corner to corner be counted as connected, half-connected, or not connected?

than 1.000 m² and by a 500 m linear distance (indicating approximately a 750 m path distance) to the edges of green spaces that are larger than 10.000 m². Since there is no national indicator for proximity in Germany, several recommendations (Bundesinstitut für Bau- Stadt- und Raumforschung (BBSR), 2018; Grunewald et al., 2017) are taken as a reference.

- **Social and ecological value**: The data collected during the field observations is analyzed according to the established criteria for determining the social and ecological value for each green space located in the spatial focus area. These observations may show, for instance, despite very high proximity and connectivity, green spaces might be devoid of social value. These are systematically documented for each observed green space in the field notes, including their photographs. Two sets of criteria are utilized:
    - Criteria for social value: This set of criteria is established based on a points-system and uses the following criteria (adapted based on Marcus & Francis, 1990) (Table 3.2):

Table 3.2: Criteria for determining the social value based on a points-system, to be considered in combination with the open space typologies of each observed green space.

Social value criteria (each criterion equaling one point)	
Variety of user groups (e.g. furnished accordingly)	
Easy access and visibility (safety and security)	
Physiological comfort (shade, silence, wind protection etc.)	
Possibility to alter the space (flexible use of space)	
Possibility of easy maintenance (adequate upkeep)	
Variety of activities (e.g. support day-care, hospital etc.)	
Total sum of points	**Classification**
0 point	none
1-2 points	low
3-4 points	medium
5-6 points	high

    - Additionally, open space types in the observed area are also taken into consideration, since accessibility plays a crucial role in determining the social value of green spaces (Appendix D, based on Dettmar, 2018).
    - Criteria for ecological value: This set of criteria is established based on land-cover types. There are a number of relevant land-cover classifications to identify ecological value. For the purposes of this research, a generic classification (Gill, 2006) and a detailed classification (I. Lehmann et al., 2014) were merged and used in combination with the ATKIS classifications of the land-cover data (Appendix E) (Table 3.3):

Table 3.3: Land-cover classifications and corresponding ecological value categories.

Land-cover type:	**Ecological value:**
Buildings	None
Transport and other impervious surfaces	
Surfaces without vegetation	Low
Rough grass, mown grass	
Agriculture, conventional (pesticides, machinery, etc.)	
Waterside zones with strong anthropogenic influence	
Shrubbery	Medium
Agriculture, ecological (community gardening etc.)	
Near-natural wetlands (moor, swamp)	High
Heathland	
Forest	
Near-natural waterside zones (lake, sea, river, etc.)	

Qualitative analysis

The interviews are conducted in German language, recorded, and transcribed using a transcription software with about 75 per cent accuracy. The length of the recordings varies from 40 to 80 minutes. The transcripts are proofread and proof-edited and translated into English language. In their final form, the transcriptions were transferred into Excel for analog coding. Content analysis is used as the method for qualitative analysis of interviews. Content analysis can be done in an inductive (from specific to general) or in a deductive (from general to specific) manner. Inductive content analysis can be appropriate where previous knowledge is lacking or fragmented, and therefore, requires inductive (i.e. exploratory) coding. A set of predetermined categories was used for coding the transcripts through deductive content analysis. As new themes emerged, inductive directions of inquiry are not completely neglected (Denscombe, 2010; Flick et al., 2004).

3.2.3. Data interpretation

A spatial analysis of urban green space parameters does not suffice to comprehensively investigate the resource conflict that emerges as a consequence of urban growth. It also falls short of revealing the interactions and interdependencies of social and ecological system. That is why an in-depth examination of institutional arrangements and governance conditions that impact resilience (following Huck, 2020) is necessary.

Concerning the practical application of the resilience concept, the *CityStrength Diagnostic Tool* introduced a methodology to address a group of qualitative aspects. The tool was developed to facilitate a dialogue about resilience between public and private sector as well as the civil society and the individuals for a variety of related sectors. The tool introduces three mandatory (urban development, community and social protection, disaster risk management) and fifteen optional modules (grouped under human services, economics, basic services including environment, and technology) with various variables for each module. The tool's environmental module aims to tackle various aspects that could help understand the highly complex environments in which the planning practice operates in (World Bank, 2018a) The structure of the environmental module (World Bank, 2018b) is therefore found useful (Figure 3.2).

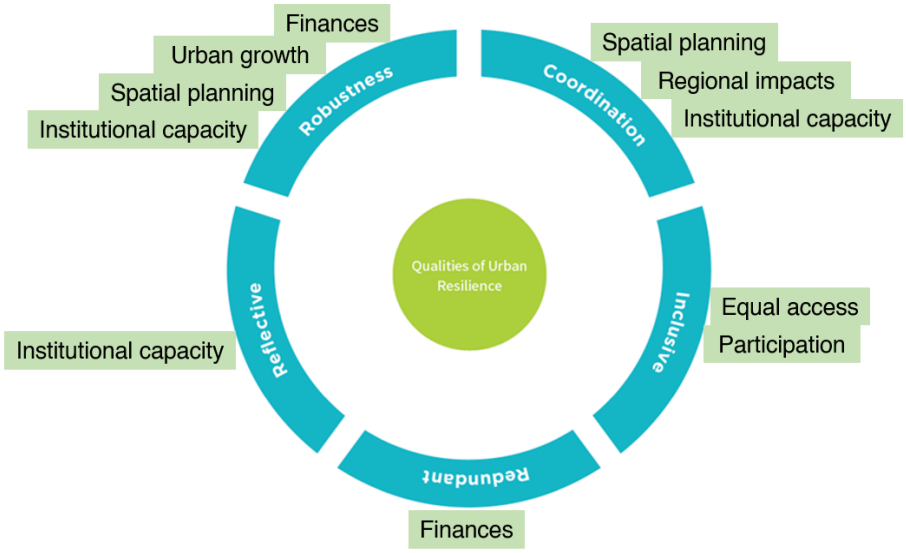


Figure 3.2: Qualities of resilience associated with variables of environmental management (adapted based on World Bank, 2018a, p. 12, 2018b).

The resilience qualities that apply to all modules are as follows (World Bank, 2018a):

- *Robustness* means that a system is constructed in a way that it can withstand impacts without significant damage to its functions, by expecting the unexpected and by reducing over-reliance.
- A *redundant* system has spare capacity to accommodate disruptions. "If one channel gets disrupted, the other can be used."
- *Reflectiveness* represents the capacity to learn from past occurrences and evolve accordingly and goes beyond the solutions limited to status quo. A reflective system can inform future decision-making.

- *Coordination* among agencies ensures knowledge-sharing and collaborative planning. This enables common goals, shared responsibilities to reach these goals and collective functioning for rapid response.
- *Inclusive* systems acknowledge different perceptions of different actors involved and that the most vulnerable are impacted the most. This establishes a shared ownership for a system that embraces various risks which various stakeholders are exposed to.

These resilience qualities are then applied to the following topics (i.e. variables) in the environmental module (World Bank, 2018b):

- *Urban growth* is associated with environmental challenges posed by the recent land-use change due to new development, and how the new development is impacted by environmental challenges in return. *Robust* urban growth allows for an optimum land-use change with minimum environmental degradation or even reverses the degradation process.
- *Planning* is a coordinated institutional process with management tools for settlement growth, infrastructure, and open space (also recently accompanied by digital development). *Coordinated* planning ensures land-use plans to include legally-binding environmental restriction areas. *Robust* planning requires environmental licensing for each new development.
- *Regional impacts* of environmental problems are rarely contained within borders. This requires regional impacts to be *coordinated* by which local and regional institutions effectively manage the impacts with actors beyond administrative borders.
- *Finances* can be the determinant factor for successful environmental management. The availability of reliable funding indicates *robustness*. *Redundancy* helps mobilize contingency reserves in case of disturbances or hazards of urbanization.
- *Accessibility* relates to equity and environmental justice. This aspect sets equal access to natural resources, ecosystem services, and recreation areas, regardless of income levels, as a prerequisite for social cohesion and equal opportunity. *Inclusivity* is the resilience quality that applies to accessibility.
- *Institutional capacity* is decisive for the facilitation of environmental management among responsible agencies. A well-*coordinated* management aligns environmental concerns with sectoral developments. Institutional capacity is *reflective* when systems for monitoring, evaluation, and accountability ensure reaching common objectives. It adds to the *robustness* of the institutional capacity when the in-house staff is regularly educated (e.g. on the impacts of climate change).
- *Participation* facilitates environmental protection and restoration through consultation with all actors, involving private sector, affected communities, and civil society. Solutions to environmental problems are *inclusive* when nuanced needs of various actors are taken into account.

Despite being created with the so-called Global South context and practical application on-site in mind, the tool's basic elements (resilience qualities, analytical categories, etc.) can be

applicable also within a scientific study, provided that the role of the tool is intentionally reduced to orientation purposes only and that its content is *translated* into the studied context (original and reworked question catalogues can be found in Appendix F). As new categories emerge from the collected data which stimulate more sophisticated discussions, only the structural elements of the *Environmental Module* of the *City Strength Diagnosis Tool* are followed as a design help for the data collection and interpretation.

The conceptual and theoretical considerations in this research revealed a lack of tangible benefits of using the term *resilience* in the context of planning practice. For this reason, the term is approached with caution and is intentionally removed from the interview questions. Rather, the building blocks of resilience were examined and interpreted in detail.

3.3. Spatiotemporal scope

The temporal scope in research is set to from 2008 onward in all aspects of the research design. This timeframe also coincides with the period that the accelerated procedures of the inner development came into effect within the Federal Building Code. Equally important, the financial crisis of 2008-2009 have had consequences that altered the ways in which European urban regions have been functioning, including the interactions and interdependencies of social and ecological systems. The Frankfurt Rhine-Main region showed relatively stable (economic) growth during the crisis, though this was not the case for most of the other regions. Against this background, it is intended that the collected data consistently covers the period between 2008 and 2019. The interview partners were encouraged to refer to this time frame while responding to the interview questions. Despite all efforts during the data collection phase, several datasets (population, housing stock, land-use change in spatial focus area) could not be retrieved for the same time frame. However, particular attention was given to keep these differences minimal.

The spatial limits to this study are two-folds: First, the regional scope defines the focus on the conurbation of the Regional Association Frankfurt Rhine-Main that is formed by its member municipalities. Secondly, the spatial analysis of the green space parameters in studied towns concentrates on an area covered by a 1.000-meter radius around the main train stations. This spatial scope is prioritized as the area for new construction—both for inner and outer development—by various plans and concepts, including the Regional Development Concept of the District of South Hesse (Regierungspräsidium Darmstadt, 2019).

4. Urban green spaces in middle-sized towns

For an analysis of the urban green spaces in Frankfurt Rhine-Main's fastest growing middle-sized towns, it is important to first understand the institutional system in which the planning practices operate.[20] In order to do that, this empirical chapter starts with introducing the basic features of the German spatial planning system. Based on that, the procedure of selecting the case study towns is given in detail. Once this is concluded, the qualitative analysis of governance conditions (e.g. recent urban growth trends, institutional capacities, integrated urban development and planning, etc.) as well as the spatial analysis of the focus area determined by a 1.000 m radius around the main train station are presented for each studied town. The chapter concludes with an attempt to establish a green space concept to demonstrate the outcomes if green space parameters are taken into account.

4.1. German spatial planning system

4.1.1. Spatial planning in Germany

A definition to spatial planning can be given as *"the anticipated coordination of spatially significant actions plans and their management, which is oriented to the spatial policy and organization"* (Lendi & Elsasser, 1986) (own translation following Linke, 2020). The spatial planning (*Raumplanung*) system in Germany has unique features. It is a configuration of multi-level institutional units with certain overlaps and fragments in terms of authorities and responsibilities. In order for this to function, the Federal Spatial Planning Act (*Raumordnungsgesetz*) defines in Section 1.3 the "multiple feedback principle" (*Gegenstromprinzip*) as *"the development and protection of smaller-scale spaces fit with conditions and requirements of the larger-scale space of which they are part, and the development and protection of larger-scale spaces take into account the conditions and requirements of their smaller-scale components."* This leads to the formation of two broad categories as local and supralocal planning, i.e. on one hand local, municipal planning and on the other regional planning and state or federal-level planning. The level of regional plan involves all the information and updates coming from the federal and state-level institutions, municipalities, and other administrative organizations and integrates sectoral plans (*Fachplanung*, e.g. transport planning, environmental planning, landscape planning). It refers to the existing structures, the desired conditions (normative components), and necessary actions (political components).

[20] The official translations for technical terms in German spatial planning are based on the publication The Planning System and Planning Terms in Germany-A Glossary (Pahl-Weber & Henckel, 2008).

Germany before the twentieth century did not require a supralocal spatial planning and policy because of its fragmented political geography under smaller states. Following that, the first half of the twentieth century was the period when conceptual groundwork of spatial planning—theories, models, and design instruments—were developed. The introduction of Garden City movement by the turn of the nineteenth century as a response to the problems resulting from industrialization (e.g. destruction of nature, unsystematic settlement structures, etc.) implied solutions at a regional scale (e.g. satellite cities) beyond the traditional city (Linke, 2020a).The first regional planning associations were established also within this period, in 1911 in Berlin and in 1920 in Ruhr area.

In the aftermath of the First World War during the Weimar Republic (1918-1933) stagnated incomes and high unemployment rates resulted in highly complex social problems. Larger cities with social-democrat majorities prioritized social issues and followed modern planning principles. For example, during this time, main tasks for regional spatial planning in the Ruhr region were green space provision and intermunicipal transport network development. Generally speaking, the main reason why regional planning became important was the worsening environmental and health conditions due to closeness of residential and industrial settlements, and lack of free, open, green spaces (Linke, 2020a). A spatial policy of the Federal Government first appeared in the year 1935. Following that, the Second World War was the period during which the spatial policy gained a top-down approach to its implementation and institutionalization as a central governmental task for the entire nation. The development of the Central Places Theory[21] as a task force in 1940 and the instrumentalization of the spatial policy for the expansion of a nationalistic view on cultural landscapes appeared in this period.

The aftermath of the Second World War between 1948 and 1960 is the reconstruction period during which the municipal planning grew strong. Reconstruction was understood as a technical and not a political process, which in turn built societal trust in the transitions. This paved the way to a decentral approach and eventually gave the authority and responsibility of framework legislations of spatial planning to federal states. The first State Planning Act (*Landesplanungsgesetz*) came into effect in 1950 in North Rhine-Westphalia.

The period between 1960 and 1975, the concept of integrated urban development appeared within advanced planning practices. In 1965, Federal Planning Act (*Raumordnungsgesetz*) came into effect. Following that, in 1967, the Conference of Ministers for Spatial Planning (*Ministerkonferenz für Raumordnung*, hereafter MKRO) was established, which is a highly

[21] See Section 2.5.2. for a more detailed look into the Central Places Theory.

important initiative still today. During this period, the region was understood not only as a spatial but also as a functional scale, taking into account infrastructure in general and commuting in particular. In the 1980s, due to the population decrease and economic stagnation, the supralocal planning might have appeared less significant.

As is currently the case, accelerated shrinkage in some city-regions occurred in parallel to an accelerated growth in others. The German reunification process in 1990 influenced in the legal changes in the Federal Spatial Planning Act. As the German Democratic Republic (colloquially East Germany) became a part of the Federal Republic of Germany (colloquially West Germany), a spatial planning concept for the construction in new states became a necessity. In response to that, a new version of Federal Spatial Planning Act involved legal changes with a progressively wider principles concerning the integration of new federal states (1993), sustainability principle (1998), and public participation (2017).

Currently, spatial planning serves to adequately address current and future challenges both in descriptive-scientific and normative-political ways. Some of these challenges are the demographic issues (e.g. increasing proportion of the elderly), climate change, developments in the field of renewable energy and digital infrastructure, and resource management. The underlying premise is that such contemporary challenges can be tackled via spatial planning in a future-oriented, systematic, and integrative manner (Linke, 2020a). Current spatial plans include decisions on spatial structure concerning intended settlement structures and central places, intended open space structures, and intended social and technical infrastructure. The nationwide guiding principles (*Leitbilder*), supralocal objectives for the benefit of the greater good, can be summarized as follows (Bundesinstitut für Bau- Stadt- und Raumforschung, 2005):

- Decentral concentration (*dezentrale Konzentration*): The growth pressure on regions should be buffered by a decentral settlement structure. Specific functions should be distributed by centers and subcenters and not be clustered at one main center.
- Inner before outer development (*Innen- vor Außenentwicklung*): Within the framework of Germany's National Sustainable Development Strategy, the daily open land take for settlement and transport development is to be reduced from 133 to 30 hectares per day (Distelkamp & Siedentop, 2011). Inner before outer development is a guiding principle in (Reiß-Schmidt, 2018):
    - Reducing initial sealing, preventing further sealing of pervious surfaces,
    - Reducing sprawl, protecting open green spaces and their functions,
    - Reducing utility provision and maintenance costs,
    - Preserving urban functions and qualities within the existing urban structures.
- Point-axial development (*Punkt-axiales Raumkonzept*): The priority is to develop central places and transport axes connecting these. Settlement and transport

development should take place at the central places, where the axes are knotted, and throughout the axes the remaining natural space is to be protected.

4.1.2. Levels of administration

The German multi-level system is composed of the federal government, 16 federal states (*Länder*) (including the city states: Berlin, Hamburg, and Bremen), government offices for the districts in some states (*Regierungsbezirke*), 313 counties (*Landkreise*) and 112 freestanding cities (*kreisfreie Städte*), and 12.302 municipalities (*Kommunen, Gemeinden*). Within the spatial planning system, each institutional level has its formal and informal tools and goals (Table 4.1).

Table 4.1: Levels of planning in Germany, their legal frameworks and main goals.

	LEGAL FRAMEWORK	INSTITUTIONAL LEVEL	GOAL	
Superordinate planning	Federal Spatial Planning Act	Federal government: Federal Spatial Planning	Spatial development of the country	Sectoral planning
	↑ Multiple feedback principle ↓			
	State Planning Act	Federal state (e.g. Hesse): State Development Plan	Spatial development of the state	←
		Region (e.g. South Hesse, District Authority Darmstadt): Regional Plan	Defining regional objectives of state spatial planning for the development of regional plans	←
	↑ Multiple feedback principle ↓			←
Urban land-use planning	Federal Building Code Building Regulations Land Utilization Ordinance	Towns and municipalities: preparatory land-use plan	Sustainable regulation of the use of the areas and plots of the municipality	
		Towns and municipalities: binding land-use plan		
	Building Regulations	Constructor: construction plan		

European level

Europe is a densely populated continent, and compared to other regions in the world, European regions may be moderately affected by urbanization. However, urbanization in Europe involves high rates of land take (Naumann et al., 2018). To combat this, a number of

European-level policies promote compact city strategies. Here, the role of the European Commission is to set relevant agendas, which are primarily intended to be realized by the member countries of the European Union. These policies have a strong influence on shaping national spatial planning strategies in the member states. Due to the heterogeneity of planning cultures in Europe, these policies are not legally-binding and there is no imposition of formal action despite strong influence over disciplines that are related to spatial planning. Some of the important spatial initiatives within the administrative framework of the European level are as follows (Linke, 2020b):

- European Spatial Development Perspective: The goal is to reduce the differences in development status in regions while following sustainable development principles. Polycentric and balanced urban systems, equity in access to infrastructure and knowledge, and sustainable development, protection of natural and cultural heritage are the main principles.
- Cohesion Policy: Complementary to the above principle, the Cohesion Policy is a financial instrument to invest and support the poorer member countries. The main fields of action are economic development, quality of life, provision of jobs, improvements in competitiveness.
- INTERREG: The aim is to stimulate territorial cooperation for the regions within and outside of Europe and promote cooperation through cross-border, transnational, and interregional systems of cooperation National borders of Germany are almost completely covered by various INTERREG projects.

The state-of-the-art European-level policies are the European Green Deal with the overall goal to make Europe a climate-neutral continent by 2050 and the New Leipzig Charter which promotes the need for integrated urban development strategies from the neighborhood to functional scales of a city. The strategies are oriented to the benefit of the common good and to be implemented through the national and regional spatial policies of member states (Europäische Kommission, 2020).

Federal government (Bundesregierung)

Based on the Constitutional Law, competence in spatial planning is assigned to the federal government (Pahl-Weber & Henckel, 2008). The Federal Spatial Planning (*Bundesraumordnung*) was the official duty of several different ministries in the past and currently it falls under the responsibility of the Federal Ministry of Transport and Digital Infrastructure (*Bundesministerium für Verkehr und digitale Infrastruktur*). Because of sectoral overlaps, the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit*) is also involved in federal spatial planning. A consultancy branch, the Federal Office for Building and Regional Planning (*Bundesamt für Bauwesen und Raumordnung*), operates as a scientific advisory

board for the fields of spatial development, housing, and real estate. The legal instrument of this level is the Federal Spatial Planning Act. Its key supportive functions in this regard are the European cooperation, reduction of open land consumption, cultural landscape development, and climate change mitigation for settlement structures, open space structures, and infrastructure (Pahl-Weber & Henckel, 2008).

An additional feature of the MKRO initiative can be mentioned here: It is formed by ministers from the federal states. The members are authorized to agree on fundamental questions and positions in spatial planning and development and, in turn, responsible for the implementation of the agenda in their federal states. A recent MKRO meeting in 2016 emphasized four fundamental concepts and strategies to guide the spatial planning and development in Germany (The Federal Institute for Research on Building Urban Affairs and Spatial Development, 2016):

1. Enhance competitiveness: A growth-driven agenda to evolve the metropolitan regions as players of the global financial system, strengthen territorial cooperation within and around a region, support the areas with special needs, and ensure a well-functioning transport and other networks.
2. Ensure the provision of public services: An action field mostly for shrinking cities to ensure that neither the population is underserved, nor the infrastructure is unmanageably large in relation to the population it serves. It promotes consistently applying the central places system, ensuring accessibility, and supply in rural areas.
3. Control and sustainably develop land-uses: The goal here is, among others, to minimize spatial conflicts of use, create large open space networks, reduce new land take.
4. Shape climate change and the transformation of the energy system: The goal is to adapt spatial structures to climate change and promote renewable energy networks. Additionally, since 2017, digitalization has also appeared in the federal government's spatial planning agenda.

Undoubtedly, it is necessary to establish supralocal spatial agendas in parallel to strategies and measures that are implementable and compatible with the requirements at the municipal level. There are various formal and informal instruments that are used in combination to steer planning procedures of institutional levels and spatial scales. Examples to formal instruments are the legally-binding federal government and federal state planning laws. Informal instruments include the informative and procedural components such as urban or regional development concepts. The informal instruments also seek to integrate and consistently involve various sectors (e.g. landscape planning, environmental planning, infrastructure and transport planning, and tourism planning).

Federal states (Landesregierung) with a focus on the State of Hesse

Despite its central and rigid connotation, the role of the federal government in spatial planning is to identify the guidelines and principles addressing contemporary societal, economic, and ecological challenges in line with national agendas and ensure that these principles reach municipal level. Based on the Constitutional Law, the federal government cooperates with the 16 federal states in Germany toward the improvement of regional structures in spatial planning.

In the federal state of Hesse, the ministries involved in spatial planning, policy, and development are the Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection, which is also the supreme state nature protection authority (*oberste Naturschutzbehörde*), and the Hessian Ministry of Economics, Energy, Transport and Housing, which is also the supreme state landscape planning authority (*oberste Landesplanungsbehörde*). The Hessian Agency for Nature Conservation, Environment and Geology, a technical-scientific state authority under the Ministry of Environment, is also directly involved in the processes at this administrative scale. Under the legal framework of the Federal Spatial Planning Act, the State Spatial Planning (*Landesplanung*) is the state-specific, supralocal and supra-sectoral spatial regulation carried out by the responsible authorities in coordination with neighboring states (Pahl-Weber & Henckel, 2008). Its core instruments are (i) the State Development Plan (*Landesentwicklungsplan*): a continuously adapting spatial plan; (ii) spatial planning procedure (*Raumordnungsverfahren*): compliance procedures of spatial plans with actual requirements; and (iii) spatial monitoring: a permanent and systematic task to observe new developments in fields such as economy, demographics, land-use and alike. In the case of Hesse, the typical contents of the State Development Plan are as follows (Pahl-Weber & Henckel, 2008):

- Categories of spatial structure (*Strukturräume*): In the German planning system, each municipality belongs to one of the following spatial categories (*Raumkategorien*):
    - Rural area (*ländlicher Raum*): Predominantly rural settlement structures, with a wide variety in character based on their population density, economic strength, proximity to agglomerations, to transport, and to natural and cultural landscapes.
    - Regulatory area (*Ordnungsraum*): Higher number of residents with a higher population and built environment density, with a wider variety of work places and transport options.
        - Agglomeration area (*Verdichtungsraum*): The core of a regulatory area. High concentration of residential, commercial, industrial settlements often with land-use conflicts.

- Central places (*Zentrale Orte*): A hierarchy and categorization of higher, intermediate, basic-order centers (respectively *Oberzentren, Mittelzentren, Grundzentren*). A consistent implementation of the concept is argued to help ensure adequate provision of goods, public and private services, and technical and social infrastructure at reasonable distances to promote compact patterns. In combination, central places together with the transport axes make up the point-axial concept.
- Open spaces: Area remaining from point-axial concept. Large-scale vegetation covers with agricultural and forest functions to be protected.
- Supralocal infrastructure: Provision of transport for people and goods cannot conflict ecological, economic, and social priorities. The transport concept in Hessen is "intermodal" transport concept: Transport hubs are offering a variety of transport services. A well-functioning transport system and a reasonable distribution of jobs strengthen one another.

One central function of the state-level administration is that, it provides the urban development promotion programs (*Städtebauförderprogramme*) for the towns and municipalities through which financial resources are tapped externally. These financial means are intended for municipalities to e.g. purchase property, renovate it, and then rent it or hand it over to an investor. Particularly for green spaces, these funds can be reallocated for greening purposes, increasing the green quality and quantity, as well as improving aspects such as connectivity of green spaces between inner areas and peripheries. Towns and municipalities can also get funding for their projects from European-level funds. Sub-state administrative levels are usually not in the position of providing financial support for the towns and municipalities.

Administrative districts (Regierungsbezirke)

Administrative districts are the regulatory regions (sections) of a federal state. This level is an interface of top-down and bottom-up directions of planning. There is a wide variety of administrative districts in Germany in terms of their size, population, and socioeconomic characteristics (Pahl-Weber & Henckel, 2008). The administrative district of South Hesse (where the Frankfurt Rhine-Main region is located) is the District Authority Darmstadt (*Regierungspräsidium Darmstadt*). Oriented to the State Development Plan, the Regional Plan substantiates higher-level spatial goals and principles for the regions and their subunits. On the one hand, it is ensured that federal- and state-level spatial principles are consistently implemented. On the other hand, regional planning remains responsive to the actual changes and needs at the municipal level. With that it has a conflict resolving function.

On another note, the *region* corresponds to three different spatial configurations in the administrative district of South Hesse: (i) the conurbation Frankfurt Rhine-Main; (ii) the

metropolitan region Frankfurt Rhine-Main, with a partial overlap with the metropolitan region Rhine-Neckar to the south; and (iii) the South Hesse administrative district itself (Figure 4.1).

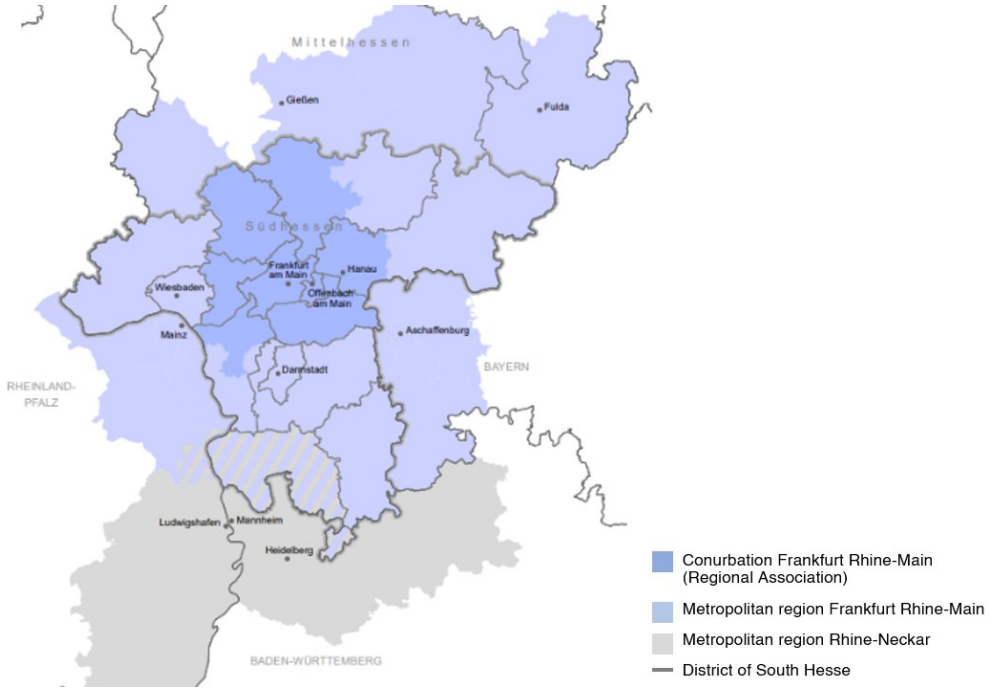


Figure 4.1: Demonstration of various representations of "region" in South Hesse (adapted and translated from Regierungspräsidium Darmstadt, 2011).

Counties and county-free cities (Landkreise und kreisfreie Städte)

Counties comprise of several neighboring municipalities predominantly with rural characteristics in a district. The practical benefit of this is that, in the cases where municipal tasks exceed the capacities of municipal resources (especially for smaller municipalities, personnel, financial resources, etc.), the existence of an additional institutional body serves as a safety net to ensure continuous provision municipal services (Deutscher Landkreistag, n.d.). There are 294 counties in Germany, covering around 96 per cent of the country and 68 per cent of the population. This shows that approximately 32 per cent of the population in Germany is living in 107 county-free cities, i.e. cities with population above 100.000. Counties and county-free cities represent the same level of administration in terms of roles and responsibilities (Deutscher Landkreistag, n.d.). Counties have a special status in German administrative system and can be perceived both as a local and a central administrative structure. They serve at the local scale while fulfilling several central administrative roles.

Regional planning associations (Regionalverbände)

In some federal states, regional planning is carried out exclusively by the administrative districts of the state where *planning regions* geographically coincide with the district's

administrative borders. In other states, there are regional associations. In this case, planning regions are geographically defined by the municipalities that are members of these associations (Pahl-Weber & Henckel, 2008). In terms of roles and responsibilities, regional planning associations represent the same institutional level as municipalities. The informal instruments of regional associations have certain advantages (Syrbe & Chang, 2018):

- Specific issues can be addressed without following rigid legal instruments,
- Multi-sectoral, multi-scale, and multi-stakeholder cooperation,
- A broad understanding through broad public discussions, and
- Cross-cutting green space issues can be addressed without the need for legal instruments.

For the case of the Frankfurt Rhein-Main region, with its 75 member towns and municipalities,[22] the Regional Association Frankfurt Rhine-Main (*Regionalverband FrankfurtRheinMain*) is the governance body of the metropolitan region in charge of developing regional plans, concepts and monitoring for its member municipalities in cooperation with various organizations, most importantly with the District Authority Darmstadt. For instance, in cooperation with the District Authority, the Regional Association provides its member municipalities with the regional preparatory land-use plan (*regionaler Flächennutzungsplan, regFNP*).[23] Member municipalities pay a fee to be a part of the Regional Association, which is represented by Association's territory (*Ballungsraum*).

Municipalities (Kommunen, Gemeinden)

In contrast to the state-directed regional planning, municipal planning is granted the autonomy to carry out the tasks to address their local needs independently (Monstadt & Meilinger, 2020b), based on the German Constitutional Law Section 28 Paragraph 2, authorizing municipal associations for self-government. This reflects itself in the fact that the property and business taxes are municipal incomes so that they can fulfil the provision of municipal services independently within their territories (Monstadt & Meilinger, 2020b). According to the Section 1 Paragraph 5 of the Federal Building Code, the goals of municipal planning are: to ensure sustainable urban development, ensure benefit of the greater good (in cases of conflicts of interest), and to contribute to environmental protection through

[22] As a very recent development, the Regional Association gained five new members and has currently 80 member municipalities (as of June 23, 2021).

[23] Heinelt et al. point out that the regional preparatory land-use plan emerged as "an attempt to combine regional planning and municipal land-use planning in order to improve mediation between competing local development goals" (2011, p. 56).

protection of natural livelihoods, contribution to climate mitigation and adaptation, preserving the cityscape and landscape image, and inner development.

Through substantializing and implementing urban land-use plans (*Bauleitplanung*), the goal in municipal planning is to reach the supralocal principles of spatial planning to individuals (Pahl-Weber & Henckel, 2008). The urban land-use plan determines the use of land in accordance with the Federal Building Code (*Baugesetzbuch*, *BauGB*), through which social, economic, ecological aspects are brought together while prioritizing the benefit of the greater good. Urban land-use planning is a two-tier process. The first step is the production of the preparatory land-use plan (*Flächennutzungsplan, FNP*) and the second is the production of the binding land-use plan (*Bebauungsplan, B-Plan*). In the preparatory land-use plan, the main features of land-use and the intended development are presented for the area of the municipality (Federal Building Code, Section 5). Based on the preparatory land-use plan, the binding land-use plan determines fixed settlement zones (i.e. residential, mixed-use, industrial, other uses) (Federal Building Code, Section 8). The goal of the binding land-use plan is essentially to protect the current status of the built environment and is an offer to the land owner. There is no legal obligation to construct, but if there will be construction, it has to comply with the land-use plan (Pahl-Weber & Henckel, 2008).

One important feature of the binding land-use plan is that it determines the maximum construction on a plot. Some of the most important of these measures relate to the density of built use are given in the Land Utilization Ordinance (*Baunutzungsverordnung, BauNVO*):

- Site occupancy index (*Grundflächenzahl*): allowed construction area for each square meter of the plot. This number gives the amount of surface on the plot that can be covered by construction (Land Utilization Ordinance, Section 19), and
- Floor area index (*Geschossflächenzahl*): allowed floor area in total for each square meter of the plot (Land Utilization Ordinance, Section 20).

4.1.3. Regional-level administration in Frankfurt Rhine-Main

Based on the information about the German spatial planning system and the levels and scales of administration in Germany, this subsection takes the first steps toward examining the Frankfurt Rhine-Main region and provides an overview of planning practices, institutional arrangements, and governance conditions with a spatial and institutional focus on the region. The information presented here emerges from relevant institutional documents (plans, concepts, policies) and semi-structured interviews conducted with the senior staff members from the District Authority Darmstadt, the Regional Association Frankfurt Rhine-Main, and the senior planning expert from AS+P.

District Authority Darmstadt (Regierungspräsidium Darmstadt)[24]

Population forecast and its implications

The Hessian State Development Plan, which is the basis of the South Hessian Regional Plan, is updated in accordance with the continuous updates to the demographic prognoses. At the time of the preparation of the still-valid 2010-version of the Regional Plan, the population forecasts indicated a stagnation (Interview 2, 2020; Interview 6, 2020; Interview 7, 2020). The state parliament recently approved an alteration to the State Development Plan, involving the changes based on the prognosis that indicated a strong population increase in many sub-regions. A shrinkage or stagnation appears to be a rare case for a few peripheral areas only. This has had direct implications on the construction activity with a possibility of further expansions of existing settlement areas, resulting in the conversion of the maximum residential density values to minimum, with the goal to ensure new residential development to reach higher densities (Table 4.2). For exceptional justified cases, a derogation procedure (*Zielabweichungsverfahren*) has to be requested.[25] Cumulatively, this shift in residential density values from maximum to minimum is expected to bring about a big land-use/land-cover change in South Hesse. This transition is anticipated to be a cumulative change in land-cover rather than few and large changes.

Table 4.2: Spatial categories are decisive in determining residential densities. The previous reference values represented the maximum allowed housing units per hectare (adapted from Hessisches Ministerium für Wirtschaft Energie Verkehr und Wohnen, 2020).

Spatial structure in South Hesse (current: minimum allowed densities)	**base value**	**higher-order center**	**intermediate-order center with partial functions of higher-order center**
Conurbation Frankfurt Rhine-Main	40	60	45
High-density agglomeration area	35	60	40
Regulatory area	30	-	35
Rural area	25	-	25
Spatial structure in South Hesse (previous: maximum allowed densities)	**base value**	**higher-order center**	**intermediate-order center with partial functions of higher-order center**
Agglomeration Frankfurt Rhine-Main	40	60	45
Other Agglomeration area	35	-	40
Regulatory area	30	-	35
Rural area	20	-	25

An additional challenge that comes with building with higher densities is that it brings more traffic load for the road and public transportation infrastructure (Interview 2, 2020; Interview

[24] This part is developed based on the interview conducted with the District Authority Darmstadt (Interview 6, 2020), unless otherwise stated in text.

[25] For instance, not reaching the minimum residential density may be allowed if a new residential development area is located at an area with village-like character (Interview 7, 2020). This relates to the debates in perceived density, as introduced in the literature review.

6, 2020) that is already reaching, if not exceeded, its limits (Interview 3, 2020; Interview 2, 2020). Because of longer routes and distances, building less densely does not automatically solve the traffic problem either. Still, it remains difficult to reach higher densities, even when 45 housing units per hectare is theoretically not too dense. This is due to the fact that the designated development areas contain all the uses: schools, daycare centers, shopping centers, mixed-use areas, and neighborhood green spaces. So, in practice, what is left for residential buildings is smaller (Interview 2, 2020; Interview 8, 2020).

Regional Development Concept, inner and outer development

The end of 1990s and the beginning of 2000s was a phase during which old military and industrial areas were undergoing conversion for the provision of more housing in the form of inner development. As the conversion potentials are becoming less, it cannot counterbalance outer development anymore. However, *"inner development is popular among politicians because it is less in conflict with citizens and environmentalists. But in reality, inner development is difficult. It means achieving higher densities but also providing green spaces […] there we have a contradiction in the meaning: inner development does take up free open space"* (Interview 2, 2020). What further complicates housing provision is that, housing is not only necessary for the increasing population, but also for the backlog demand due to the low housing provision rates in recent decades (Interview 6, 2020; Interview 7, 2020).

A strong argument for inner development is the protection of climate and the natural environment. There are few possibilities to actively promote inner development: (i) as an entirely new development on an available land in inner areas, (ii) as part of existing development plans where there are still possibilities for densification, or (iii) assigned areas that have not yet been implemented. Based on the Federal Building Code, one of the tasks within the District Authority's involvement in the municipal urban land-use plan procedures (*Bauleitplanverfahren*) is to ensure that there is justification in case outer development is preferred over inner development. This is a central task for towns and municipalities as they are well-informed about their own land availability and restrictions.

In line with the national goal to reduce land take and following the progress report *Sustainability Strategy of Hessen: Goals and Indicators* (Hessisches Statistisches Landesamt, 2016), the goal in the state of Hesse aim was to limit the open land take caused by settlement and transport to 2,5 hectares per day until 2020. The regional politics in the form of the Regional Assembly (*Regionalversammlung*) assigned this as a target value to guide the Regional Plan. In collaboration with the Regional Association, the District Authority Darmstadt commissioned an external private office for the development of the Regional Development Concept (*Regionalentwicklungskonzept, REK*) (Figure 4.2). This has been an

opportunity for regional and municipal actors to collaborate with the goal to very thoroughly analyze where exactly inner and outer development potentials are located in the 184 towns and municipalities in South Hesse, and how much of this potential could realistically be mobilized.

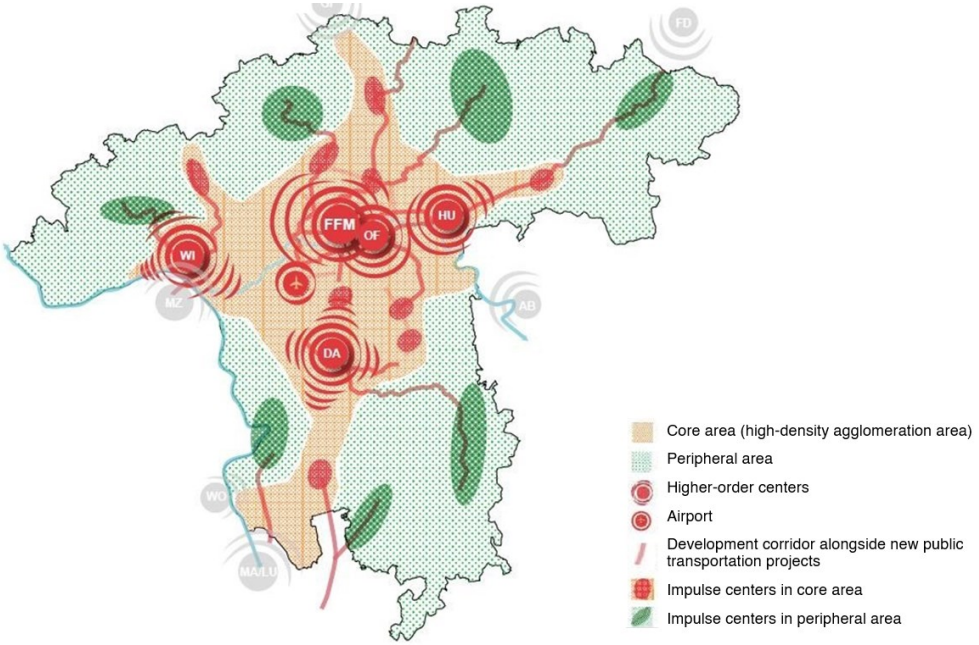


Figure 4.2: Regional Development Concept for South Hesse: regional core, peripheries, and their impulse centers (adapted and translated from Regierungspräsidium Darmstadt, 2019).

In addition to inner development before outer development, the Regional Development Concept sets as a principle to integrate transport development in settlement development. In a commuter region, there is a high reliance on a well-functioning daily commuting. This requires future settlement development to take into account the current and potential future developments of public transport and traffic network, and also applies to the potential implications of new modes of mobility: *"… the train stations have a [catchment area with a] radius of 1.000 meters. But if in the future people will travel to the station more with their electric bicycles or scooters, then the radius can be as much as four kilometers"* (Interview 2, 2020). Another principle is the compactness for the new development areas to counteract a potential leapfrogging settlement structures and to keep facilities close to one another, with less damage to surrounding agricultural or forest areas. Although this is not yet a legal requirement, in the short-term, it is expected that the Regional Development Concept gives impulse for new residential development to reach even higher densities than the State Development Plan's minimum densities. In December 2019, the political body of the District Authority, i.e. the Regional Assembly (*Regionalversammlung*), decided that the Regional Development Concept is to be developed into a so-called updated plan concept, so that the inner development potentials can be investigated more intensively (Interview 6, 2020). In its

current form, the concept as an informal instrument gives an orientation and helps visualize the implications of the formal instruments (Interview 2, 2020; Interview 7, 2020).

Regional Plan

Planning at the regional level necessitates dealing with multiple and complex land-use issues. The contents of the State Development Plan and Regional Plan (i.e. categories of spatial structure, infrastructure, open space structure) are very similar. The main difference is, while the State Development Plan sets guidelines, the Regional Plan exists for operational purposes since in addition to the state-level specifications, it also contains the information coming from and to be delivered into the municipal plans. Regarding the land-use conflicts, regional plans fulfil a mediatory function. Section 1 Paragraph 4 of the Federal Building Code regulates that the municipal land-use plans are in line with the goals and principles of regional planning. Municipalities participate in the preparatory regional plan, so the Regional Plan is not an external imposition on urban land-use planning but rather a co-creation via the multiple feedback principle. Although there is room for weighing up (*Abwägung*),[26] towns and municipalities are bound by this plan. It also has to be justified in case a town or municipality designates forest or agricultural reserves as new settlements.

The aspects worked through regional planning is immensely large and therefore the Regional Plan, as a final product, represents an integrated concept (similar to the municipal integrated urban development concepts, often *integriertes Stadtentwicklungskonzept*, hereafter ISEK[27]). At the regional scale, integrated development refers to the living, working, and logistics spaces and their interconnectedness being in-line with the climate and open space protection parameters (Regierungspr[a] sidium Darmstadt, 2011).

In-house capacities, further collaborations, politics

There are two departments at the District Authority Darmstadt principally dealing with the Regional plan: The Regional Planning Department is concerned with the outer area issues (e.g. traffic); whereas the Regional Settlement and Urban Development Planning Department focuses on settlement functions (e.g. residential, trade, and logistics). There is continuous

[26] An example for weighing up: When less soil sealing is intended, but it is not possible to prevent further sealing, then the soil with low quality at an alternative location could be prioritized for sealing (Interview 2, 2020).

[27] ISEK is made up by bringing many different concepts and interest into a common framework concept and gives an orientation for urban development through the implementation of measures. It operates at the city-level and is ideally developed with regional conditions in mind. It requires successful coordination among experts in order to find long-term and effective solutions to existing and potential problems. The establishment of a framework concept with inherent complexities is a technical and a political process, which highlights the importance of successful coordination.

contribution to the Regional Plan by both departments. The coordination of the urban land-use plans with the municipal level also lies within the responsibilities of the Regional Planning Department, so the cartographic recording of the designated areas and their implementation is kept up-to-date. There is certain flexibility in terms of redirecting personnel capacities in these two departments if needed.

As regulated by the State Spatial Planning Act, the District Authority continuously collaborates with the Regional Association in jointly developing the preparatory regional land-use plan for Association's territory. The planning of the conurbation is therefore a responsibility shared by the District Authority and Regional Association, and the planning of the remaining area falls under the District Authority's responsibility. Accordingly, the political representation of the District Authority is Regional Assembly (*Regionalversammlung*) and for the Regional Association it is the Chamber (*Verbandskammer*). Both institutions prepare relevant documents as a basis for political decision-making.

In addition, the District Authority is also in regular exchange with ministerial-level administration, most importantly: Hessian Ministry of Economics, Energy, Transport and Housing (*Hessisches Ministerium für Wirtschaft, Energie, Verkehr und Wohnen*), the administration which establishes the State Development Plan. It is noteworthy that the State Development Plan emerges based on the larger-scale guidelines at the federal level (MKRO) which give a rough direction for state plans to capture and follow. In terms of exchange with lower-level administration, the District Authority is involved in municipal land-use planning. With that, local planning intentions are known, while at the same time, the information flow from the regional to the municipal level is ensured. As an informal and non-political way to facilitate knowledge-sharing and exchange, the establishment of the Regional Development Concept was very much appreciated by the towns and municipalities (Interview 2, 2020).

Further exchange includes the specialist disciplines, too. Sectoral planning units are separate units responsible e.g. for flood areas, climate, explosive ordnance, pollution, traffic, and deal with these issues explicitly. In the end, all plans from all levels of administration interlock through the multiple feedback principle. As there is no clear top-down or bottom-up strategy, regional planning relates to all other levels of spatial planning.

Environmental issues

In Germany, issues related to environmental restrictions are well-regulated by standard planning procedures and technical precautions (Interview 2, 2020). The environmental issues in the Regional Plan are dealt with in form of information-based adoption of sectoral planning. These are mostly the restrictions to settlement and infrastructure development and

restrictions of very challenging areas where settlement planning is not possible. These restriction areas and boundaries are clearly and precisely given in the Regional Plan for information purposes. In general, main restrictions according to the legend of the regional plan are as follows:

- Priority (*Vorrangsgebiete*) and reserved areas (*Vorbehaltsgebiete*) of open spaces
- Preventive priority and preventive reserved areas for flood protection
- Reserved areas for groundwater protection
- Waste and wastewater disposal areas
- Energy provision buffer zones
- Priority and reserved areas of agricultural fields and forests

For the upcoming Regional Plan, one significant aspect is the consideration of climate protection and nature conservation areas. At the ministerial level, there are already advancements regarding the identification of the areas that fall under the restriction for nature and climate protection, with direct implications on the extent of further settlement and transport development. The Regional Assembly has already taken stance on this, and landscape, nature, green corridors, and climate protection are already determined as strong exclusion criteria for the further development of the upcoming plan.

Environmental issues that restrict settlement development in the conurbation include airport noise restrictions resulting from the noise protection in the area of the Frankfurt am Main Airport. The Aircraft Noise Protection Act (*Gesetz zum Schutz gegen Fluglärm*) designates protection zones with clear specifications for the newly-developed residential areas and facilities for the use of vulnerable populations such as childcare, schools, hospitals, and elderly care. The issue of contamination is another environmental restriction. Groundwater resources are protected by a buffer zone around them, so that no construction activity may cause leakage of pollutants into the soil and thus into the groundwater. Moreover, the explosive ordnance remainders from the Second World War especially in the conurbation have reached an age that they may occasionally become active without external intervention, which is also to be considered as an environmental challenge.

Green space

In the Regional Plan, open spaces are not planned on the basis of inclusion of an independent open space concept, but rather of exclusion of the sensible areas for climate, groundwater, agricultural, and open space protection. The conurbation has a high proportion of settlement and transport area (2020 values: approximately 28,8 per cent of the conurbation (Regionalverband FrankfurtRheinMain, n.d.). With the state and federal-level goals restricting open land take and with the minimum density values of new residential

development, the pace of further soil sealing in the outer area could be reduced and even in some cases reversed via recycling of the land. This could also mean that higher densities and resourceful use of the land might possibly limit the expansion of detached single-family neighborhoods on open land.[28]

Nevertheless, prioritizing inner development over outer development does not aim to reach complete sealing in the inner-city areas. The Land Utilization Ordinance makes it obligatory to create concepts toward multifunctional green spaces, so that small green areas with recreational functions in dense neighborhoods can be frequented. The expectation is that having a private garden will be less common in the near future because of higher densities. Not having a private garden will not only be a matter of affordability.[29]

In terms of green space accessibility, the size of the green space is stated to be less important than its reachability in terms of the time spent to reach it. A nearby park is reached more quickly as opposed to longer times needed to reach a very large park or a forest. That is why it is important to provide especially lower-income residents living in multistory settlement typologies with adequate nearby green spaces. Although this does not indicate that higher-income residents cannot be found in public parks, the need to provide adequate green space for the former group of inhabitants is greater. In terms of regional green spaces, the region provides plenty of opportunities for green space access and use. Even in the form of short *compensation travels*, e.g. when the residents of Frankfurt often choose to visit parks in neighboring Bad Homburg or Bad Vilbel, this is relatively a short distance of a 20-minute subway ride. Also, since this does not take place because Frankfurt does not offer any parks, it is difficult to justify this as a compensation travel as in other metropolitan regions in the world (Interview 2, 2020).

Regional Association FrankfurtRheinMain (Regionalverband FrankfurtRheinMain)[30]

Services provided for towns and municipalities

[28] Building more densely might reduce the possibilities to regulate rainwater infiltration on the private property. Such neighborhoods could be provided with a multifunctional public green space, contributing to rainwater infiltration. Currently, towns and municipalities are increasingly implementing the requirements of the Federal Water Act (Wasserhaushaltgesetz), e.g. a neighborhood green space with high recreational quality that also acts as a water retention basin (among others Interview 4, 2020; Interview 6, 2020).

[29] Several interviewees stated that during the pandemic lockdowns in 2020, public green spaces are used more frequently, including home owners with access to private gardens (among others Interview 6, 2020; Interview 8, 2020).

[30] This part is developed based on the interview conducted with the Regional Association Frankfurt Rhine-Main, unless otherwise stated in text.

There are several quite significant services which the Regional Association is in charge of. The Regional Association prepares the preparatory regional land-use plans, for the conurbation in close collaboration with the District Authority and member municipalities. Depending on the issue at stake, the Regional Association is in cooperation with other significant actors beyond these principle actors, for instance Rhine/Main Regional Transport Association (*Rhein-Main-Verkehrsverbund, RMV*) and the Chamber of Industry and Commerce (*Industrie- und Handelskammer, IHK*). The Association provides geoinformation-based tools and services (e.g. the register of the gaps between buildings, the register of construction sites, strategic environmental assessment, etc.). It also supports municipalities in finding appropriate state-, federal-, and European-level subsidies for their projects. The guidance of the Regional Association is not to the extent that all municipal duties are simply taken over. Yet it is very much appreciated particularly for the tasks for which municipalities are underfinanced and understaffed to conduct.

The Regional Association publishes annual open-access monitoring tackling a wide range of topics (e.g. environment, population and demographic composition, economy, land-use change, etc.) both for the conurbation and the metropolitan region. For instance, regarding the monitoring of the construction potential, the municipalities are now curious to know how much land potential there is and what has recently changed. For politicians, monitoring is a basis for political decision-making: The fact that only 1.600 hectares of regional settlement development area is available is an issue of political concern. Also, politicians may specify certain topics of focus for a closer look in the monitoring. Currently, the monitoring with a focus on public services provision (*Daseinsvorsorge*) is underway. Previous highlights included commercial and residential areas and retail concepts.

Recent developments in Frankfurt

In 2008, the time when the global financial crisis occurred, the demographic prognoses indicated stagnation in general and decrease for some parts of the conurbation. During that time, the strategy was to provide single-family housing located at the well-connected peripheries of Frankfurt in order to make Frankfurt attractive for young families to counteract stagnation. One of the prime examples for this kind of settlement development is the Riedberg neighborhood. The stages of development in Riedberg represent how settlement development strategies have changed with time (e.g. from single-family housing to university campus). Now with the recent prognoses in the opposite direction, the construction activity in the area around Frankfurt is clearly increasing, especially surrounding municipalities are tackling large areas, and Frankfurt had to catch up with that. One recent development is the Europaviertel neighborhood in Frankfurt, a large-scale conversion project located at the

defunct railway areas of Deutsche Bahn directly at the northern side of the railway tracks at the Frankfurt Central Station. The settlement growth in Frankfurt was mostly through mobilizing inner development potentials, but in order to fully respond to the demand, mobilizing outer development areas seems unavoidable. If inner development potential is fully mobilized, it would theoretically cover only one thirds of the demand.

As per the preparatory regional land-use plan there are 163 hectares of residential and 178 hectares of industrial/commercial settlements are being planned for the city of Frankfurt (Regionalverband FrankfurtRheinMain, n.d.). But the pressure for residential space is so high that it causes commercial spaces being converted into residential spaces, despite the need for sufficient commercial space.

Because of that, there is a search for alternatives: How could towns around Frankfurt buffer the growth pressure concentrated on Frankfurt? These towns do not have to be geographically close but well-connected in terms of the time taken by public transportation to reach Frankfurt. This was the main idea of the development of the project Großer Frankfurter Bogen (see subsection 2.6.2. Growth Management), by which the Hessian Ministry of Economics, Energy, Transport and Housing provides subsidies to mobilize new residential settlements (Interview 5, 2020). The *inner before outer development* principle applies to this project, as well. As a matter of principle, it is promoted that the newly designated outer development areas are primarily located at the 1.000-meter radius around the train stations, provided that the area has sufficient social and technical infrastructure.

Recent developments in the conurbation

Between 2000 and 2009 the proportion of inhabitants with migration background decreased in the conurbation from 17,2 per cent to 15,8 per cent, but from 2009 onward there has been a clear increase, currently reaching 23,1 per cent (Regionalverband FrankfurtRheinMain, n.d.). Since there was a decrease in housing constructions in the 1990s (excluding Frankfurt), the regional housing demand is not only shaped by the recent influx, but also by the backlog demand caused by the lack of sufficient housing provision prior to that. Currently, approximately 200.000 housing units are needed altogether in the conurbation, accompanied by an increase in the pace of annual housing unit provisions (Regionalverband FrankfurtRheinMain, 2016c).

In the region, the settlement growth in relation to housing provision is rather heterogeneous. Despite sufficiently available spaces in terms of total area, there are often environmental restrictions or a lack of political will which slows down the processes or stops them altogether. For instance, it was found out that 900 hectares of already designated new

development area has to remain dormant due to restrictions such as biodiversity protection and airport noise (Regionalverband FrankfurtRheinMain, 2018). Some municipalities in the north of the conurbation have larger areas sufficient for new development; whereas at the core where the demand is the highest this is not the case. The available space is very unfavorably distributed (Hartmann, 2020). In general, due to space availability being widely different from one municipality to the other, the recent development has also been quite scattered.

In terms of a spatial strategy to activate settlement spaces, the priority given by the State has always been the point-axial system. What is different now is that the construction is denser, as specified by the minimum density values in the State Development Plan. Gaps between the buildings are helpful to achieve higher densities in the already existing settlement areas, but the minimum densities do not intend to increase residential densities in old settlement cores. The gaps are being surveyed by the Regional Association based on aerial images since 2011. It was observed that the number of available gaps is gradually decreasing. Perhaps a more efficient inner development strategy in comparison to the gaps between buildings is conversion of old military and industry areas. For instance, in Hanau, 300 hectares were made available through this strategy, and the city is now tackling the few remaining available sites. Practically, Europaviertel in Frankfurt is also a brownfield development and an example of conversion. Overall, densification to a limited extent, and conversion to a larger extent, have prevented intensive outer development, but the availability of gaps and conversion is now dramatically declining.

When the region evaluated the potential, it was found that, theoretically, in the case of full exploitation (all available gaps between buildings, conversion, vertical densification), 50 per cent of the demand could be met through inner development. But in reality, the State Development Plan's minimum densities are not always easy to achieve and thus require a stronger framing in the regional land-use plan (as mentioned in Interview 2, 2020, remaining space for construction is limited as residential land-use includes all functionalities of a residential settlement). What remains highly political is the goal to achieve higher residential densities around train stations, because how the density is perceived differs a lot. This is what the Regional Development Concept tried to illustrate.

Regarding outer development, there are two important discussions beyond residential settlement development: logistics and data centers (*Rechenzentren*). The conflicting situation with the location preferences is that, logistic areas usually prefer large warehouse centers closer and connected to the conurbation, so that goods are efficiently transported to smaller distribution centers in towns. Currently many logistic operations are being agglomerated

alongside the highway A45 (which connects to Dortmund). It is well-known that logistic areas are space-invasive and require high degree of soil sealing, but it now has a new dimension.[31] The discussion with the data centers is relatively new. There is a tremendous demand for space especially in and around Frankfurt (two examples mentioned: Frankfurt Hanauer Landstraße and Hanau Großauheim). Although these centers usually require less space than logistics centers, the space can only be provided via outer development, because there are many specific requirements and parameters, e.g. buffer distances from residential areas, power supplies, etc. The main challenge with the outer development is therefore to provide logistics and data centers without consuming too much land and with minimum impact on the existing settlement structures. A concept to tackle this in the long-run proves necessary.

Environment, integrated concepts, conflicts

Soil sealing, fresh air corridors, groundwater, and habitat protection are the main environmental themes at the Regional Association. Additionally, the links between settlement development and increased heatwaves and air pollution are acknowledged. Climate adaptation is already integrated with land-use management in previous publications (Regionalverband FrankfurtRheinMain, 2016b). For each new settlement development, all restrictions, e.g. fertile soil, cold air corridor, groundwater etc., are checked as a standard procedure within the environmental report for both preparatory and binding land-use plans.

Regarding large-scale soil sealing in the region from 2008 onward, in addition to some big logistics areas, the Riedberg and Europaviertel neighborhoods (the Europaviertel area was in fact partially sealed) in Frankfurt, the additional runway built for the Frankfurt Airport is mentioned, which is principally a transport-related development. It is noted that *"Settlement development in the form of large-scale soil sealing has to be considered with the aspect of rail and traffic development, because in some cases a large new development area is created because it is anticipated that a new federal highway will be built with a cycle and a pedestrian path next to it, which is also a huge sealing project in itself"* (Interview 7, 2020).

In terms of integrating the environmental and other related aspects, the Settlement Development Concept (*Siedlungsentwicklungskonzept*) brought together the settlement plans, landscape plans, traffic, and open space concepts. The integration requires a constant weighing up of priorities. For instance, the Settlement Development Concept prioritizes development in the area of 1.000 m around train stations, but the landscape plan may indicate that exactly one of these areas has a rare species to be protected, or the mobility

[31] Due to the pandemic, there are more internet orders. The logistics space requested by internet suppliers are expected to increase (Interview 7, 2020).

plan may show that traffic there is already overloaded. Therefore, all these aspects have to be taken into account, and if necessary, some of the priority areas around train stops have to be excluded. This could be done on the basis of integrating the municipal ISEK and finding a compromise again at the smaller scale municipal-level planning if needed. Also, concepts from traffic infrastructure in addition to the open and green space concepts are incorporated into so-called overall spatial planning concepts (*gesamträumliche Planungskonzepte*), which is the basis for political decision-making by the Chamber of Association.

In terms of the integration regarding the federal and state-level goals and strategies and their implementation at the local-level, the level of detail in the specifications coming from the higher levels are important for a successful alignment of goals and their implementation. One example for a potential misalignment could be the national goal to limit the daily open land take, which aims to reach 2,5 hectares per day by 2030 in Hesse. The designation of each new settlement area brings further sealing (including transport) and the conurbation clearly needs more space for development (in comparison to North and Middle Hesse). Perhaps taking this into account would be effective, so that a differentiation of regulations among districts could support meeting the demand. In general, conflicts are almost with no exception emerging from the tremendous pressure for space, and it is challenging to reconcile the legitimate municipal needs with current strategies to limit further development (also in Interview 6, 2020).

The need for citywide concepts

When a binding land-use plan is established according to Section 8 of the Federal Building Code, it ensures appropriate compensation measures. The Regional Association's projects help facilitate compensation procedures; for instance, the dual inner development policy, which can be seen as a holistic compensation concept and a guideline, has already been a matter of further investigation in the Regional Association's projects and is both directly and indirectly recommended. The project *Potentials for additional housing space in the existing settlements from 1950s to 1970s – Results from a model project for a climate-friendly land management* (Regionalverband FrankfurtRheinMain, 2016b) dealt with the dual inner development topic regarding the potential of inner development in general and further densification in particular in pilot neighborhoods. It was shown that mobilizing the potential for inner development in the form of densification can be achieved without impairing the green space quantity and quality. Within the current legal frameworks, these approaches cannot be enforced. Still, the concept is becoming more mainstream and planning departments of municipalities are getting more familiar with it. The compensation measures

as per the Federal Building Code is an accustomed practice, but the concepts such as dual inner development need time and acceptance to become a widespread methodology.

4.2. Pre-analysis: Selection of the case study units

4.2.1. Spatial classification as a criterion

In order to analyze the spatial green space parameters and the institutional arrangements and resultant governance conditions, the fastest growing middle-sized towns in the Frankfurt Rhine-Main in terms of the increase in population in the region are selected according to the following spatial criteria:

- **Middle-sized towns** (population between 20.000 and 100.000, following Baumgart et al., 2004) with the highest increase in population from each administrative county (*Landkreis*) in the region, namely Kreis Groß-Gerau (GG), Hochtaunuskreis (HTK), Main-Kinzig-Kreis (MKK), Main-Taunus-Kreis (MTK), Landkreis Offenbach (OF), and Wetteraukreis (WTK): In growing regions, not only the central cities, but also the middle-sized towns are facing a pressure to provide more settlement areas. As in the case of polycentric Frankfurt Rhine-Main region, the pace of recent increase in population and construction activity in these towns cannot be neglected. The reason for selecting one case town per each administrative county is that the counties are usually made up of towns with similar characteristics. Selecting one town for each county ensures a spatially homogeneous distribution of studied towns.
- **Located in the densification area of the region**: 52 of the 75 municipalities in the conurbation are located in the densification area, 21 are located in the regulatory area, and two in the rural area. This criterion may be imposing a strict division that is not realistically capturing a town's characteristic (e.g. a town with a rural character may be classified as peripheral). However, this classification is still in use today in the planning system and that is why it is involved as a criterion for the case selection.
- **Classified as an intermediate-order center** according to the Central Place Theory: Similarly, the categories of the Central Place Theory may be outdated to properly represent a town's characteristics, but it is still in use in planning system which implies certain specifications including provision of goods, services, and infrastructure. Many middle-sized towns are also intermediate-order centers, but there are exceptions.

Based on these criteria, the middle-sized towns in the Frankfurt Rhine-Main conurbation that are located in the densification area and classified as intermediate-order centers are as follows:

- GG: Groß-Gerau, Mörfelden-Walldorf, Rüsselsheim am Main (hereafter Rüsselsheim)
- HTK: Bad Homburg vor der Höhe (hereafter Bad Homburg), Friedrichsdorf, Oberursel
- MKK: Bruchköbel, Maintal

- MTK: Bad Soden am Taunus, Eschborn, Flörsheim am Main, Hattersheim am Main (hereafter Hattersheim), Hofheim am Taunus, Kelkheim (Taunus)
- OF: Dietzenbach, Dreieich, Langen, Mühlheim am Main, Neu-Isenburg, Obertshausen, Rödermark, Rodgau, Seligenstadt am Main
- WTK: Bad Vilbel

4.2.2. Population and construction activity as a criterion

The population increase percentages since 2011 among the towns that fall under the above mentioned set of criteria show that the fastest growing ones in each district and their 2018 populations are as follows (Regionalverband FrankfurtRheinMain, n.d.) (Table 4.3):

Table 4.3: Middle-sized, intermediate-order towns in the agglomeration area in the conurbation with highest population increase.

Town	2011 population	2018 population	Population inc. %
Rüsselsheim	59.307	65.440	10,34
Bad Homburg	51.625	54.248	5,08
Maintal	36.021	39.298	9,10
Hattersheim	24.864	27.590	10,96
Neu-Isenburg	35.051	37.668	7,47
Bad Vilbel	31.673	33.990	7,32

A case selection that is solely based on population increase is insufficient to claim that these towns are also the ones with the highest construction activity. There are cases in which population increase is high, but housing stock is not, indicating a change in the average household sizes (e.g. Neu-Isenburg in Kreis Offenbach: 37.512 inhabitants in Neu-Isenburg in 2017 showing the highest population increase in Kreis Offenbach since 2008, but Neu-Isenburg ranks ninth in Kreis Offenbach in terms of the increase in the housing stock). This shows that population increase alone does not necessarily indicate construction activity increase and cannot be decisive in selecting the fastest growing middle-sized towns in each county. It is therefore necessary to bring together the population growth and construction activity data. In order to do this, the housing stock data is retrieved from the Regional Association's Statistics-Viewer (Regionalverband FrankfurtRheinMain, n.d.).[32] The second-tier analysis for the case selection took place as follows:

[32] This data is available from 2013 to 2019 and it gives an overview of the annual increase in the housing stock (relative and absolute). In order to expand the timespan and better relate to the period of analysis, the 2012 and 2011 housing stock data is retrieved from Regional Databank of Germany (Statistischen Ämter des Bundes und der Länder, 2015). The data sheets can be found in Appendix C.

- GG: Among the three municipalities in Kreis Groß-Gerau that qualify as middle-sized town and intermediate order center that is located in the agglomeration area, Rüsselsheim has the highest rate of population growth and housing provision. However, Groß-Gerau has the highest proportional increase in the housing stock (Table 4.4). The case study selection for Kreis Groß-Gerau therefore requires a comparison of land-use change.

Table 4.4: Population and housing stock increase in the middle-sized towns in Kreis Groß-Gerau.

County	Town	Population increase			Housing stock increase			
		2018	2011	relative %	2019	2011	relative %	absolute
GG	Groß-Gerau	25.559	23.876	7,0489	11.529	10.783	6,9183	746
GG	Mörfelden-Walldorf	34.891	32.634	6,9161	16.315	15.585	4,6840	730
GG	Rüsselsheim	65.440	59.307	10,3411	29.938	28.656	4,4738	1282

- HTK: In Hochtaunuskreis, Bad Homburg has the highest population increase, however, this is not reflected in the housing stock increase. Oberursel has provided almost twice as much housing (Table 4.5). Therefore, the case study selection for Hochtaunuskreis requires a comparison of land-use change.

Table 4.5: Population and housing stock increase in the middle-sized, intermediate-order towns in Hochtaunuskreis.

County	Town	Population increase			Housing stock increase			
		2018	2011	relative %	2019	2011	relative %	absolute
HTK	Bad Homburg	54.248	51.625	5,0809	27.088	26.479	2,2999	609
HTK	Friedrichsdorf	25.194	24.436	3,1020	12.029	11.522	4,4003	507
HTK	Oberursel (Taunus)	46.248	44.209	4,6122	22.476	21.368	5,1853	1108

- MKK: There are two municipalities in Main-Kinzig-Kreis that are middle-sized towns and intermediate order centers located in the agglomeration area. Maintal has a higher rate of population growth and construction activity (Table 4.6) and is therefore selected as a case study town.

Table 4.6: Population and housing stock increase in the middle-sized, intermediate-order towns in Main-Kinzig-Kreis.

County	Town	Population increase			Housing stock increase			
		2018	2011	relative %	2019	2011	relative %	absolute
MKK	Bruchköbel	20.427	20.326	0,4969	9.878	9.644	2,4264	234

MKK	Maintal	39.298	36.021	9,0975	18.872	18.205	3,6638	667

Although in the initial phase Hanau was considered as a case study town, an interview with the planning department in Hanau on September 4, 2019 gave some important insights that the town should rather be excluded because of the following reasons:

- Hanau is in the process of becoming a county-free city, meaning it will not belong to the county of Main-Kinzig and become a city with its own functions and capacities like Frankfurt am Main and Offenbach am Main. This transition is intended for 01.01.2022.
- Hanau's population is already around 99.000 and increasing. Although by population standards Hanau still counts as a middle-sized town, it is categorized as a higher-order center.
- The spatial focus area to analyze the green space parameters in this study is determined by a 1.000-meter radius around the train stations. However, Hanau has multiple train stations, and no spatial focus area would be representative of the multiple transitions that the town is currently undergoing.

- MTK: Among the six municipalities in Main-Kinzig-Kreis that qualify as middle-sized town and intermediate-order center located in the agglomeration area, Hattersheim has the highest population and relative housing stock increase while Hofheim provided more housing units in total (Table 4.7). The case selection is therefore to be verified following a land-use change comparison.

Table 4.7: Population and housing stock increase in the middle-sized, intermediate-order towns in Main-Taunus-Kreis.

County	**Town**	**Population increase**			**Housing stock increase**			
		2018	**2011**	**relative %**	**2019**	**2011**	**relative %**	**absolute**
MTK	Bad Soden am Taunus	22.645	21.102	7,3121	11.519	11.074	4,0184	445
MTK	Eschborn	21.488	20.395	5,3592	10.505	10.030	4,7358	475
MTK	Flörsheim am Main	21.572	19.930	8,2388	9.782	9.350	4,6203	432
MTK	Hattersheim am Main	27.590	24.864	10,9636	13.091	12.333	6,1461	758
MTK	Hofheim am Taunus	39.766	37.982	4,6970	18.819	17.965	4,7537	854
MTK	Kelkheim (Taunus)	29.055	27.777	4,6009	13.675	13.130	4,1508	545

- OF: Among the nine municipalities in Landkreis Offenbach that qualify as middle-sized town and intermediate-order center located in the agglomeration area, the highest population increase rate can be observed in Neu-Isenburg followed by Langen. However, the population increase in Neu-Isenburg is not reflected in the housing stock increase as Langen has the highest number of completed housing units. The relative housing stock increase has been the highest in Seligenstadt, where the new settlement development took place predominantly on the outskirts of the city (Table 4.8). In any case, population and housing stock analysis is insufficient to decide on the case selection and a third-tier analysis is necessary.

Table 4.8: Population and housing stock increase in the middle-sized, intermediate-order towns in Landkreis Offenbach.

County	Town	Population increase			Housing stock increase			
		2018	2011	relative %	2019	2011	relative %	absolute
OF	Dietzenbach	34.019	32.030	6,2098	14.128	13.936	1,3777	192
OF	Dreieich	42.091	39.526	6,4894	20.429	19.866	2,8340	563
OF	Langen	37.902	35.303	7,3620	18.221	17.163	6,1644	1058
OF	Mühlheim am Main	28.403	26.918	5,5168	13.724	13.152	4,3491	572
OF	Neu-Isenburg	37.668	35.051	7,4663	19.251	18.875	1,9921	376
OF	Obertshausen	24.943	23.814	4,7409	11.733	11.238	4,4047	495
OF	Rodgau	45.202	42.945	5,2556	20.482	19.750	3,7063	732
OF	Rödermark	28.071	26.297	6,7460	12.561	12.012	4,5704	549
OF	Seligenstadt	21.293	20.059	6,1519	10.372	9.580	8,2672	792

- WTK: In Wetteraukreis, Bad Vilbel is the only town that fits the criteria of being a middle-sized town and intermediate order center that is located in the densification area (Table 4.9). It is therefore selected as a case study town.

Table 4.9: Population and housing stock increase in the middle-sized, intermediate-order towns in Wetteraukreis.

County	Town	Population increase			Housing stock increase			
		2018	2011	relative %	2019	2011	relative %	absolute
WTK	Bad Vilbel	33.990	31.673	7,3154	16.655	15.521	7,3062	1134

4.2.3. Land-use change as a criterion

A town may grow in terms of population and increased construction activity, but this would be insufficient to presume an increase in the settlement development, especially when there is a spatial limitation. The population increase, in combination with the increase in housing

provision, might be simply taking place outside of the spatial focus area. Since the urban green spaces that are located within a 1.000-meter radius around train stations are of central concern to this study, the land-use change in this spatial focus area becomes the third tier of the pre-analysis, for situations where a case selection could not be made based only on population and housing data. Based on this, this research also uses the 1.000-meter radius around the main train station as the spatial scope of investigation in each case study town. After the population and construction activity analysis, the towns subject to a land-use change analysis in the spatial focus area are:

- GG: Rüsselsheim and Groß-Gerau
- HTK: Bad Homburg and Oberursel
- MTK: Hattersheim and Hofheim

Several train stations located in one town causes a methodological challenge. For Langen, Rüsselsheim, Groß-Gerau, and Maintal, it is not possible to decide which train station can be representative for the spatial focus area just by looking at maps or aerial images. To resolve this, the Deutsche Bahn's train station categorization system is used. For the purposes of maintenance of the train stations and setting the pricing accordingly, Deutsche Bahn classified approximately 5.400 train stations into seven categories according to the number of platforms, maximum platform length, number of travelers, and presence of service personnel (Deutsche Bahn Datenportal, 2019) (Appendix A). The selected train stations for towns with more than one station are as follows:

- Langen: There are two train stops in Langen, one belonging to category 4 (Langen), and the other to category 5 (Langen-Flugsicherung). Therefore, the Langen station with ID number 3524 is selected.
- Rüsselsheim: There are two train stations in Rüsselsheim, Rüsselsheim and Opelwerk. Opelwerk belongs to category 4 and Rüsselsheim to category 3. Therefore, the Rüsselsheim station with ID number 5440 is selected.
- Groß-Gerau: There are three train stops, Groß-Gerau, Groß Gerau-Dornberg, and Groß Gerau-Dornheim. Dornberg station belongs to category 3; whereas Groß-Gerau is listed as category 4 and Dornheim as 6. Therefore, the train stop Dornheim with the ID number 2300 is selected. However, the area around this station does not show an urban characteristic. So, the train station Groß-Gerau with the ID number 2299 is included in the investigation.
- Maintal: There are two train stops, Maintal Ost, belonging to category 4 and West, belonging to category 5. Therefore, the train stop Ost with the ID number 2809 is selected.

For all the other towns subject to land-use change analysis at the spatial focus area (Bad Homburg, Hattersheim, Hofheim, Neu-Isenburg, Bad Vilbel) there was no such selection

necessary, since these towns have only one train station. For the final selection procedure, a higher increase in residential land-use within the spatial focus area is taken as a justification for selection (Table 4.10). In cases where an increase in residential land-use cannot be found, the town with a higher increase in residential and mixed-use areas was selected as the case study:

- GG: The population data showed that Rüsselsheim is growing the fastest and has provided a greater number of housing units, but a relative housing stock increase in Groß-Gerau was higher. For both towns, no positive change for the residential areas can be observed, but the mixed-use increase is clearly higher in Rüsselsheim. Therefore, Rüsselsheim is selected as a case study.
- HTK: The population and construction activity showed quite similar trends in Bad Homburg and Oberursel. The spatial analysis however showed an increase in the residential land-use in Bad Homburg's spatial focus area; whereas there was a slight decrease in Oberursel. Therefore, Bad Homburg is selected as a case study.
- MTK: The population and construction activity data showed that Hattersheim is growing the fastest. The spatial analysis also indicated a higher increase in residential land-use in Hattersheim in comparison to other towns. Therefore, Hattersheim is selected as the case study.

Table 4.10: Summary of case selection. The increase in residential areas for final decision, when inconclusive, the increase in mixed-use areas are decisive factors.

County	**Town**	**Residential land-use increase 2012-2019, %**	**Conclusion**	**if inconclusive: Residential and mixed-use land-use increase 2012-2019, %**	**Final selection**
GG	Groß-Gerau	0,0000	inconclusive (no or negative change)	0,0000	Rüsselsheim
GG	Rüsselsheim	-8,4728		0,0276	
HTK	Bad Homb.	2,4931	conclusive		Bad Homburg
HTK	Oberursel	-2,4646			
MKK	Maintal	0,031	already selected		Maintal
MTK	Hattersheim	0,0895	conclusive		Hattersheim
MTK	Hofheim	0,0023			
OF	Langen	-0,0022	inconclusive (no change / negative change)	0,0099	Langen
OF	Neu-Isenb.	0,0000		0,0000	
OF	Seligenstadt	-0,0399		-0,0013	
WTK	Bad Vilbel	0,2494	already selected		Bad Vilbel

In the following sections of this chapter, the case study towns are analyzed first by introducing their local characteristics as a middle-sized town.[33] This is done by briefly

[33] These data are from 2019 and retrieved from Statistics-Viewer of the Regional Association on 29.12.2020.

describing the relevant settlement and open space structure of the town within its administrative borders. To give an idea of the spatial change going on at the spatial focus area, a visual comparison between the current land-cover structure and the aerial images from the year 2006 (the only available year on Regiomap) is provided.[34] Second, the spatial analysis looks into the green space parameters including the field observations, which are also presented cartographically. A detailed look into the social and ecological value of each observed vegetation cover during the field visits and a complementary open space classification according to intended purpose and accessibility is provided in Appendix H. Finally, the qualitative investigation looks into the institutional settings and resultant governance conditions from the perspective of the municipal planning, with a focus on urban green spaces.

[34] The built-up density in the focus area in terms of soil sealing based on Urban Atlas is also given. The Urban Atlas categories are limited to residential areas only, and thus does not provide information about the soil sealing percentage of other (e.g. industrial) settlements. This information is publicly available through the online tool Regiomap.

4.3. Kreis Groß-Gerau: Rüsselsheim

Rüsselsheim is the fourth most populous town in the conurbation (after Frankfurt, Offenbach, and Hanau) with a population above 65.000, 29 per cent of which with migration background. In terms of spatial categorization, Rüsselsheim has a special status as an intermediate-order center with partial functions of a higher-order center (*Mittelzentrum mit Teilfunktionen eines Oberzentrums*). The town has provided 229 housing units in 2019. It covers an area of 5.829 hectares, slightly above the conurbation average. Settlement and transport land-use portion reaches around 35,5 per cent that is balanced out by a relatively higher forest cover about 43 per cent. As of 2019, new settlement development designations are made up of 29 hectares for residential and 23 hectares for industrial settlements.

Rüsselsheim is situated at the southern side of the Main river. The Opel factory determines the town's urban morphology to a large extent. The southern part of the Frankfurt Airport is also partially located within the town's administrative borders. Apart from the residential areas at the riverside and in between the highway A60 and the federal road B43, the western side of the B519 federal road is dominated by the Opel factory's partially active industrial functions. The eastern side of B519 is a predominantly densely built residential area, with some industrial and commercial uses in between. In the south, there is the industrial settlement Hasensgründ, mostly settled by automobile dealers. The Königstädten neighborhood lies in the southeast, which is located rather close to the central Rüsselsheim. The Bauschheim neighborhood lies in the southwest and is situated somewhat detached from the other settlements in Rüsselsheim. There are two main city parks, one is directly at the Main river (Stadtpark), and the other (Ostpark) is bordering the Haßloch neighborhood to the west (Figure 4.3).

4.3.1. Planning from a green space perspective[35]

Recent trends in spatial development

Back in 2008, the stagnating population growth and resultant low construction activity was evident in Rüsselsheim, too. Large-scale projects that had been planned for years never reached implementation phase. Now with the changing demographics, a very large settlement project, Eselsweise, is being implemented in Bauschheim after twenty years of planning. Before that, the most important settlement development was Blauer See in Königstädten, which was implemented twenty years ago. Recently, occasional opportunities for development have proven beneficial so far for the housing demand: Soccer fields became available (Ostpark) as the club moved to another location; Opel-Altwerk will be converted into

[35] This subsection is developed on the basis of Interview 5 (2020) unless otherwise stated.

mixed-use after 15 years of vacancy; Karstadt, an old shopping center in the town center, is currently under construction for new housing. In the words of the planning expert from the city administration, *"… these all more or less happened by chance. Before that, it was quite inactive for years"* (Interview 5, 2020).

There are less and less large gaps available in the inner areas and there is no new settlement development being planned, especially now that the Eselsweise project is moving forward. The town's housing association, GEWOBAU, has been active in densifying (and also renovating) the neighborhoods they previously in the 60s and 70s. These processes are relatively fast, because the housing association is the owners of the land and the buildings and the bureaucracy is rather uncomplicated. It can be said that this is usually not the case with inner development, since private owners have different interests than municipal planning, which is one of the factors that make settlement provision on the outer area more easily manageable.

One challenge has been the retail vacancies in the neighborhoods from 60s and 70s, a period during which Rüsselsheim grew very strongly. These retail centers provided services that are not needed anymore. Since these are either vacant or not in a great condition, their potential could be used. But given the high number of private ownership and different interests, it is not possible to mobilize this potential immediately.

Floods, heatwaves, green spaces

As Rüsselsheim is located directly at the Main river and very close to the Rhine river, flood protection is a part of municipal planning and urban land-use plans. For the recent development in Bauschheim, the planning department used a computer simulation. The simulations showed that the impact would be low if the dike breaks during an extreme flood event, and that there would be two to three days for evacuation in case of a tidal wave, which were taken into account during planning. Regarding the heatwaves, especially for the central areas of the town where soil sealing is quite high, the planning department is considering alternatives to intensive soil sealing. Such intentions are becoming increasingly important for the politicians and citizens alike. A recent example is the consideration of a central garage at the Eselsweise neighborhood that serves as a neighborhood car parking facility, so that private gardens are not paved as driveways. However, this is done usually at smaller scales for new development, and currently such efforts do not yet have a citywide resonance.

The town administration has adequate resources for the maintenance and provision of green spaces. In Rüsselsheim, especially in the central parts of the town, there are only a few public green spaces that shape the town's character. These spaces are being frequented as

public spaces more intensively. Although smaller green patches that are located in between buildings are not frequented as much, they are still maintenance-intensive spaces.

Challenges pertaining to social housing

In Rüsselsheim, the percentage of rental social housing is quite high (above 30 per cent). One implication of this is that the residents of social housing do not have private gardens and are dependent on the provision of open, public green spaces in close proximities. However, for a long time there were disapproving voices among residents against social housing (no new neighbors, no social housing, no unemployed people were desired). As a matter of fact, in Rüsselsheim, in the past, social housing was located in the peripheries, while the single-family housing was designated at more favorable locations (Interview 5, 2020). Fortunately, this is no longer the case. This was countered by strong statements to communicate the advantages of social mix and shortcomings of segregation. The acceptance resulting from better choice of location has been now leading to a positive change. Learning from the past, a positive change accompanied local political discourses.

Challenges pertaining to administrative levels and scales

There are numerous financial support programs of the State, but currently, the Großer Frankfurter Bogen project is of particular interest to Rüsselsheim. The basic condition to take part as a municipality is a maximum of 30-minute train distance, which will have implications on the existing capacities of the public transportation infrastructure.

The spatial planning goals of the state and federal government are very much appreciated by the local level, but there are inevitable challenges which the planning departments need to resolve or go along with. For instance, *"… the owner comes into play, who is not interested in all this at all, but rather interested in being able to get the best possible price for their property on the free market following a development plan"* (Interview 5, 2020).

One example relates to social housing. Despite the municipality's intention to provide more social housing, there is no legal enforcement for a certain percentage of social housing which is often left to investor's willingness. This exemplifies that the legal means introduced by the Building Law in favor of implementation of federal and state-level goals can be *"a bit thin"* (Interview 5, 2020). Another example is about the daycare centers. According to the German Social Security Code, each toddler has the right to a place at a daycare center. But favorable location for a daycare center from the viewpoint of parents is not always where they are located in a land-use plan. Given the limited space availability, parents have to be content if a daycare center can be provided at all. It is noted that this is regarded suboptimal, because

parents might have no other choice than driving their toddlers to a daycare center, which is not a climate-friendly solution.

Cooperation, coordination, collaboration

Rüsselsheim does not have a politically-agreed ISEK, but settlement and infrastructure development and open space protection are inseparable in day-to-day municipal planning processes. Regarding the actors and the representation of interests, it is highlighted that the signals for development nearly exclusively come from the politics, and then these ideas become a part of administrative tasks. It proves a challenge that upon completion of these tasks, the results are not always in line with what the politics anticipates in the beginning: *"Politicians might think of a new residential settlement as a single-family housing [neighborhood] with large beautiful gardens, where people move in who pay a lot of taxes. But we as the administration might prioritize building a multistory neighborhood"* (Interview 5, 2020). How this is resolved after this point depends on the political climate at that moment. In the case of Rüsselsheim, the current local politics has a rather dynamic character, and the mismatches between the outcomes of a municipal process and political expectations do not really constitute a problem, as the politics will be open and keen to take on contemporary approaches and rely on technical expertise. The citizens are referred to as the *other equally important actor.* Regarding the representation of interest, it is difficult to pinpoint whether dominant arguments from the citizens' side represent the arguments of the majority: *"the voice of the loudest is not always the voice of the majority"* (Interview 5, 2020). Because of that, the politics has to ensure that all voices are heard, by resolving, not avoiding, the conflicts that might arise.

Regarding intermunicipal cooperation, it was mentioned in the interview that the municipalities in the conurbation tend to turn their attention inward: Because the tax revenues are the main source of municipal income, there tends to be more competition among municipalities than cooperation. The cooperation occurs only when an extensive consultation with neighbor municipalities is unavoidable, e.g. on the basis of a cross-border settlement or infrastructure development.

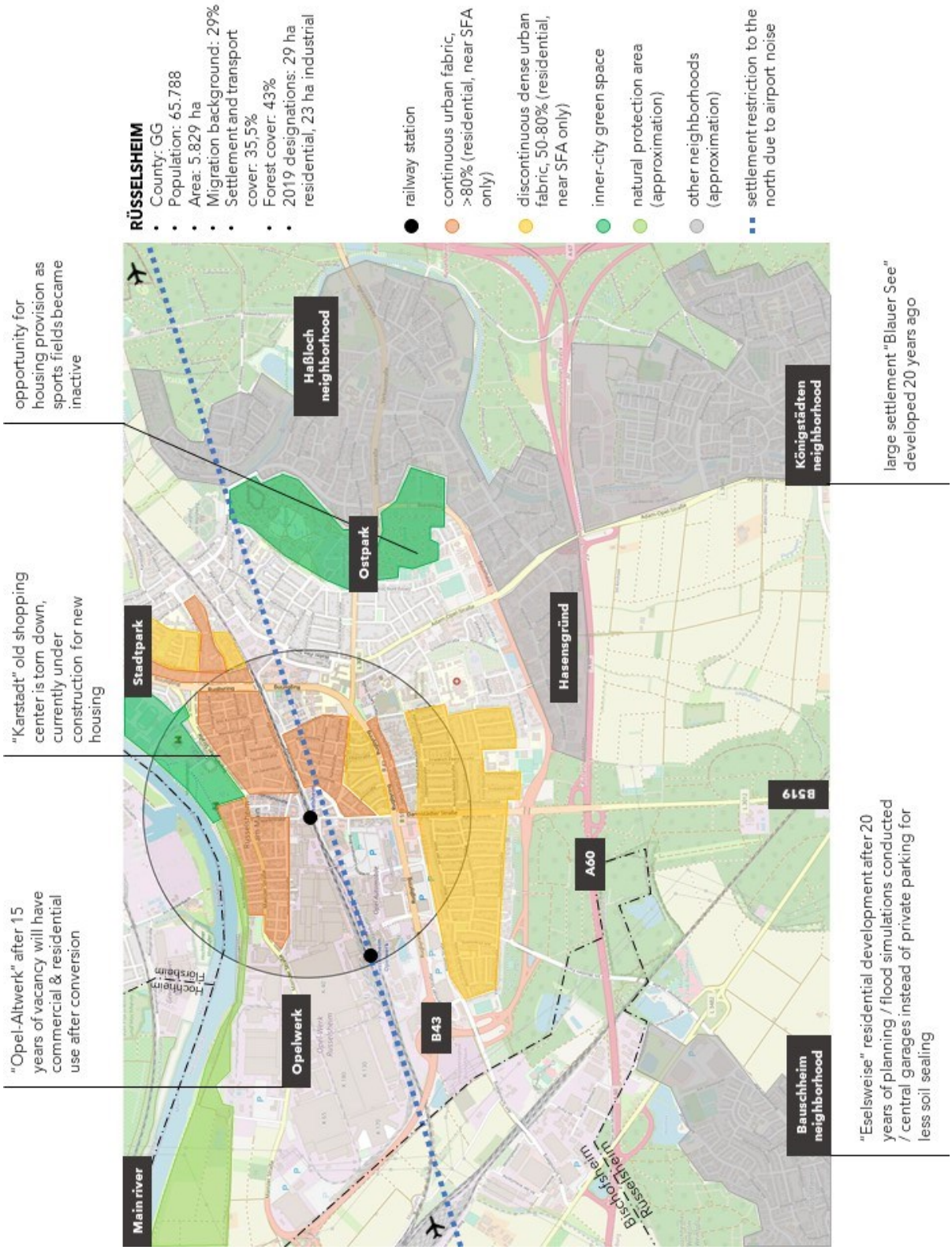


Figure 4.3: Key information on Rüsselsheim recorded on OpenStreetMap (own illustration).

4.3.2. Spatial focus area

The structure of the spatial focus area in Rüsselsheim is quite special because a large area of it is covered by the Opel factory. It is recognizable on the aerial images from 2006 that the main new developments in the focus area since then were a large car parking area at the Opel campus, new housing blocks, single-family housing, and few selective densifications in the already existing building stock to the east, and a new hotel building at the Main river. Through a comparison of aerial images and up-to-date land-cover maps, it is apparent that the limited availability for space caused the transformation to be relatively moderate. The spatial change has been mostly in the form of inner development and in some cases densification. It can be recognized that the new construction took place mostly on empty lots and some of these were built on already sealed areas (conversion). As parts of the Opel factory campus is not being used anymore, a conversion with various functions is currently underway. The aim is to provide a mixed-use space with commercial and residential purposes functions and for various activities and events (Figure 4.4).

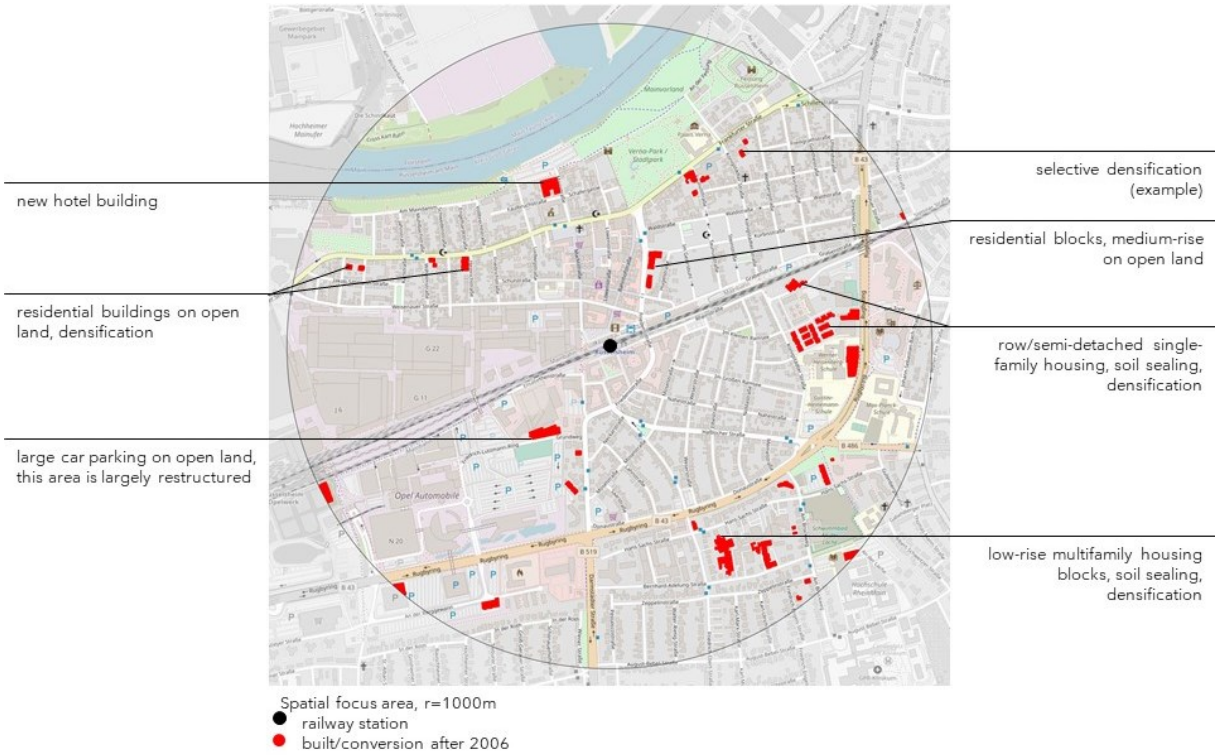


Figure 4.4: Changes in the spatial focus area in Rüsselsheim since 2006 recorded on OpenStreetMap. Analysis done by visual comparison of maps and crosschecked based on interview data and internet research. There may be unintentional flaws in the illustration (own illustration).

Green space parameters

The green cover takes up 11 per cent of the spatial focus area in Rüsselsheim, around 5 per cent of which is classified as sport, leisure, and recreational areas within settlement land-use. The green stripe alongside the Main river to the north is the only large continuous green patch in the focus area, while remaining green spaces are rather dispersed and located

mainly at the eastern side within a predominantly residential area. For the recreational green cover within settlement areas the edge density is 25,10 m/ha. There is no forest area or agricultural field within the focus area. The percentage of settlements (residential, industrial/commercial, and buildings with other functions) served by green spaces is relatively high, around 90 per cent (Figure 4.5).

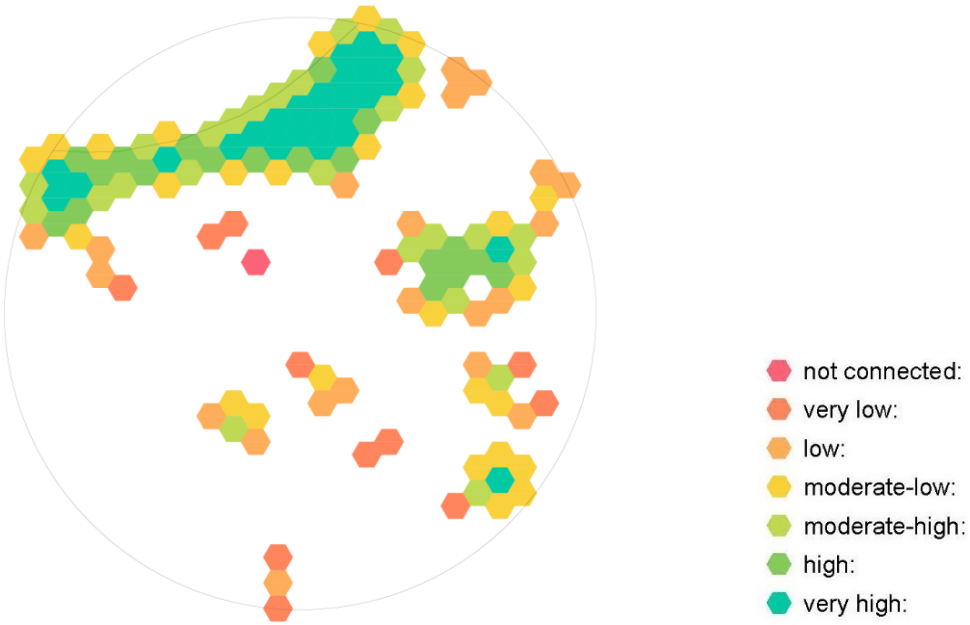


Figure 4.5: Connectivity of the landscape cover in Rüsselsheim's spatial focus area (own illustration).

There are dispersed large green spaces at the eastern side where residential areas are situated. Some residential areas are located within catchment areas of multiple green spaces (Figure 4.6). As shown on the aerial image, several new developments since 2006 appeared on open land at the western side of the spatial focus area. If these were to become urban green spaces, the results of the proximity analysis would have indicated a more favorable distribution. A large portion of the settlement areas is dependent only on one green space.

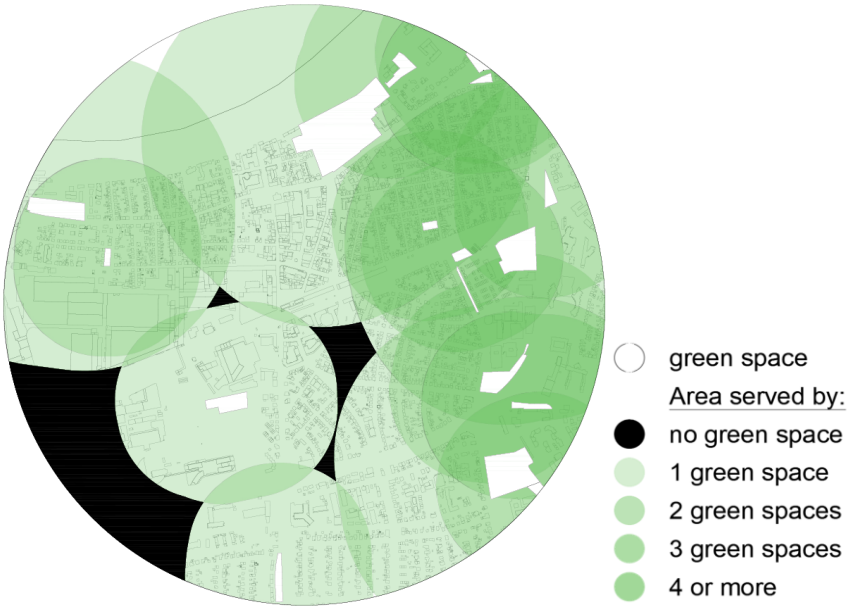


Figure 4.6: Proximity of the recreational green cover in Rüsselsheim's spatial focus area (own illustration).

Social and ecological value

Among the 34 total observed green spaces in the spatial focus area, 24 were found to have no or low social value. There are also several spaces indicated as open spaces with high social value: the large green space alongside the Main river, the market square, several parks, and playgrounds. In terms of intended purpose and accessibility, the majority of these spaces can be classified as public open spaces, with free access without restriction, either as open public spaces (mainly parks) or as purpose-dependent open public spaces with a dominant function (mainly playgrounds, parking lots, roadside green). The highest social value places are public squares (Fields 7, 7a), playgrounds (Fields 10, 19), and the pedestrian area alongside the Main river (Field 5). Most of the observed green spaces are found to have low to medium ecological value. These predominantly have rough grass/mown grass covers in parks and bare soil surfaces or surfaces without vegetation in playgrounds. During the field visit, some areas that are indicated as open spaces in maps were observed to be parking lots (Fields 4, 16, 20) with no significant ecological value. Some others are private interior courtyards that are not publicly accessible, and thus fulfilling a very limited recreational and ecological function. Overall, the actual ecological value of open spaces is found low. One exception is the multifunctional green patch alongside the Main river with an additional flood-proofing function. Based on the open space typology classification, there is a tendency that the areas with the highest social and ecological value are publicly accessible without restriction (exceptions: semi-public areas e.g. swimming pool and sports field, cultivated areas of community gardens, open spaces of industry) (Figure 4.7, Figure 4.8, Figure 4.9).

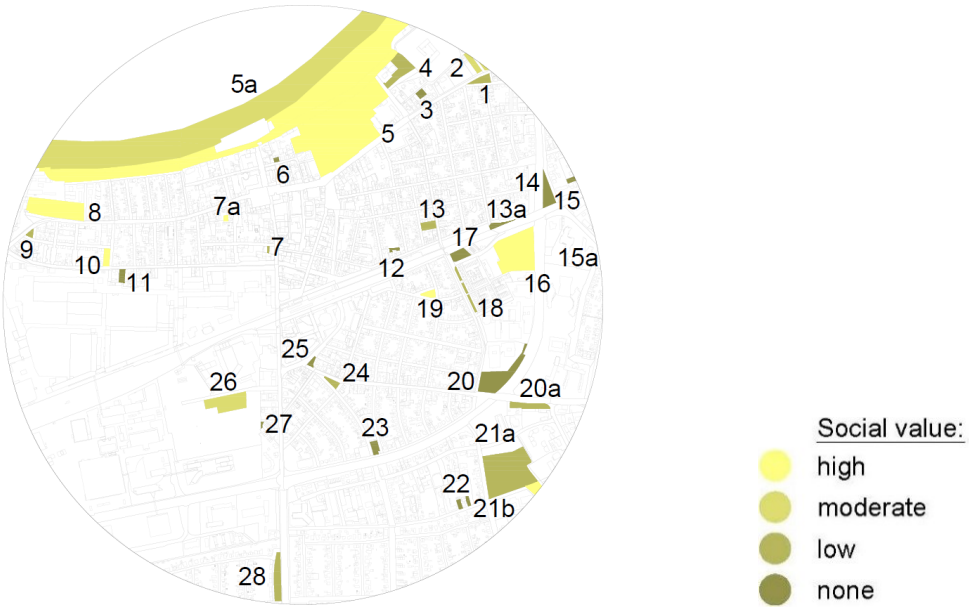


Figure 4.7: Social value of the green cover in Rüsselsheim's spatial focus area (own illustration).

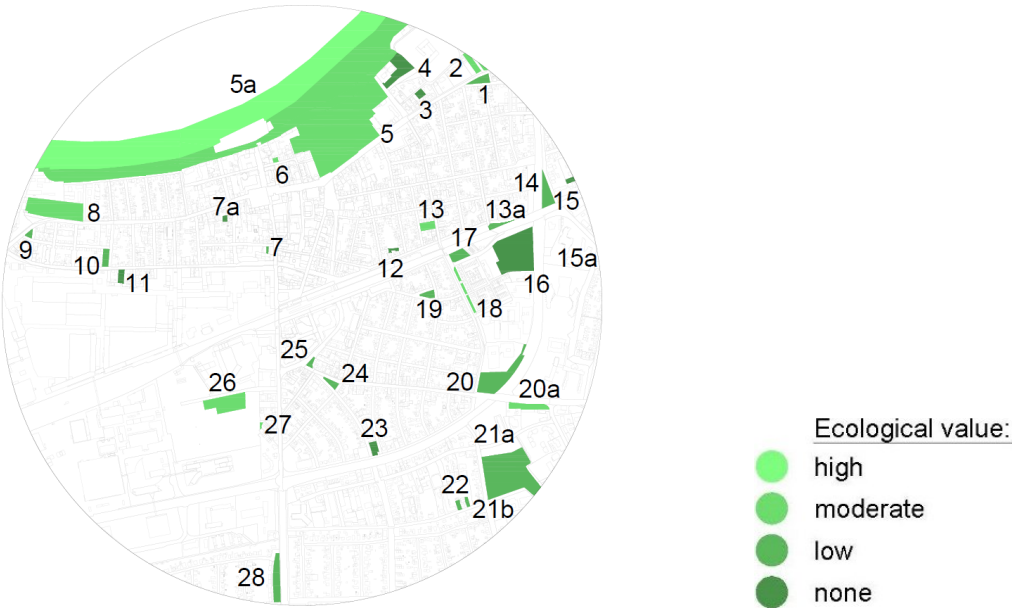


Figure 4.8: Ecological value of the green cover in Rüsselsheim's spatial focus area (own illustration).

Figure 4.9: Field 3 (top left): already densified; Field 7 (top right): public square with high social low ecological value; Opel factory (bottom left): parking lot with high sealing; Field 5 (bottom right): multifunctional green cover (own photos).

4.4. Hochtaunuskreis: Bad Homburg

The case study town in Hochtaunuskreis is Bad Homburg, the most populous town in the county. The growth rate in terms of completed buildings are currently rather low: In 2019, only 71 housing units were constructed. Bad Homburg covers an area of 5.114 hectares. Around one fifth of the population has migration background with a slight increase in the past years. Settlement and transport areas make up around 30 per cent of the town's area, with a relatively slow increase over the years. 41,4 per cent of Bad Homburg's area is forest cover. As of 2019, 42 hectares of new residential and 14 hectares of new industrial areas are designated in the land-use plan.

In addition to the town's central areas there are six neighborhoods: Dornholzhausen in the northwest with a predominantly residential structure, bordered by forest on the north; Kirdorf neighboring Dornholzhausen with similar characteristics; Gonzenheim to the east with a subway station mostly with residential settlements; Ober-Eschbach bordering Gonzenheim to the east also with a subway station and industrial areas; Ober-Erlenbach at the eastern side of the A5 highway with residential character, bordering Frankfurt and detached from the rest of the town by agricultural fields in between; and Berliner Siedlung to the southwest. The northern part of Bad Homburg has continuous environmental protection areas of forest and agricultural fields. In the south, the area between the industrial zone at the southern side of the train tracks and the A661 highway is also a continuous agricultural strip. Additionally, there are many streams flowing in the northwest-southeast direction, and it is intended that the settlement structure follows a matching alignment. Only the central Bad Homburg partially falls into the spatial focus area, including parts of the two most important green spaces, Schlosspark and Kurpark (Figure 4.10).

4.4.1. Planning from a green space perspective[36]

Current themes in municipal planning

Currently there are only a few developments running in parallel in several locations in Bad Homburg, mostly through conversion of inner brownfields. One example is the Vickers-Areal, with access to existing technical infrastructure and planned improvements to social infrastructure. The intention is to provide a mix of housing typologies in order to establish a social mix. The town's planning department aims to go beyond the usual *"buy a villa–tear it down–build a larger villa"* cycle (Interview 4, 2020). Another new settlement development where social mix is intended is Südcampus in the Ober-Eschbach neighborhood which will provide around 400 dwellings with good transport connections. Additionally, a new

[36] This subsection is developed on the basis of Interview 4 (2020) unless otherwise stated.

development on open land, a strip of commercial development located around the hospital area on the A661 highway, is given importance, also from a financial point of view, since business taxes are the primary municipal income sources.

Regarding densification, the reason why the densification potential cannot be reached is not because there are no available gaps between buildings, but because there is unwillingness from the side of the private owners, and consequently, from the side of the politics. Still, the planning department is currently working on establishing a register of gaps. Regarding conversion, although the town principally prioritizes inner areas before resorting to the outer, new daycare centers have been an exception. But this was done with conversion of use in mind: If and when needed, these could be converted into elderly care centers.

The most important challenge with new development appears to be the traffic load, and the fact that conventional methods of traffic development are no longer adequate, because the carrying capacity in the metropolitan region in general is reached (Interview 2, 2020; Interview 3, 2020; Interview 4, 2020). Creating more street space tends to cause more intensive traffic and more congestion in the inner-city areas. This could be an expected outcome of the Südcampus development as well as a potential future development of the Bornberg neighborhood, unless the existing road and transport network is improved. Bornberg could provide space for high-quality housing, and in case of a potential development, the municipality has purchased land there for ecologically valuable green space provision. This approach supports the implementation of the planned extension to the rapid transit in the medium to long-term, despite the costs it may bring with it.

Environmental considerations

The city of Bad Homburg has developed ISEK with various strategies for a 2030 vision. These strategies are currently being implemented, which will be followed by an evaluation of progress. On the basis of ISEK, the intention is not necessarily to enable denser settlements, as this could be done rather selectively by adding floors on existing buildings. ISEK as an integrated concept has the potential to provide much more in terms of dealing with surface sealing with a focus on heatwaves and floods. From this perspective, ISEK can be an overarching instrument to ensure new settlements are built in a climate-friendly way and old settlements are improved.

Apart from ISEK's potential to encourage climate-friendly interventions, the legal frameworks based on the Federal Building Code and Building Law precisely define the processes of environmental impact for each construction and compensation measures. However, currently, going beyond the legal standards is becoming more and more important: *"With every project we initiate here, we think about compensation and we try to design it in such a way that it*

is not just a mathematical compensation, but a compensation that also benefits people who live there and the nature" (Interview 4, 2020). The motivation for adaptation measures–such as green roofs, building orientation, and a well-functioning drainage–stems from the viewpoint that every construction brings a potential environmental risk. However, it would be beyond municipal regulation when developers choose not to use environmentally-friendly construction materials.

There are several important cases regarding environmental considerations, particularly related to flooding. First, Am Hühnerstein in the Ober-Erlenbach neighborhood is a development area that faces flood risk. This risk was mitigated by a large multifunctional green space allocation with high social value (e.g. park and playground) and ecological value (water retention basin, in line with the Federal Water Act). Second, given the town's morphology which stretches in the northwest-southeast direction following the main direction of the streams, building orientation is an aspect that is approached with extreme care, so that there is no blockage against the cold air flow circulation, and the high air quality can be preserved. Third, the town has had benefited from simulations for both heavy rain and flooding events for the entire town. With that it could be decided whether a small-scale preventive measure helps manage the outcomes of heavy rain or flooding. This includes a consideration of cascading effects, e.g. power boxes are made flood-proof.

The reason why flood-related issues are considered extensively is because of the flood-sensitive areas in the entire town. Due to topographical reasons, the old core of Bad Homburg is a flood-sensitive area that would act like a retention basin in the case of heavy flooding. Also, during the severe flooding in the Ober-Erlenbach neighborhood, basements and large fields were under water. Flood-proofing and flood damage recovery have implications on municipal households. Financial decisions require a careful investigation: The costs of flood-proofing may be too high in comparison to damage recovery costs for impacts that are less intense. In that case, standard prevention and recovery measures can be financially more sensible than a high-end flood-proofing.

There are several key aspects regarding the urban green in Bad Homburg. Bad Homburg has a network of approximately 55 kilometers of streams accompanied by green spaces which are intended to be kept unimpaired. In addition to flood risk reducing functions of urban green, as set by ISEK's agenda, the town intends to improve green space connectivity. Moreover, there exists an open space and landscape concept in order to continuously monitor the key flora and fauna of each neighborhood. Additionally, there are efforts in the direction of land recycling and unsealing, e.g. a fully sealed commercial area was

demolished and converted into residential block perimeter with ideal residential densities and green space.

Financial resources and capacities

During the time of the interview, it was mentioned that the pandemic altered the municipal household conditions dramatically, caused trade tax losses and further expenses. But in general, the town is in a comfortable financial situation due to high trade tax and subsidies from the federal and state government (for instance, water renaturation and subway extension are costly processes for which the town receives subsidies). It was underlined that such initiatives are not dependent on the availability of external subsidies (e.g. stream renaturation), and the town has the financial capacity to realize these from its own budget when necessary. This approach is also in solidarity with other municipalities which might be in more urgent need for state subsidies. *"Urban planning is an important political instrument,"* and it provides the basis for politics to approve spending (Interview 4, 2020). Monetary concerns are ideally not an initial limitation when taking on a project, as the first approach is purely technical with a vision for the benefit of the greater good.

Moreover, the town commits to environmental initiatives such as taking part in the *Hessian Towns for Climate* network or committing to climate adaptation measures such as promoting green roofs and building orientation, as well as open space and landscape concept, despite the lack of legal imposition. All these commitments are at times quite costly, but a proactive approach in developing these concepts pays off in getting state subsidies in a less complicated way: since the strategies are already drafted, they just have to be submitted and do not have to be developed from scratch.

It can be said that the dual inner development has always been on Bad Homburg's urban development agenda and is also implemented, perhaps not under this terminology. The municipality purchases land not only for construction, but also for unsealing purposes, pointing to a holistic management approach to finances, construction, and green provision. There are different sources for the budget with no separation for allocation and spending: *"The money is taken from what we have, or it is requested and then we spend it on a resilient planning, on a planning that is not only densification, but that is environmentally just. We are also quite proud of that"* (Interview 4, 2020).

Local politics and citizen's views

The politics and citizens count as the most important actors in planning and the two main partners of municipalities. The debates around densification can be a good example to illustrate the relationship between politics and citizens. The acceptance for inner development, especially in the form of densification, is rather low, since the private property

owners have different interests than technical agendas, and they will not be willing to sell their properties unless they need to (low interest rates cause more investment on land, as also mentioned in Interview 5, 2020; Interview 6, 2020). Therefore, this opinion resonates in the political willingness in setting agendas.

The acceptance for change is generally low. Bad Homburg is a town which offers a very high standard of quality of life and a degree of sense of entitlement is to be expected. It proved politically challenging to convey that this does not align in the long run with sustaining the quality of life. The struggle is that, if the residents do not want any change to a point where improvement is not possible, then stagnation is inevitable. For instance, there is immediate reaction if a tree had to be cut down for a water renaturation project. In such cases, the projects might have to be paused until the politics successfully communicates the inevitable tradeoffs with citizens. Another recent discussion was the potential extension of subway line to ease the traffic congestion, which received a rather strong resistance.

Within the framework of ISEK, the town has been proactive for the participation processes. The goal was to proactively reach out to underrepresented target groups, such as young people, lower-income groups, and people with disabilities. In the case of ISEK, the visions for the town are to be communicated with every resident; however, *"people are not suddenly more satisfied with what is happening because you have informed them beforehand"* (Interview 4, 2020), emphasizing the distinction between *being informed* and *co-managing*. The town is currently working on developing a public participation guideline which in principle aims at more citizen power and co-management.

In-house capacities and cooperation

Regarding in-house capacities, one shortcoming is the lack of a statistics office. Normally, the data is collected for specific sectors and then put in use in planning in addition to the data provided by the Regional Association. In general, the cooperation with the Regional Association is found very beneficial. The tool for inner development (the register of gaps between buildings) is also a beneficial database, but it cannot be readily put in use because it is based on aerial images and requires verification from municipalities. A further procedure based on the tool could be a design proposal for a given area, so that it could be communicated with the residents on a visual basis how a concept or a plan would actually look like. Nevertheless, the expected and actual benefits of a potential gap analysis require a careful consideration, because unless there is a momentum for change, the resources put into this sort of monitoring might not bring the expected outcomes (in this case: inner development mainly through densification).

Furthermore, the minimum density values for new residential development within the framework of the Regional Plan is that it does not always work as a one-size-fits-all prescription, because some neighborhoods have a village-like character where high densities are not in harmony with the already existing built environment. In such cases, an agreement has to be reached with the District Authority, which is also ensured by a well-functioning cooperation.

This could be considered as a counterargument that there is not necessarily a conflict between federal and state-level strategies and local-level implementation: *"The federal and state governments leave us enough room for interpretation to actually do what we think makes sense"* (Interview 4, 2020). On the contrary, it is stated that the federal and state-government's offers are not always exploited to the full extent. For instance, during the asylum seekers influx in year 2015, not enough local resources were tapped, and the city administration of Bad Homburg had to quickly purchase properties with affordable housing, renovate those to basic standards, keep their ownership, and rent the apartments cheaply. Given the financially comfortable situation of the municipality, these actions could be taken without external intervention and as an immediate response but tapping external resources could have been beneficial.

Social institutions and organizations are mentioned as further significant partners. The informal aspect of communication with current and new partners is not unimportant: An open dialogue and exchange of ideas at eye level, even before ideas become official projects, safeguard transparency.

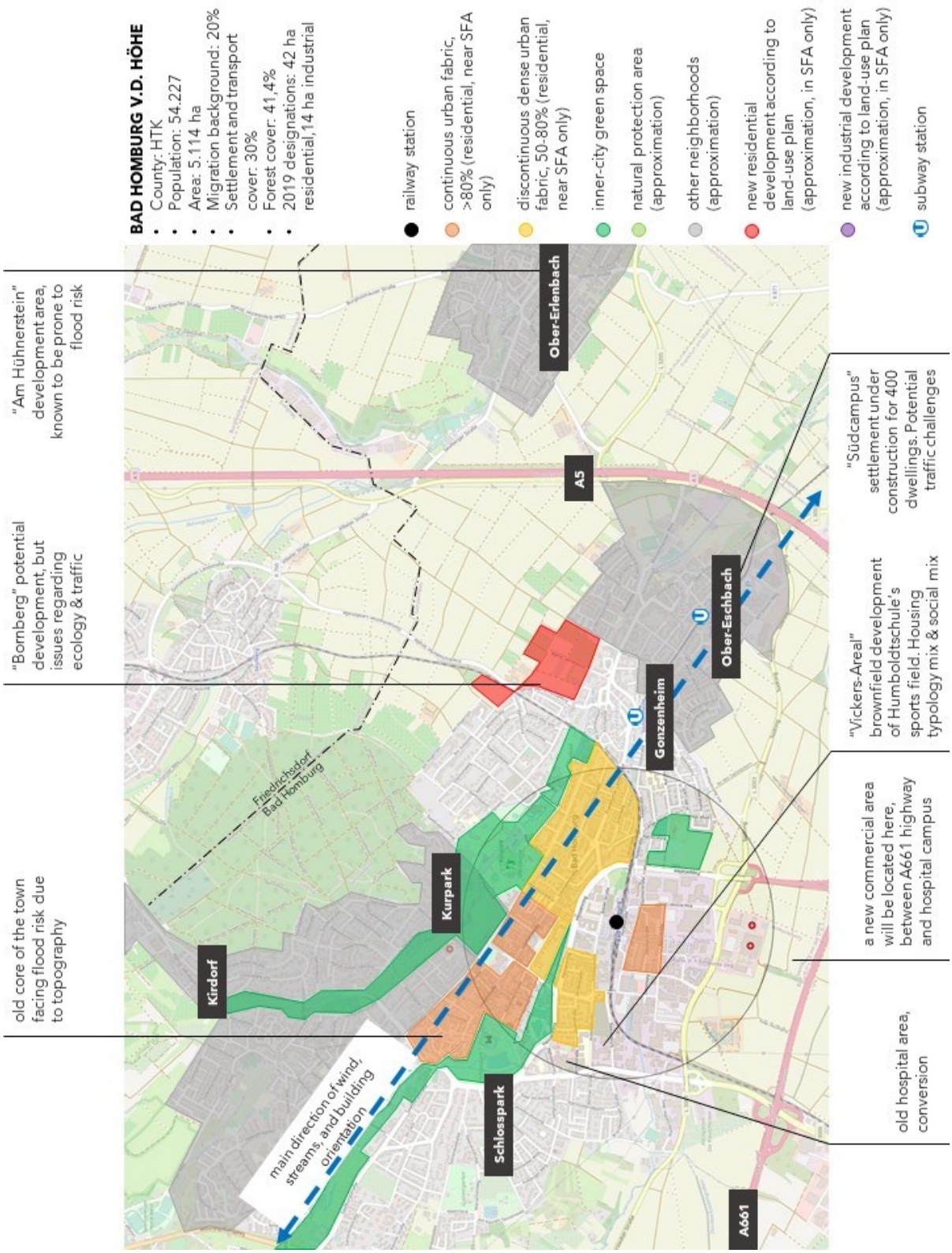


Figure 4.10: Key information on Bad Homburg recorded on OpenStreetMap (own illustration).

4.4.2. Spatial focus area

As the comparison between the current land-cover of Bad Homburg and the aerial images of 2006 shows, the change in the built environment in the spatial focus area has been relatively low, and mainly for non-residential uses. On the open land at the southern side of the railway, the Hochtaunus General Hospital campus was built. The buildings appearing in the area between the hospital and the train tracks after 2006 have a predominantly commercial character, such as a new bank building and additional buildings for the companies. A green patch in this area was converted into a parking lot. Additionally, the area adjacent to the train tracks to the south was previously a parking lot, but it was redeveloped now with a multistory parking house, a rental mailbox service, various accommodational buildings, buildings for software and consultancy companies were provided. At the northern side of the tracks, there has been selective and small-scale alterations in the built environment. This includes several new single-family houses and one housing complex of four multistory blocks, in addition to commercial spaces such as the shopping mall (Figure 4.11).

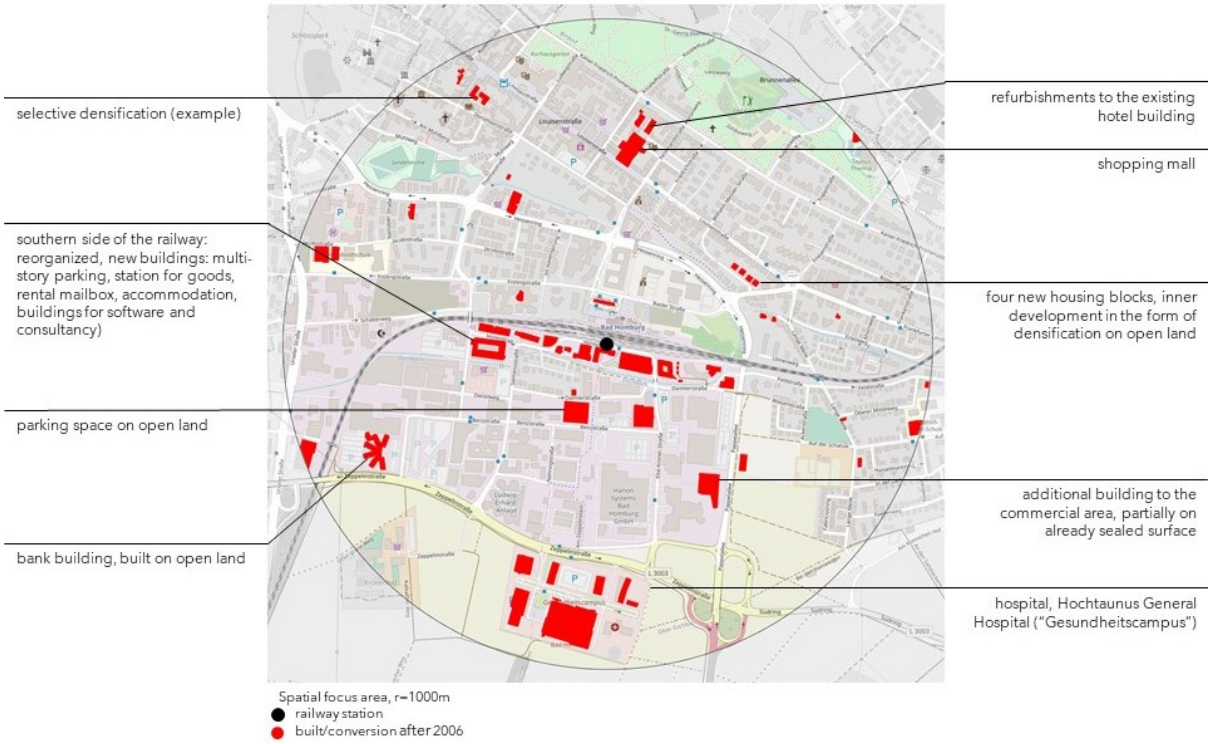


Figure 4.11: Changes in the spatial focus area in Bad Homburg since 2006 recorded on OpenStreetMap. Analysis done by visual comparison of maps and crosschecked based on interview data and internet research. There may be unintentional flaws in the illustration (own illustration).

Green space parameters

In Bad Homburg, the total vegetation cover (including recreation, agricultural fields, woods, and flowing water) amounts to 21 per cent of the spatial focus area. Both large parks, Kurpark to the north and Schlosspark to the northwest, fall partially within the spatial focus area, with a coverage of nearly 10 per cent. A small part of the nature protection area in the

south falls also within the spatial focus area, adding to the high connectivity of vegetation cover (Figure 4.12). In terms of green space distribution, the edge density of recreational green spaces is around 42 m/ha, which represents a moderately even distribution. This is because the green spaces in the spatial focus area are not very dispersed and rather central and large. This reflects itself in the proximity analysis that the settlements located at the southwestern part of the focus area are not well-served by the green spaces, as only 67,33 per cent of buildings are located within the catchment areas of recreational green spaces. However, it is important to note that the land-use at the area of lower proximity is predominantly industrial, and the green cover (Field 5a, equestrian facility) that is adjacent to it does fulfill a recreational function. Since this area is neither classified as an agricultural field nor as settlement green space, it was not included in the proximity calculations (Figure 4.13).

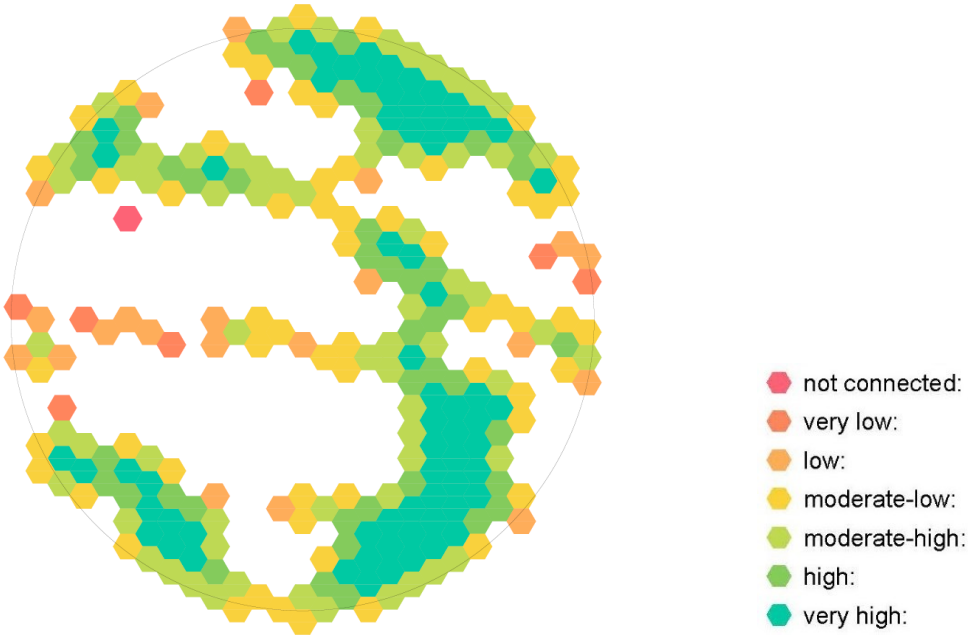


Figure 4.12: Connectivity of the landscape cover in Bad Homburg's spatial focus area (own illustration).

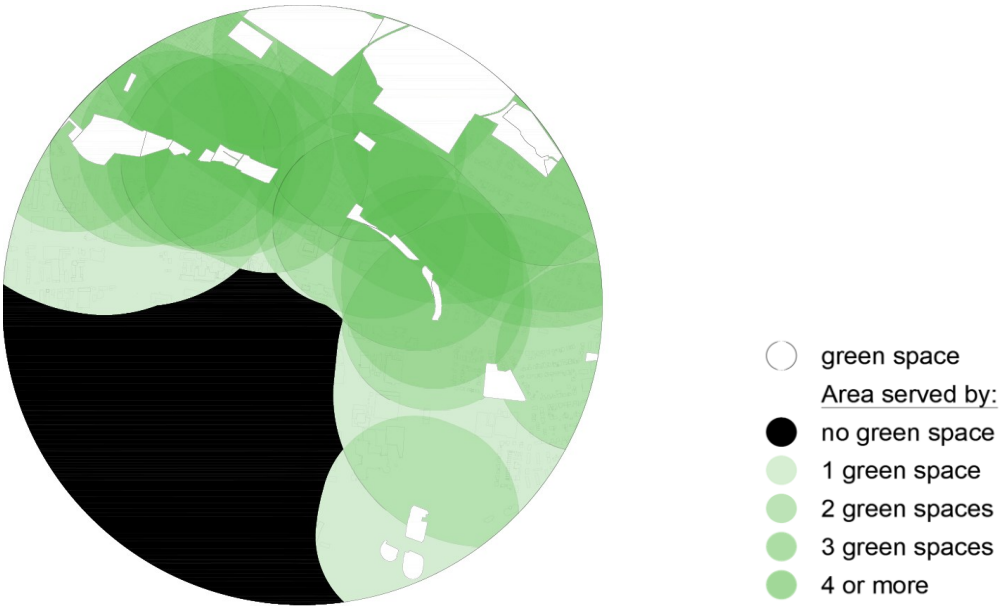


Figure 4.13: Proximity of the recreational green cover in Bad Homburg's spatial focus area (own illustration).

Social and ecological value

During the field visit, 25 vegetation covers were observed. 8 open spaces were found to have high social value (Fields 1, 8: sports field; Field 5a: equestrian field; Field 8a: playground; Fields 10, 14: parks; Field 12a: streets including roadside green; Field 15: schoolyard); whereas 7 green spaces were found to have no social value (Fields 3a, 4: agricultural fields; Fields 7, 11a: narrow roadside green; Field 11b: gaps between buildings private property; Field 11c: predominantly parking lot). The remaining areas are predominantly open green covers, roadside green patches, or agricultural areas that have an onsite recreational compensation function for adjacent settlements (e.g. for taking the dog for a walk, etc.) and have either low or medium social value. Three smaller green space areas (Fields 9a, 14a, 14b)—which are present as green cover in maps and thus included in the green cover analysis—were observed to be inaccessible parts of private properties. These are therefore not categorized for social and ecological value. Another green space (Field 11d) could not be found onsite, as it is most likely already densified. In terms of ecological value, 8 of the observed green spaces have low (mainly the ones with rough/mown grass cover in addition to agricultural fields) and 11 have medium (mainly shrubbery) value. Inner-city forests (Field 9, as a green connector) and shrubbery with near-natural water components (Field 14, Kurpark) have high ecological value. In terms of open space categories according to their intended purpose and accessibility, apart from a few areas (Fields 2: horticulture; Field 9a: courtyard; Field 11b: private property; Field 13: private garden; Fields 14a and b: courtyards), the majority of the green cover allows unrestricted public access, and a few others are conditionally accessible (e.g. equestrian facility and schoolyard) (Figure 4.14, Figure 4.15, Figure 4.16).

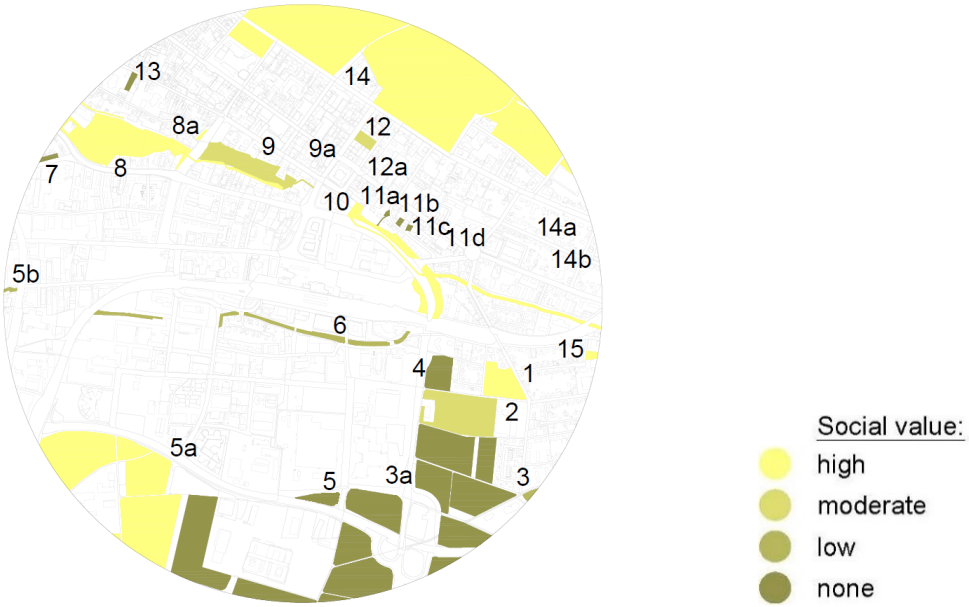


Figure 4.14: Social value of the green cover in Bad homburg's spatial focus area (own illustration).

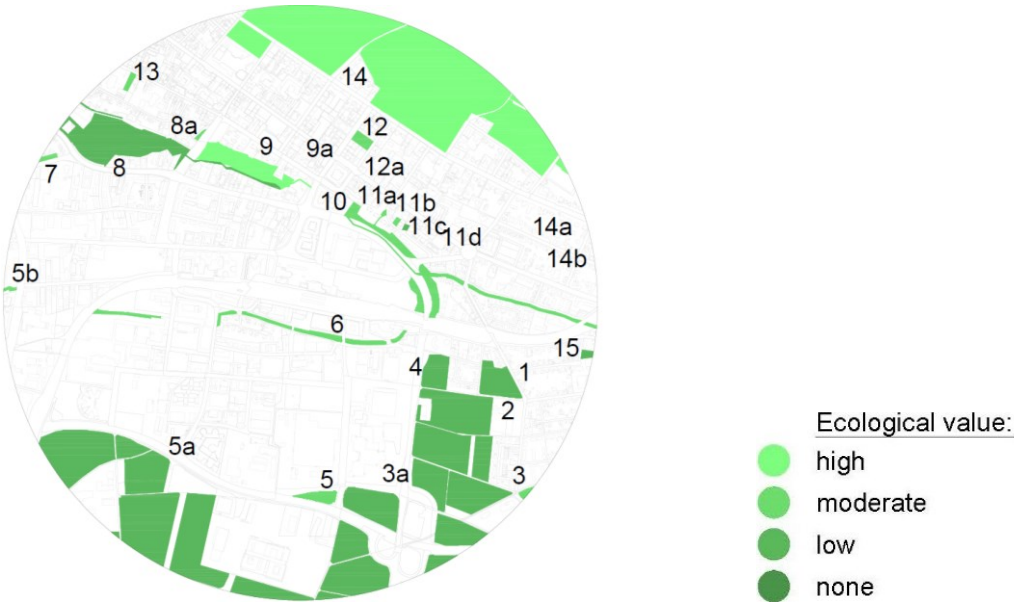


Figure 4.15: Ecological value of the green cover in Rüsselsheim's spatial focus area (own illustration).

Figure 4.16: Field 6 (top left): one of the streams, inaccessible but has high ecological value; Field 8 (top right): a part of the Schlosspark; Field 12 (bottom left): one of the many parks in the city; Vickers-Areal (bottom right): the conversion area for residential development (own photos).

4.5. Main-Kinzig-Kreis: Maintal

Maintal is an intermediate-order center and the second most populous town in the Main-Kinzig county after Hanau. A quarter of the town's population has migration background, and the proportion is steadily increasing. It covers an area of 3.241 hectares, one-thirds of which is used for settlement and transport purposes. The recreational land-use and forest cover is relatively low (respectively 2,9 per cent, slightly above the conurbation average, and 17,0 per cent, quite below the conurbation average), while the agricultural fields cover approximately 45 per cent. In 2019, 195 housing units were completed in Maintal. In the land-use plan, 15 hectares are designated for residential and 36 hectares for industrial settlement development.

Maintal is situated at the northern side of the Main river and has four main neighborhoods that are physically close but separated from one another by agricultural fields and/or transport infrastructure: Bischofsheim on the west, closer to the Maintal West train station; Hochstadt to Bischofsheim's east, predominantly with residential character; Wachenbuchen at the northeast, a detached residential settlement surrounded by agricultural fields; and Dörnigheim to the south, closer to the Maintal Ost train station. There is forest cover to the east and west. The open fields to the north have predominantly agricultural character with environmental protection zones. The train tracks and the highway A66 run in the east-west direction. The area between the two has an industrial and commercial character (Bischofsheim and Dörnigheim). In Dörnigheim there is an additional industrial area to the east. The spatial focus area involves mainly parts of Dörnigheim and a small area of Hochstadt (Figure 4.17).

4.5.1. Planning from a green space perspective[37]

Recent settlement development

In the past twenty years, settlement development has clearly been more inner development than outer. The majority of binding land-use plans facilitated conversion from commercial/industrial to residential. One exception was the new neighborhood in Hochstadt that was built after 2006 and developed on an outer open space. This was an area where the county administration intended to build a hospital about thirty years ago, which was later negotiated for a residential development instead. The other exception is the Berghof area in the Wachenbuchen neighborhood. The area was formerly a gardening area with sealed surfaces that appeared on the land-use plans as agricultural field. So, this was technically an outer development with no further soil sealing. An important settlement development which is

[37] This subsection is developed on the basis of Interview 1 (2020) unless otherwise stated.

about to start soon is the intermunicipal commercial area bordering Frankfurt (binding land-use plan already completed). It is anticipated that this development will bring impacts beyond the town's borders, especially because of the traffic infrastructure.

At the moment, there is densification potential especially in residential areas of the 70s and 80s. Since these are large housing estates with large open spaces, they could be densified without losing too much green. Yet, densification is dependent on the availability of space, and the inner development potential through densification is finite. Especially for the case of Maintal, an outer development potential is also limited due to multiple restrictions (flood protection, nature protection, agricultural fields, forests, high voltage infrastructure, and barriers such as railway and highways). Because of that, inner development is higher in comparison to other middle-sized towns with comparable characteristics. Generally speaking, in meeting the housing demand, politics aligns with ISEK's goal to achieve moderate densification: *"densification is desired, but only to a tolerable degree,"* because *"the growth in the already existing stock is very high"* (Interview 1, 2020).

Within ISEK, the town brought together concepts and frameworks for open spaces, infrastructure, and settlement development both for the inner and outer area. Adding to the aspects of integrated urban development, it was mentioned that the compensation measures are taken into account with each development as per the Federal Building Code (dual inner development was not familiar as a terminology). An example beyond legal frameworks within the context of integrated approaches is the rededication of one inner-city playground in 2015 to quickly provide refugee accommodation. Integrated approaches might have played an enabling role for the maneuver to resolve conflicts of objective.

Environmental and other impacts

Maintal is bordered by the Main river to the south and there are also several other streams within its borders. Currently there is no settlement development directly at the riverside. Because the town's historical center is located quite close to the river, the Dörnigheim neighborhood has a flood protection wall. The risk of impairment of water cycles caused by new construction and soil sealing is found concerning. Recently, a daycare center was built on the main direction of flow of rainwater, which required intensive preventive measures against potential damages resulting from heavy rain. Heavy rain in general is a concern that limits extreme densification. Another environmental challenge has been soil contamination resulting from settlement development. Recently, the development of a commercial area had to be restricted because of contamination, which was not only an environmental problem, but also a high cost factor. The city administration is also currently resolving the illegal disposal of contaminated construction materials at the riverside.

The environmental objectives within legal frameworks emphasize increasing the green area ratio (Stadt Maintal, 2020). This involves using informal tools, e.g. the encouragement campaign for private housing and front gardens. The front garden competition was organized by the city administration for homeowners to green their front gardens. However, homeowners often choose to keep this area paved for driveway and parking. It is noteworthy that although the small-scale green ratio in residential settlements–such as front gardens–are not readily detectable within land-cover data, these spaces might in fact add up to large sums with environmental benefits.

Provision and maintenance of green space

In Maintal, there are not many recreational green spaces within the settlement areas and these are rather located on the outer area. The town is part of the Hessian Ministry of Economy's urban development program *Growth and Sustainable Renewal* (*Wachstum und nachhaltige Erneuerung*), formerly known as *Future Urban Green* (*Zukunft Stadtgrün*). This is a state-level urban development promotion (*Städtebauförderung*) allowing for external subsidies. The town also makes use of internal financial resources. Depending on the situation, the municipality and the politics provide the necessary budget allocation for the provision and maintenance of green spaces. As far as the external resources are concerned, the *Growth and Sustainable Renewal* program is the significant one. It is noted that benefiting from these support programs require a lot of effort and it is time and work-intensive to meet the requirements of highly elaborate preparation processes, which may be the reason why these subsidies are not fully used.

Citizens, politics, acceptance

From the perspective of the planning department, the role of the local administration within the relationship between politics and citizens has various inherent complexities. The politics sees the municipality as the representation of citizens, while the citizens see the municipality as the executive of politics. However, city administrations not only fulfill these one-directional roles but also have further legal and technical responsibilities.

The issue of *acceptance* is given as an example to illustrate these complexities. During the refugee shelter provision in 2015, residents were aware that this was a humanitarian emergency and there were not many opposing voices following the decision to turn a low-value green space to accommodation for those who were in immediate need. However, the opposing voices against the daycare center that was to be constructed on a green space were louder, not only because the construction was planned on a green space, but also because of the traffic problems it would bring with it. In cases in which tradeoffs are inevitable (e.g. refunctioning of a green space with ecological value into a daycare center

with social value), acceptance cannot be assumed as a simple matter. Densification, as a process of tradeoffs, is no exception: *"[In Maintal] there is hardly acceptance for densification in general, and no acceptance for densification on green space"* (Interview 1, 2020).

The level of acceptance for densification is likely to relate to the existing building stock typology. The views on densification in the already existing building stock as in the Section 34 of the Federal Building Code[38] could be different. Although no big enthusiasm from the direct neighbors is to be expected, densification in the already existing building stock aligns with political agendas and ISEK to promote moderate densification. For a few new multistory buildings, settlement typologies offering large available spaces could be more appropriate in comparison to single-family housing neighborhoods.

The fact that the national goal to reduce daily open land take cannot be reached might be indicating a procedural flaw either with the federal instruments or with the processes of urban land-use plans. The contradiction is that, even though the federal instruments impose inner development, the regional-level arguments emphasize the need for outer development, as inner development alone would fall short of meeting the housing demand. All in all, the acceptance for higher densities are rather low which might be the reason why the instruments are sometimes contradicting and cannot guarantee the desired outcome. A strategy could look into unfavorable distribution of available space: *"there are places where we are fighting to ensure that space gets used at all … the areas are left fallow, residential buildings stand empty, commercial areas become meadows. Perhaps the densification of open, empty or underused areas could be more sufficiently regulated by the state"* (Interview 1, 2020).

In-house and further collaboration capacities

Public participation is an important aspect of municipal planning practices. The municipal administration has a separate department called *Voluntary Agency Maintal* (*Freiwilligen-Agentur Maintal*) for citizen involvement and co-management through workshops, educational sessions, and meetings. The goal is to ensure that the involved parties work together with one another. Municipal co-management also includes associations and social institutions that are significant in citizen's daily life.

In terms of external collaboration, the Regional Association is seen as a key partner. It is mentioned that the Association's land-use overview is quite well-developed. Though this alone would not suffice in steering a sustainable development, because the towns should

[38] Section 34 regulates the development in the inner areas where there is a preparatory land-use plan but no binding land-use plan. Construction is permitted if it fits into the surrounding built-up structure (Keller, 2012).

primarily be capable of fulfilling their own responsibilities and also make use of other services. For instance, the quite bureaucratic processes to update the land-use changes at the regional-level could be optimized. Although the municipality would have liked to contribute to procedural efficiency, this is not possible due to suboptimal resources and capacities. Regarding further collaboration partners, it is perceived quite beneficial that the Regional Association takes the lead and organizes the meetings for the heads of building authorities for information exchange and learning from one another. Additionally, the heads of building authorities in Main-Kinzig-Kreis are in regular exchange. It is mentioned that the *German Association of Cities* (*Deutscher Städtetag*) and the *German Institute of Urbanism* (*Deutsches Institut für Urbanistik*) are valuable open knowledge repositories. The town also partakes in the *Local Mobility Working Group* (*Arbeitsgemeinschaft Nahmobilität Hessen*).

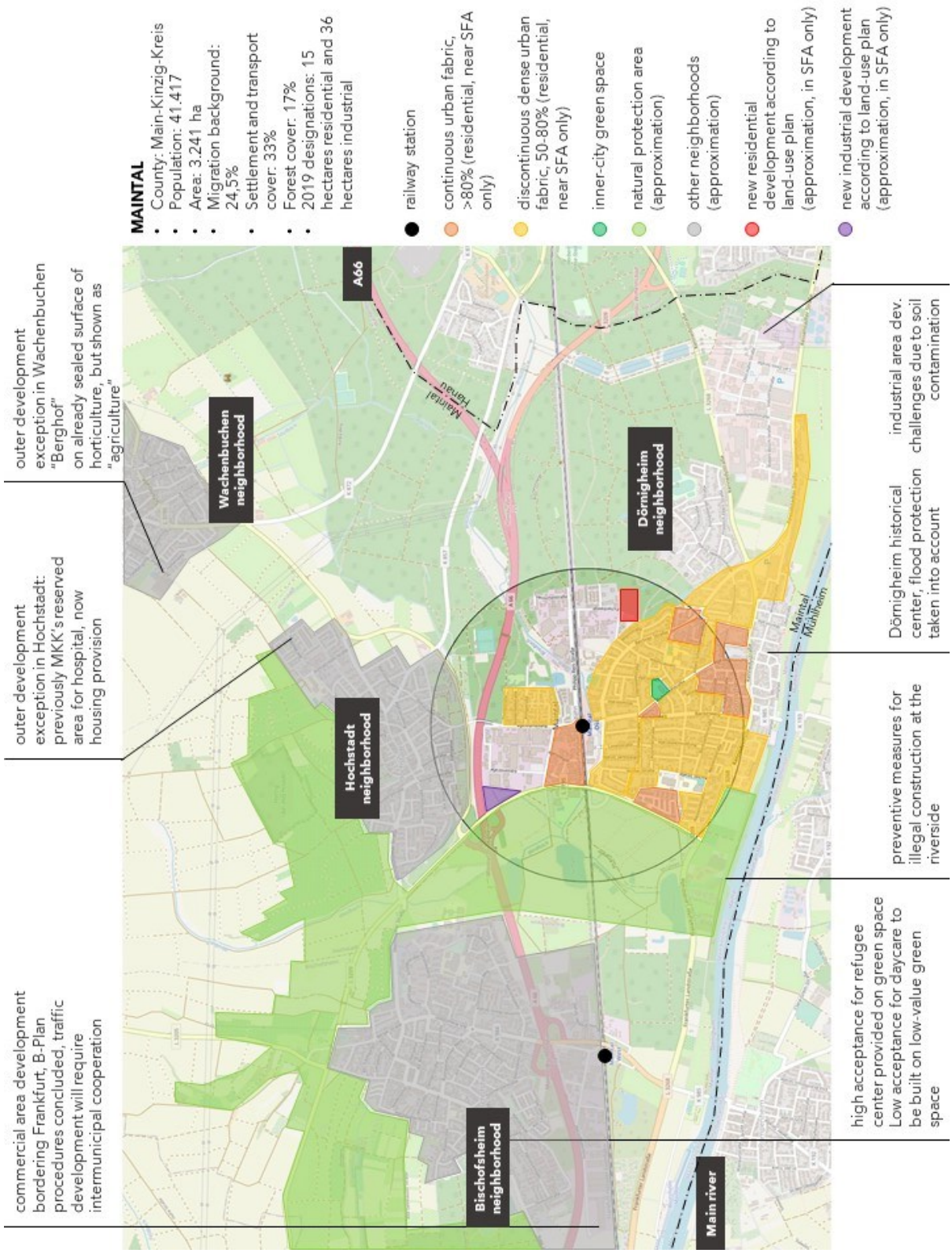


Figure 4.17: Key information on Maintal recorded on OpenStreetMap (own illustration).

4.5.2. Spatial focus area

Over the last fifteen years, the change in the built environment in Maintal's focus area has not been too intense. At the southern side of the train tracks, housing provision was often in the form of small-scale selective inner development and densification where available. Larger changes were at the retail areas directly at the train tracks and an indoor sports hall. Apart from that, two large areas were converted for multistory residential use. It can be seen that a new traffic development included two new bridges over the train tracks and the connection highway to the north. A housing development emerged in close proximity to the train station at the northern side of the tracks (Figure 4.18).

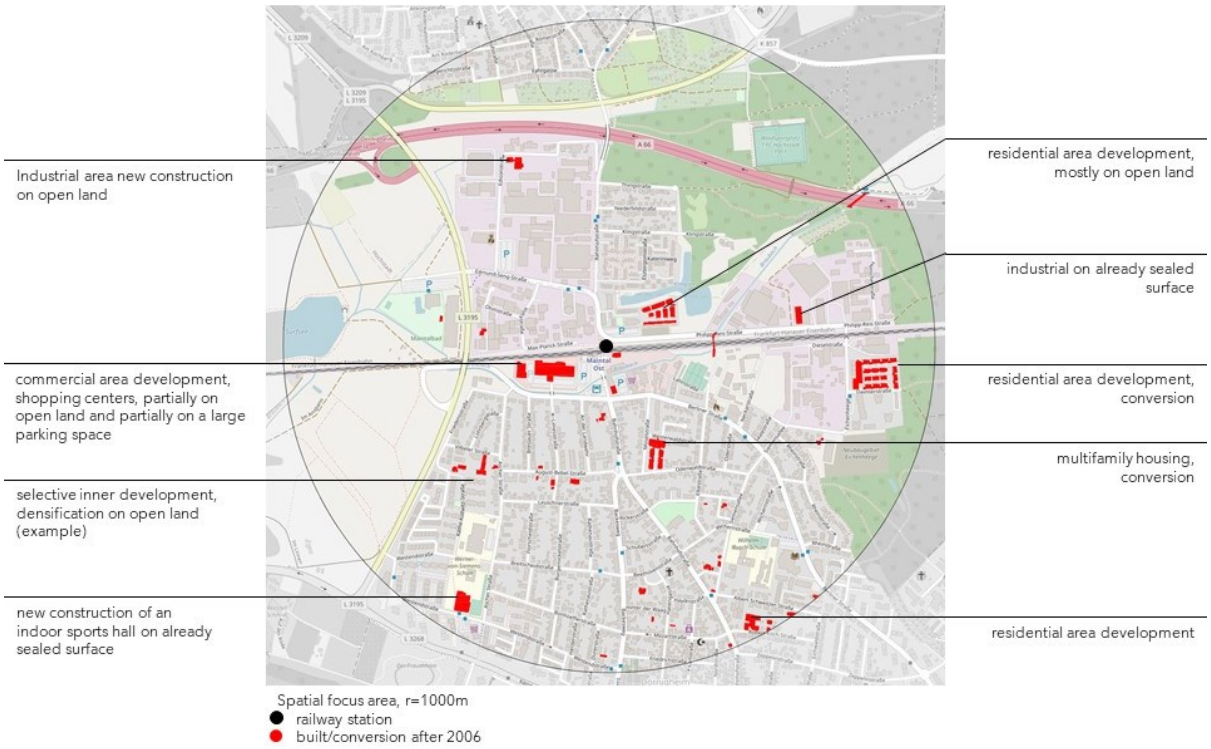


Figure 4.18: Changes in the spatial focus area in Maintal since 2006 recorded on OpenStreetMap. Analysis done by visual comparison of maps and crosschecked based on interview data and internet research. There may be unintentional flaws in the illustration (own illustration).

Green space parameters

About 31,32 per cent of the focus area is covered by vegetation, including nature protection areas to the north and west, on both sides of the A66 highway. The green cover located within settlements (sports, recreational, and leisure functions) covers 7,22 per cent of the focus area. The distribution of the settlement green is slightly lower for a middle-sized town with an edge density of 33,10 m/ha. The spatial configuration of open green spaces shows that these few large patches are rather clustered than distributed. The main ecosystem connector is the Braubach stream in the east-west direction. Without it, the connectivity would be significantly lower (Figure 4.19). When the proximity of sports, leisure, and

recreational green spaces is considered, it is found that 93,11 per cent of all buildings in the spatial focus area are located in catchment zones of green spaces, and only a small area to the southwest is underserved. Although the settlements at the eastern side of the spatial focus area are rarely served by multiple green spaces, the chance for compensation provided by the availability of peripheral open spaces is high (Figure 4.20). The same could be the case for the underserved areas in the south since these are located closer to the Main river.

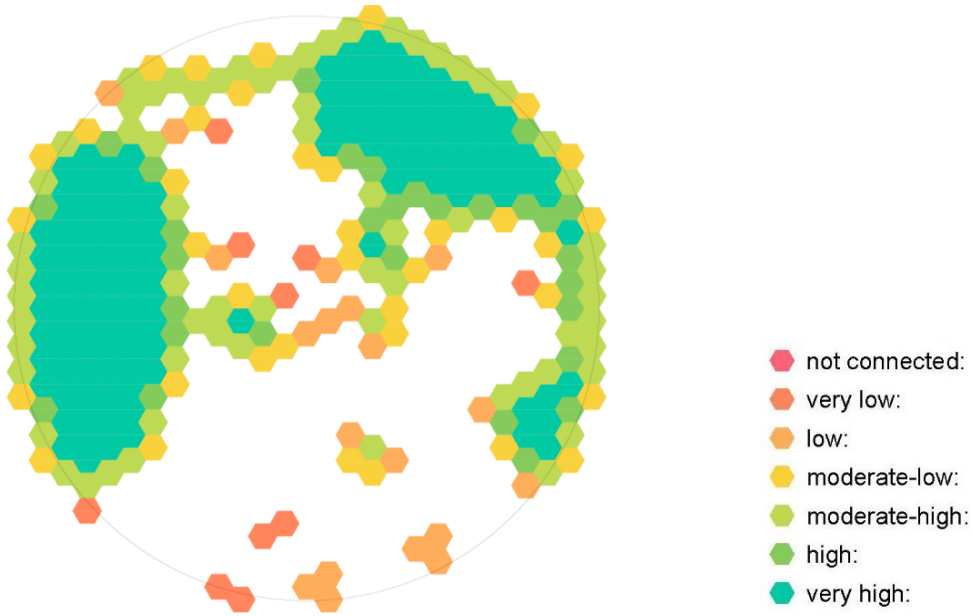


Figure 4.19: Connectivity of the landscape cover in Maintal's spatial focus area (own illustration).

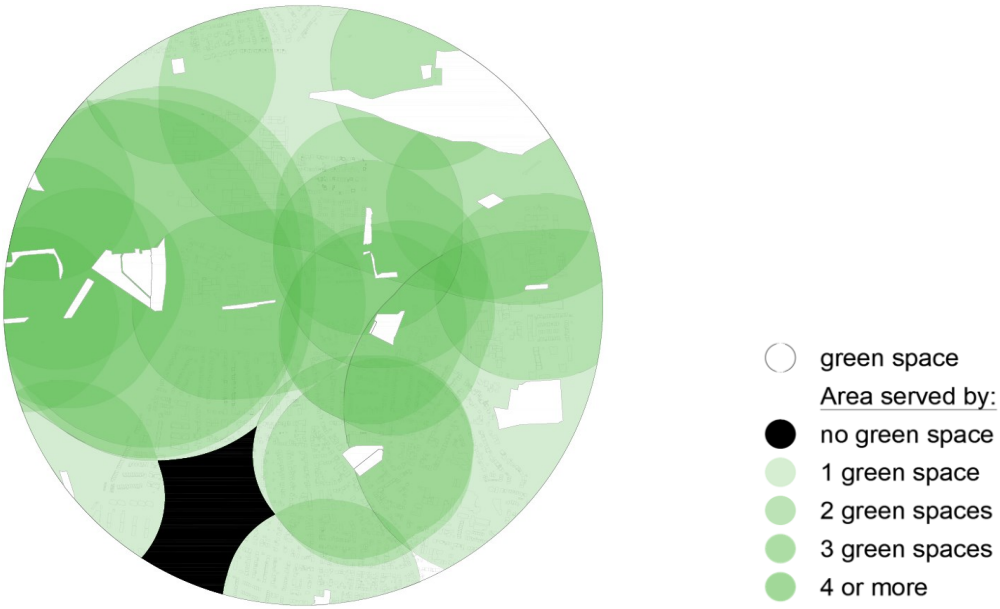


Figure 4.20: Proximity of the recreational green cover in Maintal's spatial focus area (own illustration).

Social and ecological value

In the spatial focus area of Maintal 20 green areas were observed. Around 9 of these spaces were found to have no or low social value (Field 1: roadside green; Fields 2, 5: densification; Fields 4, 16: private, inaccessible; Field 7: horticulture; Field 11: construction site in preparation; Field 13: green buffer; Field 20: construction site). This is countered by 7 high social value green areas (Field 3: cemetery; Field 6: park and playground; Fields 8 and 19: community gardens; Fields 10, 12, 15: sports areas and swimming pools). In terms of ecological value, two of the observed green covers had low (rough grass/mown grass) and 11 had medium (mainly shrubbery in combination with conventional and ecological agriculture) ecological value. Large nature protection areas to the east and northwest (Fields 9, 14, 15, 17) have relatively high social values in addition to their high ecological value, with the land-cover types forest and shrubbery in combination with waterside zones and ecological agriculture (community gardens). As far as the open space classification of green cover is concerned, it was found that low or no social value areas are also private open spaces that are not publicly accessible. Most of the green areas with high social value are conditionally accessible open spaces (community gardens, sports areas). Green covers with high ecological value allow public spaces with no access restrictions (e.g. nature protection areas) (Figure 4.21, Figure 4.22, Figure 4.23).

Figure 4.21: Social value of the green cover in Maintal's spatial focus area (own illustration).

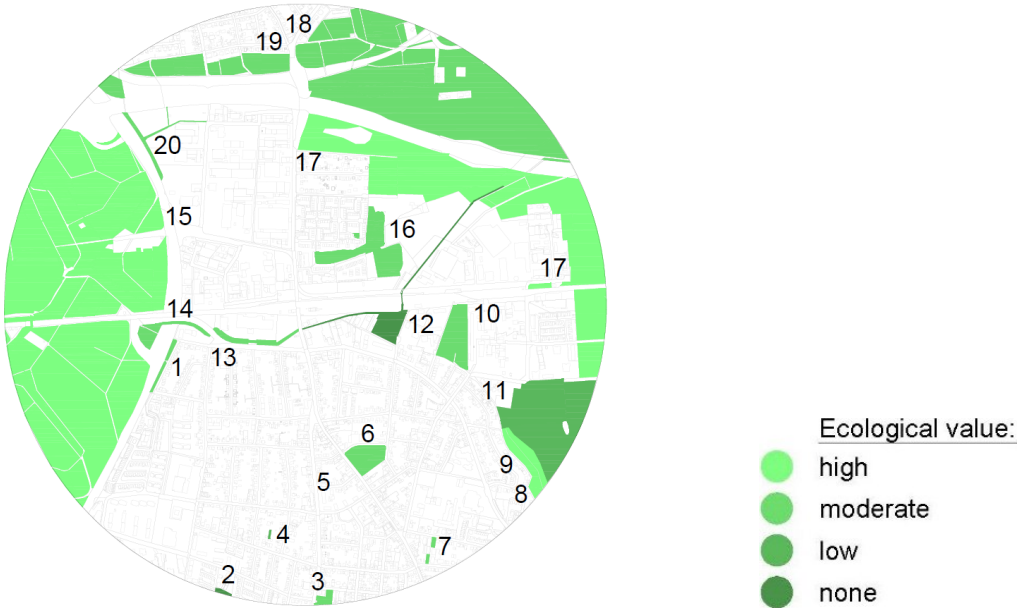


Figure 4.22: Ecological value of the green cover in Maintal's spatial focus area (own illustration).

Figure 4.23: Schwanengasse/Kennedystraße (top left): example of inner development; Field 6 (top right): one of the few inner-city parks; Field 11 (bottom left): outer development; Field 14 (bottom right): peripheral open spaces frequented for compensation (own photos).

4.6. Main-Taunus-Kreis: Hattersheim

Hattersheim is the third most populous town in Main-Taunus-Kreis with a relatively stable population. 20,3 per cent of the town's population has a migration background. The town has an area of 1.580 hectares, which is among the smallest in the conurbation. About 41,7 per cent of the town's land is covered by settlement and transport. Forest cover and recreation are among the lowest in the conurbation, but the Regionalpark compensates this. A highlight for the town is its steady increase in employment provision over the past years. The land-use plan in 2019 designated 36 hectares of new residential development and 10 hectares of new industrial development.

In addition to the town's central areas there are two other neighborhoods: Okriftel, a residential/industrial neighborhood to the south and Eddersheim, a predominantly residential neighborhood to the southwest. Hattersheim is bordered by the highway A66 to the northwest that runs parallel to the train tracks, contouring a predominantly residential part of the town's center. Parts of the federal road B40 and the highway A3 border the northern and southern ends of the town respectively. All three neighborhoods, central Hattersheim, Okriftel, and Eddersheim, have industrial/commercial zones. The remainder of the land is made up of agricultural fields and an environmental protection area to the west. Hattersheim is located very close to Frankfurt's industrial neighborhood Höchst (Figure 4.24).

4.6.1. Planning from a green space perspective[39]

Limitations to growth

In Hattersheim, there can be seen a clear separation between inner and outer development in terms of a spatial strategy. Because of the settlement provision pressure, various opportunities for land mobilization had to be considered. In early 2000s, a framework plan for Hattersheim Süd (conversion of the former chocolate factory) was developed for residential and partially commercial functions. Back then, the strategies were not concerned with density, but rather with distribution of use. Hattersheim Süd generated a very rapid development in the surrounding area, including the so-called *mill neighborhoods* (*Mühlenviertel: Urbansmühle, Ölmühle*) alongside the Schwarzbach stream. This area is currently under construction and very densely built.

Hattersheim Süd has been a decisive project in many aspects: The former chocolate factory was abandoned in 1994 which shaped the image of the town as a *chocolate city* and brought

[39] This subsection is developed on the basis of Interview 3 (2020) unless otherwise stated.

the working class. Then, in 2000s, the area was converted into a residential area, which brought various new businesses. In addition to housing, a local supply center was also provided in the Hattersheim Süd area. *"In the past it was always said that the A66 was the border between the rich Main-Taunus-Kreis in the north, e.g. Hofheim, and down below south Flörsheim and Hattersheim, which were rather the poorer or socially weaker communities"* (Interview 3, 2020). It is intended to take advantage of this impulse by providing more social infrastructure, e.g. schools and daycare centers.

Additionally, Hattersheim Südwest is another new development whose initial phases go back to 2000s. As part of an inner development framework plan, this area was developed in phases as an extension to an already existing settlement, with slower paces and lower densities in comparison to today's standards. In Hattersheim Südwest, the core of an existing commercial area was shifted into the newly-developed area. Currently, Innovationspark is being developed. As companies have been choosing to settle in Hattersheim, the image of the town has experienced a positive change.

In the outer area, open fields surrounding the settlements are the conurbation's landscape park and are therefore sensitive areas. Additionally, several agricultural fields fulfill recreational functions as large available open spaces given their close proximity to residential areas. The strategy therefore is to avoid consuming these fields as much as possible. Flood-prone zones of the Schwarzbach stream and the Main river are additional sensitive areas that are to be protected. An additional environmental oncern is contamination, which has been a recent theme during the conversion of an old industrial brownfield (PHRIX) into a high-quality residential area.

The new large development areas designated in the northeast did not have to be mobilized immediately, since the inner development conversion of Hattersheim Süd helped catching up with the housing demand. Another reason for that is the high voltage line there, which requires large buffers as per regulations. With all these limitations, the space available for new settlement development is already quite reduced. Despite the housing provision pressure, no new areas other than the ones given in the regional land-use plan are planned.

Spatial planning processes

One implication of the Section 34 of the Federal Building Code (see Footnote 8) has been that the settlement development is shaped strongly by the investors. Regarding the Section 13a of the Federal Building Code (see Chapter 2.6, Growth management), in the areas where densification opportunities emerged, the binding land-use plans were superimposed on existing land-use plans so that a bit more could be achieved. However, the availability of gaps between buildings in general is quite scarce, and the empty ones are not necessarily

available, e.g. due to private owners' interests. Additionally, the Eddersheim and Okriftel neighborhoods have a village-like character, where densification is intentionally slowed down. Similarly, when multistory housing is constructed in a single-family housing neighborhood, this creates *"resentment"* among the residents there, as *"this is something that perhaps does not quite correspond to the character and also the self-image there"* (Interview 3, 2020). The Section 34 allows for densification decisions to be taken quickly *"at the desk"* (Interview 3, 2020), but a careful consideration of the consequences of these decisions onsite is necessary.

Hattersheim's ISEK is currently underway, the process was delayed due to personnel capacities and other priorities. The most important contribution from ISEK is that it enables tackling unplanned areas as well as the potential in the existing built-up area very systematically. It is found very beneficial that it gives a certain framework to bring together all aspects of the town's overall urban development. These aspects are the ones that are considered in day-to-day planning, but it is important to have an agreed vision and a guidance to reach that. This helps reframe the discussions with investors, e.g. an approved green space concept is a strong argumentation why no development can take place there. Moreover, ISEK proves helpful in estimating, for instance, whether further densification within Section 34 would be tolerable. Since densification is a slow process, it is a challenge to estimate the outcomes of interventions in advance. This would not be the case for outer development, because the number of housing units provided is a basis for determining what services are needed in that area. This can only be figured out in densification once the building permit is granted. The main challenge is that it is possible to *plan ahead* only to some extent: *"How long does a concept remain up-to-date? How much will it be overtaken by developments that one may not have anticipated?"* (Interview 3, 2020).

Municipal household

Recently, the high pressure for residential development has been quite costly for the town's budget but trade taxes counterbalance the spending. For this reason, outer development for commercial areas is unlikely to be given up. A long-term refinancing scenario should ideally look into the costs of social and technical infrastructure and open space maintenance. In the last few years, Hattersheim has been receiving more subsidies in general. Subsidies specific for green spaces have been rather less, but the parks department of the city administration has been very proactive in safeguarding a standard amount of open green space for residents' use within contracts with the investors. A while ago, when the town was under state protection due to a high likelihood of bankruptcy, there were no financial resources available, especially for green spaces due to their high maintenance costs. During this time, several plots of land was for sale, and among these were green spaces. This was stopped

thanks to a citizens' initiative, but the green space maintenance had to be decreased to a minimum and the provision of new green spaces was not sufficient. This is "*very regrettable"* especially in terms of social value and climate adaptation (Interview 3, 2020). Fortunately, the budgetary situation has improved, and the provision and maintenance of green spaces can now be managed under better circumstances.

Limits to infrastructure, responses from key actors

Increased residential density brings increased pressure on existing infrastructure, and green infrastructure is no exception. The town tries to provide new and high-quality green spaces, so that the entire load is not on the existing green spaces. There are different considerations depending on the settlement structure. Multistory housing usually does not provide private green spaces and particularly these neighborhoods should be provided with sufficient public green spaces, while for a single-family neighborhood a playground could be sufficient. Similarly, with denser settlements, additional stationary and moving traffic load could perhaps be reduced by underground garages. The fact that more cars parking tightly on the sidewalk is a topical concern. Moreover, the social infrastructure has also *"reached, if not exceeded, its limits,"* as it is barely possible to find a place at a daycare center or at a sports field (Interview 3, 2020).

The key actors involved are the local politics and the investors, and for the time being, politics itself does not shape the processes as much as the external initiators of development do. Investors approach the city and buy the land, and politics takes political responsibility for it. The municipality's position is mediatory to ensure that the technical and legal frameworks are applied. The local politics is in charge of decision-making by taking the citizens' and investors' interests into account. This ultimately makes politics the most critical actor. Once an entire election campaign focused on a construction area, where there were protests and the politics was then inclined to not move forward with the development. This is an example that in principle, citizens are better heard as powerful players when they unite because it would be politically unaffordable to lose so many votes. From the politics standpoint, it is important to consider the extent to which a development contributes to the benefit of the common good.

Internal and external capacities

The Regional Association's services for its member municipalities are highly appreciated, because otherwise it would not be possible to provide these internally due to personnel capacities. Additionally, the regular exchange the Regional Association enables is very beneficial in terms of both formal and informal knowledge-sharing, which is particularly useful when tackling similar challenges. Due to the highly dynamic phase of current development in

Hattersheim, the attention in day-to-day planning is directed to what is to come and is less concerned with looking back and monitoring. That is why the monitoring reports and tools provided by the Association are very useful. Especially the Strategic Environmental Assessment (*Strategische Umweltprüfung*) is often used by the town to determine whether it is realistic to open a new development idea for discussion at all. The Regional Association's web-based cadaster of gaps between buildings helped indicate where densification potentials were located and where to have a closer look if needed. The information was found very sensitive which could potentially further complicate real estate speculations.

Regarding the federal- and state level goals and local-level implementation, it is mentioned that despite the complexities of spatial planning system it is reliable in that it prevents uninformed decisions at the municipal level, since the municipal plan has to be in accordance with the higher-level plan, which aligns with a development perspective. If that were not the case, the Federal Building Code could allow for any trend to be adopted. For instance, Section 13b of the Federal Building Code is not quite compatible with the national goal to reduce open land take. Despite Section 13b, municipalities have focused on inner development this past twenty years, but the price inflation especially in the conurbation has been the downside.

The financial profiles of the renewal of an old town core, recycling of inner-city contaminated sites and their conversion into residential areas are different to the financial profiles of development on agricultural fields. Municipalities have to address both the actual needs onsite and the strategies of state and federal levels. For the field of construction, municipalities have to respond to demands, e.g. investors invest with the anticipation that the town will continue to grow, while citizens can be skeptical about change. Municipalities' position in these relationships is a critical one, but not without the tools to navigate the processes.

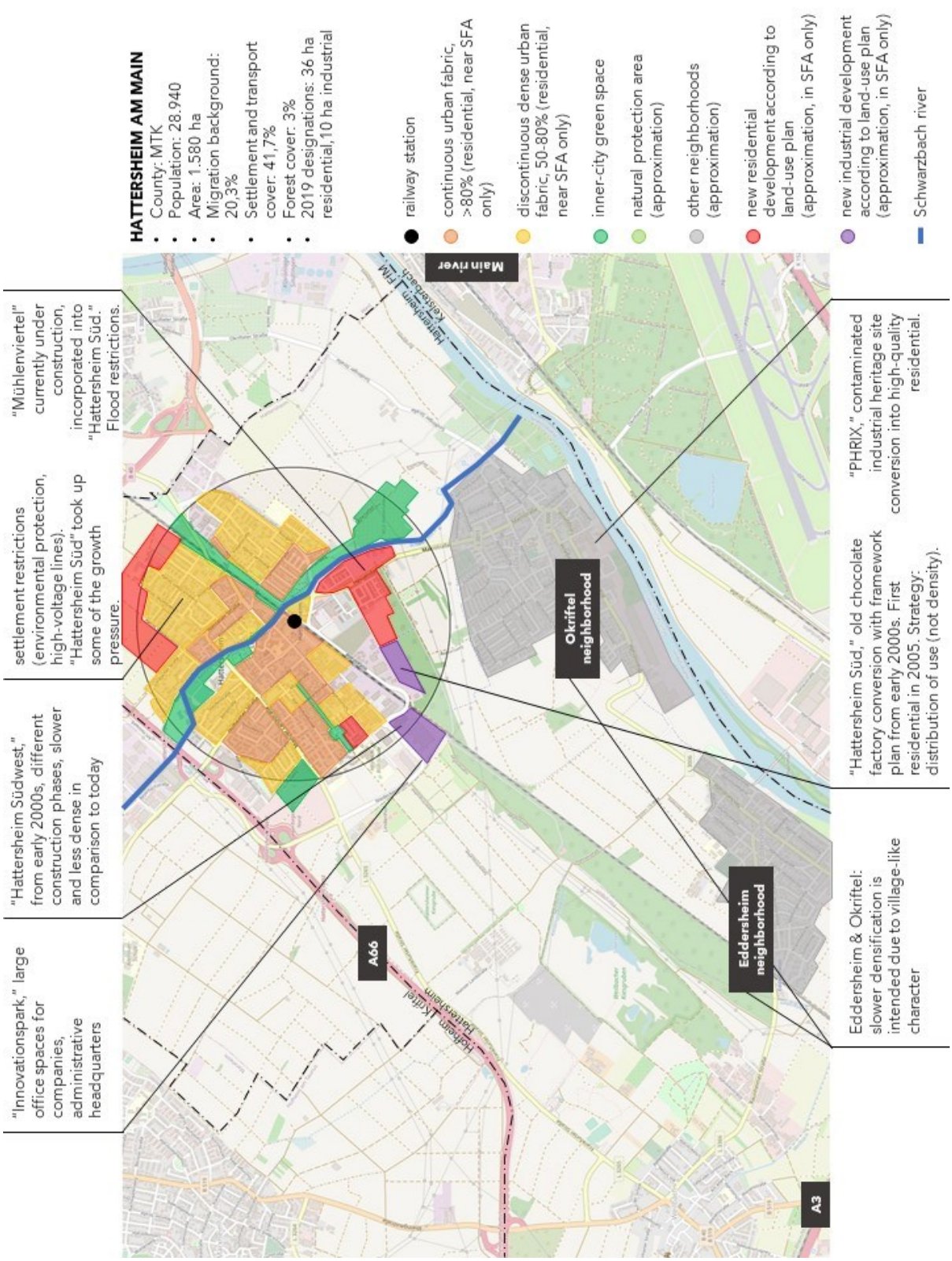


Figure 4.24: Key information on Hattersheim recorded on OpenStreetMap (own illustration)

4.6.2. Spatial focus area

The spatial comparison of the focus area in Hattersheim in year 2006 and its current situation shows that the area has been going through an intense change. There were four large residential developments, partially on open land. A majority of these was three-floor multistory housing, combined with single-family housing. Further housing has been provided in the form of densification, but this was quite less in comparison. At the southern half of the spatial focus area, the spatial restructuring for conversion from industrial to residential as well as further industrial and commercial development can be seen directly adjacent to both sides of the train tracks. Some of these buildings replaces old ones but some were built on open spaces (Figure 4.25).

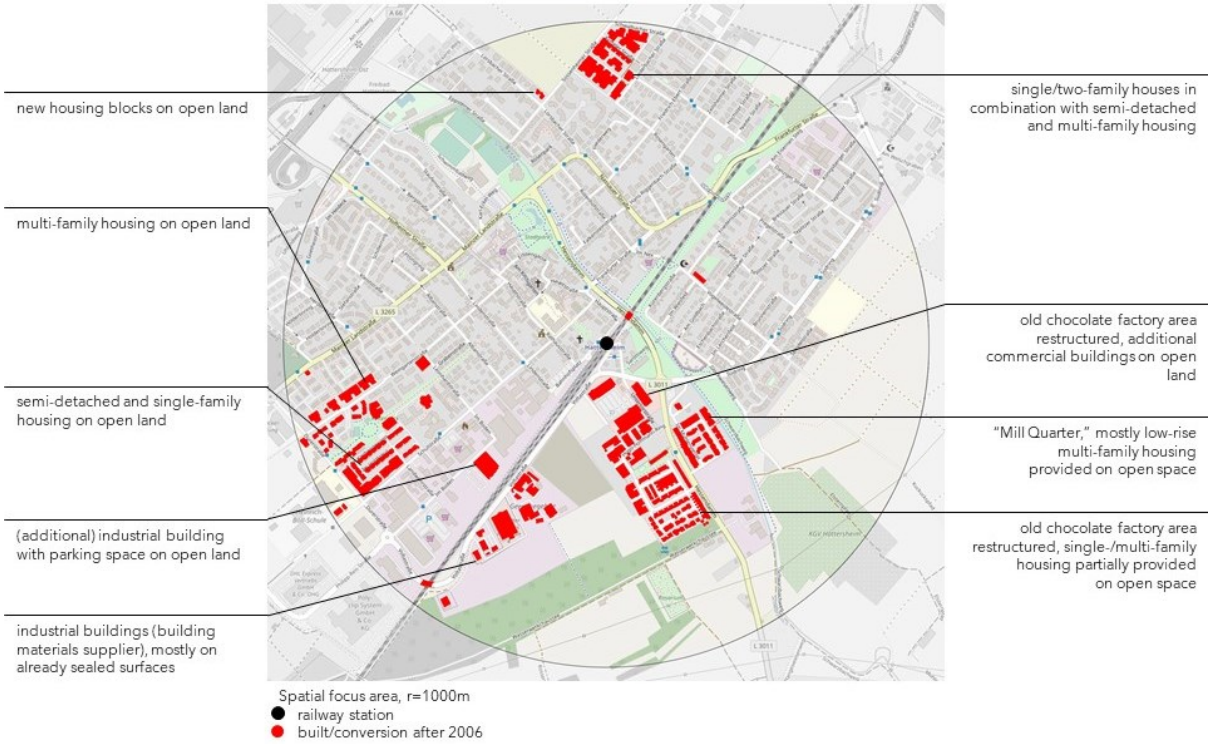


Figure 4.25: Changes in the spatial focus area in Hattersheim since 2006 recorded on OpenStreetMap. Analysis done by visual comparison of maps and crosschecked based on interview data and internet research. There may be unintentional flaws in the illustration (own illustration).

Green space parameters

The spatial focus area in Hattersheim has 31,29 per cent vegetation cover and 9,77 per cent recreational green cover. The large nature protection area to the southeast contributes to the high vegetation cover and the green space alongside Schwarzbach in the northwest-southeast direction provides a high percentage of recreation cover as a green corridor. It also adds to the high connectivity of vegetation cover (Figure 4.26). Regarding distribution, an edge density value of 62,50 m/ha indicates a quite even distribution of sports, leisure, and recreational green spaces in the focus area. As far as the proximity of recreational green cover is concerned, it is found that 99,38 per cent of the settlements are located in the

catchment areas of recreational green spaces. Only some parts of the industrial settlements at the southwest are less served by green cover within the focus area, but this is evened out by the adjacent nature protection area and the Regionalpark corridor (Figure 4.27).

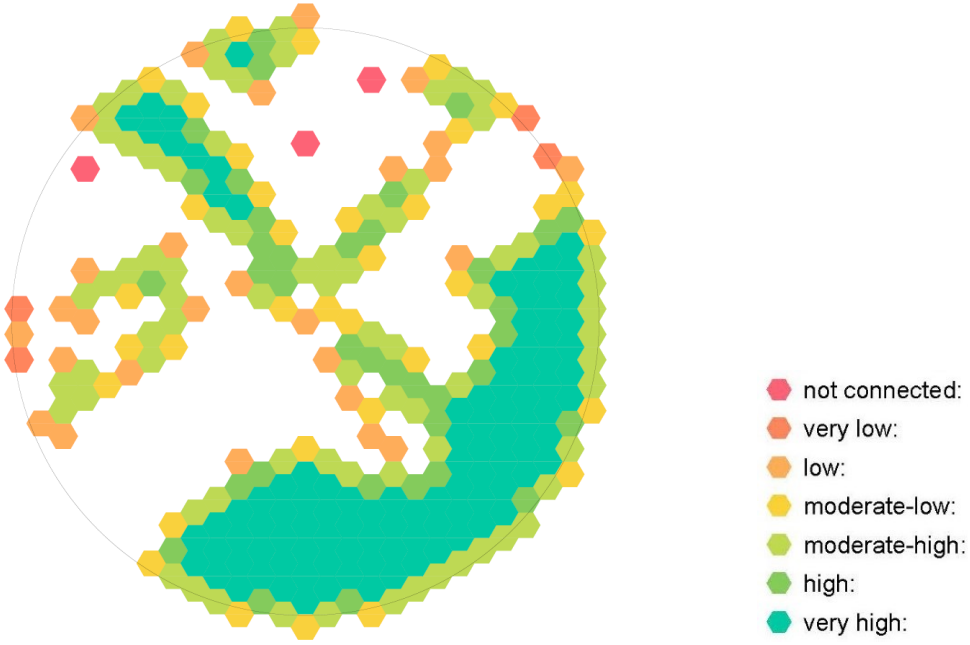


Figure 4.26: Connectivity of the landscape cover in Rüsselsheim's spatial focus area (own illustration).

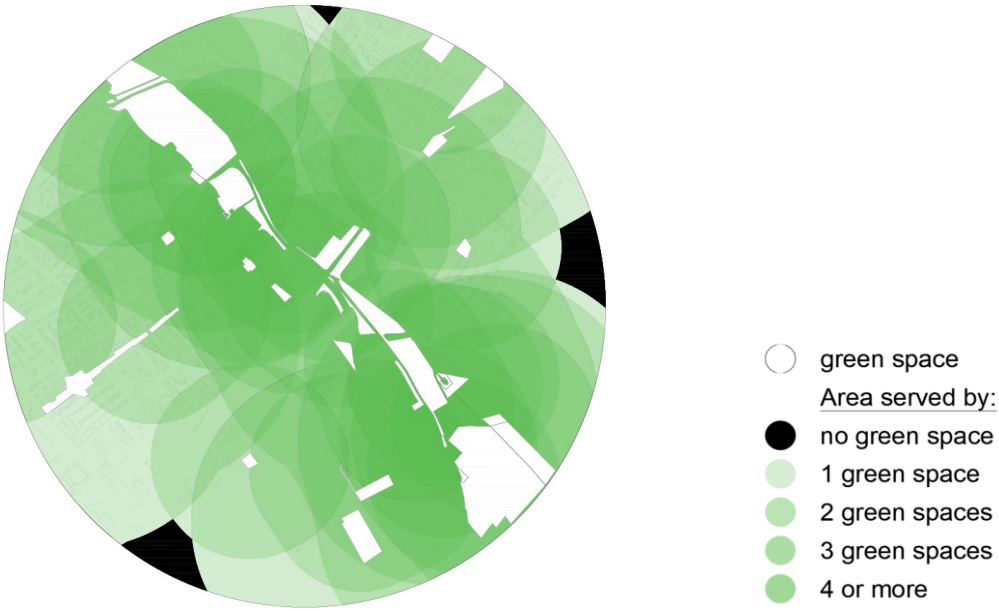


Figure 4.27: Proximity of the recreational green cover in Rüsselsheim's spatial focus area (own illustration).

Social and ecological value

During the field visit, 32 green covers were observed. Around 14 of these were found to have no social value (Fields 2, 11, 15, 26: roadside green; Field 4: private garden; Field 7: private courtyard; Field 14: green connector without access/use; Fields 16, 28, 29: agricultural field;

Field 17: parking lot; Field 23: industrial brownfield; Fields 24a, 25: construction site). Also, two areas (Fields 5 and 6) were not accessible. These are courtyards of private properties despite being involved in the data as recreational green. The remainder of the observed green spaces include cemeteries, playgrounds, diverse parks, sports fields, community gardens, and animal parks with medium to high social value.

A clear majority of observed spaces has medium to high ecological value (most importantly, Fields 9 and 14: shrubbery with water components, green connector; Field 24: "Tierpark"). The classification according to intended purpose and accessibility of open spaces showed that more than half of the observed green cover is accessible without restriction, though some are purpose-dependent with a dominant function (e.g. playgrounds, sports fields). Around 10 of the observed spaces have no public access (e.g. private gardens, cultivated areas of agriculture, courtyards, brownfields or construction sites). The publicly accessible and semi-accessible green cover provides almost the entire social and ecological value (Figure 4.28, Figure 4.29, Figure 4.30).

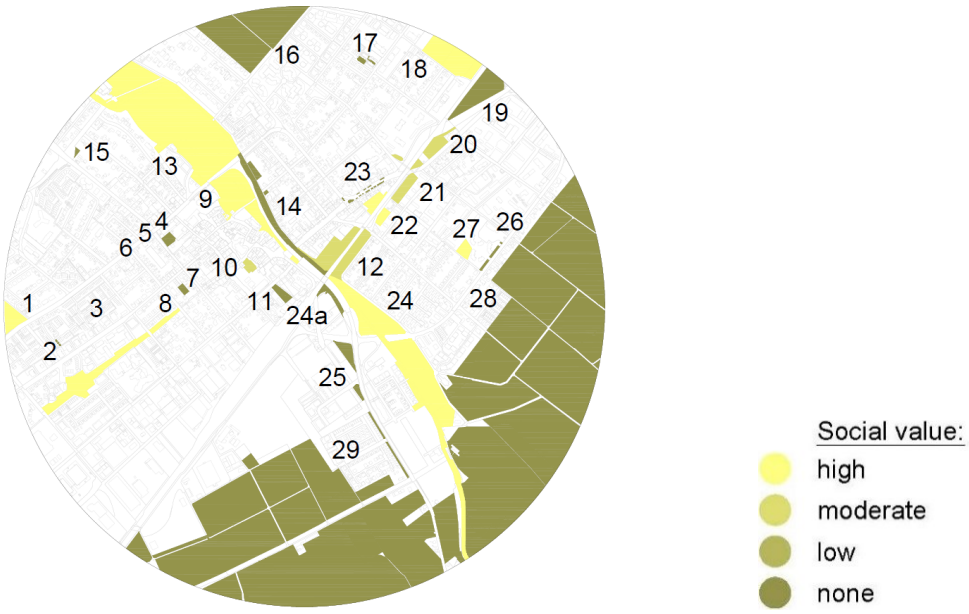


Figure 4.28: Social value of the green cover in Hattersheim's spatial focus area (own illustration).

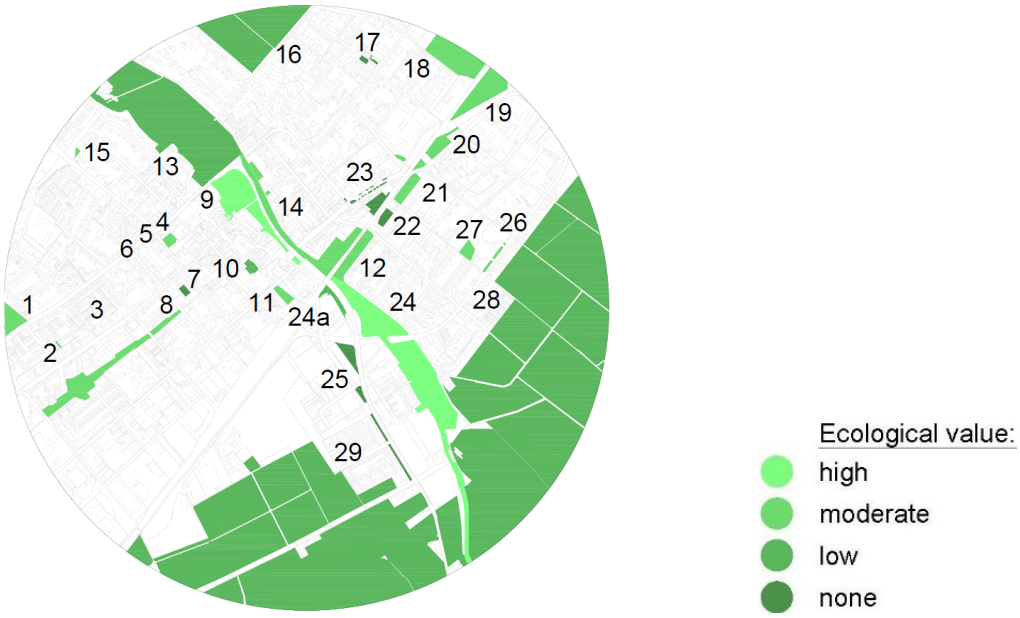


Figure 4.29: Ecological value of the green cover in Hattersheim's spatial focus area (own illustration).

Figure 4.30: Field 14 (top left): Schwarzbach stream; Field 16 (top right): new residential development area on open land; Field 24 (bottom left): Tierpark; Hessendamm (bottom right): example to new dense development (own photos).

4.7. Landkreis Offenbach: Langen

Langen is covers an area of 2.912 hectares, 28,9 per cent of which is used for settlement and transport. Despite a low proportion of recreational areas (2,3 per cent), the town has a very high proportion of forest cover (50,75 per cent). Recent housing provision rate has been particularly high in Langen, and in 2019 with 232 completed housing units, Langen was the third in the conurbation following the county-free cities of Frankfurt and Offenbach. Although the proportion of inhabitants with migration background (20,8 per cent) is below the conurbation average (23,1 per cent), there has been a stable increase after 2008. In 2019, 32 hectares of new residential and 36 hectares of new industrial areas are designated in the land-use plan.

Langen has quite densely built settlements, which are surrounded by large forest areas to the west and agricultural fields to the east and south, including an environmental protection area. The highway A661 is located at the eastern end of the town. In addition to its old center in the east, the neighborhoods in Langen are: Neurott in the northwest with predominantly industrial and partially residential characteristics; Oberlinden and Linden to the west of the train tracks with residential settlements; Nordend in the north with multistory housing; Steinberg in the southeast with relatively new single-family houses, and Loh in the south. All these neighborhoods grew adjacent as an amalgamation and no neighborhood is physically detached or separated (Figure 4.31).

4.7.1. Planning from a green space perspective[40]

Recent settlement development

At the moment, Langen is experiencing a very strong settlement development in the areas that were defined in the urban land-use plans and currently no new settlement areas are designated other than the ones that are already in the regional land-use plan. Some areas that were initially designated for commercial use have been rezoned for residential and mixed-use. Most of these areas are located in the outer areas. In the development of new settlements, compliance with the minimum residential density values of the State Development Plan does play a role, as there are exemptions for exceeding these values at the area of the train station, where the values reach 62 housing units per hectare at certain locations.

[40] This subsection is developed on the basis of Interview 8 (2020) unless otherwise stated.

Regarding the limitations to settlement growth, soil contamination appears to be an issue when restoring surfaces for housing development during conversion. But this is usually manageable and also worthy because of the higher profit margin of new residential developments in inner areas. When the conversion potentials of commercial areas are being considered, flood risk is one of the most important concerns that has to be appropriately coordinated, so that necessary measures are taken. Nature protection areas, together with other spatial restrictions, reduce the available space for housing provision. Unfortunately, it is an expected outcome that housing affordability will depend on the availability of space.

Langen is very densely built and there are barely any available gaps between buildings which could allow for densification. The gaps one could see on satellite images or perceive in the town are either in the process of development or the development process has slowed down due to the pandemic, as priorities had to be shifted. This means for the inner spaces of Langen that there is not so much is left for speculation.

An important recent residential development is located at the western side of the train station. Currently, the development is being put into perspective with ongoing discussions with the developer. At the development areas that are located to the east of this area, the construction has started already, and it is anticipated that this area will provide housing for around 4.000 new inhabitants in the next ten years. An additional large outer development area lies in the north. This area was planned for commercial use since the late 1960s based on a binding land-use plan, but no development has taken place since then. In terms of visual perception, the development of this large agricultural field (with local recreation functions despite being private property) will be an immense spatial transformation. However, for sixty years, the area has had a land-use plan and the development is being realized only now, after its conversion to residential development.

Integrated concepts and green space

The development that is currently taking place in Langen was within the framework of a previous ISEK. ISEK had many advantages basically because it involved all actors at an early stage, ensuring that all aspects of urban development could be tackled early on, including step-by-step considerations of finances and budgeting of these specific aspects. But ISEK, as stated in the interview, is not an absolute necessity for all these to be achieved in planning processes, another form of framework can also be successful.

Dual inner development, as an example to integrated development approaches, is known by the planning department; however, no dual inner development measures were applied given the lack of spatial reserves. That is why the compensation measures that are currently being

applied are limited to the ones that are specified by the legal frameworks. Also, tackling major inner development measures would not address any actual challenge, because there are no potential areas for inner development that would have otherwise been preferred not to be developed. In this case, additional efforts for compensation would be redundant and uneconomic in comparison to the conventional measures that are being carried out.

Regarding the use of green space, the tendency is that, private property owners use their own gardens; whereas public green spaces are frequented more by multifamily-housing residents. This is not to indicate that private property owners do not use public green spaces. Especially with the pandemic, there has certainly been an increase in the use of public green, which is especially the case for playgrounds and parks. Despite the fact that the provision and maintenance of green spaces are cost factors, purchase and upkeep of public green spaces are given importance.

Co-operation and institutional levels

Regarding the extent to which state and federal-level spatial strategies are compatible with the actual needs at the local-level, the abstract nature of higher-level goals is mentioned as a point of concern. Firstly, the debates around density values bring about potential conflicts, because the State Development Plan's reference density values cannot be regulated by the Federal Building Code. The Federal Building Code is ultimately the legal instrument by which any implementation has to be in accordance with, but it cannot guide or provide legal basis for decisions, e.g. how many dwellings there should be. This is usually an estimate based on building typologies and forms, which hinders the opportunity for a visually less compact design, since usually the maximum is strived for. Secondly, there are a number of usage requirements for a given property, for instance an adequate amount of parking lots. This means that in an area that is designated as "residential" in land-use plans not only the residential building but also its basic infrastructure has to be realized. This leaves less room for dwellings as imagined, makes the land extremely exploited and expensive, leaving less room for spaces available for other requirements (also mentioned in Interview 2, 2020). The municipality aims to address these by measures such as green roofs. It is a contradiction that a sustainable construction in its entirety would then make affordable housing impossible.

Politics, citizens, and communication

Given the high pace of settlement growth, particularly for the large outer areas that have been not built on so far but were pending, settlement development is viewed rather critically. It is mentioned, that it is hard for the citizen to recognize that these areas were already designated commercial building areas and that *"it will certainly be a challenge in terms of quantity to communicate this accordingly"* (Interview 8, 2020).

Opinions as to how dense the town should be are very differentiated. For instance, despite the residential settlement growth pressure, there is also a demand or anticipation that there will be more single-family or semi-detached housing provision. The technical argumentation for higher residential density should be then communicated with the local political committees. Despite the new green spaces planned within the development plans, the minimum residential density values have to be reached in the new residential settlements. This is a challenge because in some areas this will transform the cityscape drastically. The rationale behind this transition needs to be well-communicated with the citizens alike.

The municipal administration, political committees, and citizens are the three most important actors. The municipal administration acts as the mediator between the public and private interests, by weighing up interests of technical matters, based on legal frameworks. The town does not have a permanent body for citizen involvement, this is rather scattered for specific groups such as the one for the youth parliament or the economic promotion one in contact with the local tradesmen. The latter also enables initial inquiries regarding representation of interests within an industrial property development. Due to the lack of a permanent body for citizens' initiatives, these are scattered and thus do not reach beyond the specific issues of concern. An integration of those would be beneficial.

A recent example in terms of a conflict between private and public interests emerged because of the regional-scale bicycle highway (Radschnellweg) project. One stage of this project involves the construction of the bicycle highway between Frankfurt and Darmstadt, cutting through several towns in between, including Langen. There were a few opposing voices against this project, which were taken into account as far as possible. Various suggestions were worked out with the individuals. But fundamentally, a quite promising regional project with benefits to the local society is not given up, when it is possible to find a middle ground.

Internal and external capacities

For the provision and upkeep of urban green spaces there is neither additional or special funds nor separate budget allocation. The town was particularly impacted by the recent storm event in Autumn 2019 during which the city forest as well as the inner-city green spaces were damaged. To repair this damage, some funds were set aside. For specific components of the natural environment, such as orchard meadows, external funds from the state-level are mobilized through an orchard meadow program.

Regarding the in-house monitoring and evaluation capacities, it is touched upon that the tools that are provided by the Regional Association are known, but these can only be

updated as far as the in-house personnel capacity allows for it. Currently, these are updated from time to time when needed. It is in some respects rather outdated and should be updated. For the preparatory land-use plan Langen is in close collaboration with the Regional Association as one of its member municipalities.

The town is part of further exchange through via e.g. the meetings of heads of planning departments. There is also close collaboration with the neighboring municipalities especially regarding the issues which would potentially impact them, e.g. traffic development, but not necessarily in the context of urban green spaces.

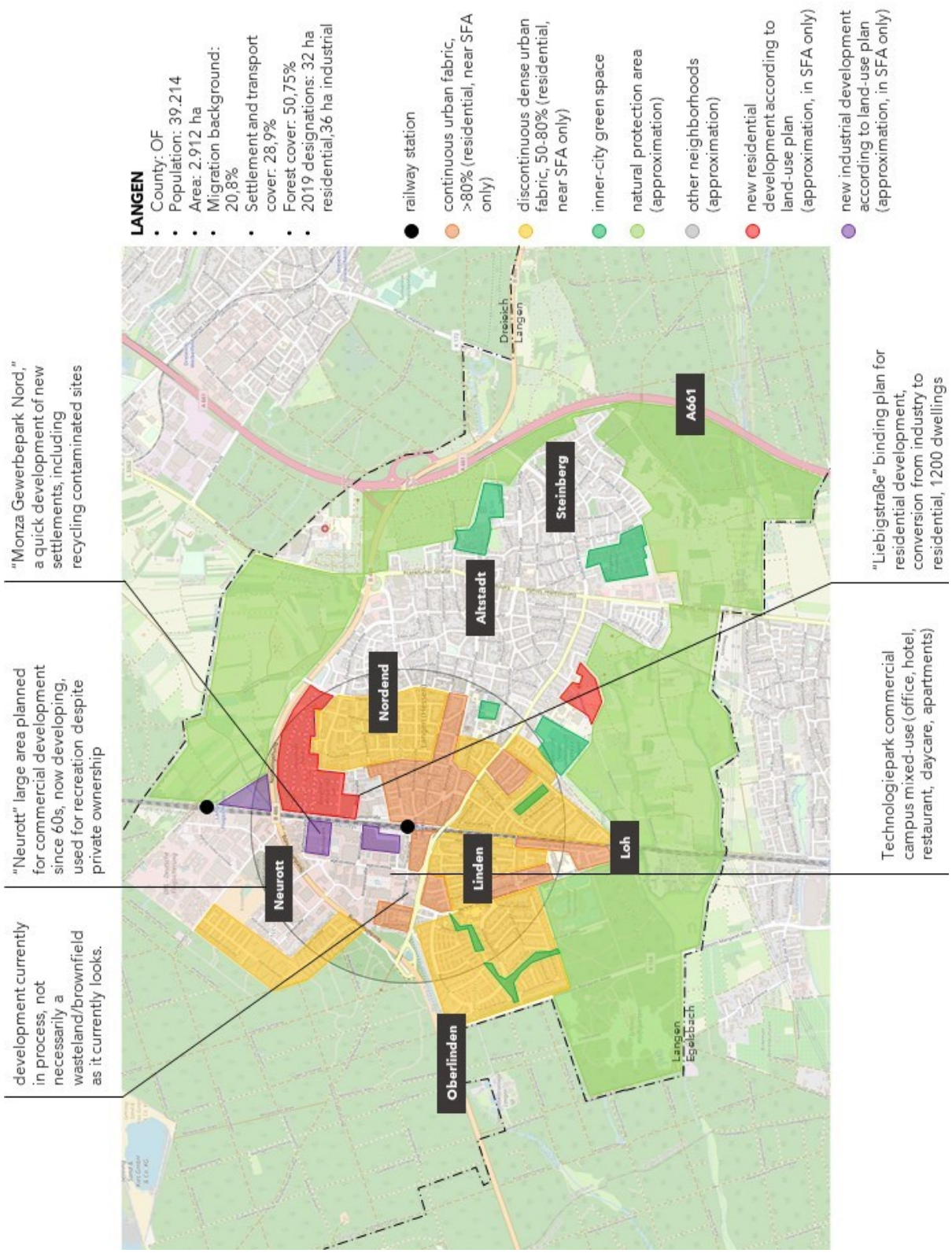


Figure 4.31: Key information on Langen recorded on OpenStreetMap (own illustration).

4.7.2. Spatial focus area

The majority of the transformations in the focus area has been for commercial and residential uses (mostly multistory). There were new industrial areas at the northwestern part of the focus area and commercial spaces with large parking lots on open land. In the same area there were two indoor sports buildings provided (principally through inner development), one in the form of densification on open land and other as a reconstruction of an already existing building. The southwestern part of the focus area has a residential character. In addition to the provision of new multistory housing blocks there (densification on open land), there were also more single-family houses appearing on few available spots. On the area directly at the eastern side of the train station, several multistory housing blocks were provided on open land. As the town is already quite densely built, available reserves have been mobilized as much as possible. Based on aerial images of the spatial focus area, this took place often in the form of inner area densification and conversion (Figure 4.32).

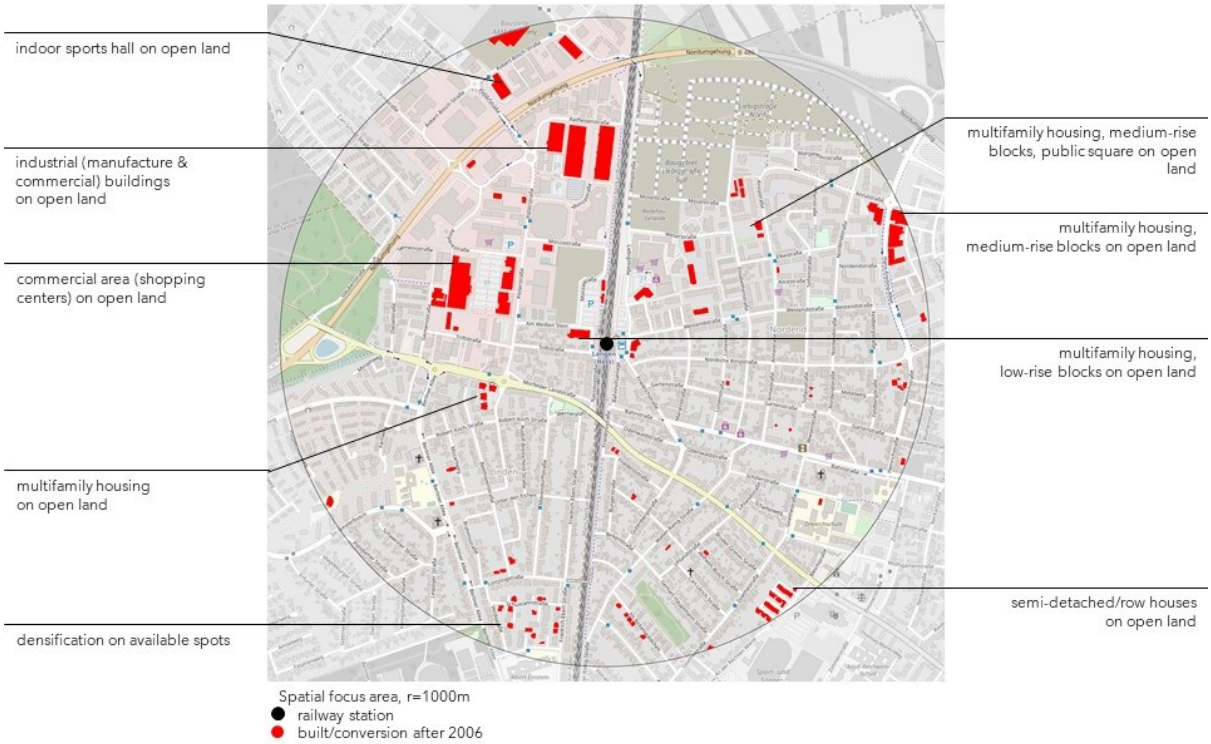


Figure 4.32 :Changes in the spatial focus area in Langen since 2006 recorded on OpenStreetMap. Analysis done by visual comparison of maps and crosschecked based on interview data and internet research. There may be unintentional flaws in the illustration (own illustration).

Green space parameters

In the focus area the vegetation cover is around 8,30 per cent. The settlement green cover for sports, leisure, and recreation in the focus area is also low, around 2,45 per cent. Still, the high amount of forest cover surrounding the settlement areas in Langen is compensating for the limited green space availability and vegetation cover. Despite the low amount in surface cover, the edge density value (33,02 m/ha) of recreational spaces in the focus area indicates

that the distribution is actually not too low for a densely built up area. However, given the dense settlement structure, even the shortest distances among vegetation patches are high, which indicates low connectivity (Figure 4.33). As far as the proximity of recreational green spaces to settlement areas is concerned, it is found that 87,05 per cent of the settlements are being served by green spaces. This is quite high especially considering the dense settlement structure; however, a large part of settlements is located in the catchment zones of singular green spaces and therefore dependent on one green space only (Figure 4.34).

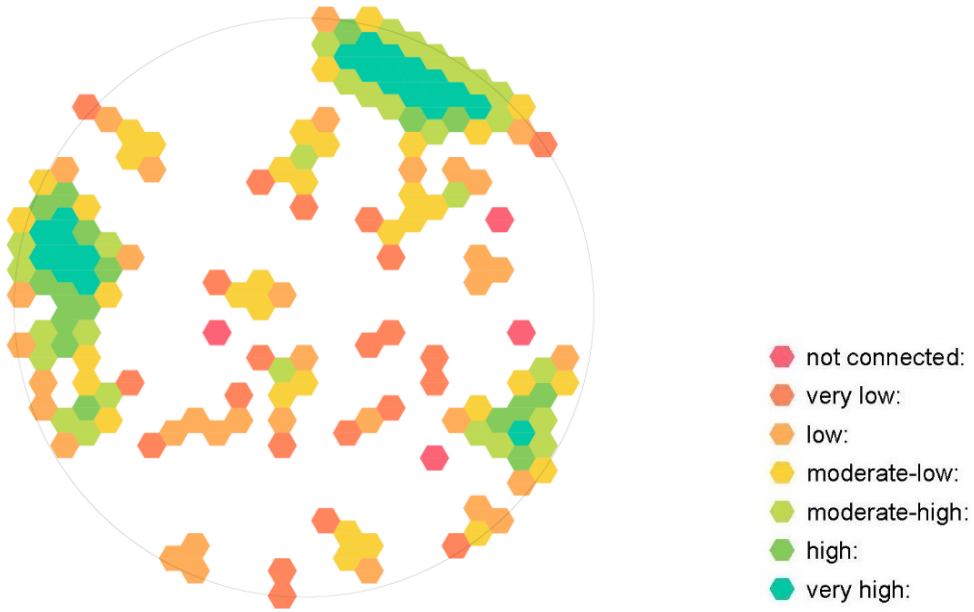


Figure 4.33: Connectivity of the landscape cover in Langen's spatial focus area (own illustration).

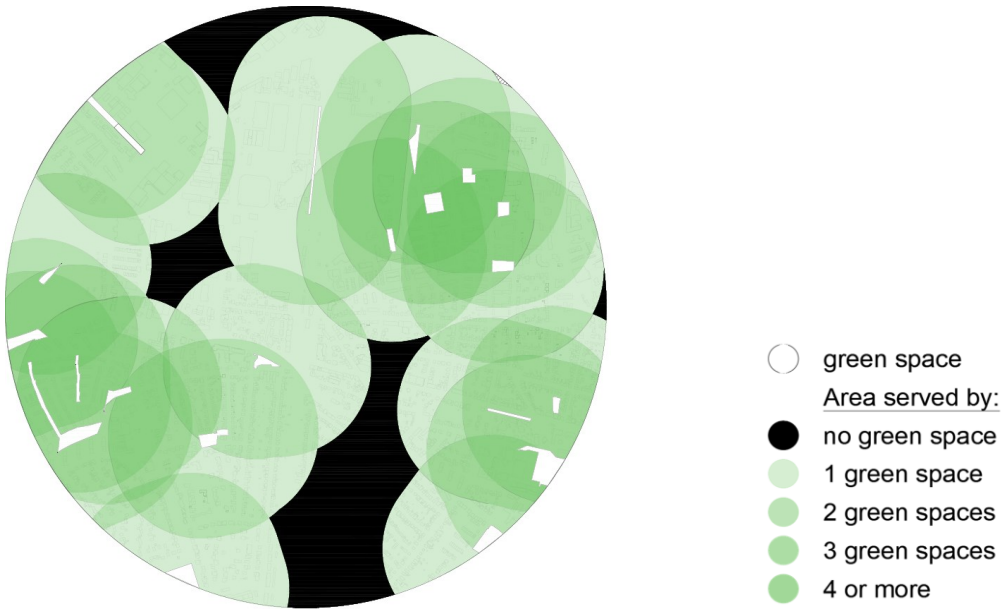


Figure 4.34: Proximity of the recreational green cover in Langen's spatial focus area (own illustration).

Social and ecological value

During the field visit in Langen, 36 green areas were observed. Social and ecological value of seven of these spaces could not be determined (Fields 4a, 5a: inaccessible buffer between residential and industrial; Fields 12a, 19a: does not exist on the field despite marking on the map; Field 19b: inaccessible, most likely courtyard; Fields 22a, 22b: do not exist, most likely already densified). Moreover, 15 areas were observed to have either no or low social value (Fields 1, 2, 4: open spaces of industry; Fields 3, 16: green area between railway and street; Fields 6, 9, 11, 12: green area alongside walkway; Fields 8, 28: parking lot; Field 14: small green patch; Field 20: inaccessible private property; Fields 29, 30: construction sites). Majority of these areas showed lower or nonexistent ecological value (e.g. surfaces without vegetation, transport surfaces, and grass cover). According to the open space typology classification of intended purpose and accessibility, these were classified as private open spaces that are not publicly accessible (e.g. construction sites, courtyards, open spaces of industry areas, brownfields) apart from the ones that could be classified as roadside green. The remaining areas were found to have relatively higher social value (e.g. forests, parks, playgrounds, sports fields, and schoolyards) accessible without restrictions (though some are purpose-dependent with a dominant function). Around 20 of the observed areas were found to have low to medium ecological value with land-cover types of rough grass, mown grass, surfaces without vegetation, or shrubbery. The highest ecological value is provided by the forest cover (Field 5) followed by the park area (Field 17) (Figure 4.35, Figure 4.36, Figure 4.37).

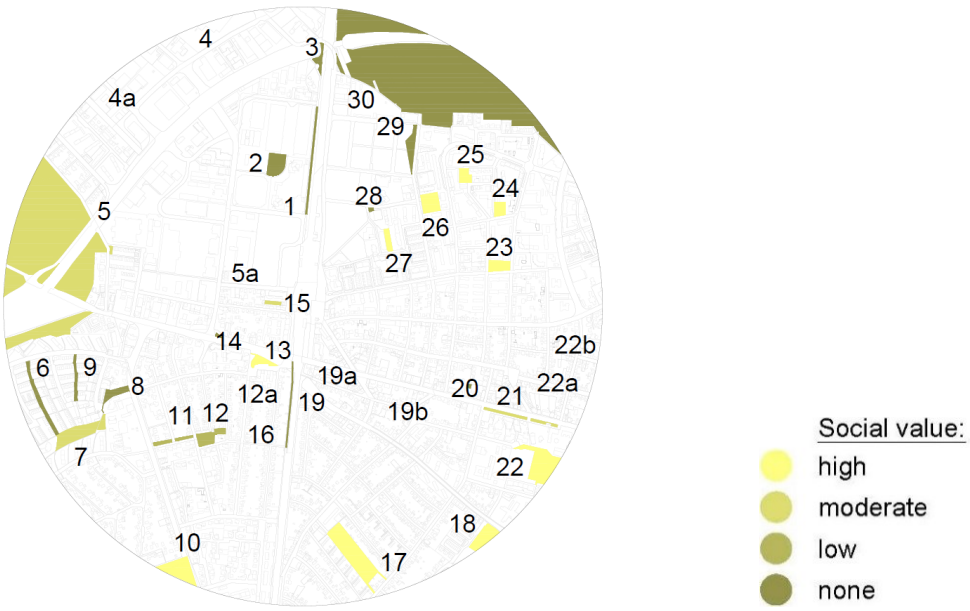


Figure 4.35: Social value of the green cover in Langen's spatial focus area (own illustration).

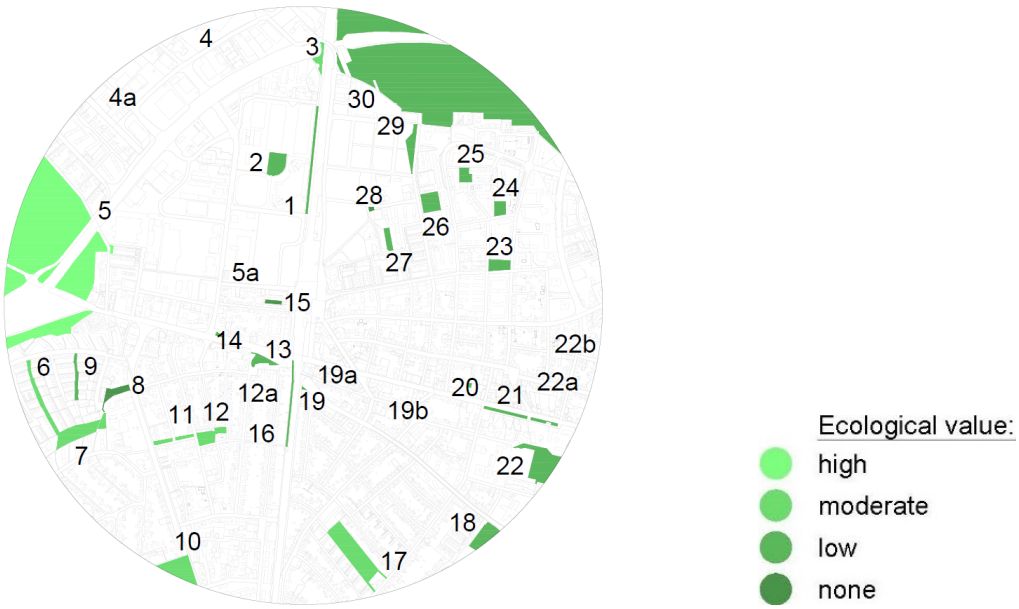


Figure 4.36: Ecological value of the green cover in Langen's spatial focus area (own illustration).

Figure 4.37: Field 2 (top left): water retention; Field 15 (top right), Field 26 (bottom left): public square with high social low ecological value; Field 30 (bottom right): new outer development area to the north (own photos).

4.8. Wetteraukreis: Bad Vilbel

With a population above 35.000, Bad Vilbel is one of the fastest growing towns in the conurbation. In the past ten years, the proportion of inhabitants with migration background has increased and recently reached 16,8 per cent. Bad Vilbel's territory is relatively small, it covers 2.568 hectares, 38,8 per cent of which is covered by settlement and transport with a steadily increasing trend. 6,2 per cent has recreational function and 6,7 per cent is forest cover. In 2019, there were 223 housing units completed. The land-use plan included 27 hectares of new residential and 41 hectares of new industrial development.

Bad Vilbel is situated alongside the Nidda river and comprises four historical neighborhoods: Dortelweil to the north, somewhat separated, with residential and industrial/commerical settlement; Gronau to the east, detached residential neighborhood; Siedlung Heilsberg to the southwest, bordering Frankfurt and predominantly residential; Massenheim to the west, with residential and industrial settlements, separated by the federal road B3. These settlements are surrounded by large agricultural fields and forest on the southeast. The most important components of the spatial focus area in Bad Vilbel are the Nidda river and the parks around it (Kurpark, Burgpark), B3 highway on the west, settlement areas of Heilsberg and Massenheim, as well as the agricultural and forest areas. In the spatial focus area, green-blue and technical infrastructures (e.g. the river, train tracks, highways) are creating patches of built and natural environment (Figure 4.38).

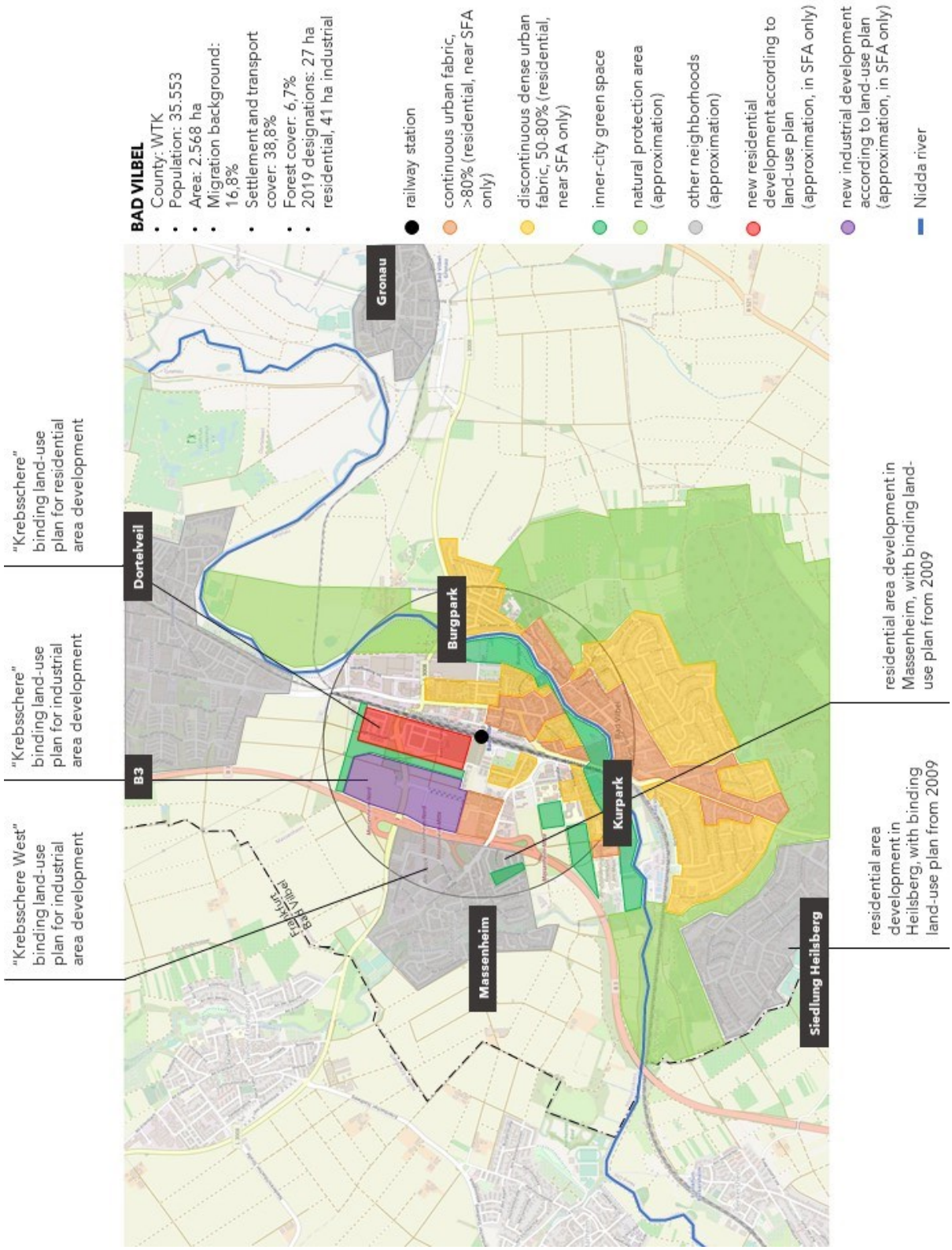


Figure 4.38: Key information on Bad Vilbel recorded on OpenStreetMap (own illustration).

4.8.1. Spatial focus area

The recent spatial transformation in terms of both inner and outer development in the past 15 years has been intense. At the western side of the train tracks, a residential settlement of multistory buildings was provided on large open land. There were also additional industrial/commercial buildings in Massenheim at the western side of the highway. In the same area, conversion from industrial to residential took place and provided space for a predominantly single-family housing neighborhood. The segment bordered by the train tracks and the Nidda river underwent conversions from industrial to residential (multistory housing provision). The industrial zone was also restructured and included new buildings as well as large parking spaces on open land. In the same area, selective densification took place on open land where space was available (e.g. new buildings on the second rows). In the south, a city library was built over the Nidda river, directly adjacent to new housing blocks provided on an already sealed surface (former parking lot) (Figure 4.39).

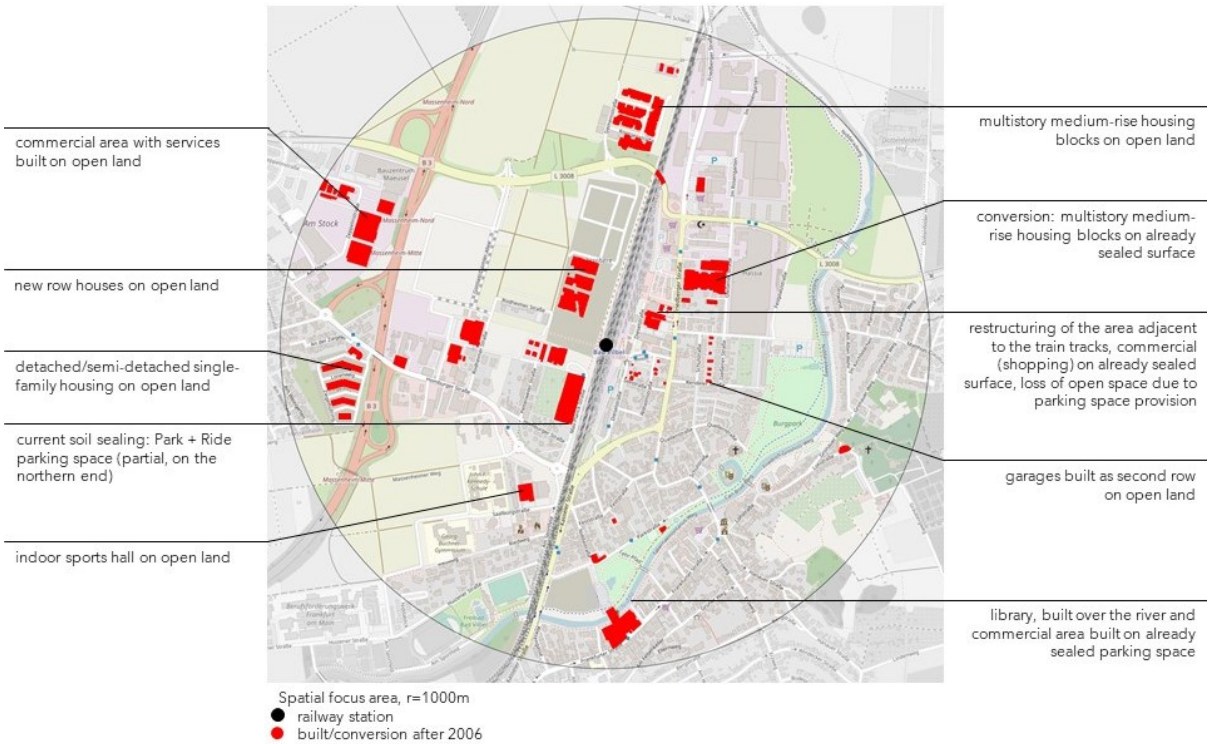


Figure 4.39: Changes in the spatial focus area in Bad Vilbel since 2006 recorded on OpenStreetMap. Analysis done by visual comparison of maps and crosschecked based internet research. There may be unintentional flaws in the illustration (own illustration).

Green space parameters

In the spatial focus area, the amount of vegetation cover is 33,12 per cent, 9,88 per cent of which is recreational green cover. As indicated by an edge density value of 40,83 m/ha, the recreational green has a moderately even distribution. It can be observed that the Nidda river in the southwest-northeast direction is the main landscape connector; whereas other vegetation covers are separated large patches that are closely located to one another. In

general, the connectivity in the focus area is high (Figure 4.40). Regarding the proximity of recreational green spaces, it is found that 89,50 per cent of all settlements are located within the catchment area of at least one green space. Especially the northern part of the focus area is rather underserved by green spaces in comparison to the southern end where the majority of settlements are served by multiple green spaces. It is also to be taken into account that the area with low proximity is predominantly an agricultural field with planned industrial and residential areas with a green buffer in between (Figure 4.41).

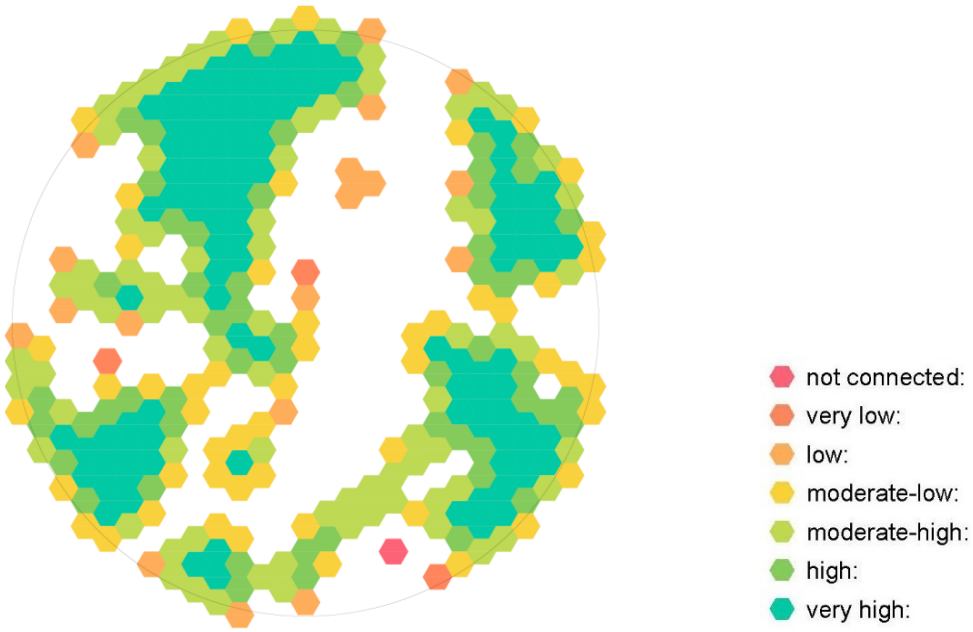


Figure 4.40: Connectivity of the landscape cover in Bad Vilbel's spatial focus area (own illustration).

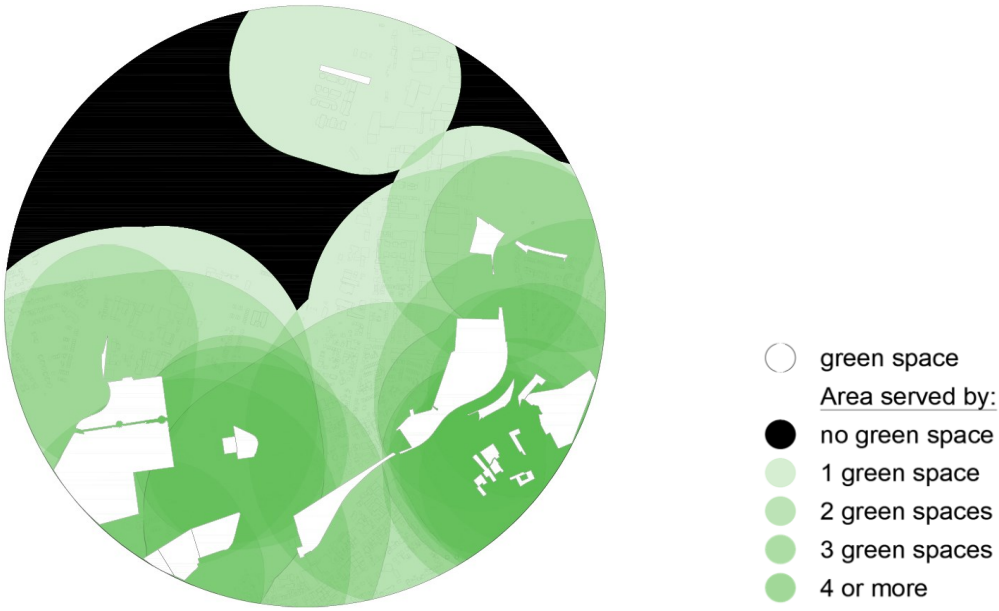


Figure 4.41: Proximity of the recreational green cover in Bad Vilbel's spatial focus area (own illustration).

Social and ecological value

During the field visit in Bad Vilbel, 21 green spaces were observed. Apart from one area marked on the maps (Field 3a: private courtyard), all areas could be observed and classified. It is found out that eight of the observed green spaces do not have any social value (Fields 2, 5, 12: roadside green; Field 6: private property; Field 7: agricultural area with preparations for construction; Fields 9, 11b, 13: cultivated agricultural area). These areas were found to have low to medium ecological value (shrubbery roadside green). In addition, six areas were observed to have low to medium social value (Field 1: schoolyard; Fields 3, 14, 17: unfurnished parks; Field 19: private garden areas of community gardens), and the remaining six high social value (Field 4: green connector alongside the river; Field 8: sports field; Fields 10, 16: park alongside the river; Field 15: common areas of the community garden; Field 18: cemetery). It is also found out that these areas are actually the ones with the highest ecological value (especially Fields 4, 10, 16, 18). In general, only a few areas do not have any ecological value (Field 1: schoolyard with impervious surface; Field 8: sports campus with impervious surface). The fields with rough/mown grass cover (Fields 6, 14) and conventional agriculture (Fields 7, 9, 11b, 13) have lower ecological value. The areas with shrubbery (Fields 5, 12, 17) and community gardens (Fields 15, 19) were found to have medium ecological value. The Nidda river together with its green areas alongside provides the highest ecological value. According to the intended purpose and accessibility categorization, green spaces with the highest social and ecological values are also open public spaces with no access restriction (Figure 4.42, Figure 4.43, Figure 4.44).

Figure 4.44: New residential neighborhoods (top left): a typical example; Field 4 (top right): Nidda and its green spaces with high social and ecological value; Field 6 (bottom left): vegetation cover of large private property; Field 7 (bottom right): new development starting on large agricultural field (own photos).

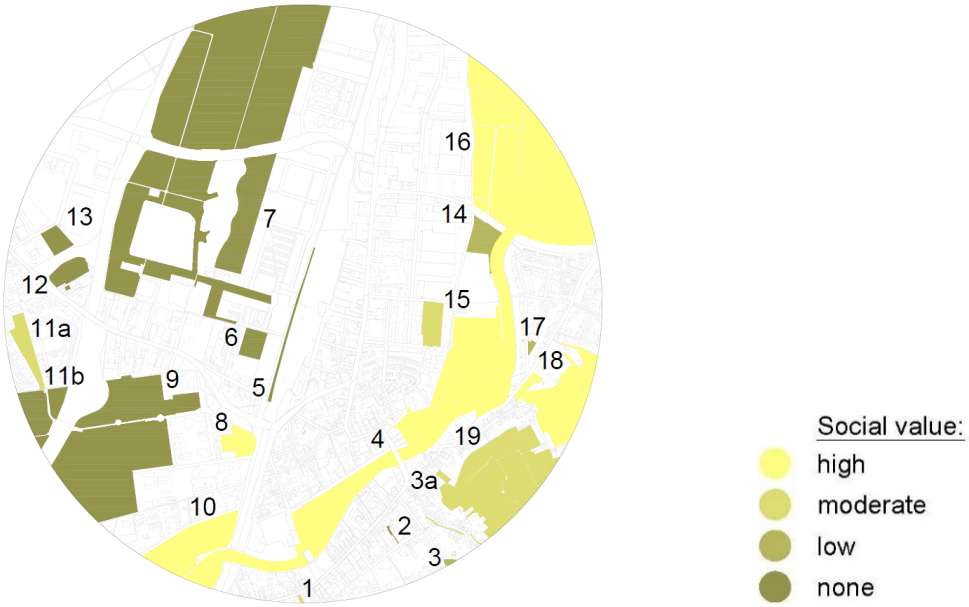


Figure 4.42: Social value of the green cover in Bad Vilbel's spatial focus area (own illustration).

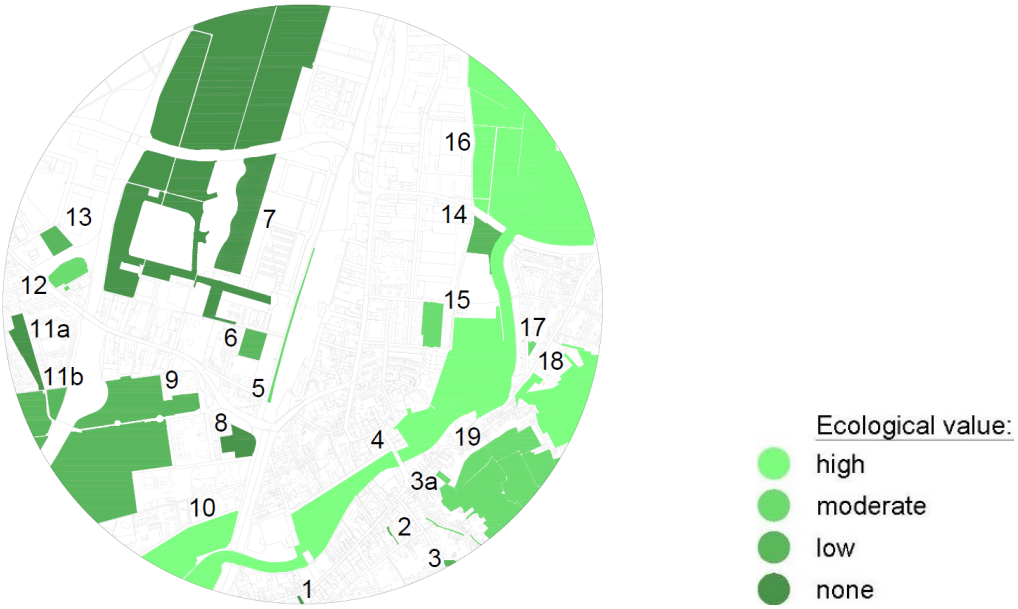


Figure 4.43: Ecological value of the green cover in Bad Vilbel's spatial focus area (own illustration).

Figure 4.44: New residential neighborhoods (top left): a typical example; Field 4 (top right): Nidda and its green spaces with high social and ecological value; Field 6 (bottom left): vegetation cover of large private property; Field 7 (bottom right): new development starting on large agricultural field (own photos).

4.9. Toward a green concept

An advantage of working with CAD-based green space parameters in combination with on-site observations to determine social and ecological value is that it provides an overview of strengths and weaknesses of green space configuration in the studied area. In combination with the insights gained from the interviews, the spatial analysis provides a foundation for a green space methodology that could help locate the opportunities and threats to develop a medium- to long-term strategy.

This could be tried out on the example of Hattersheim. The spatial focus area in Hattersheim has a high percentage of sealing due to settlement and transport cover and rather low forest cover in the outer area. Still, the town has a very favorable green space configuration with high connectivity, proximity, and social and ecological value despite high rates of construction. Based on that, a green space methodology, which could potentially be expanded as a citywide concept, is drafted for Hattersheim's spatial focus area.

To do this, first, general observations based on the outputs of the spatial analysis of green space parameters for Hattersheim is outlined. Second, the input from the interviews are included to determine the interactions and interdependencies between the two datasets. With the goal to not lose sight of social-ecological systems thinking, a very thorough examination of institutional and governance aspects is an important approach. Finally, the raw data is updated based on on-site observations (e.g. removing already built-up spaces that were given as green spaces) and two scenarios were compared based on the updated spatial parameters. The first scenario assumes no improvement; whereas the second scenario assumes all spotted weaknesses are improved.

4.9.1. General observations

Based on the outputs of the spatial analysis of green space parameters and in-person field visits, the most important features of each green space are as follows:

Fields 4 (left) 5, 6, and 7 (right) are either private gardens or courtyards with no public access.	 

Field 8 is a green pedestrian street, but it is not connected to the Schwarzbach corridor.	
Field 13 is a sports campus and a part of the Schwarzbach axis. It has high social but low ecological value.	
Field 16 is a large cultivated area designated for residential development. As the proximity map shows, this area is underserved by urban green spaces.	
Field 17 is an elevated parking space and has neither social nor ecological value despite designation as green space in the raw data.	
Field 18 (left) is an agricultural activity garden and Field 19 (right) is a community garden. Both have relatively high social and ecological value and they contribute to connectivity.	 
Field 19a is a small green patch with low social value and part of a well-connected axis.	

Field 22 is already built up despite designation as green space in the raw data. This weakens the connectivity in the green space axis from center to northeast.	
Field 23 is an already sealed surface with potential for improvement.	
Field 25 is a construction site despite designation as green space in the raw data.	
Field 28 is a large and ecologically significant area (climate functions, priority area for regional green corridor). Its proximity to recreational green to the east is low.	
Field 29 is a large and ecologically significant area (climate functions, priority area for regional green corridor), bordered by the Regionalpark corridor to the south. As per the preparatory land-use plan this area is undergoing development. There is low proximity to recreational green to the southeast.	

(Source: Author)

4.9.2. Contrasting scenarios

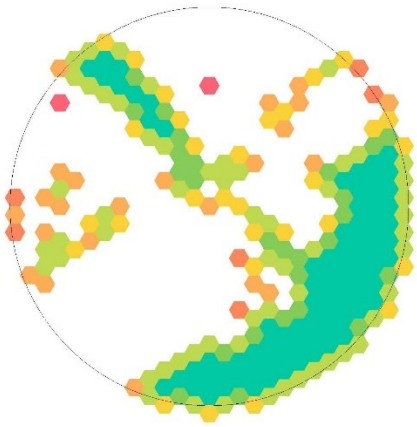
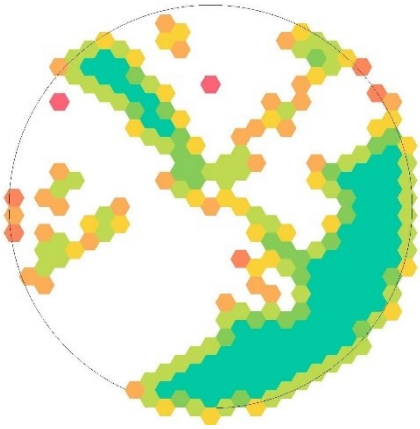
Following the identification of the main green space features, two scenarios (without and with improvements) are developed. It was necessary as an initial step to update the raw data based on the conflicting observations during the field visit. Additionally, new development areas according to the preparatory land-use plan were taken into account. This implies in some cases removal of vegetation cover in case an area is designated for new settlement

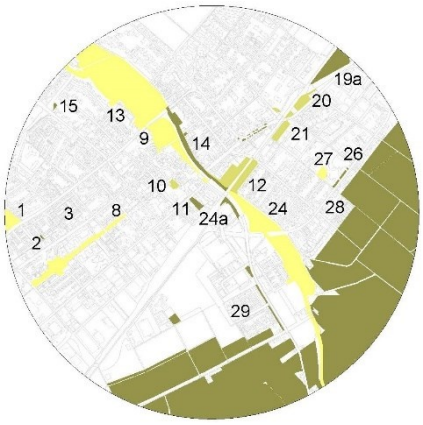
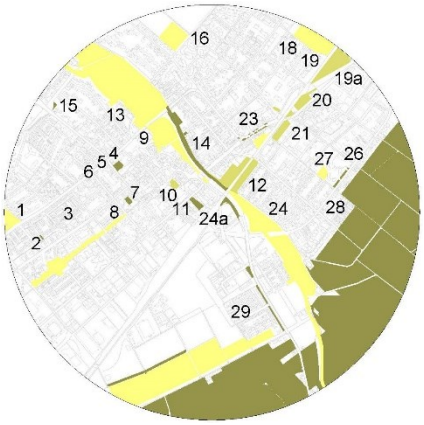
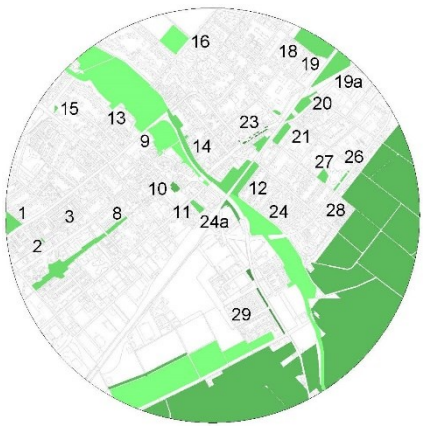
development. If and when applicable, the scenario with improvements assumes green space provision (e.g. for Field 16) and protection (e.g. for Field 29). The following decisions regarding each observed green space can be noted:

- Fields 4, 5, 6, and 7 had to be removed from the raw data. This impaired connectivity and minimally reduced proximity.
- In case Field 8 (Keltenpark) can be connected to the Schwarzbach axis, the impaired connectivity could be improved. An extension as such is challenging, since it would have to go across the densely built old town center with narrow streets. A realistic short-term improvement on this could not be shown.
- It is assumed that the ecological value of Field 13 could be improved, e.g. through increasing pervious surface cover, integration of rainwater concepts for contribution to groundwater formation, improvement of the vegetation cover with various additional plant species.
- The area around Field 16 is underserved by green spaces. The development could potentially be compensated by a park with high social and ecological value that covers an area of at least 10.000 m². This could help improve the low proximity in the north but not resolve the low connectivity in that area.
- Field 17 had to be removed from the raw data. This had implications on connectivity and proximity.
- As per the land-use plans, Field 18 (Abenteuerspielplatz) will be partially developed for residential settlements. This could have strong implications on all parameters, unless additional green spaces with high social and ecological value with connectivity functions are realized. A realistic improvement could be supported by the Regionalpark corridor there.
- The social value of Field 19a could be improved.
- Field 22 had to be removed from the raw data. This had strong implications on connectivity.
- Field 23 could be utilized partially for inner development and partially for green space functions.
- Field 25 had to be removed from the raw data. This minimally reduced connectivity and proximity.
- There is no development planned on Field 28. The area to the east (predominantly agricultural area with no residential area in its immediate surroundings) has low proximity to recreational green.
- The social and ecological value of the green patch in Field 29 could be improved. The area in the southwest (predominantly industrial/commercial neighborhood with no residential area immediately attached) has low proximity to recreational green.

Overall, the Schwarzbach axis in the northwest-southeast direction has high social-ecological value and is well-connected. However, some parts can be improved. The additional axis from the center to the northeast has high social value and high connectivity, but there are some weak spots due to new constructions. Additionally, the remaining green spaces are of high

value, and except for several selective potentials (e.g. partially Field 23) it could not be possible to recommend densification to take place at any of the green spaces. As the inner development potentials decrease with each conversion, it is likely that outer area developments will be inevitable. Below is a contrastive summary of the two scenarios:

Scenarios / Green space parameters	**Scenario 1**	**Scenario 2**
Proximity  	No significant difference despite data update (removal of several areas smaller than 1.000 m² that are not green space). Lower proximity in the east and southeast. 	Better proximity results to the north since 10.000 m² green space is added to Field 16. Lower proximity in the east and southeast. 
Connectivity  	Connectivity interrupted on the southwest-northeast axis. Connectivity impaired in the north (residential) and south (industrial): 42,75 per cent. 	Connectivity less interrupted on the southwest-northeast axis (courtyard green spaces removed). Better connectivity on the north due to green space protection (Fields 18, 19) and provision (Field 16): 45,84. 
Social value	Several areas with high social value (Fields 18, 23 due to planned development, Field 22 due to already completed building) are removed: 10 per cent less green space with high	Field 18 remained, Fields 19a, 23, 29 improved, Field 4 given public access, Field 16 added: +46 per cent more high social value.

high moderate low none	social value. 	
Ecological value high moderate low none	Field 18 with moderate ecological value (partially) removed. Otherwise no value increase. No change in green space with high ecological value. 	Fields 13, 18, 19 with moderate ecological value increased to high value. Fields 23, 29 improved: 301 per cent more high ecological value. 

(Source: Author)

4.9.3. Input from the qualitative data

Although these scenarios give an idea of how green space parameters would change in the spatial focus area with the planned settlement development in two different directions, it is only a visualization exercise unless the potentials and constraints are examined within the institutional and governance debates. It is therefore necessary to consider these scenarios on the basis of supportive and restrictive governance conditions. This can be facilitated by extracting the relevant information from the qualitative investigation. Some considerations are as follows:

- A strategy could look into compensating the lack of small green patches of Field 4, 5, 6, and 7 in the near vicinity. The ecological connectivity of Field 8 (Keltenpark) to the dominant green space axis of Schwarzbach could be a long-time perspective. The sealing of Field 22 impairs the connectivity on the second axis, but the area alongside the railway (up until Spielplatz Friedensstraße) is not very densely built. There might

be ways to slightly increase the built-up density while protecting and providing green space there. These could be a subject of discussion for Hattersheim's upcoming ISEK.

- In Hattersheim, there was no exclusive inner or outer development strategy due to the high settlement development pressure, while the Hattersheim Süd conversion has helped slow down outer development. That is why new large development areas to the northeast in the area of Field 18 did not have to be mobilized immediately. Currently the neighborhoods adjacent to Hattersheim Süd are being built very densely (Urbansmühle), including Field 25. This necessitates a strong protection for the nearby green spaces, especially for Field 24 (Tierpark). Given the high residential densities of the neighborhood exceeding the minimum values in the State Development Plan to provide more living space, it is to be considered that the green spaces around will be frequented by more visitors.
- Residential development with increased densities is associated with an increased load on the existing social and technical infrastructure and therefore with an increased demand for parking spaces. This already reduces the available land for buildings. Field 17 was observed to be a parking space during the field observation, and its removal from the green space analysis has impacted the connectivity and proximity results. A strategy could consider alternatives (e.g. several central underground garages etc.).
- The municipality's park department has been proactive in securing a minimum amount of green space with each new development within the contracts with investors. This justifies that it is in fact quite realistic to think about a publicly accessible green space with high social and ecological value, located at the southernmost tip of Field 16. What would be ideal is to improve connectivity and proximity in the area between Field 16 and 18. The Regionalpark corridor already located in this area could facilitate this. This area is underserved by green spaces. Currently, this is not a big problem because the area has no function, but it is intended to be developed for residential use. It could be beneficial to consider these aspects early on.
- Hattersheim Südwest is being developed on the basis of a framework plan since the 2000s. Field 29 is in close vicinity to this predominantly commercial development area, with residential and commercial development planned. It could be beneficial to consider a value increase in the green space corridor to the south. The low green space proximity in that area is not very concerning given the predominantly commercial land-use. Nevertheless, the existing green could be continued to ensure minimal intervention on outer open fields, despite Section 13b of the Federal Building Code. Additionally, it is to be considered that agricultural fields sometimes fulfill recreational functions for the residential settlements located at the peripheries.
- It should be highlighted that inner development contributed to the inflation of inner-city real estate prices due to its higher profit margin and different financial profile than outer development (often cheaper and quicker). Although the accelerated procedures as per Section 13a of the Federal Building Code could be effective in favor of inner development, densification is still strongly shaped by investor's will. It is noteworthy

that for Hattersheim's case, most designations are on the outer area in accordance with the preparatory land-use plan. It is a highly valuable opportunity that the town could integrate the aspects of green space protection and provision while responding to the settlement development pressure.

5. Results of the investigations

In the previous chapter, the German spatial planning system is explained, the characteristics of the Frankfurt Rhine-Main region are discussed, and the selected towns are described based on municipal planning and green space parameters. This chapter analyzes the findings from the previous chapter. It does so by first outlining the findings related to the Frankfurt Rhine-Main region as the *holistic* case. Second, findings from the qualitative analysis of the governance conditions are provided. This part is structured according to the main topics of the investigation for each case study town as *embedded* cases. Each variable is then evaluated with one or several of the applicable resilience qualities. Third, the findings from the spatial configuration analysis of the vegetation cover and green spaces in the spatial focus area of each case study town are provided. The findings from the site visits are also included as these observations are necessary to determine the social and ecological value of each documented green space. Finally, the findings are synthesized to provide an overview with relevance to municipal and regional levels.

5.1. Spatial planning system and regional planning

As the previous chapter discussed, the Regional Plan is a central component of the spatial planning system where local and supralocal planning are merged. Managed by district authorities, regional plans contain the guidelines coming from the federal- and state-level administrations, so that these could be adhered to at the municipal level. Regional plans also involve the information and updates coming from the municipal level and therefore ensure that ministerial and municipal priorities coexist, potential conflicts are mediated, and compromises are found via legal procedures (e.g. derogation procedures, weighing up, etc.). Through the municipal participation in the establishment of the regional preparatory land-use plans, these plans are rather co-created and not so much of an imposition. In essence, regional plan processes are enabled by the multiple feedback principle and not through a clear bottom-up or top-down strategy.

In the Frankfurt Rhine-Main region, land-use conflicts emerge from the tremendous pressure for space. It remains a challenge to reconcile legitimate needs of municipalities with national and international strategies to limit development. Such conflict resolution is defined by legal frameworks and is the backbone of the regional planning process which involves various actors and sectors, as well as various interests and agendas. Weighing up of (public and private) priorities within legal frameworks is therefore an important part of the day-to-day business in municipal and regional planning.

As far as the demand for space in the region is concerned, it is found that the population increase since 2009 was initially accompanied by a stagnating housing provision. This situation created the current backlog demand. Growth pressure is evident in the entire conurbation, but the construction activity is highest in the largest cities, in Frankfurt, Offenbach, and Hanau. In terms of space availability, there are large areas available for development in the north of the region, but this is not the case in the core, where the demand is the highest and where the gaps between buildings and conversion potentials are gradually decreasing. It can be said that even though there is enough space in the conurbation to meet the housing demand, these spaces are very unfavorably distributed throughout the region. Nevertheless, there has been quite a few very large developments on open land, which is often a consequence of infrastructure development attracting new settlement development around it. Also, infrastructure (mainly transport) development itself should be seen as a large-scale outer development and soil sealing.

The current expectation is that the change from maximum density values to minimum density values will bring the most sealing in new residential settlements as a cumulative change in the foreseeable future. An additional insight regarding the availability of inner-city green spaces is, that less and less new households will have private green space, not because of affordability but because climate considerations being taken into account in land-use planning. Based on this anticipation, it is important to enable provision of more public open green spaces that are not necessarily large but are multifunctional (e.g. a playground functioning also as a water infiltration function) and distributed evenly.

Settlement development on the outer area is not only concerning due to usual challenges pertaining to settlement expansion, it can also be highly challenging to mobilize the land due to various other reasons. What complicates the circumstances for the outer settlement development is the current demand for space for logistics centers. Logistics centers are usually space-invasive and associated with a high level of soil sealing with a clear preference of location closer to the urbanized areas. Similarly, data centers are also requiring space, they are smaller in comparison to the logistics centers but have to adhere to specifications e.g. the buffer distance as well as technical requirements e.g. power supply. A concept for outer development could address this, so that the data centers and logistics centers are provided with the space but without consuming too much land and with minimum impact on existing settlement structures.

5.2. Institutions, governance, resilience

In the following subsections, the findings from each aspect of resilience (i.e. the variables: urban growth, planning, regional impacts, finances, accessibility, institutional capacity,

participation) are analyzed. Each introductory paragraph provides a brief general information on each aspect, its relevance, and the ways to identify and verify the qualities based on the questions catalogue that guided the semi-structured interviews (Appendix F). Following that, the analysis looks into the resilience quality or qualities that each of these variables are associated with (i.e. coordination, reflectiveness, robustness, inclusivity, redundancy). The goal of this analysis is to find out whether the examined conditions are supportive for or restrictive to the evaluated resilience quality for each case study town. Observations are based on the main premise that institutional arrangements shape governance, and governance conditions impact resilience (following Huck, 2020). Additionally, insights gained from the German spatial planning system are consistently taken into account.

5.2.1. Urban growth (robustness)

The degradation in the natural environment occurs mainly due to the open land take for settlement and infrastructure development purposes. The goal of analyzing the robustness of urban growth is to indicate the direct and indirect linkages between population increase (as a driver of construction activity) and construction activity (as a driver of environmental problems). The analysis involves a wide spectrum of discussions on inner and outer development as well as the prospects of potential land-use changes. The recent shift in settlement patterns, whether new settlement patterns pose risks to environment, and whether new settlements are impacted from environmental risks in return are the aspects which indicate the degree of robustness of urban growth. The debates around urban growth are not limited to the settlement growth and transformations in the built environment (e.g. extensions to infrastructures, chances in available workplaces, etc. with a focus on “the transformative power of cities for the common good,” as in the New Leipzig Charter) are not excluded.

Rüsselsheim: The town center is densely built up with a dominating industrial settlement area that will soon partially undergo a large-scale conversion. The town grew during the 60s and 70s the most. Therefore, the current growth rate is relatively less due to limited availability of remaining space. The largest residential growth took place twenty years ago in peripheral neighborhoods. But currently, due to increasing pressure on housing demand, stagnated projects are being implemented. Additionally, inner development potentials are realized rather quickly once the opportunity arises. As the spatial focus area analysis demonstrated, only few inner areas could be densified for residential development. Gaps between buildings are very scarce for densification and the main potential comes from conversion. Some areas are particularly available for mixed-use development via conversion. The conversion of Opel’s old factory area is likely to result in a contemporary example of

post-industrial conversions with high economic activity and mixed-use, with substantial contributions to the housing provision. Regarding environmental impacts, for a large outer residential development project located in close vicinity to a flood-prone area, very low flood risk could be confirmed via flood simulations. Soil sealing is constantly tried to be reduced, but this is a project-specific consideration and not supported by a technical agenda. Part of the town is restricted to settlement development due to airport noise protection measures. There is no fundamental shift in the town's settlement patterns, there are risk-prone areas where the potential hazards are respected and perhaps require citywide agendas rather than project-specific considerations only. It is also beneficial that the local politics in Rüsselsheim is keen to rely on local administration's technical expertise. Based on that, it can be said that Rüsselsheim's urban growth is moderately robust, with improving conditions regarding project-based environmental considerations and the proactive nature of the current local politics when it comes to challenges of urban growth.

Bad Homburg: Recent urban growth is rather slow apart from few exceptions. Currently only inner area conversions are taking place, and a new large industrial development on outer area will be underway. Densification cannot be turned into a complementary strategy due to the misalignment between the interests of private owners and technical agendas. There is no immediate threat of an intensive densification in terms of a loss of unsealed gaps between buildings, but it is avoided that this does not result in an extensive outer development. Still, the analysis of the spatial focus area showed several selective densifications and that the change in the focus area was concerned almost exclusively with the restructuring of industrial and commercial areas. Reaching the minimum density values in newly developed neighborhoods can prove challenging due to the rural character of the surrounding built environment. Regarding environmental challenges, Bad Homburg's topography requires careful attention to cold air flow and building orientation, as well as to flood-prone areas and cascading impacts of a potential flooding event. There is a lot of learning from past floods. A current challenge is the traffic load new developments bring, by which conventional solutions prove inadequate as the carrying capacity is reached. There is no fundamental settlement pattern shift in the town. Generally speaking, new settlements are not prone to environmental risks and are not posing environmental threats either. For these reasons, from a perspective of environmental issues, Bad Homburg's current state of urban growth can be considered robust.

Maintal: Settlement growth is restricted to the inner area due to multiple outer area restrictions. This led to a settlement growth that takes place exclusively in the form of inner development, mainly via conversion, but also through selective densification within the existing building stock. The spatial focus area analysis shows that several inner residential

areas were developed as a dense conversion. The residential settlements from the 50s till 80s could potentially be available for densification, without risking a big quantitative and qualitative loss of green space, since these settlement typologies typically provide large open public spaces. Regarding environmental challenges, flooding is extremely important as the town is directly located at the Main river, although there are no settlements directly at the riverside. Flood protection areas indicate a clear restriction where no development is allowed. There were instances where soil sealing and construction was permitted once flood-proofing measures were taken. Conversion from industrial to residential settlements necessitate dealing with contamination. Although settlement patterns do not indicate a big shift, and new developments neither radically damage the environment nor get impacted by environmental problems. Up until now, inner development through conversion, and densification provided spatial reserves to keep up with the settlement growth pressure, but due to persistent demand and decreasing space availability, there are certain limits to this. Current urban growth in Maintal is robust but there might be negative trends in time.

Hattersheim: The town is going through a quite dynamic phase. The initiation of the current settlement development partially dates back to twenty years ago and is being implemented step by step. Inner development in the form of densification alone is not realistic because the gaps between buildings are scarce and not readily available due to private ownership. Although outer development was slowed down because inner development helped catch up with the high demand quite successfully, the town's settlement structure has slightly shifted. Also, outer development is not preferred because agricultural fields bordering peripheral neighborhoods are frequented by residents and thus have a compensation function. The spatial focus area analysis showed that conversion does not always take place on already sealed surfaces. In comparison to the former degree of soil sealing, conversion areas are often more densely built due to density requirements and may be argued to bring more efficient use of space. There are two main environmental challenges with regards to the current urban growth. First, the contamination of the former industrial sites which will be converted to residential settlements, and second, restrictions due to flood protection. Shifting settlement patterns due to dense residential development on formerly industrial areas took place with cautious management of actual and potential environmental problems. Therefore, in Hattersheim, there are both restrictive and supportive conditions for a robust urban growth, with a positive trend.

Langen: Langen is also going through a very intensive urban growth currently. The town is a dense amalgamation of neighborhoods, surrounded by protection areas, with no spatial reserves in between. The analysis of the focus area indicates several inner development areas (conversion and densification) which took place almost entirely on open land. Current

inner development potential is quite reduced. Older outer development plans are currently being realized. For instance, a large peripheral agricultural field will soon be developed into a residential area. The plans of this area date back to the 60s as an industrial area and will now be reallocated to provide a high number of housing units, aligning with higher density requirements of the State Development Plan. In terms of environmental challenges, conversion of existing industrial areas to residential areas requires elimination of soil contamination. Settlement patterns will be moderately shifted due to lack of inner area availability, and this may contribute to impacts of ongoing soil sealing on open land. Given the high pressure to settlement development and tendency to develop outer areas due to unavailability of space, urban growth in Langen is currently moderately robust with both restrictive and supportive conditions.

Overall, all case study towns were found to face flooding and contamination issues. Densely built neighborhoods will necessitate more multifunctional green spaces, e.g. recreational functions as well as water infiltration function, which is a practice that is becoming more widespread. There is also more awareness and more preparedness in terms of investment for renaturation projects. As far as densification is concerned, since the real estate prices show a strong upward trend, private land owners are not interested in selling their property. For the time being, hyper-compact middle-sized towns does not seem to be an immediate risk, but it is also difficult to rely on densification as a strategy to manage growth. In addition to formal plan and law enforcement, there are also formal tools that allow for flexibility, ensuring that the Regional Plan is always up-to-date, e.g. derogation procedures permitting less than prescribed minimum densities. This is a desired outcome of the multiple feedback principle.

It is found that the towns which grew strongly in the past decades (e.g. Rüsselsheim, Langen), cannot grow as much unless opportunities are realized. Generally speaking, towns are bound to settlement development via large-scale conversion in the inner area (e.g. Hattersheim), especially when outer area is strictly restricted (e.g. Maintal). To keep up with the settlement development pressure, many stagnating projects of the past are being picked up. A striking example is the case of Langen, where a very large industrial development project on the outer area with plans from the 60s is now being reallocated for residential and commercial use. It is also observed in the analysis of the spatial focus areas that conversion from industrial to residential or mixed-use does not necessarily limit open land take. Open spaces of formerly industrial areas are oftentimes more intensively used, sealed, and built up when converted into residential settlements. This is sensible in terms of making more efficient use of available space for housing, but conversion does not guarantee no further soil

sealing. Though it is a costly but environmentally beneficial outcome that if these spaces are contaminated, they have to go through a recycling procedure.

Currently, densification in its various forms (building in existing built environment on gaps between buildings, vertical densification) does not contribute so much to the existing housing demand (an exception could be Maintal). The available gaps between buildings for densification are getting less and less. It is easier to provide dense housing via outer development because the interests of private owners of inner-city properties do not align with the goal to provide more housing via densification. However, the trend is different when investors want to purchase inner areas and construct these as densely as possible. Oftentimes the densification at sites of residential settlements from the 50s till 80s could be more feasible for three reasons. Firstly, these settlements can still provide large public open green spaces after densification; secondly, it would be easier to accept new multistory development in an area where there are already multistory buildings; and lastly, if these are not privately owned, decision-making and approval processes can be quicker.

5.2.2. Spatial planning (coordination, robustness)

The integratedness of settlements, infrastructure, and open space in the physical urban space requires their concepts and plans also to be integrated to function well. The integrated approach could be a way to manage the interdependencies, potential conflicts, and tradeoffs at an early stage. It is therefore important to find out whether settlement development concepts and plans are integrated with open space and infrastructure concepts and plans. Consequently, the advantages of an integrated approach can materialize as good spatial planning practices (e.g. small-scale interventions at neighborhood-scale with cumulative positive impact) or as planning policies (e.g. dual inner development).

In order to determine the robustness of spatial planning, environmental impact assessment requirements for new developments are decisive. In order to determine the level of coordination in spatial planning, the integration of environmental and urban planning plays a decisive role. The integration in this case is not limited to the integration of physical plans of various sectors and includes integrative procedures and approaches in general. The binding capacity of land-use plans is also to be taken into account.

Coordination

The discussions on integrated urban development for each case study town reveal many aspects of overall conditions of coordination. ISEK provides a systematic consideration of the development potential, ensures regular reflection, and facilitates an agreed vision and argumentation in terms of what can be done and what not. This is especially helpful in

dealing with the shortcomings of the silo thinking and strict sectoral approaches despite shared responsibilities. ISEK involves all actors at an early stage, has a systematic step-by-step structure. Some municipalities benefited from a political decision in favor of ISEK; whereas some did not. ISEK proved beneficial because the process brings together the actors and factors of technical and social infrastructure, protection and provision of free open space, and settlement development, often with climate, energy efficiency, and digitalization. Synergies and conflicts are well-managed when all spatial components are worked on altogether. A politically approved ISEK is not a precondition for positive outcomes, though it is supportive in achieving these outcomes. Moreover, since successful policy implementation also depends on good coordination, it is investigated whether the dual inner development policy or other relevant policies from the national-level are known and/or implemented. This is a complementary assessment of the capacity to take up and potentially implement relevant policies. The evaluation of the spatial planning conditions for the case study towns are thus as follows:

Rüsselsheim: In Rüsselsheim, there is no ISEK currently, but the settlement, environment, and infrastructure planning are coordinated in the day-to-day business. Rüsselsheim does not implement the dual inner development policy as a methodology and it is not known also as a terminology. Conventional compensation measures are conducted as baseline compensation, limited to the specifications by the Federal Building Code, likely to disregarding a qualitative improvement of green spaces. Therefore, the coordination in spatial planning with respect to green spaces is found to have both restrictive and supportive conditions.

Bad Homburg: Bad Homburg's ISEK with a vision on 2030 not only includes innovative approaches to participation, but also brings together measures for climate-friendly development, including green roofs, proper drainage, building orientation, multifunctional green spaces e.g. water retention basins, green connectivity, and water renaturation. In Bad Homburg, compensation measures are always taken into consideration, though not under the methods introduced by dual inner development. There is still an effort to go beyond mathematical compensation to ensure qualitative improvement and therefore the conditions for a coordinated planning is supportive.

Maintal: Spatial planning has both supportive and restrictive aspects of coordination. ISEK brings together the aspects of open space, infrastructure, and settlement development as a conceptual but structured management instrument and, among other goals, aims at moderate densification in the existing building stock. Similar to Rüsselsheim's case, the dual inner development strategy in Maintal is not applied as a methodology and is not known as a

terminology, and compensation is defined only by the legal specifications. The coordination conditions in planning have both restrictive and supportive aspects, with a positive trend for improvement.

Hattersheim: An ISEK is currently being developed and is expected to be completed in the near future. Despite the fact that there are many developments which will potentially be concluded by the time ISEK is approved, it is still perceived as a short-term and long-term progress. Therefore, the conditions in coordinated planning have both restrictive and supportive aspects, with a tendency toward improvement.

Langen: There is no ISEK for the time being and the current development is mainly based on a previous integrated urban development concept, though the implementation of measures such as green roofs could be ensured in Langen's case without ISEK. In Langen, the dual inner development strategy is known, but compensation beyond the specifications of the legal frameworks is considered inapplicable due to low inner development potential. Therefore, the coordination in spatial planning is found to have restrictive conditions.

Robustness

In determining the robustness of spatial planning, environmental licensing requirements for new developments are decisive. Land-use plans, and with that environmental restriction areas, are enforced from the regional-level planning. Similarly, environmental impact assessments are mandatory for each development, the most fundamental indicator of robustness is safeguarded through legal frameworks. Although within the legal frameworks of binding land-use plans environmental factors have to be examined with each construction project, simplified procedures (Section 13 of the Federal Building Code) and accelerated procedures (Section 13a of the Federal Building Code since 2007 for inner areas, Section 13a of the Federal Building Code temporarily between 2019 and 2022 for outer areas) may allow for an exemption from the requirement of environmental impact assessment (*Umweltverträglichkeitsprüfung*). Regarding simplified procedures (Section 13a), when densification opportunities emerge, binding plans are superimposed on preparatory plans, so that a bit more could be achieved, i.e. more sealing. This may create certain weaknesses if potential environmental problems remain unattended. Since robustness is determined by legal enforcement from higher levels, the robustness of spatial planning for all studied towns is assessed supportive but accompanied with a negative trend in time.

5.2.3. Regional impacts (coordination)

Environmental problems (pollution, traffic, contamination, noise, etc.) can reach beyond administrative borders and have regional impacts. Effective management of these impacts

require coordination among local and regional administrations. In order to determine the extent to which environmental strategies are coordinated across municipal borders, recent large-scale developments which posed environmental challenges are to be investigated. The overall aim is to indicate the regional problems that impact the livability in the city and the measures that were taken to overcome these challenges. The analysis revealed that the increased load of stationary and moving traffic is a common challenge. Usually, traffic issues originate at one location, often following a new settlement development, but it has impacts on the entire road network. Another common aspect for all studied towns is that, there has not necessarily been a single large-scale development recently, and the recent ongoing developments rather cumulate into an unprecedented rate of land-use change. This adds not only to the intensity of heatwaves, floods, droughts, but also to the traffic problem and environmental issues associated with that, e.g. pollution. Despite the complexity of challenges, if and when there are impacts beyond borders, municipalities do cooperate with one another. For this to succeed, regional-scale institutions provide guidance. Therefore, for all observed towns, despite the degree of intensity of problems at regional scale, the coordination of regional impacts is found to have supportive conditions for coordination.

There are, of course, particularities of each town regarding regional impacts. Specific to the case of Rüsselsheim, the town is impacted strongly both by the airport noise and the airport noise restrictions which restricts new development. Though the restrictions are well-coordinated based on legal instruments and land-use plans, while at the same time ensuring the inclusion of various citizen's initiatives. For the case of Bad Homburg, despite the subway line serving the town, problems with the road traffic system are challenging while planned extensions to public transport will not be realized immediately. In Maintal, the relevant example is the development of the new intermunicipal industrial settlement where Maintal borders Frankfurt, during which intermunicipal coordination for impacts beyond municipal borders, e.g. traffic and other infrastructure, are to be ensured. In Hattersheim, regional impacts play perhaps a subtler role in the development of the outer industrial area, (Hattersheim West), as the town attracts new businesses. And in Langen, cooperation with neighboring municipalities often occurs on the basis of infrastructure in general and traffic issues in particular. This involves not only problems but also new intermunicipal projects such as the bicycle highway (Radschnellweg).

5.2.4. Finances (robustness, redundancy)

Financial capacities can usually become the decisive factor when institutions have to react quickly and respond adequately to risks, hazards, and disturbances. Similarly, the municipal household can be the decisive factor for green space provision and protection. It is therefore

necessary to point out whether there are reliable financial resources given the dependency of green space provision, maintenance and upkeep. The availability of state- and federal-level financial support programs are also investigated—this indirectly provides insights to cross-level coordination and institutional capacities. It is noteworthy that financial situation of one municipality can be very different than a neighboring municipality. It is therefore not possible to refer to a standard conditions for municipal household.

Robustness

As a general rule of thumb, municipalities want to remain attractive to new businesses, since trade taxes paid by businesses is the main municipal income. Municipal income is then channeled and mobilized to provide municipal services, a cost factor which increases with each new resident. Even though outer development could be limited to a minimum for residential development, it is therefore unlikely to be given up for potential industrial and commercial development. As a general rule of thumb, finances are evaluated as robust when there are reliable internal and external resources (for environmental management in general, for urban green spaces in particular) that are coordinated across agencies.

Rüsselsheim: Regarding external funds, although not directly relating to green spaces, one of the most discussed state-level funding projects is Großer Frankfurter Bogen, as described briefly in Chapter 2 and Chapter 4.

Bad Homburg: Regarding the dependency of the quality and quantity of urban green spaces on municipal household, the stable financial situation of the town even enables land purchase for green space provision. There are reserved subsidies for costlier processes like renaturation projects, but there is no dependency on external funds for these projects to be realized. This indirectly contributes to solidarity with towns that are in more urgent need for state subsidies.

Maintal: The federal-level program *Zukunft Stadtgrün* has been the most important among other external subsidies, but the bureaucracy around proposal submissions for these programs are criticized to be overly complicated, which makes it harder to tap these resources for the towns that are in need the most.

Hattersheim: When the town was under state protection due to its critical financial situation, selling off of green spaces was on the table to zero the maintenance costs and to generate income. Though the process was stopped thanks to a citizen's initiative, this case exemplifies the high vulnerability of green spaces depending on municipal household conditions. Also, not only the purchase and provision of green space but also its upkeep and maintenance are cost factors.

Langen: A recent example of mobilizing internal funds for green space recovery took place in the aftermath of the storm events of the 2019 late summer Langen. The town was rather quick to set aside in-house recovery funds. External funds for green spaces cover only special matters.

The analysis of the findings showed supportive conditions for Rüsselsheim and Bad Homburg and supportive and restrictive conditions for Maintal, Hattersheim, and Langen. These findings are cross-checked with the data made available by the Regional Association (municipal tax incomes of year 2020, Regionalverband FrankfurtRheinMain, n.d.).

Redundancy

Redundancy exists when the city has an environmental contingency fund set aside to restore the environment after hazards. For the studied towns, it is hard to speak of a budget that is exclusively allocated for green space protection, provision, and damage recovery. In terms of internal resources, it is often the case that the politics decides and then the administration allocates funds. When a municipality is in a financially comfortable situation, an undivided budget can ensure a certain level of flexibility (as is the case for Bad Homburg), so that settlement development and green space provision and protection can become one integrated process reducing conflicts and allowing synergies. However, the towns facing financial problems often have to set priorities in favor of financial improvement (as formerly was the case in Hattersheim). Given the lack of contingency funds, financial redundancy for all case study towns were found restrictive, but each municipality has had its own unique challenges and emergency responses. Also, the Regional Association assists its member municipalities in finding potential funding programs e.g. from the European level which could be received e.g. within the framework of an intended project. These aspects indicate a positive trend in redundancy.

5.2.5. Accessibility (inclusivity)

Inclusive accessibility is a fundamental quality of equity, social cohesion, and (environmental) justice. The goal is therefore to find out whether all residents are able to use and benefit from natural resources, ecosystem services, and recreational areas equally. This question does not exclude a further understanding of whether all residents are also equally impacted from risks, hazards, and damages. Another point of investigation is the increasing use pressure on existing urban green spaces in cases in which green space provision lagged behind while the town's population increased. This opens up a complementary debate on the level of acceptance among residents and their views on new development in general and on densification in particular.

Rüsselsheim: There is high use demand for open public spaces, because the town's central parts are densely built with only a few parks that are frequented very intensively. This is already a restrictive precondition for equal access to limited green spaces. A change regarding social housing has indirect positive impacts: Several decades ago, the town provided its social housing at the town peripheries while single-family houses were located at more favorable areas. This is now changing with positive implications on provision of public green spaces (residents of multistory housing usually do not have private green space and that is why public green space has to be provided for each social housing project). This makes Rüsselsheim's green space accessibility more inclusive, with improving conditions.

Bad Homburg: While the current new developments in conversion areas focus on a typology mix to ensure social mix, the acceptance not only for densification but also in general for change is very low. Despite a high sense of place attachment, this may endanger sustaining the quality of life in the long run. This is rather a restrictive condition, to an extent that it may limit improvements.

Maintal: Similar to Rüsselsheim's case, the use pressure in public open green spaces is high because of their low number. Additionally, there are also quite a lot of outer area restrictions. Thus, the acceptance for densification (especially on green space) is in general low. An exception was the refugee shelter provision on a green space, as residents stood in solidarity during an exceptional situation. As previously explained, appropriate settlement typologies are considered as potential priority areas for a moderately dense building stock. However, currently, restrictive conditions due to the low number of parks weigh heavier than supportive conditions.

Hattersheim: It is intended to secure a minimum amount of green space with each new development. Still, increased inner development means increased pressure on infrastructure, and green space is no exception. Also, as density increases, so does the stationary and moving traffic. Central parking spaces or underground garages could reduce the load on the sidewalks, so that these can be accessible for all. Similarly, the pressure on social infrastructure increases accordingly (e.g. daycare centers, sports centers). The town tries to consistently consider all these outcomes of increased pressure for space in their day-to-day business, which is a supportive approach amidst restrictive conditions.

Langen: Similar to Maintal, there are a lot of outer area restrictions, nature protection areas, forests, flood protection zones, etc. This leaves the town with a limited spatial reserve to build residential settlements which inflates real estate prices and puts affordability at risk, i.e. a restrictive condition for access to affordable housing. Similar to Hattersheim, increasing

stationary and moving traffic load in Langen leaves even less room for other uses of open space. Overall, Langen's conditions in terms of inclusivity of accessibility are found restricted.

What is common for all studied towns is that, density, both in inner and outer development, has been a point of criticism by residents. For the inner areas in the already-existing built environment, this indicates a change in the familiar environment. For the newly developed areas, density values are supposed to comply with the minimum values given in the State Development Plan that are often higher than accustomed densities in the familiar environment. It is usually a common goal of the local administration (technical agendas), local politics (political agendas), and investors that a high number of dwellings is achieved. This makes higher densities a point of criticism: The general view is that densification should take place where settlement typology is appropriate in the surrounding area. Not every gap has to be built and smaller gaps can rather be turned into high quality green spaces like pocket parks.[41]

5.2.6. Institutional capacity (coordination, reflectiveness, robustness)

Internal and external institutional capacities are key for the facilitation of successful environmental management. The investigation is firstly concerned with coordination, assessed by the responsibilities of different sectors and agencies in planning, management, and implementation. Here, a valuable input is provided by the reflections on potential incompatibilities between state- and federal-level goals and strategies with local-level needs and the ways of sharing knowledge and responsibility. The second key factor is reflectiveness, indicated by a well-functioning system of monitoring, evaluation, and accountability. The third key factor is the robustness, indicated by the level of awareness of the in-house staff about the risks, hazards, and coping strategies to deal with the impacts of the climate change within their day-to-day work.

Coordination

Analysis of the findings reveal that the higher-level spatial goals are appreciated by the local-level. However, there are certain drawbacks. Legal frameworks of the Building Code enforce implementation of the federal-level goals, but there may be incompatibilities with what is going on at the local-level. For instance, the temporary Section 13b of the Building Code may be argued to be in conflict with the national 30-hectares-goal. The land in inner areas are

[41] Another common aspect is that, since multistory housing does not provide private green space, it increases the need for easy access to public green space. This is not to claim that the private garden owners do not use public parks. On the contrary, currently because of the pandemic, private home owners are more appreciative of and using more often the public green spaces, especially playgrounds. This has unexpectedly increased the use pressure.

more expensive, and it is often financially and management-wise more preferable to initiate outer development. Currently, the Section 13b allows for adjoining outer area in certain conditions with accelerated procedures. Moreover, the switch from maximum to minimum densities is often given as another example. Towns usually exceed these minimum values to provide adequate housing, though the minimum density value cannot be regulated by the code in the inner areas, because reference values are estimations based on existing typologies.

Despite the restrictive character of such conflicts, it is the local administration's responsibility to navigate through these processes. Municipalities do have the tools to mediate the processes by taking into account the investor's anticipation that the town will keep growing, citizen's anticipation that there will not be drastic changes, and legal frameworks to ensure compatibility with higher-level goals and specifications. The processes tend to run more smoothly especially when internal departments work in close cooperation with one another (applies to all studied towns but with varying degrees) and when the personnel capacities are sufficient to keep up with heavy bureaucracy (which needs improvement in all studied towns). It can be argued that the Regional Plan functions as a cross-level management tool, enabling higher-level and local-level integration, which indicates a positive quality. Therefore, it can be said that the coordination capacities have both restrictive and supportive conditions.

Reflectiveness

The institution which plays a critical role here is the Regional Association. In the context of this study, the tools made available by the Regional Association are perceived supportive for monitoring the land-use change and evaluating the current development situation. The Regional Association is an important partner in general but the data services, especially the land-use overviews and Strategic Environmental Assessment (*Strategische Umweltprüfung*, *SUP*), are highly appreciated especially by its underfinanced and understaffed municipalities. Generally speaking, services that could normally get outsourced are the Regional Association's accustomed services for its member municipalities. However, financial and personnel capacities of municipalities could at times be so low, that even the already provided tools and services cannot be utilized to the full capacity or used only when there is an absolute need to do so. For monitoring, evaluation, and prognoses, a high degree of dependence on the services of the Regional Association is observed. This external support is necessary for institutional reflectiveness. Each observed case is found to have specific features shaping restrictive and supportive conditions applying to its reflectiveness:

Rüsselsheim: In addition to the common challenges mentioned above, the discussions of reflectiveness in Rüsselsheim also involved rather "softer" aspects, e.g. learning from the

outcomes of unfavorable past decisions, as in the case of better choice of location for social housing projects and the change in the "far-from-sight-far-from-mind" approach, for the politics, for the residents, and for the administration alike. Institutional reflectiveness in Rüsselsheim is therefore observed to have some generalized restrictive conditions but also case-specific supportive conditions.

Bad Homburg: The "softer" aspects of reflectiveness, e.g. learning from previous experiences, can be seen in the flood risk management strategies and flood-proofing. Regarding monitoring and evaluation, it is found that the lack of in-house statistics office proves challenging because data is collected by specific departments and then brought together in planning and is not managed centrally. The town is establishing a register of gaps between buildings. The Regional Association's register is found helpful and useful, but a shortcoming is that it is based on aerial images and requires verification from the municipality. Bad Homburg developed an open space and landscape concept to monitor the status of flora and fauna of each neighborhood. Despite a few generalized limitations, the town is sufficient in terms of reflectiveness.

Maintal: The services of the Regional Association are well-known and used, but shortcomings in terms of the time taken for information to get updated in the regional land-use plans is seen as a point of improvement. Additionally, in-house capacities are mentioned to be barely sufficient to be able to keep up with the bureaucracy. Therefore, the conditions for reflectiveness in Maintal have both supportive and restrictive conditions.

Hattersheim: The services of the Regional Association are highly appreciated because otherwise the town itself would not be able to do these on its own due to lack of personnel capacities. Though the cadaster of the gaps between buildings is approached with caution because it might bring too much speculation. Therefore, the conditions for reflectiveness in Hattersheim are found to be both restrictive (lack of personnel resources) and supportive (efficient use of Association's tools and services).

Langen: Services of the Regional Association can only be useful as far as the in-house personnel capacities allow for it. Currently their services are used only when there is a need to do so. Therefore, the conditions for reflectiveness in Langen are found restrictive, mainly due to limited personnel capacities.

Robustness

Since in the German context all interviewed staff members showed very high level of climate awareness and good knowledge of the strengths and weaknesses of their towns, the focus for robustness is shifted to the actual and perceived value of knowledge-sharing, exchange,

and learning from others (knowledge co-creation, strategic network management, enhancing connectivity, mainstreaming) with a focus on environment. In general, regular exchange events facilitated by the Regional Association are quite important. This allows for towns and municipalities to learn from each other's experiences, where common challenges are discussed and good practices in one town inspire solutions in another. Regular meetings of heads of planning departments are also found very beneficial. It is therefore found for all studied towns that there are supportive conditions for robustness, as indicated by a high level of exchange and learning. Additionally, in Maintal and Bad Homburg, there is a proactive involvement beyond the accustomed networks and use of knowledge repositories which is assessed as an additional positive quality.

5.2.7. Participation (inclusivity)

Participation ensures consultation with the society and institutions that are of importance to the general public. This includes the private sector, too, as industrial activities are associated with the greatest impact on the natural (e.g. via resource use) and built environment (e.g. pollution, contamination). The degree of citizens' and civil organizations' participation in planning is decisive for inclusivity.

Since in the German context public and institutional participation processes are embedded into planning processes through legal frameworks (Section 3 of the Federal Building Code), for this study, the goal is to investigate the roles of the most important actors in urban development processes (e.g. the municipality, other governmental bodies, investors, politics, citizens) and the representation of interest and power relations among them.

It is observed for all towns that the local politics and citizens are the two main partners of municipalities, politics as the decision-making mechanism and the main client and citizens as co-managers. As a general rule of thumb, when citizens are against any technical agenda, this may resonate itself as an unwillingness in political agendas, because it may cause a loss of political support. However, in towns where politics relies on technical guidance, it takes a stance to communicate the necessities with the citizens accordingly. Here the role of the municipality is to mediate between the parties in accordance with the legal frameworks.

Rüsselsheim: Ideas come from politics and the town implements these, but the results may not always be what the politics initially imagined, e.g. for a residential development the municipality may prioritize multistory dense housing instead of developing a single-family neighborhood. But this is not a challenge in Rüsselsheim because local politics relies on technical expertise and contemporary approaches and do not avoid taking a stance to communicate technical necessities to citizens. Citizen's initiatives are also ensuring that the

voices get heard, but several examples showed that the loudest is not necessarily the one that represents the majority, and it is important to navigate these processes with extreme care. The conditions of inclusion are therefore evaluated supportive.

Bad Homburg: Citizens' unwillingness, e.g. for densification concepts, reflects itself in political reluctance, though the administration prioritizes technical necessities for the benefit of the common good. Additionally, participation took a proactive turn with ISEK and the town now develops a public participation guideline for more citizen power in steering. Social institutions are players in participation, too. The conditions of inclusion in Bad Homburg is therefore evaluated supportive, with a positive trend.

Maintal: Regarding participation, Maintal has a separate *Agentur* to ensure citizen participation and co-management, including associations and institutions of primary importance to citizen's daily life. The conditions of inclusion in Maintal is therefore evaluated supportive with a positive trend.

Hattersheim: Local politics and investors are the most important actors. Investors initiate processes, politics takes the responsibility. Through politics' decision-making processes, citizen's and investor's interests are taken into account, which ultimately makes politics the most important actor. If citizens unite, they are powerful to steer processes. Given the mediatory role the municipality plays in balancing interests, the conditions of inclusion in Hattersheim is evaluated supportive.

Langen: Similar to Rüsselsheim, different actors may have different anticipations (e.g. citizens might expect more single-family housing, but the municipality has to convey the technical necessities to politics as to why multistory housing has to be realized instead). The large outer development that is about to start after 60 years of planning may be seen critically by the citizens. This development will also be denser and change the cityscape. So, the politics has to convey the rationale to the citizens. Overall, local politics, administration, and citizens are the most important actors and the administration's role is basically to weigh up the public and individual interests. There is no permanent body for participation. Although citizen's initiatives are active, these are not united and actually could be integrated. The conditions of inclusion in Langen therefore involves both supportive and restrictive conditions.

5.2.8. Summary

This section looked into the aspects of institutions, governance, and resilience for each case study town and investigated whether the conditions are supportive for or restrictive to the evaluated qualities. It is found that some of the supportive and restrictive conditions are

generalized and some are highly differentiated. For some of the evaluated qualities, namely the robustness of spatial planning, coordination of regional impacts, redundancy of finances, and coordination of institutional capacities, factors beyond the municipal-level were decisive and the results were the same for each case study town. Also, it proved necessary to include the positive and negative trends for each evaluated quality, since in some cases the supportive/restrictive classification falls short of capturing the current situation (Table 5.1).

Table 5.1: An overview of the evaluated resilience qualities and associated governance conditions. [42]

Town \ Evaluated quality	Urban growth (robust)	Spatial planning (robust)	Spatial planning (coordinated)	Regional impacts (coordinated)	Finances (robust)	Finances (redundant)	Accessibility (inclusive)	Institutional capacity (coordinated)	Institutional capacity (reflective)	Institutional capacity (robust)	Participation (inclusive)
Rüsselsheim	↑	↓				↑	↑	↑			
Bad Homburg		↓				↑	↓	↑		↑	↑
Maintal	↓	↓	↑			↑		↑		↑	↑
Hattersheim	↑	↓	↑		↑	↑		↑			
Langen		↓				↑		↑			

Legend:

- Supportive conditions for evaluated quality
- Supportive and restrictive conditions for evaluated quality
- Restrictive conditions for evaluated quality
- ↑ Positive trend in time
- ↓ Negative trend in time

5.3. Spatial parameters

Analyzing green space parameters helps understand the green space configuration in a given area and its implications. The quantitative land-cover analysis of the green space parameters—amount, distribution, connectivity, and proximity—in the spatial focus area gives an understanding of what has to be taken into consideration to preserve green space quality and quantity. It captures which locations to choose for new green space provision for a more even distribution, where to increase connectivity, which settlements are underserved by green spaces in a given area, and where to potentially consider densification. The analysis of quantitative parameters has to be complemented by an analysis of the quality of each observed green space, i.e. their social and ecological value, so that the opportunities and constraints can be identified more precisely and are not only limited to numerical values.

[42] The illustration of the table is inspired by how the supportive and restrictive conditions and positive and negative trends in time are depicted in the Governance Assessment Tool by Bressers & Bressers (2016).

5.3.1. Amount

The urban green space amount in the spatial focus area is calculated in terms of percentage cover of the entire vegetation cover including agricultural fields, forests, parks, and rivers and sports, leisure, and also in terms of recreational green space cover. This division is necessary because the distribution and proximity variables are concerned more with green spaces with recreational qualities; whereas for the connectivity and social-ecological value, the entire vegetation cover should be subject to analysis. The findings are as follows:

Despite the high amount of forest cover in the entire town, Langen's spatial focus area has the lowest vegetation cover (8,30 per cent) and recreational green cover (2,46 per cent) among all studied towns. This is in line with the anticipations since the spatial focus area in Langen is a very dense settlement area with only a few parks and a small patch of forest. Similarly, the spatial focus area in Rüsselsheim also has low overall vegetation cover (11,00 per cent) and recreational green cover (4,73 per cent). Maintal's spatial focus area has relatively high percentage of vegetation cover (31,32 per cent) but a lower percentage of recreational cover (7,22 per cent). This is because there are several agricultural and nature protection areas that partially fall within the focus area, but not many parks. In Bad Homburg, the vegetation cover in the spatial focus area is moderate (20,86 per cent), but it has the highest recreational share (9,94 per cent) among other case study towns. The spatial focus area in Hattersheim shows ideal characteristics as it has high vegetation and recreational cover (31,29 and 9,77 per cent respectively). Similarly, in Bad Vilbel, the observed area has the highest percentage of vegetation cover (33,12 per cent) and high recreation cover (9,88 per cent).

5.3.2. Distribution

The distribution variable shows whether the recreational green spaces are evenly distributed in a given area. This is measured by dividing the total edge length of the green spaces by the total area of observation, in meters per hectare.

In line with expectations, in Rüsselsheim, the distribution of recreational green is found to be the lowest (25,10 m/ha), as there are almost no green spaces located at the western side of the spatial focus area where the Opel factory is the dominant structure. In Langen, despite limited recreational green spaces in comparison to Rüsselsheim, their distribution is found to be higher (33,02 m/ha). In Bad Homburg and Bad Vilbel, the amount of recreational green cover is very close, and their distribution values are also very similar (42,16 m/ha and 40,83 m/ha respectively). Although Maintal has almost three times as much recreational green space as Langen, the distribution is almost the same as Langen (33,10 m/ha). In

Hattersheim, the distribution of recreational green cover (40,83 m/ha) is found to be the highest among all studied towns.

5.3.3. Connectivity

The connectivity of the vegetation cover is calculated according to the methodology provided in the third chapter. The goal in analyzing the connectivity as a variable is to indicate how much and how well the patches of vegetation cover are connected in the spatial focus area.

In Rüsselsheim's spatial focus area, similar to the distribution values, the connectivity of vegetation is found to be the lowest (27 per cent) with a moderate to low quality, since the only major connector is the Main river and the open area alongside it. In the spatial focus area of Langen, due to the high percentage of dense settlements and scattered distribution of green spaces, connectivity is low (30 per cent). In Bad Homburg, Maintal, and Hattersheim, spatial focus areas are found to have high connectivity (51, 54, and 55 per cent respectively). In Bad Homburg, the two parks in the spatial focus area contribute to the high vegetation cover connectivity. In Maintal, the stream and large patches of nature protection areas increase the overall connectivity. In Hattersheim, the Schwarzbach stream and the green spaces alongside the stream is the main landscape connector. Similarly, in Bad Vilbel, the Nidda river and the green areas around it provides a continuous recreational green cover and thus the connectivity is found to be the highest (60 per cent).

5.3.4. Proximity

The proximity analysis is concerned with the percentage of settlement areas that are located within the catchment areas of recreational green spaces. According to the adopted criteria, the catchment area of a recreational green space that is larger than 1.000 m² is 300 m and that is larger than 10.000 m² is 500 m. The proximity percentage is a valuable analysis especially when it is mapped as it helps detect settlement areas that are underserved or not located in the catchment area of any recreational green space.

In Bad Homburg, given the lack of green spaces at the southwestern part of the spatial focus area, the proximity of recreational green spaces is the lowest (67,33 per cent) despite the highest percentage cover and high connectivity. In Langen's and Rüsselsheim's spatial focus area, a high portion of settlements (87,05 per cent and 89,92 per cent respectively) are found to be served by recreational green spaces, but these settlements are mostly located in the catchment area of only one green space and are not served by multiple green spaces. In Bad Vilbel, a high percentage of settlements in the spatial focus area (89,50 per cent) is served by recreational green spaces. Despite the highest vegetation cover, high recreational cover, high distribution, and the highest connectivity, proximity value in Bad Vilbel is

moderate. In Maintal, most of the settlements (93,11 per cent) are located within the catchment area of at least one recreational green space, but some settlements are relatively underserved (e.g. only by one green space with low social and ecological value). In Hattersheim, in line with the expectations based on the highest distribution of recreational green spaces, proximity is also the highest. Almost all settlements (99,38 per cent) in the spatial focus area are located within the catchment areas of recreational green spaces.

5.3.5. Social and ecological value, open space type

The social and ecological values of green spaces and their open space type are the variables that were observed during the field visits. As explored in Chapter 3, for each of these variables, a certain set of criteria was applied to enable objective and replicable observations. For these observations, a distinction between vegetation or recreational green cover was not necessary and as many open green spaces were observed and documented as possible. The number of observed and documented green spaces vary from 20 in Maintal to 36 in Langen. Since the number of green spaces is case-specific, this variation is anticipated and does not have any implications on the outcomes.

In Rüsselsheim and Langen, it was found that despite several exceptions, most of the observed green spaces have low social and ecological value but are publicly accessible without restriction. It is a positive aspect that most green spaces are publicly accessible. But the ones with high social and ecological value are low in number. In Langen, several green spaces could not be classified due to inaccessibility. In Maintal, slightly more than half of the green spaces have moderate to high social and ecological value; however, access to these spaces are often conditional or private. The remaining green spaces have low or very low social value and moderate or low ecological value (e.g. agricultural fields, private gardens) with a few exceptions (e.g. cemeteries, community gardens). In Bad Vilbel, about half of the observed green cover in the focus area has low to very low social and ecological value; whereas for the other half the opposite is the case. In Bad Homburg, a high portion of the green cover has very high social and ecological value and allows for unrestricted public access, which is an ideal combination. In Hattersheim, optimal distribution and proximity of green spaces is accompanied with at least half of the observed green spaces with moderate to high social and ecological value and with public access without restriction.

5.3.6. Summary

The results of the spatial quantitative analysis and the results of the field observations are summarized in the table below. The goal is not necessarily to provide a comparison, but rather to figure out whether there are any correlations or tendencies among these green

space variables and what these correlations or tendencies may imply (Table 5.2). For a detailed breakdown of the documentation of each observed green space, see Appendix H.

Table 5.2: An overview of green space parameters in the spatial focus areas of the case study towns.

SFA parameters / Town	Amount of vegetation cover (%)	Amount of recreational green cover (%)	Distribution of recreational green (edge density m/ha)	Connectivity of vegetation cover (%, dominant quality %)	Proximity of recreational green, catchment area (%)	Number of total observed on-site	Social value, dominant quality	Ecological value, dominant quality	Open space type, dominant quality
Rüsselsheim	11,00	4,73	25,10	27%, "moderate-low" (21%)	89,92	34	24 none to low	21 none to low	23 access without restriction
Bad Homburg	20,86	9,94	42,16	51%, "very high" (25%)	67,33	25	11 moderate to high	14 moderate to high	15 access without restriction
Maintal	31,32	7,22	33,10	54%, "very high" (43%)	93,11	20	11 moderate to high	15 moderate to high	13 conditional or private
Hattersheim	31,29	9,77	62,50	55%, "very high" (36%)	99,38	32	15 moderate to high	17 moderate to high	16 access without restriction
Langen	8,30	2,46	33,02	30%, "moderate-low" (23%)	87,05	36	15 none to low	21 none to low	23 access without restriction
Bad Vilbel	33,12	9,88	40,83	60%, "very high" (34%)	89,50	21	11 none to low	11 none to low	11 access without restriction

In calculating the amount, it is found that it can only provide an overview of percentage vegetation cover and percentage recreational cover. If the number of inhabitants living in the spatial focus area was known, an indicator of green space per capita could have been applied. Overall, the important outcome of the amount-related findings is that it could be used for comparative purposes, but these findings do not imply any specific outcome on any other parameter, for instance a low vegetation cover neither implies a low recreational green cover nor low connectivity (e.g. Bad Homburg).

For the distribution of recreational green spaces, Bad Homburg and Bad Vilbel have similar edge density values, which is in line with anticipation that these two towns should also have a similar amount of recreational green cover. However, Maintal and Langen also have nearly the same distribution level, which shows that a high coverage does not guarantee even distribution. As long as other parameters are also supportive, a more even distribution could be a more favorable condition than a high green space cover alone.

Regarding connectivity, it is found that rivers and streams, particularly the ones that are accompanied with green spaces, are contributing tremendously to connectivity. Renaturation and accessibility to increase the social value (walking, biking, recreational use etc.), e.g. for

the case of Maintal, could strengthen the already high connectivity. It is also observed that especially in a densely built area with smaller green patches, if distribution is high but green space patches are small, connectivity is low. Not surprisingly, these areas tend to have lower agricultural and forest cover. Low connectivity is correlated with high built-up density (e.g. Rüsselsheim, Langen).

It can be argued that proximity is the parameter that relates to the characteristics of the built environment and use of green spaces the most. As in the example of Langen and Bad Homburg, neither the amount nor the distribution correlates to the level of proximity. Although agricultural fields are serving adjacent residential settlements at the peripheries for compensation when available, these areas are not included in the proximity calculation because they are not classified as recreational green space. Another important observation through proximity is that, if a settlement area is located in the catchment area of only one green space, this creates a certain dependency. For instance, if social and ecological values of this green space is low, or when it is not publicly accessible, then principally the settlements that are located in the catchment area of this *green* space have no real benefit.

Complementarily, the findings related to social and ecological value and open space type provide an overview of more specific features. These findings are particularly beneficial to take into account for new settlement development, but also for considerations related to where to provide/where to protect urban green spaces. Some green spaces with suspected high social and ecological value (e.g. private gardens) could not be documented due to conditional access or private ownership. Publicly accessible green spaces with high social and ecological value, such as riversides, are shown to be of extreme importance. However, high social value is not always coupled with high ecological value and vice versa. In such cases, it could be a priority to increase the lower value. The most favorable condition occurs when a green space has high social and ecological value and is publicly accessible.

6. Discussions: Implications and interpretations

Based on the factual presentation of the empirical results of the investigations, the previous chapter presents the outputs of the qualitative and spatial analysis for the region and the selected case study towns. It shows the results of the qualitative (explanatory) inquiry of governance conditions with a focus on urban green spaces and from the perspective of planning. It also shows the results of the spatial (exploratory) investigation of the green space parameters in the spatial focus areas of the studied middle-sized towns. Building on that, this chapter explains how these findings should be interpreted and what their implications are. This is done by first discussing and relating the findings to the scholarly debates and conceptual models. The goal is to interpret the meaning of these results and to show how they fit into the debates and gaps that were addressed in Chapter 2. The debates around resilience and planning are revisited and a more complete picture of the conceptual framework with new insights gained from the research (for the social subsystem through the investigation of governance conditions and for the ecological subsystem through the investigation of spatial analysis of urban green spaces) is provided. Second, the research findings are addressed in relation to the research aims, research questions, and the hypothesis on the basis of the methodological framework as laid out in Chapter 3. Finally, the limitations of the study are identified.

6.1. Planning and the region

The spatial planning system has a complex structure of institutional responsibilities and operates at international, national, several subnational, and local levels. The functioning of the system is based on a very thorough legal foundation, which ensures stability, but in some respects may also indicate a rigid structure with vulnerabilities resulting from that.

Municipal planning can be at times slow, but it is more flexible; whereas higher-level plans are based on long-term perspectives, so they commit to these perspectives more rigidly, but they are supposed to change and adapt faster. The regional planning level has exceptions as it provides certain flexibilities. It brings together higher-level goals and strategies and the actual needs and implementation at the municipal level based on the multiple feedback principle. It ensures that the municipal land-use plans are in accordance with the federal- and state-level goals.

Overall, the planning system allows continuous flow of information in multiple directions (e.g. through the Regional Plan). Its responses to unexpected disruptions might be slow or not readily available. On another note, the derogation procedures at the regional plan level, as a

management procedure (among others for perceived density), often fulfills a correction function through the *predetermined* flexibilities of legal frameworks.

Principally, the entire system is designed to ensure that there is not necessarily a discrepancy between the supralocal and local-level planning and the conflicts are resolved and not avoided. It is noteworthy that it is only the local-level planning where the federal- and state-level objectives (e.g. state-level spatial objectives: decentral concentration, inner before outer development, and point-axial development, federal-level spatial objectives by the MKRO: are to enhance competitiveness in growing cities and regions, to ensure public services in shrinking cities, to safeguard sustainable land-use, and to support climate and energy transformation) can be realized (either by direct implementation of strategies or by ensuring land-use decisions supporting these objectives). In this respect, it can be said that supralocal goals are shared responsibilities by all administrational levels (goal setting: supralocal level, implementation: local-level). This makes the institutional capacities of local administrations one of the decisive factors in achieving these objectives.

6.2. Conceptual framework revisited

6.2.1. Resource conflict

In the Regional Plan, green spaces in the outer area belong to the category *Freiräume*, which could be referred to as free, open spaces and includes all vegetation covers such as water, agricultural fields and forests. The protection and provision of these spaces take place essentially on the basis of exclusion of areas that are not suitable for settlement and infrastructure development. As far as green spaces in urbanized areas are concerned, a separation as such between the built and the natural environment is neither possible nor necessary. At this point, density and its implications on soil sealing becomes an important debate, but the debate can evolve in many directions depending on how density is defined or measured, e.g. the percentage of sealed surface in a given area,[43] or the number of housing units per hectare. The latter refers to a commonly-used unit in planning while having dependencies on the former, because one can achieve a predetermined number of dwellings per hectare resulting from a variety of design choices with different implications on soil

[43] Based on the Urban Atlas categories made available via the Regiomap, it is found for all case towns that the residential settlements in the spatial focus areas are consistently a combination of continuous urban fabric (with more than 80 per cent soil sealing) and discontinuous dense urban fabric (soil sealing between 50 to 80 per cent). Urban Atlas categories did not include other settlement typologies, which in this case limits an overview of the actual land-cover situation (e.g. due to the exclusion of large industrial parking lots). The Urban Atlas is not concerned with the soil sealing in non-residential settlements, which could be seen as a weak spot in an otherwise useful tool.

sealing and availability of public parks and/or private gardens (as in Lehmann, 2017). This is not to advocate for any specific arrangement of the residential buildings. On the contrary, it is perhaps more important to ensure that any new development is in harmony with its surrounding built and natural environment including high quality open green space. However, this *perceived* density is of course in some respects a "softer" parameter as it is not measurable. Still, the binding land-use plans, in which building heights and floor area ratios are precisely defined, could become a tool to serve this purpose.

Integrating additional strategies, e.g. the dual inner development, within the framework of land-use plans could perhaps be a supportive approach. Despite obvious challenges in their operationalization, their role is to help navigate through certain conflicts through certain strategies. For instance, the dual inner development policy is a methodology that is designed for compact inner development while keeping green quality and quantity unimpaired. Based on a geoinformation analysis the policy ranks green spaces by size, connectivity, vegetation cover, sealed cover, anthropogenic effects, biodiversity, as well as the significance of the green space for the neighborhood and for the city in order to determine its overall availability for inner development. A consistent application of this methodology, ideally in combination with the additional parameters (e.g. distribution, proximity) and through onsite confirmation via field observations, could capture a clearer picture of where exactly opportunities for inner development arise, and likewise, where green space protection and provision has to have absolute priority over settlement development.

In the Frankfurt Rhine-Main region, the resource conflict occurs due to the tremendous pressure for space. An unprecedented amount of settlement space has to be provided, not only for residential but also for industrial and commercial use. Although the housing demand has played a central role in this study, the evidence from the analysis is consistent with Naumann et al.'s argument that population increase (high demand for housing) and economic activity (high demand for workspace) are strongly linked (Naumann et al., 2018). The current outer development trend for industrial settlements (e.g. data centers and logistics) adds another layer of complexity to the population increase-economic activity relationship. It appears unrealistic that the outer development will be given up despite the level of demand for outer industrial settlement development; whereas it could theoretically be possible to limit residential development to the inner areas. The findings also further support the idea that this relationship is to be observed in the land-use and land-cover change (Alberti et al., 2003; Lambin et al., 2001). For the case of Frankfurt Rhine-Main, the pressure for both residential and industrial/commercial settlement development is the highest at the core of the conurbation, where the available land is very scarce.

Currently, densification does not pose an immediate threat of loss of large sums of vegetation cover in the studied middle-sized towns. The challenge is rather that the gaps between buildings are getting quite scarce and cannot be mobilized due to private ownership. This combined with the decreasing conversion potentials in the inner-city areas, makes outer development despite the national goal to limit open land take inevitable.

Still, densification is only one way to realize inner development. Conversion of old military areas and industrial zones are far more effective in activating inner-city spaces. Conversion is also done with the aim to build more densely. As a result, it can be argued, for instance, that Rüsselsheim's urban heat island problem and Langen's recent flood damage may have been closely linked to the high percentage of impervious surfaces. This confirms that the compactness adds to the functionality of a town, which mitigates climate change impacts but limits adaptation (Reißmann & Buchert, 2018).

Densification in the scholarly literature refers to the *process* of becoming compact, and density refers to the measurement of how compact an urban setting is. This research dealt with different measurements of density (S. Lehmann, 2017), for instance with residential built-up density through the Urban Atlas and residential density through the State Development Plan. The soil sealing percentage takes only residential settlements into account and excludes the industrial and commercial areas. For residential settlement development, the housing unit per hectare is a practical indicator. Although it cannot tell much about the perceived density (as argued in Swedish National Board of Housing, 2017), it could help predict the additional load on the existing social and technical infrastructure and guide small-scale solutions. This could be beneficial especially for the traffic infrastructure, since almost all studied cases reported that the moving and stationary traffic has reached its carrying capacity.

The concept of carrying capacity applies to green infrastructures, as well. Within the context of compensation travels, high-quality green spaces are frequented also by nonlocal visitors from nearby towns. It is important to note that the reason for a Frankfurt resident to visit Bad Homburg's or Bad Vilbel's parks with a 20-minute ride is not because Frankfurt does not have any green spaces to offer. However, in a scenario in which the use intensity of public green spaces increases while the amount of green spaces remains constant or decreases, a more intense compensation travel might become inevitable, which would then confirm the compensation travel hypothesis (Haaland & van den Bosch, 2015). It is therefore extremely important to ensure the provision of publicly accessible nearby green spaces, especially for large-scale housing projects.

The density debate alone might lead to misleading conclusions on sustainable urban form, since any urban form could be proven to have advantages over another. However, aiming only at an ideal form might overlook its implications on the equity and justice aspects. Many studies have proven that lower-income communities have more unequal access to facilities, including green spaces (Barbosa et al., 2007; Burton, 2000; Heynen, Perkins, et al., 2006; Wolch et al., 2014). The results of this study can neither confirm nor deny this, because in the studied towns it is rather observed that the residential settlement from the 50s till 80s, that are typically for lower-income households, are provided with large public green spaces. As much as these settlements provide realistic opportunities for densification, protecting large and high value public green spaces, especially for the disadvantaged communities, is to be ensured.

Overall, studying the resource conflict from the perspective of urban green spaces and through the concepts of inner and outer development provides insights for a more complete picture of the priorities and conflicts in planning (Figure 6.1). Firstly, the property conflict is evident as it is difficult to mobilize inner-city gaps for inner development, unless the owner is willing to make the property available for development. Due to negative interest rates, the value of a plot of land in the conurbation is likely to increase. At the same time, with the involvement of the investors in purchasing inner area properties for dense development (especially within the framework of Section 34 of the Federal Building Code), another trend in parallel is that some locations in the inner areas become disproportionately denser in comparison to their surrounding area.

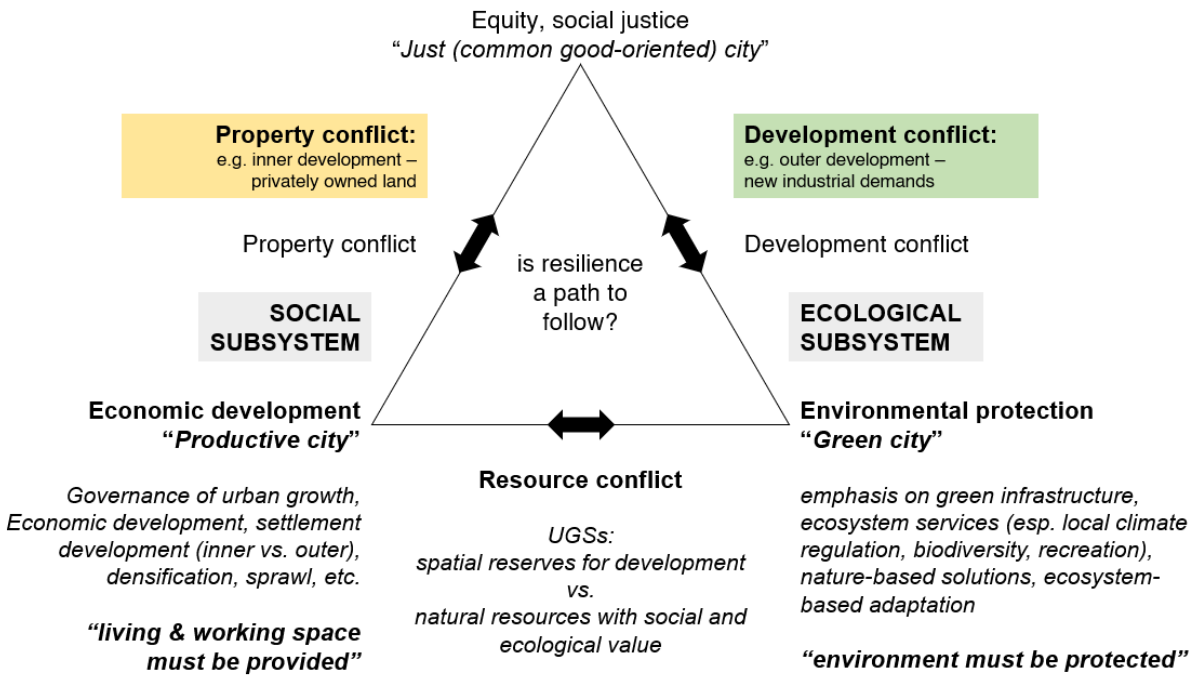


Figure 6.1: Conceptual framework updated with insights from the property conflict and development conflict debates (adapted from Campbell, 1996).

Secondly, the current demand for industrial and commercial settlements, especially data centers and logistics centers, presents a prime example of development conflict. Developing industrial settlements is attractive for municipalities, since the trade tax is the main municipal income, and it is also a positive aspect that the town is providing workspaces. Even if outer development is given up for residential settlements, it is unlikely to be the case for industrial or commercial settlements. In growing towns, the demand for industrial/commercial settlement development is higher, while at the same time, smaller towns located outside of conurbations face a rapid increase in retail vacancies, dramatically reducing the vitality of these towns (e.g. the demand for space in the conurbation vs. the increasing residential and retail vacancies in the Odenwald county).

6.2.2. Resilience thinking

Social and ecological aspects play a central role in investigating the resource conflict from the perspective of urban green spaces and their social and ecological value. The initial tendency could be to prioritize urban green spaces with low social and ecological value as spatial reserves for settlement development. But the spatial analysis in this study shows that ideally it should be decided at the scale of each individual green space whether increasing the social and ecological value is more important or urgent than settlement development.

Social and ecological components are, of course, not limited to the social and ecological value of green spaces. Social-ecological systems are by definition integrated and

interdependent systems of societies and ecosystems with reciprocal feedbacks (The Resilience Alliance, 2010). In hindsight, the systems-thinking approach has shaped this research more substantially than the resilience concept did. Given the width and depth of the debates revolved around urban growth and environmental protection, systems-thinking provided the insights for the establishment of the conceptual and methodological frameworks and enabled an investigation of the interrelations and interdependencies of social and ecological subsystems of the studied case.

For instance, the degree of soil sealing is expected to increase faster in the Frankfurt Rhine-Main region as new residential settlements now have to comply with the minimum density values in the State Development Plan (i.e. a component of the social subsystem). This anticipation does not only refer to a quantifiable change in the ecological subsystem due to the changes in the social subsystem, but also exemplifies a strong interdependency between the two aspects in that it will inevitably result in intensified use of social and technical (and green) infrastructure. It is also likely that its drivers and consequences will impact different portions of the society disproportionally, unless planning practices are equipped to address this.

The combination model of social-ecological systems adequately captures the above correlation (The Resilience Alliance, 2010; Virapongse et al., 2016). As an action and intervention from the social subsystem (i.e. institutions) the switch from maximum to minimum density in the State Development Plan can be observed as a *disturbance* that influences the slow-changing components of ecological subsystem (i.e. land-use and land-cover), which will potentially result in higher amounts of soil sealing, and therefore, impact the ecosystem services. Moreover, due to the interdependency/integratedness of subsystems, this can be also understood as a management response to the fast-changing demographic and economic dynamics, whose efficiency is impaired by slow-changing social and ecological components (e.g. land).

6.2.3. Social subsystem: institutions and governance

The City of Frankfurt and the Frankfurt Rhine-Main region show the typical contemporary characteristics of global city-regions. The findings can confirm that the city is dependent on the functioning of the region around it, the in-between rural and urban characteristics intensify, and the spatial categories (such as the central places) cannot be relied on anymore. These are typical features of global cities (Olofsdotter et al., 2012). Following the most important scholarly work (Brenner & Keil, 2014; Keil, 2011; Sassen, 2005), the roadmap of this study indicated that it is indeed accurate to study the institutional and governance dynamics at the regional scale.

As the institutional findings in this study revealed, self-management of involved actors is a central aspect of governance. In the studied case, the Regional Association plays a central role in enabling self-management by involving all related actors and sectors. The self-management on the basis of regional (land-use) plan is designed to be responsive to uncertainties and complexities in response to the rigidity of the spatial planning system and further limitations at the local scale (e.g. personnel and financial capacities). Aiming for a fully adaptive governance, under these circumstances, could be a *gamble*, as Metzger et al. (2021) put it. Despite its obvious advantages, adaptive governance is not a prerequisite for processes supporting social-ecological resilience.

The deliberate choice to exclude the word *resilience* and instead to focus on institutional arrangements and governance conditions in the interviews with municipalities helped avoid the ambiguity of the term, while enabling an in-depth investigation of resilience variables and qualities. It is already a valuable result that the variables and qualities can be empirically studied without a fixed, universally agreed definition of resilience.

Furthermore, the analysis of the findings related to institutions and governance helped identify the resilience qualities for each analyzed variable (urban growth, planning, regional impacts, finances, accessibility, institutional capacity, participation). For urban growth, the correlations among population growth, economic activity, and land-use change could be observed. Generally speaking, drastic shifts in the settlement patterns are to be avoided. It is also observed that a dense inner development can take place through conversion from old military and industrial areas as well as unutilized railway infrastructure, but the availability of these spaces is decreasing. Overall, inner spaces are hardly available unless there is opportunity for conversion, especially in denser towns (e.g. Rüsselsheim and Langen). The towns which could not grow outwards had to mobilize inner areas and ended up with high perceived densities and observably high construction activity in the inner areas (e.g. Maintal). These examples show that no “urban form” is capable of ensuring “sustainable growth” and stimulates a critical questioning whether “sustainable growth” is possible at all.

The line of thinking “institutional arrangements shape governance; governance conditions affect resilience” has proved applicable to the studied case. Therefore, the findings of institutional capacities can be discussed within the institutional strategies (as laid out by Huck, 2020) as follows:

- Knowledge co-production: The initial phase of the Regional Development Concept has been a valuable opportunity to bring all towns and municipalities in South Hesse together, even the ones beyond the conurbation. Additionally, the Regional Association’s regional events, concepts, and projects bring towns and municipalities

together and contribute to the informal learning from one another. There are various possibilities for formal and informal communication, coordination, cooperation at this pivotal position. When it comes to monitoring, prognoses, evaluation, assessments etc. the knowledge production is rather one-directional, from the Association to the town. Even then, due to limited resources, some municipalities cannot readily benefit from the Association's services.

- Network management: An opportunity for a substantial contribution to a strategic network management emerges when towns and municipalities adopt integrated urban development concepts. Although it is not absolutely necessary to have a politically agreed integrated urban development concept for a successful actor and network management, the clear advantage is that all actors and sectors are involved at the very beginning and throughout the process.
- Enhancing connectivity: It is observed that especially in the presence of regional-level intermediary institutions such as the Regional Association and the District Authority, the connectivity among the subnational institutions can be successfully enhanced. The state-level can also be considered connected because of the constant interaction between the state and the district. However, federal-level may remain too abstract for the local-level. It is often the case for towns that the higher-level goals and ambitions are often in conflict with local-level demands. Despite the adaptable and flexible features of the Regional Plan, this vertical gap is found the most difficult to bridge.
- Mainstreaming: Mainstreaming would be encouraging for local administrations to invest time, effort, and finances on policies and strategies that address the current challenges in planning. The success of mainstreaming can be confirmed when status quo is being challenged by big discussions such as promoting higher densities and *Einfamilienhausverbot*.[44] Mainstreaming in planning in this case addresses the interplay between urban development and sustainability and ideally should not be limited by the capacities of institutions.

6.2.4. Ecological subsystem: urban green spaces

The qualitative analysis of this study showed that the components of landscape ecology, i.e. green infrastructure, ecosystem services, nature-based solutions, ecosystem-based adaptation, are in fact included as considerations in planning, but perhaps not strategized through concrete measures. The contribution of urban green spaces to climate adaptation measures appeared frequently in the results of this study: All local administrations are in favor of adopting supportive climate adaptation measures for and through the green infrastructure. For instance, although it is not a direct compensation to soil take up, Bad Homburg and Langen are already implementing green roofs, which is a political decision. Rüsselsheim and Maintal are working with flood simulations for their new settlement development areas. In Bad Homburg, water renaturation, unsealing, and multifunctional

[44] A relatively recent debate referring to the prohibition to construct new single-family housing.

green spaces are being implemented. These results are in line with Davoudi et al.'s (2012) argument that adopting adaptation measures does not require big shifts in institutional settings and governance arrangements. Still, for the studied case, it appears necessary to safeguard financial contingency for municipal adaptation efforts.

From a green infrastructure point of view, the City of Frankfurt am Main and the Frankfurt Rhine-Main region are both very special because of the Frankfurt Greenbelt, which further expands into the region as the Regionalpark and provide high landscape connectivity via the regional green corridors. Besides being a growth management tool, the Greenbelt and the Regionalpark are strictly protected multifunctional urban green spaces with unique sociocultural, environmental, and spatial features, serving Frankfurt and the conurbation. The Greenbelt's/Regionalpark's ecosystem services are not only the local climate regulation (e.g. the regional green corridors providing fresh air flow as in the case of Bad Homburg), but also a strong support for biodiversity and recreation including activities such as walking and cycling. When it comes to nature-based solutions and ecosystem-based adaptation, the municipal scale and its neighborhood green spaces is a focal point. The efforts to enhance renaturation, e.g. through unsealing of impervious surfaces, water renaturation projects, and implementing water retention functions at public parks, are examples of nature-based solutions. The implementation of these strategies can often be limited by municipal financial challenges. Although there are financial support programs from the state- and federal-level governments, receiving external budget is perceived to be a highly bureaucratic process.

The spatial analysis of the quality and quantity of urban green spaces in the spatial focus area serves multiple purposes. The connectivity parameter takes the entire vegetation cover into consideration; whereas the distribution and proximity parameters focus on the recreational green cover only. The amount of green cover is calculated both for the vegetation cover and the recreational green cover. The spatial analysis allows for a very fine level of detail in terms of analyzed parameters for each green space. Additionally, the site visits provided very valuable input regarding the actual social and ecological value of each observed green space and pointed out the patterns of inconsistencies between the geoinformation data and actual onsite situation. An overview of the implications are as follows:

- When the vegetation cover connectivity is low, and the built-up area is dense, roadside green could be increased.
- When some settlements are underserved, high value green spaces could be provided within proximity standards.

- If new settlement development is to take place in near vicinity of underserved areas, the new development could provide high quality, publicly accessible green spaces (e.g. Rüsselsheim Opelwerk, Bad Homburg Vickers-Areal).
- When the ecological value of intensively used open spaces (e.g. squares) is low, ecological value could be increased (e.g. the squares in Rüsselsheim and Langen).
- If the built-up density is already too high and inner development potential is limited (e.g. Maintal, Rüsselsheim, Langen), it could be beneficial to provide high value public green spaces with each new outer development.
- If multiple low and high social and ecological value green spaces are serving the same settlement area, the low value space could be considered for development.
- If a single low value green space is serving a settlement area, its social and ecological value could be increased. In the context of proximity analysis, singularity creates dependency. If possible, more green space in near vicinity could be provided.
- If no green spaces are to be found within proximity standards, new high value publicly accessible green could be provided.
- Streams and rivers provide high ecological connectivity. If they are supported with recreational areas (e.g. Bad Vilbel and Hattersheim, partially in Rüsselsheim and Bad Homburg), they tend to have high social value, too. Otherwise, the potential for a high social value cannot be realized (e.g. Maintal). Anthropogenic influence on blue infrastructure could be reversed via renaturation and unsealing.
- It is observed that high recreational green cover does not guarantee an even distribution; especially large distant patches could be balanced out by the provision of many small patches instead of a few large.
- In towns in which there are high rates of inner development (e.g. Maintal) through densification, protective measures and public accessibility could be ensured, if new provision is not possible.
- When a tradeoff for location choices of green space provision is inevitable, the areas with multistory residential settlements could be prioritized rather than single-family residential settlement with access to own private garden.

Land-cover analysis with a focus on the green space parameters amount, distribution, connectivity, proximity in addition to the social and ecological value analysis gives a detailed overview of where inner development could take place, where green spaces must be protected, and where more green spaces are to be provided. This analysis is conducted for the spatial focus area of the selected towns only, but local authorities could benefit from expanding this analysis for the entire town within their administrative borders to detect inner area potentials. The analysis could then involve the data on settlement typologies, so that it helps detect whether there are any correlations between specific typologies and underserved locations. With this in mind, the outputs of the analysis in this study could be further developed for a study of environmental justice.

The vulnerability of green spaces could be considered as a limit to new settlement development. For a reliable overview of which green spaces need improvement and which ones could perhaps be sealed, a management strategy could look into the establishment of an overall municipal green space concept. With this, qualitative (in terms of social and ecological value) as well as quantitative loss of green spaces could be avoided, while a moderate level of density could be achieved. Still, the standards of green space per capita and proximity would have to be adhered to. A systematic and structured planning process as such would be an additional effort and require a precise knowledge of specific features of the town and its green spaces.

The functioning of this methodology is based on the premise that inner development and green space protection and provision can indeed coexist. The citywide green methodology is inspired from some of the aspects of dual inner development policy in that it helps balance out what is important and what is urgent. A consistent application of this methodology, ideally in combination with the additional parameters given in this study, i.e. distribution and proximity, could reliably indicate where exactly opportunities for inner development emerge and where green space protection and provision has absolute priority over settlement development.

Moreover, implementation of this methodology would require going beyond a geoinformation analysis. This requires a good knowledge of the actual functions of each green space onsite and the socio-spatial characteristics of their catchment areas. Also, for a citywide concept, keeping up with the benchmark values of amount per capita, distribution, and connectivity parameters are important. Despite the obvious benefits of implementing a methodology as such, it can bring the outcomes is promises only in the presence of certain management conditions. Institutional limitations may hinder its consistent application.

6.3. Methodological framework revisited

6.3.1. Exploring urban green spaces in transition

The methodological framework in this research is a roadmap for the empirical parts that is established on the basis of the conceptual model. The explorative investigation was guided by the question *"to what extent does recent settlement growth impact the quality and quantity of urban green spaces?"* and focused on the ecological subsystem and its interrelations with the social subsystem. The aim was to provide an understanding of the phenomenon of resource conflict through the spatial analysis of urban green spaces in the selected case study towns.

In order to achieve that, firstly, the fastest growing middle-sized towns in the conurbation for each county had to be identified. Growth, in this sense, means population increase that is

accompanied by an increase in the construction activity and a land-use change particularly at the spatial focus area. Understanding the transitions in the spatial focus area is important because as a walkable and bikeable distance, 1.000 meters around central train stations indicates a priority area for inner development. The anticipation of a reduced car dependency in Frankfurt Rhine-Main as a commuters' region is based on this premise. Although it was not possible to determine the extent of the quantitative change due to unavailable past land-cover data, a before/after comparison could be done through a visual comparison of the current and 2006 aerial images for each spatial focus area. Observed changes were crosschecked with the interview data and regional land-use plans as much as possible. This analysis revealed that the space availability in the observed area is getting less, accompanied by an increase in the sealed surfaces due to residential and industrial or commercial development. The intensity of the change differs from town to town.

Generally speaking, settlement development—both inner and outer—seems to impact the vegetation cover drastically, unless the new development ensures publicly accessible green spaces with high social and ecological value. The quality and quantity of recreational green spaces that are designated as green spaces in the land-use plans are impacted rather moderately in comparison to the outer area directly adjacent to the urbanized area of the town. Nevertheless, a certain built-up and residential density is indeed necessary for infrastructure to operate efficiently (e.g. bus lines in smaller towns are not very efficient for very short distances).

The applied green space parameters helped provide an understanding of the spatial configuration of the urban green spaces. The analysis confirmed that a high percentage of green space cover in an area does not guarantee that a high percentage of settlements are served by these green spaces. Still, a GIS-based spatial configuration analysis alone has its shortcomings and it has to be complemented by site visits. The data were often found incomplete or inaccurate, which could only be determined through field observations. That is why a qualitative analysis of the social and ecological value of urban green spaces is necessary; otherwise the outputs of the spatial parameter analysis can be quite optimistic in comparison to the actual situation.

6.3.2. Explaining institutional settings, governance, resilience

The second research question investigated the context in which the resource conflict phenomenon occurs and focused on the social subsystem and its interrelations with the ecological subsystem. In search of a response to the question *"in what ways are the governance conditions supportive for or restrictive to urban social-ecological resilience?"*, institutional arrangements and governance conditions were analyzed. It was interesting to find out that

the supportive conditions are in fact the aspects which aim at or actually contribute to a balance between *productive city* and *green city* priorities that create the resource conflict at the first place. The intention was to detect the supportive and restrictive governance conditions for each case study town, without losing the focus on the supportive and restrictive conditions of the regional scale. In line with the expectations, throughout the analysis, more categories emerged than the predetermined ones:

Inner/outer development: With regards to current rates of settlement growth, it is a supportive condition that there are still inner reserves for conversion of old industrial, military, and railway infrastructure areas. However, the availability of these spaces is getting less. In order to exploit the potential, the State Development Plan turned the maximum residential density values into minimum, but this could be considered as a restrictive condition as it is anticipated to bring higher percentages of soil sealing, hence intensifying the resource conflict. Still, legalities allow for project-based flexibilities in the inner areas in case the surrounding built environment has a village-like character, which is a supportive condition. Despite generally low potential of densification, the settlements from the 50s till 80s were seen as places that are available for densification, with the condition that a high quality and amount of green space is provided or protected.

Intensified use of social, technical, and green infrastructure: Each town has shown different tendencies regarding the pace of residential and industrial/commercial settlement growth. While some towns are planning more industrial settlements (Langen, Maintal, Bad Vilbel), the others are planning more residential settlements. Although it is not possible to make a general statement, industrial settlement development tends to be more space-invasive on the outer area. Having said that, inner development does not guarantee less soil sealing, either. It is perhaps more resourceful to make efficient use of existing infrastructure, but when infrastructures are used more intensively, this may put equity (who benefits from infrastructure services, who cannot) in question. All studied cases confirmed that the social and technical infrastructures, including green infrastructures, have (almost) reached their carrying capacities.

Environmental challenges: An example supportive practice in managing environmental challenges is the very clear definition of the restricted areas for flood protection in the Regional Plan. Facilitating anything beyond that (e.g. simulations, flood-proofing, etc.) is highly dependent on the municipal capacities. There are examples of project-based reduction of soil sealing, but this is not yet a widespread spatial strategy. Still, a number of towns have successfully integrated adaptation measures such as green roofs and multifunctional water retention basins. This could be observed as a case in which mainstreaming has provided

tangible benefits. Environmental challenges cannot be discussed in isolation, e.g. focusing only on green infrastructure but not on traffic problems or restricted areas due to airport noise protection or soil and groundwater contamination would disregard the integrity of the entire system.

Integrated urban development concept: ISEK has very advantageous aspects as it brings all actors and sectors together for an agreed vision of the town. It enhances synergies, eliminates conflicts, and reduces silos. ISEK is a political decision and neither a legal nor a technical requirement. It is therefore not a consistently implemented practice.

Compensation: The Federal Building Code (Section 3.1a) regulates the compensation of interventions to the natural environment. This is mainly a mathematical compensation and is specified within legal frameworks. However, a more qualitative compensation methodology beyond specific projects, such as the one the dual inner development strategy recommends, is not yet implemented. Although it is supportive that a guidance as such exists, it needs more grounding at the local level.

Impacts beyond borders: All towns confirmed an increased stationary and moving traffic load, which is coordinated within the traffic planning of neighboring municipalities. A similar cooperation can be seen in the context of intermunicipal settlement (e.g. Frankfurt-Maintal industrial area) or regional infrastructure (e.g. bicycle highway) development. In some cases, regional-level institutions provide guidance (e.g. the Radschnellweg concept). The overall conditions for intermunicipal coordination are found supportive.

Finances: Despite cooperation there is also competition among municipalities, because each municipality wants to remain attractive for businesses, as the trade tax is the main municipal income. It is a stimulating discussion whether the new businesses compensate the town's investments for new residential development. Municipal households can be at times highly vulnerable.

Finances for green spaces: The conditions of green spaces in a town is found to a great extent dependent on the financial situation. While the stable financial situation in one town enables land purchase for green space provision, green space could be sold to immediately generate income and eliminate maintenance costs in another. The federal- and state-level financial support programs are appreciated as they help realize e.g. renaturation projects but are seen too bureaucracy-intensive. A supportive condition arises as the Regional Association assists its member municipalities in finding potential funding programs e.g. from the European level which they could receive to realize their projects. There are no separate contingency funds for green space recovery and maintenance, which is only an advantage

when the town has no financial challenges (e.g. budget allocation can succeed easily for green space provision or immediate recovery).

Acceptance: It is well-understood by the citizens that inner development is a reasonable solution to meet the housing demand, but it receives criticism. The acceptance is low not only for new development only, but also for any alteration in the accustomed built and natural environment. This is rather a restrictive condition to an extent that it may limit improvements. Density, both in inner and outer development, has been a point of frequent criticism by the residents, now with the switch from maximum to minimum residential densities even more so.

Equal access: As the residential density increases, so does the use pressure on the existing social and technical infrastructure, including the green infrastructure. It is a supportive move when a minimum amount of green space is always secured with the developers for the new residential development, which would require a proactive move from the municipality's side. Another important point is that the residents of multistory housing usually do not have private green space and that is why public green space has to be provided for each multistory housing project. On another note, new developments in conversion areas now tend to focus on a typology mix to ensure social mix.

Conflicting goals: Higher-level spatial goals are very much appreciated by the local-level, especially the ones that relate to climate change. Legal frameworks of the Building Code address the implementation of higher-level goals, but there may still be incompatibilities when it comes to the realization at the local-level. For instance, the conflict between simplified and accelerated procedures of the Federal Building Code (especially the temporary Section 13b for quicker settlement development on the adjacent outer area) and the national goal to limit open land take to 30 hectares per day by the year 2030 creates certain weaknesses in argumentation in both directions.

Intermediary institutions: The services of the Regional Association for its member municipalities, e.g. the strategic environmental assessment and the land-use monitoring, are beneficial. Due to the lack of in-house capacities, some municipalities cannot make use of these services to the full potential. The cadaster of the gaps between the buildings for densification purposes is found to have two main shortcomings: firstly, it requires confirmation as it is based on aerial images, and secondly, it involves speculative information. The Association collaborates with various public and private actors and sectors and initiates knowledge-sharing and exchange events that are much appreciated. Still, this is limited to the regional level and below. There could be benefits of a more enhanced cross-level interaction with the higher levels, but the findings provide no evidence to reflect on that.

Actors and participation: All case studies almost with no exception confirm that the most important actors in planning processes are the citizens as *co-managers* and the local politics as the *customer*. There were several major tendencies observed: First, when local politics is traditional, it may choose to avoid conflicts with citizens, and citizen's unwillingness reflects itself directly in the political unwillingness. When the local politics is more proactive, technical necessities—e.g. housing provision for multifamily housing instead of single-family—can be better communicated. More proactive modes of participation are slowly being adopted by municipalities to reach underrepresented parts of the society. The second tendency is concerned with the role of the municipality. There is a perceived conflict between the view of politics: *"municipality represents citizens"* and the view of citizens: *"municipality executes politics"*. While both is true, the municipality fulfills further technical and legal functions and plays a mediatory role in balancing interests in both directions. The third tendency relates to the role of the investor. When there are weaknesses in the power balances among the three main actors, i.e. municipality, citizen, local politics, some aspects of urban planning may be left to the investor's will. This can cause certain weaknesses on the ground, such as large residential development projects with limited consideration of social housing or green spaces.

6.3.3. Main hypothesis revisited

The main hypothesis of this research is based on the integration of the two research questions that guided the two lines of inquiry. It states that *"if and when the governance conditions are supportive for and not restrictive to social-ecological resilience, settlement growth in the studied towns of the region can take place without a negative impact on the quality and quantity of urban green spaces."* The hypothesis relies on the premise that inner and outer development can in fact be balanced and an optimal density with high green space quality and quantity can indeed coexist.

A complementary strategy in this research for testing the hypothesis was to apply the green space parameters at Hattersheim's spatial focus area (ecological subsystem) together with the field observations and to elaborate on the potentials and constraints based on the insights gained form the governance analysis (social subsystem).

One of the insights gained was the ways in which the ecological subsystem is dependent on the social subsystem. As Hattersheim's case exemplifies, the quality of urban green spaces strongly depends on the financial situation of the municipality due to upkeep costs. Same is the case for the amount of green spaces, because with tight budgets they might be removed or sold for profit. As the results from the other studied cases confirm, a politically-agreed integrated urban development concept fostering holistic planning is beneficial both for social

(e.g. involvement of all actors throughout the process) and technical (e.g. detecting the inner development potentials) planning aspects. Furthermore, given the recent high demand on outer development especially for industrial and commercial development, it can be argued that setting inner development as a priority, at least for the residential development, could be beneficial, despite the less complicated procedures of outer development.

Based on these highlights, the hypothesis can neither be confirmed nor refuted in its original formulation. The positive governance conditions can support that the green spaces are abundant, well-maintained, interconnected, and well-distributed to serve all citizens. The conditions in the social subsystem can be quite supportive for and not restrictive to social-ecological resilience, but this is not a guarantee that the settlement development will have no negative consequences on the urban green spaces in the inner and outer area. Therefore, the evidence proves the following reformulation of the hypothesis: *"if and when the governance conditions are not supportive but restrictive to social-ecological resilience, settlement growth in the studied towns of the region cannot take place without a negative impact on the quality and quantity of urban green spaces."*

6.4. Limitations

In this study, the impacts of urban growth on urban green spaces are analyzed through the perspective of social-ecological systems thinking and the fastest growing middle-sized towns in the Frankfurt Rhine-Main region. The research brings together the scholarly debates on urban and regional growth and landscape ecology to tackle the resource conflict. It does so by developing a methodology based on a scientifically sound conceptual model to analyze a real-life phenomenon. However, there are certain limitations.

First, the literature review in this research benefits from a wide variety of global debates in order to develop comprehensive theoretical and conceptual frameworks. It is rather the local debate that is examined in-depth, whereby the phenomenon as described in global debates was contextualized. A compromise between the breadth and depth of global and local debates was inevitable. However, it is intended to overcome this limitation by creating added value for global debates through the depth of local debates (e.g. a "forward projection" of the sustainability and resilience debates through the New Leipzig Charter) and for local debates through the breadth of global debates (e.g. a study of inner-city green spaces as social-ecological systems).

Second, several limitations to data availability might have impacted accuracy. The town Bad Vilbel could not be interviewed due to several rejections from the municipality's planning department. Also, due to the strict time restriction of the funding duration, it was not possible

to involve non-governmental organizations such as BUND and NABU and higher-level institutions such as the Hessian Ministry of Economics, Energy, Transport and Housing in interviews, which could have provided complementary qualitative data for the analysis. For the same reason, it was not possible to survey recreational green space users in the studied towns, which could have provided an additional quantitative deliverable demonstrating the views on accessibility as well as acceptance for densification. However, several questions in the expert interviews specifically addressed these issues and provided valuable insights on potential tendencies among the citizens.

Third, the change in the built and natural environment in the spatial focus areas of the studied towns could only be detected through a visual comparison of current aerial images and aerial images from 2006 (retrieved from Regiomap). Although the most up-to-date data was available, upon which the spatial analysis of the current green space configuration was based, data from previous years could not be retrieved. Consequently, the land-cover change with a high level of detail and precision could not be quantified. Nevertheless, this comparison was crosschecked as much as possible with the interview data and relevant land-use plan documents of municipalities that were found online. A similar limitation applies to the pre-analysis to determine the case study towns which relies on population, construction activity, and land-use change data. Due to limited data availability, these datasets cover slightly different timespans (2011-2018, 2011-2019, and 2012-2019 respectively).

Fourth, the 1.000-meter radius around the train stations introduced a spatial scope for the green space analysis in the studied towns and follows the principle as in the Regional Development Concept of South Hesse. The spatial analysis focuses on this area because as a walkable and bikeable distance it justifies the anticipation for reduced car dependency and increased use of public transportation. The spatial scope proved beneficial for providing a specific spatial focus to analyze the green space parameters, but it is not a flawless model because it might neglect e.g. a recreational green space that is directly outside the focus area but actually serve a settlement area that is inside the focus area. In addition, not all neighborhoods of one town has similar characteristics and there are various residential densities at various locations. This limits a precise indication of recreational green space per capita, which is by far the most developed benchmarking in the scholarly and policy literature among all green space parameters. Because of these reasons, a citywide application of the green space parameters has clear advantages in terms of methodological accuracy. However, this is not expected to interfere with the generalizability of the results.

It is beyond the scope of this research to analyze the remaining middle-sized towns that were not the fastest growing ones. There are 24 towns in total that are categorized as middle-sized towns in the Frankfurt Rhine-Main conurbation, six of which were selected as case study towns. It could have provided a more complete picture if the remaining 18 towns could be studied in the same level of detail as the six case study towns. The results showed that the growing middle-sized towns face common urban development challenges, but each one has its own specific strengths and weaknesses. Replicating the methodology for the remaining middle-sized towns could provide a more complete understanding at the regional scale.

Moreover, there were several geoinformation data inaccuracies which could only be detected onsite during the field observations in person. Some areas that are shown as green spaces in the data were found to be private gardens or courtyards, large parking spaces, or already densified, with no accessible social or ecological value. There were also cases where a green space existed onsite, but not in the land-cover maps, because it is impossible to detect vegetation cover that are located within areas that are designated as “settlements.”

Finally, the geoinformation data is composed of patches that sometimes overlap (e.g. bridges over flowing water bodies). This might have slightly impacted the accuracy of the connectivity analysis. Perhaps more importantly, the land-cover data does not make the distinction between (intended) land-use (e.g. residential settlement, industrial settlement, etc.) and vegetation cover which exists within that land-use. It is therefore impossible to indicate the actual amount of vegetation cover. Land-cover data involves the exact locations of the buildings, but subtracting the paved surfaces covered by buildings and transport will not automatically yield in the amount of vegetation cover, because it cannot be simply assumed that any land-cover that is not impervious is vegetation cover. That is why the green cover analysis had to exclude private front gardens. There is currently no way to detect the contribution of such vegetation cover unless all binding land-use plans are analyzed one by one for each plot located in the settlement areas. Alternatively, a remote sensing update on the data could be beneficial, but this would most certainly require verification. Therefore, green space in the study refers to the ones that are detectable within the contents of the land-use and land-cover data. This caused imperfections in the analysis of green space parameters but is not expected to interfere with the overall findings.

6.5. Summary

This chapter discusses and relates the findings of the study to the scholarly debates. It puts the findings in perspective by revisiting the research aims, research questions, and the

hypothesis. It interprets the results of the empirical investigation, reveals implications of these results, and acknowledges the limitations.

There are several pivotal points throughout the discussions that need to be recapped here. First, it was identified that the German spatial planning system is designed to ensure compatibility during planning processes. However, the system is highly complex and has a deterministic structure, leaving room for *predetermined* flexibilities. It is observed that the level of regional planning is where these flexibilities take place. Regional planning brings together higher-level objectives and municipal-level requirements by which conflicts are inevitable. So, the regional scale planning has to be equipped with the tools and strategies to resolve conflicts. For instance, the switch in the Hessian State Development Plan from maximum to minimum residential density values following the population increase prognoses is an extremely important development for the South Hessian Regional Plan. However, although the demand for residential development was the point of departure for this research, it is found that the current demand for commercial development is no less important. It is noteworthy that for the time being inner residential development, despite accelerated procedures, is likely to cause less damage in comparison to outer industrial/commercial development. This is in conflict with the national goal to limit daily land take.

Second, it was quite beneficial that the resilience debate introduced the concepts such as uncertainty, complexity, adaptability, and transformability. However, social-ecological systems thinking has influenced the research design more strongly than the resilience concept itself. From the perspective of resilience, the switch from maximum to minimum residential densities was found to be a clear example of the interactions and interdependencies between the social and the ecological subsystem, justifying the embeddedness of the debate in planning. The anticipation of increased densities, and consequently increased soil sealing in new residential development, can be perceived as a disturbance. It is noteworthy that the increased residential densities challenge the carrying capacities of the social and technical infrastructure in the region, especially in the conurbation. As a result of the urgency the quickly provide residential and industrial/commercial settlement areas, a more intensified use of green infrastructure and an increased demand for protection and provision of high value green spaces is to be expected.

Third, the institutional arrangements and governance conditions as components of the social subsystem were discussed on the basis of interviews with the planning experts from the municipalities of the selected case study towns in addition to the regional planning experts. The facilitating role the intermediary institutions such as the Regional Association play was

found quite important. It was also shown that the advantages of adopting an integrated urban development concept outweighs the challenges associated with it (e.g. political willingness or continuous reflection). Additionally, although there are discrepancies between institutional levels and scales, there are tools (e.g. the Regional Plan) to minimize potential misalignments. Overall, it can be confirmed that the institutional strategies (knowledge co-production, network management, enhancing connectivity, and mainstreaming) are closely linked to institutional capacities and its qualities (coordination, reflectiveness, robustness).

Following that, the main urban green space functions in this study, namely biodiversity, local climate regulation, and recreation, could all be taken into account for the spatial analysis of green space parameters (biodiversity: ecological value and connectivity analysis; local climate regulation: ecological value and impervious cover percentage; recreation: social value and proximity analysis). Without the integration of the concepts of landscape ecology, this could perhaps not be approached in a structured and systematical manner. Based on this investigation, several correlations and their implications for planning could be listed. Also, since the spatial analysis consists of both quantitative and qualitative inquiries, it helped detect the inconsistencies between the geoinformation data and actual situation onsite.

Building on that, the research aims, questions, and the hypothesis were revisited. The explorative line of inquiry provided context-specific responses to the question of how much settlement growth impacts urban green spaces. Although due to data unavailability it was not possible to quantify the actual change in land-cover, with the help of visual aerial image comparisons and the spatial analysis of the green space parameters, it is found that the both inner and outer development are impacting the green spaces to a great extent, in currently growing towns (e.g. Bad Vilbel, Hattersheim) more drastically than the towns which have already completed their fast development pace several decades ago (e.g. Rüsselsheim, Langen). Although conversion as an inner development strategy is beneficial in mobilizing inner-city areas and effectively slows down outer development, there are two challenges: First, inner development potential is not endless, it causes intensified use of social and technical infrastructures, including green infrastructures, that are already reaching their carrying capacities. Second, the outer development is currently cannot be avoided due to the high demand for industrial and commercial settlement development.

Parallel to that, the explanatory line of inquiry looked into the ways in which the governance conditions—which are shaped by the institutions—support or restrict urban social-ecological resilience with a focus on urban green spaces. As new themes emerged, this provided additional valuable insights on other related topics (e.g. views on compensation, road

network, finances) as well as on the relations among the most important actors in urban management, i.e. local politics, citizens, investors, and the municipality as the mediatory actor, weighing up public and private interests on the basis of technical and legal aspects.

As a next step, on the basis of the responses to the two research questions, the hypothesis is revisited. It was necessary to go back to the example of Hattersheim in Chapter 4, where the green space parameters were studied on the basis of scenarios and in combination with the insights from the interviews. The analysis of institutions and governance with a focus on municipal and regional planning aspects showed that the governance conditions affect the social-ecological resilience to a great extent. It is also stated that perhaps an optimally "balanced" settlement growth cannot ever be reached, despite all policies, goals, strategies strive for reaching a balance one way or another. Although it could not be confirmed that supportive conditions ensure high quality and amount of green spaces, the findings were more in line with the statement that the restrictive conditions do impair the quality and amount of green spaces.

Due to time limitations and rejections on interview requests it was not possible to conduct several additional interviews which could have been beneficial for the generalizability of the results. Another limitation is the slightly different timespans of several data which had to be used in combination. However, attention is paid to keep this difference at a minimum. Moreover, although the spatial focus area has provided a clear focus to study the green space parameters, it would beneficial to apply the methodology citywide. Also, it would be interesting to replicate the study in the remaining 18 middle-sized intermediate-order towns in the conurbation for a more complete understanding of all middle-sized towns. Building on the insights in this chapter, the next chapter focuses on the contribution and significance of this study and reflects on the limitations to propose new directions for further research.

7. Summary and conclusions

7.1. Executive summary

This research is inspired by the scientifically researchable debates in the planning practice. It is concerned with the impacts of urban growth on urban green spaces and the drivers and consequences of inner and outer development in current planning debates. The importance of urban green spaces is studied through the example of middle-sized towns in a growing European metropolitan region. Urban green spaces are acknowledged as social-ecological systems by taking into account the institutional arrangements and governance conditions that influence the green space contribution to biodiversity, recreation, and local climate regulation.

Chapter 1 provides the problem statement and the reasons for undertaking this study. The research problematizes the anticipated unprecedented rates of population growth and associated peak rates of housing demand in the Frankfurt Rhine-Main region. Prioritizing available spatial reserves in the inner areas is a resourceful way to activate spaces for residential development and has clear advantages over outer development. However, this approach may put the urban green spaces in the inner-city areas and their biodiversity, local climate regulation, and recreational functions at risk. For instance, due to housing provision urgencies, an inner-city spatial reserve with low social and ecological value might be preferred to be developed for residential purposes instead of increasing its social and ecological value. It is questioned whether the search for an ideal, an *optimal* urban development to resolve the resource conflict would ensure sufficient green space provision while prioritizing inner area development. The research seeks to understand the extent to which urban growth impacts urban green spaces in the fastest growing middle-sized towns around Frankfurt and the ways in which the institutions and governance is supportive for or restrictive to green space protection and provision.

In order to do this, Chapter 2 builds a conceptual model on the priorities and conflicts in the planning discipline which is then reframed with social-ecological systems thinking. This helps address the most important concepts, findings, hypotheses, and gaps and investigate the phenomenon of resource conflict in the context of Frankfurt Rhine-Main and social subsystem (institutions, governance, planning), ecological subsystem (green space itself), and their interactions and interdependencies. It is mainly concerned with the debates of protecting and providing green space during settlement development. A look on social subsystem involves scholarly discussions on globalization, global city-regions, metropolitan regions, and the motivation for economic growth that is correlated with population and

settlement growth. Additionally, institutions and governance as components of the social subsystem are addressed. Complementary to that, ecological subsystem is reviewed with a focus on the local climate regulation for floods droughts and heatwaves, recreational, and biodiversity functions. The study of green spaces in planning inherently involves the concepts of landscape ecology: Urban green spaces are green infrastructures that provide ecosystem services which help develop nature-based solutions to societal challenges and provide ecosystem-based adaptation. Building on that, the literature review highlights that the executives of planning (e.g. all institutions from federal to municipal) are to be well-understood because their arrangements shape governance conditions, which either support or impair the resilience of the social-ecological system.

Following that, Chapter 3 outlines the methodology for the empirical part of this study. The research objectives and aims are defined for a holistic case study (the region) with embedded units (selected middle-sized towns). The research questions guide two lines of inquiry, upon which the research design is constructed. Moreover, the chapter contains the information on how and when data is collected and analyzed, and it justifies the approaches and tools chosen to analyze the collected data. Overall, this part provides the rationale for (i) the case study selection (fastest growing towns in terms of population, housing stock, and land-use data), (ii) green space variables and indicators (amount, distribution, connectivity, proximity, in combination with their social and ecological value), and (iii) semi-structured interviews with the variables (urban growth, integrated spatial planning, regional impacts, finances, accessibility, institutional capacity, participation) and their qualities (coordination, inclusivity, redundancy, reflectiveness, robustness).

Chapter 4 builds on the methodology outlined in Chapter 3. It starts with an overview of the German spatial planning system and the investigation of the Frankfurt Rhine-Main region as the holistic case based on the interview data. It then continues with the selection of the case study towns. After determining the case studies, the remainder of the chapter is divided into sections for each case study town. Case study sections investigate the urban green spaces in the spatial focus areas and the current most important issues in municipal planning, with a focus on settlement development and its impact on the quality and amount of urban green spaces. This chapter concludes with bringing the two lines of inquiry together on the example of Hattersheim. This way the spatial green space parameters could be studied in depth for individual green spaces in combination with the insights gained from the qualitative inquiry. This serves to show how social and ecological systems interact and provides valuable input for testing the hypothesis, which concentrates on the interface of the two lines of inquiry.

As the next step, Chapter 5 discusses and factually presents the results of the spatial and the qualitative investigation in three main parts. First, it focuses on the implications of the German spatial planning system on the Frankfurt Rhine-Main region. Second, it focuses on the findings from semi-structured interviews and is structured according to the qualitative variables. Findings from each town are analyzed according to their supportive and restrictive conditions and provide a comparative overview. Third, based on the spatial analysis of the green space parameters and in-person observations of green spaces within the spatial focus area, the amount of vegetation and recreational green cover, distribution, connectivity, proximity, and their social and ecological value are documented and mapped. The output of this investigation is a comparative table, but it also shows specific correlations, e.g. dense cores tend to have less green space connectivity, or high amount of green space cover does not guarantee an even distribution and/or proximity.

Finally, Chapter 6 discusses and relates the empirical findings to the debates in the literature review and to the research questions, aims, objectives and the research hypothesis. It shows that the studied case justifies that downgrading the entire urban growth debate to inner versus outer urban development is ineffectual in addressing how growth impairs urban green space quality and amount. Although the point of departure for this research was the housing demand prognosis and associated increase in inner land take, it is found that currently outer development tends to be more invasive and is driven by reasons beyond housing provision. A major lesson learnt is that the outer development for industrial/commercial settlement development is here to stay, even when residential development could theoretically be limited to the spatial reserves in the inner areas.

7.2. Contribution of this study

This research conveys a simple message: Urban green spaces as social-ecological systems are of vital importance for human and nonhuman components of the built and natural environment, especially in towns facing a high pressure for activating living and working spaces. However, urban green space quality and amount are quite vulnerable to growth-driven urban transformations. Urban green space resilience, and at times its existence, depends on the governance conditions that are shaped by institutional settings. Since the planning discipline provides the tools for growth management, it is its duty to be equipped to safeguard the multiple functions of green space and their social and ecological value.

The main contribution of this research is that, on the basis of the Rhine-Main region and its fastest growing middle-sized towns, it brings together two lines of inquiries which are often studied individually. The study is inspired by the motivation to make use of landscape ecology concepts in the planning discipline and lays the social-ecological systems thinking as

a foundation for the empirical parts of the study. It therefore observes the transition in the built and natural environment that is accompanied by the institutional and governance qualities in the studied context. It does so by addressing the concepts of resilience, adaptability, transformability, uncertainty, complexity. This approach is favorable because it sees the land-use change in the direction of soil sealing as a disturbance to the social-ecological system with its uncertainties and complexities. This change is not a sudden shock or disaster as often discussed in resilience debates, but it is rather a disturbance or stress that brings hazards and damages with it in the long run.

Resilience and its related concepts are quite inspiring for the debates in the planning discipline. They open up new avenues and new approaches within the environments the planning practice operates in. However, these tools for thinking will remain intellectual exercises unless they are operationalized for concrete actions. Although there is no single instruction encountered during the literature review, it is noteworthy that there are indeed context-dependent ways to achieve operationalization: For instance, this research alone showed that the social-ecological systems thinking can be the foundation to empirically study the impacts of settlement growth on urban green spaces through a replicable methodology.

It can be concluded that the management tools in planning (especially the informal concepts) can successfully address current urban growth challenges but are rather modest than assertive. They succeed in bringing together all related actors representing various interests, most importantly, the politics, citizens, and investors, under the technical and legal expertise of municipal administrations. However, in cases in which the municipality is underfinanced and understaffed, representation of interests may lose balance and the benefit of the common good may not be prioritized. At the end of the day, it is the municipality's responsibility to balance out the public and private interests while at the same time complying with the technical agendas and specifications from the higher-level plans and goals.

The research pinpointed the strong and weak points in institutional arrangements and identified various governance conditions and their implications on green space protection and provision. Within institutional arrangements, the vital role that the *region* plays—as an institutional level as well as a spatial scale—can be easily distinguished. A crucial aspect within regional planning was found to be its predetermined flexibilities. Intermediary regional organizations such as the Regional Association shares responsibilities and contributes to that as it facilitates knowledge-sharing and exchange. However, the potential of making full use of its services is still dependent on the capacities of municipal administrations. Additionally, as a close partner to the Ministry, to the municipalities, and to the Regional Association, the role of the District Authority is critical in fixing incompatibilities. Overall,

despite its complexities, the spatial planning system is designed to mediate change, balance out tradeoffs, and bridge the *vertical gap* as identified to be present between local-level and higher-level institutions.

Moreover, as a result of the spatial analysis, the research underlined the importance of green space quality and social and ecological value, in addition to quantitative parameters such as proximity and connectivity. Proximity is identified as a very important parameter, because it serves as a reference point for an investigation of equity, in that it reveals which green space serves which settlements. If benchmarking will be made possible in the studied context, this parameter can easily provide a basis for an understanding of whether all residents, regardless of which settlement typology they live in, are benefitting equally from high-value green spaces. The connectivity of vegetation cover is also an important parameter, too, especially from the viewpoint of ecological subsystem and biodiversity; whereas the green space amount per capita is an inadequate indicator if used alone. These outcomes could complement other methodologies.

Similar to the criticism on resilience that it should not indicate *a state of being to reach to*, reaching a balance in urban growth as per the hypothesis of this research is not realistic. However, it can be observed that the most beneficial strategies, principles, and policies in planning are the ones that are successful in navigating current challenges with finding an optimum in mind. This can be exemplified by the national goal to limit development on open land and the dual inner development strategy. Still, the motivation to reach a balanced state is not necessarily freed from conflicts. Although these strategies and principles originate from the motivation to enable resourceful settlement growth, they are open to conflicts and financial profit-oriented exploitations.

There is indeed a potential for creating added value through the qualitative improvement of green spaces while addressing the housing demand through inner development. The scenarios in Chapter 4 proved the necessity for a methodology to detect and locate these potentials (this is in line with the dual inner development strategy). However, these potentials remain dormant to a large extent. The extensive bureaucracy, low societal acceptance and political willingness might be the reasons for that. But more importantly, current inability to address the resource conflict and/or realize these potentials shows that solutions of the past run short of solving today's problems. That is why the attempt to upgrade the Leipzig charter can be seen as an extremely important advancement for planning practice toward emphasizing the need to update the tools necessary for navigating through contemporary challenges.

Whether attempts as such alone are sufficient for planning scholarship is another debate. More has to be done for a systematic implementation of these strategies, e.g. of dual inner development and the methodology used in this research, as this will be an unavoidable additional governance challenge for all involved parties. But it appears that there is no alternative to taking this step if planning discipline (practice and scholarship) is to deliver the solutions it promises. Turning one parking space into a public and water-sensitive green space, for instance, will automatically introduce multifunctionality by reversing soil sealing and inviting inclusivity. As parts of—ideally citywide—concepts, these selective solutions with "added value" will have a cumulative effect and consequently a transformative power.

7.3. Outlook

This research looked at the issue at hand from various angles and attempted to fully explore and examine the complexities of the studied case. While responding to the initial questions, it brought about new unanswered questions. This section provides suggestions for further research and policy directions with structural linkages to the limitations given in the previous chapter. Despite the promising results, the goal is to give concrete ideas for how future work can build on areas that this research proves necessary to address.

To begin with, there is abundant room for progress in determining the characteristics of the German spatial planning system from the perspective of social-ecological systems thinking. In higher institutional levels, the long-term commitments are less flexible but have to change faster; while in lower levels processes are slow and flexible. This is a favorable condition, but local-level capacities might be limited e.g. due to the spatial rankings introduced by the central places theory being still embedded in the planning system, which might currently be causing more harm than good. This structure prevented sprawl for a long while, but it currently sharpens the growth/shrinkage divide between conurbation towns and rural towns. While the towns in the conurbation have to activate more spaces for settlement development, rural areas are facing high rates of residential and retail vacancies. Moreover, projects such as the Großer Frankfurter Bogen might be intensifying these consequences by creating de-facto rankings (criteria: 30 train minutes to Frankfurt as target towns, but not coupled with providing better train connections to rural towns). These arising issues could be taken into consideration in the planning policy and practice, and their implications can be a potential trajectory for further research.

Another point of investigation could specifically focus on the outcomes of the changes in the laws, legislations, and plans. For instance, as the outcomes of the switch from the maximum to minimum residential densities in the Hessian State Development Plan might become evident in the land-cover change in a few years of time, a further study could look into

quantifying the change in the sealed surfaces and also a percentage increase in the residential density. Another similar inquiry could be to quantify the alterations in the built and natural environment resulting from the Sections 13a and 13b of the Federal Building Code. This could be done with the resource conflict as the point of departure and green spaces are approached as social-ecological systems in combination with the methodology introduced in this study to spatially analyze the green space parameters for its clear advantages, e.g. eliminating the shortcomings of different datasets through field observations parallel to GIS-based analysis. Alternative methods to crosscheck the data prior to the analysis could be very beneficial as it would increase data accuracy, unless in-person field observations are not possible.

Moreover, it is notable that the spatial methodology introduced in this study will prove most beneficial when applied for the entire town, ideally through a regular before/after analysis of green space parameters. This could provide a reliable input in terms of green space per capita and eliminate the shortcomings of working with a strict spatial boundary. The methodological framework allows for spatial and temporal replication and could make geographical and temporal comparisons possible. It has the capacity to evolve into a foundation to further the research in the field of environmental justice. Especially the land-cover analysis could be used to identify sensitive areas for development as it can reveal where soil sealing might cause impaired connectivity or reduced proximity. A further study should definitely overlay the proximity analysis with settlement typologies and if possible with resident's income levels in combination with user surveys.

This study limited the focus on the fastest growing middle-sized towns in the conurbation. If the same methodology is replicated for all middle-sized towns in the region, the debate could be more inclusive of discussions beyond urban growth (e.g. shrinkage) and growth-driven interventions (e.g. post-growth debates). Some towns in the conurbation have more available spaces but these are not the towns with the highest pressure. This is an unfavorable distribution of spatial availability. A more holistic understanding of the approaches to tackle this could inspire both planning scholarship and policy.

Additionally, discussions about compensating the impacts of settlement development on the natural environment appeared often throughout this study, starting from literature review discussions to the case study findings. Although it is beyond the scope of this research to come up with a compensation strategy, it proves necessary for future research to investigate in detail how compensation is done as per the Federal Building Code, how it could be done also as a qualitative improvement, and whether qualitative improvement could compensate for the quantitative loss of green space and if possible develop a consistently applicable

strategy to ensure provision and protection of publicly accessible, high-value green spaces for each new development. Complimentary to the dual inner development policy, nationally-coordinated efforts could ensure that the potential advantages of small-scale interventions unfold for the benefit of the common good through concretization at the municipal level.

To add to the discussions on the municipal level, the lack of financial capacities is observed as a common challenge. Particularly for green spaces, it could be beneficial for municipalities if higher-level measures could look into mainstreaming specific strategies to ensure financial contingency for municipal green space budgets. Currently this is supported by several state and federal programs and subsidies, but these are criticized to be a bit too bureaucratic to get at, as the lack of personnel capacities in municipalities is a limitation here as well.

On a final note, this research took the housing demand and the pressure for activating settlement spaces via inner development in the Frankfurt Rhine-Main region as the point of departure, but during the investigations had to acknowledge the demand for activating space for industrial settlements, particularly via outer development. Undoubtedly, for urban green spaces, the potential negative outcomes of inner development and densification in the studied towns is equally concerning as the potential negative outcomes of outer development and sprawl. The challenge is that the potentials of inner development as a resourceful strategy is not limitless, and for social and ecological concerns inner development should not result in hyper-densities in the existing built environment. But the pressure on the outer land for industrial settlement development is unfortunately not less concerning. Further research is needed to establish a framework to investigate this phenomenon, ideally through the social-ecological systems thinking perspective.

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Appendix

Appendix A – Deutsche Bahn Categories

(Source: Deutsche Bahn Datenportal, 2019)

- Kategorie 1 („Die 21 deutschen Bahnhöfe der Kategorie 1 verfügen über eine große und leistungsstarke Infrastruktur, sind stark frequentiert und technisch stufenfrei. In repräsentativen Gebäuden, die im Zentrum der Großstädte liegen, finden Bahnreisende und Bahnhofsbesucher grundsätzlich sämtliche Dienstleistungen rund um die Bahn. Das Angebot wird ergänzt durch zahlreiche Einkaufsmöglichkeiten, wobei auf persönlichen Kundenservice großer Wert gelegt wird. Hochwertige Ausstattungsmaterialien sorgen für ein angenehmes Ambiente.“)
- Kategorie 2 (“Die 87 Bahnhöfe der Kategorie 2 sind häufig wichtige Zustiegspunkte für den Fernverkehr oder Schnittstellen zu den großen Flughäfen und Hauptbahnhöfe größerer Städte. Alle bedeutenden infrastrukturellen Einrichtungen sowie Dienstleistungen rund um die Bahnreise sind vorhanden. Zudem ist eine Betreuung der Reisenden in den Hauptverkehrszeiten durch unsere Mitarbeiter gewährleistet. Ausstattung und Service haben ein ähnlich hohes Niveau wie an Bahnhöfen der Kategorie 1.”)
- Kategorie 3 („Bahnhöfe der Kategorie 3 sind häufig Hauptbahnhöfe kleiner bis mittelgroßer Städte. Die verkehrliche Bedeutung bzw. die Anzahl der Reisenden an den 239 Bahnhöfen dieser Kategorie ist in der Regel dementsprechend groß. Die Ausstattung orientiert sich daran: moderne Fahrgastinformationsanlagen, Aufzüge und Fahrtreppen sind an solchen Bahnhöfen vorzufinden. Viele dieser Bahnhöfe verfügen über ein Empfangsgebäude mit verschiedenen Einkaufsmöglichkeiten.“).
- Kategorie 4 („Rund 630 Bahnhöfe sind der Kategorie 4 zugeordnet. Darunter zählen z.B. Bahnhöfe in Ballungsräumen, die stark durch den Regional- und Stadtverkehr geprägt sind. Die Reisenden sind daher häufig Pendler mit kurzen Aufenthaltszeiten am Bahnhof. Die funktionale Ausstattung ist mit der eines Busbahnhofs vergleichbar und beinhaltet in der Regel Wetterschutz und Sitzgelegenheiten.“).
- Kategorie 5 (“Die Kategorie 5 beinhaltet Bahnhöfe kleinerer Städte und zahlreiche Stadtteilbahnhöfe, die größtenteils von Pendlern genutzt werden. Diese rund 1.000 Bahnhöfe sind weniger belebt, weshalb auf eine robuste Ausstattung geachtet wird, die Vandalismus standhält. Weniger ist hier oft mehr: Statt in nicht benötigte Ausstattung zu investieren, werden finanzielle Mittel wirkungsvoller für Reinigung und Instandhaltung eingesetzt.”).
- Kategorie 6 (“Die über 2.500 kleineren Bahnhöfe liegen meist in dünn besiedelten Gegenden an Standorten mit geringen Reisendenzahlen und stellen die Grundversorgung im Schienenpersonennahverkehr sicher. Die Ausstattung beschränkt sich zumeist auf das Notwendigste.”). Kategorie 7 (“Bahnhöfe dieser Kategorie können allgemein als „Landhalt“ bezeichnet werden. Die ca. 900 darunterfallenden Bahnhöfe verfügen in der Regel über eine sehr einfache bzw. geringe Infrastruktur (z.B. nur eine Bahnsteigkante), sind aufgrund ihrer ländlichen Lage nur sehr gering frequentiert und bedürfen daher in der Regel weder den Einsatz von Service-Personal noch Anlagen der technischen Stufenfreiheit.”).

Appendix B – ATKIS classifications

(Source: Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV), 2018)

SIEDLUNG – 41000: Die Objektartengruppe mit der Bezeichnung ‚Siedlung' und der Kennung ‚41000' beinhaltet die bebauten und nicht bebauten Flächen, die durch die Ansiedlung von Menschen geprägt werden oder zur Ansiedlung beitragen. Die Objektartengruppe umfasst die Objektarten:

- 41001 'Wohnbaufläche' ist eine baulich geprägte Fläche einschließlich der mit ihr im Zusammenhang stehenden Freiflächen (z.B. Vorgärten, Ziergärten, Zufahrten, Stellplätze und Hofraumflächen), die ausschließlich oder vorwiegend dem Wohnen dient.
- 41002 'Industrie- und Gewerbefläche' ist eine Fläche, auf der sich Industrie-, Gewerbe-, Handels- und Dienstleistungsunternehmen sowie deren Betriebsflächen befinden.
- 41003 'Halde' ist eine Fläche, auf der Material langfristig gelagert wird und beschreibt die auch im Relief zu modellierende tatsächliche Aufschüttung. Dauerhaft anders genutzte Halden werden als Objekte entsprechend der tatsächlichen Nutzung erfasst.
- 41004 ‚Bergbaubetrieb' ist eine Fläche, die für die Förderung des Abbaugutes unter Tage genutzt wird.
- 41005 'Tagebau, Grube, Steinbruch' ist eine Fläche, auf der oberirdisch Bodenmaterial abgebaut und für die Förderung des oberirdischen Abbaugutes genutzt wird. Rekultivierte Tagebaue, Gruben, Steinbrüche werden als Objekte entsprechend der vorhandenen Nutzung erfasst.
- 41006 'Fläche gemischter Nutzung' ist eine bebaute Fläche einschließlich der mit ihr im Zusammenhang stehenden Freifläche (Hofraumfläche, Hausgarten), auf der keine Art der baulichen Nutzung vorherrscht. Solche Flächen sind insbesondere ländlich-dörflich geprägte Flächen mit land- und forstwirtschaftlichen Betrieben, Wohngebäuden u.a. sowie städtisch geprägte Kerngebiete mit Handelsbetrieben und zentralen Einrichtungen für die Wirtschaft und die Verwaltung.
- 41007 'Fläche besonderer funktionaler Prägung' ist eine baulich geprägte Fläche einschließlich der mit ihr im Zusammenhang stehenden Freifläche, auf denen vorwiegend Gebäude und/oder Anlagen zur Erfüllung öffentlicher Zwecke oder historische Anlagen vorhanden sind.
- 41008 'Sport-, Freizeit- und Erholungsfläche' ist eine bebaute oder unbebaute Fläche, die dem Sport, der Freizeitgestaltung oder der Erholung dient.
- 41009 'Friedhof' ist eine Landfläche, die zur Bestattung dient oder gedient hat, sofern die Zuordnung zu Grünanlage nichtzutreffender ist. Waldbestattungsflächen werden der Nutzungsart Wald zu-geordnet.

VERKEHR – 42000: Die Objektartengruppe mit der Bezeichnung ‚Verkehr' und der Kennung ‚42000' enthält die bebauten und nicht bebauten Flächen, die dem Verkehr dienen.

- 42001 'Straßenverkehr' umfasst alle für die bauliche Anlage Straße erforderlichen Flächen und die dem Straßenverkehr dienenden bebauten und unbebauten Flächen.
- 42002 'Straße' ist ein befestigter, dem allgemeinen Verkehr dienender Verkehrsweg einschließlich der auf Brücken oder in Tunneln verlaufenden Abschnitte sowie die begeh- und befahrbaren Flächen in einer Fußgängerzone. Eine Straße ist einbahnig, wenn deren Fahrbahnen physisch nicht getrennt sind (keine Bauwerke wie z.B. Leitplanke, Grünstreifen). Eine Straße ist mehrbahnig, wenn nebeneinanderliegende Fahrbahnen durch Bauwerke getrennt sind und der Verkehr auf den einzelnen Fahrbahnen in Richtungen geführt wird. Ein wesentlicher Teil einer Straße ist der Straßenkörper. Zu diesem gehören Fahrbahnen, Seiten- und kleinere Trennstreifen, begleitende Gräben zur Entwässerung der Straße, kleinere Böschungen, Parkstreifen und ähnliche Ein-richtungen sowie begleitende Fuß- und Radwege, wenn der Abstand zum Fahrbahnrand < 3 m ist.
- 42006 'Weg' umfasst alle Flächen, die zum Befahren und/oder Begehen vorgesehen sind. Zur Wegfläche gehören auch Seitenstreifen und Gräben zur Wegentwässerung.

- 42009 'Platz' ist eine Verkehrsfläche in Ortschaften oder eine ebene, befestigte oder unbefestigte Fläche, die bestimmten Zwecken dient (z. B. für Verkehr, Parkplätze, Märkte, Festveranstaltungen).
- 42010 'Bahnverkehr' umfasst alle für den Schienenverkehr erforderlichen Flächen und die dem Schienenverkehr dienenden bebauten und unbebauten Flächen.
- 42015 'Flugverkehr' umfasst die baulich geprägte Fläche und die mit ihr in Zusammenhang stehende Freifläche, die ausschließlich oder vorwiegend dem Flugverkehr dient.
- 42016 'Schiffsverkehr' umfasst die baulich geprägte Fläche und die mit ihr in Zusammenhang stehende Freifläche, die ausschließlich oder vorwiegend dem Schiffsverkehr dient.

VEGETATION – 43000: Die Objektartengruppe mit der Bezeichnung ‚Vegetation‘ und der Kennung ‚43000‘ umfasst die Flächen außerhalb der Ansiedlungen, die durch land- oder forstwirtschaftliche Nutzung, durch natürlichen Bewuchs oder dessen Fehlen geprägt werden.

- 43001 'Landwirtschaft' ist eine Fläche für den Anbau von Feldfrüchten sowie eine Fläche, die beweidet und gemäht werden kann, einschließlich der mit besonderen Pflanzen angebauten Fläche (einschließlich landwirtschaftlichen Brachlands).
- 43002 'Wald' ist eine Fläche, die mit Forstpflanzen (Waldbäume und Waldsträucher) bestockt ist.
- 43003 'Gehölz' ist eine Fläche, die mit einzelnen Bäumen, Baumgruppen, Büschen, Hecken und Sträuchern bestockt ist.
- 43004 'Heide' ist eine Fläche mit typischen Sträuchern, Gräsern und geringwertigem Baumbestand.
- 43005 'Moor' ist eine unkultivierte Fläche, deren obere Schicht aus vertorften oder zersetzten Pflanzenresten besteht. Torfstich bzw. Torfabbaufläche wird der Objektart 41005 'Tagebau, Grube, Steinbruch' mit AGT 'Torf' zugeordnet.
- 43006 'Sumpf' ist ein wassergesättigtes, zeitweise unter Wasser stehendes Gelände. Nach Regenfällen kurzzeitig nasse Stellen im Boden werden nicht als 'Sumpf' erfasst.
- 43007 'Unland/Vegetationslose Fläche' ist eine Fläche, die nicht dauerhaft landwirtschaftlich genutzt wird, wie z. B. Fels-, Sand- oder Eisflächen, Uferstreifen längs von Gewässern und Sukzessionsflächen.
- 43008 Unbekannt.

GEWÄSSER – 44000: Die Objektartengruppe mit der Bezeichnung ‚Gewässer‘ und der Kennung ‚44000‘ umfasst die mit Wasser bedeckten Flächen. Die Gewässer werden geometrisch begrenzt durch ihre Uferlinie. Dies ist bei ‚Meer‘ die Uferlinie bei mittlerem Tidenhochwasser, bei den sonstigen Gewässern die Uferlinie bei mittlerem Wasserstand.

- 44001 'Fließgewässer' ist ein geometrisch begrenztes, auf dem Festland fließendes Gewässer, das die Wassermengen sammelt, die als Niederschläge auf die Erdoberfläche fallen oder in Quellen austreten, und in ein anderes Gewässer, ein Meer oder in einen See transportiert oder ein in einem System von natürlichen oder künstlichen Bodenvertiefungen verlaufendes Wasser, das zur Be- und Entwässerung an- oder abgeleitet wird oder ein geometrisch begrenzter, für die Schifffahrt angelegter künstlicher Wasserlauf, der in einem oder in mehreren Abschnitten die jeweils gleiche Höhe des Wasserspiegels besitzt.
- 44003 'Kanal' ist ein für die Schifffahrt angelegter künstlicher Wasserlauf.
- 44005 'Hafenbecken' ist ein natürlicher oder künstlich angelegter oder abgetrennter Teil eines Gewässers, in dem Schiffe be- und entladen werden.
- 44006 'Stehendes Gewässer' ist eine natürliche oder künstliche mit Wasser gefüllte, allseitig umschlossene Hohlform der Landoberfläche ohne unmittelbaren Zusammenhang mit 'Meer'.
- 44007 ‚Meer‘ ist die das Festland umgebende Wasserfläche.

Appendix C - Pre-analysis: case study selection

Population increase (2011-2018) and housing stock increase (2011-2019) for each 24 of the middle-sized towns in the conurbation (Source: Regionalverband FrankfurtRheinMain, n.d.; Statistischen Ämter des Bundes und der Länder, 2015).

		Population increase			Housing stock increase			
County	Town	2018	2011	relative %	2019	2011	relative %	absolute
GG	**Groß-Gerau**	**25559**	**23876**	**7,0489**	**11529**	**10783**	**6,9183**	**746**
GG	Mörfelden-Walldorf	34891	32634	6,9161	16315	15585	4,6840	730
GG	**Rüsselsheim**	**65440**	**59307**	**10,3411**	**29938**	**28656**	**4,4738**	**1282**
HTK	**Bad Homburg v.d.Höhe**	**54248**	**51625**	**5,0809**	**27088**	**26479**	**2,2999**	**609**
HTK	Friedrichsdorf	25194	24436	3,1020	12029	11522	4,4003	507
HTK	**Oberursel (Taunus)**	**46248**	**44209**	**4,6122**	**22476**	**21368**	**5,1853**	**1108**
MKK	Bruchköbel	20427	20326	0,4969	9878	9644	2,4264	234
MKK	**Maintal**	**39298**	**36021**	**9,0975**	**18872**	**18205**	**3,6638**	**667**
MTK	Bad Soden am Taunus	22645	21102	7,3121	11519	11074	4,0184	445
MTK	Eschborn	21488	20395	5,3592	10505	10030	4,7358	475
MTK	Flörsheim am Main	21572	19930	8,2388	9782	9350	4,6203	432
MTK	**Hattersheim am Main**	**27590**	**24864**	**10,9636**	**13091**	**12333**	**6,1461**	**758**
MTK	**Hofheim am Taunus**	**39766**	**37982**	**4,6970**	**18819**	**17965**	**4,7537**	**854**
MTK	Kelkheim (Taunus)	29055	27777	4,6009	13675	13130	4,1508	545
OF	Dietzenbach	34019	32030	6,2098	14128	13936	1,3777	192
OF	Dreieich	42091	39526	6,4894	20429	19866	2,8340	563
OF	**Langen (Hessen)**	**37902**	**35303**	**7,3620**	**18221**	**17163**	**6,1644**	**1058**
OF	Mühlheim am Main	28403	26918	5,5168	13724	13152	4,3491	572
OF	**Neu-Isenburg**	**37668**	**35051**	**7,4663**	**19251**	**18875**	**1,9921**	**376**
OF	Obertshausen	24943	23814	4,7409	11733	11238	4,4047	495
OF	Rodgau	45202	42945	5,2556	20482	19750	3,7063	732
OF	Rödermark	28071	26297	6,7460	12561	12012	4,5704	549
OF	**Seligenstadt**	**21293**	**20059**	**6,1519**	**10372**	**9580**	**8,2672**	**792**
WTK	**Bad Vilbel**	**33990**	**31673**	**7,3154**	**16655**	**15521**	**7,3062**	**1134**

Land-use change analysis for the towns in which the population and housing stock analysis was insufficient to determine the case town:

	YEAR	Residential area (Wohnbaufläche) 41001		Industrial and commercial area (Industrie- und Gewerbefläche) 41002		Mixed-use area (Fläche gemischter Nutzung) 41006		Area with special functional character (Fläche besonderer funktionaler Prägung) 41007		Area for sports, free time, and recreation (Sport-, Freizeit- und Erholungsfläche) 41008		Cemetery (Friedhof) 41009	
		Count	Area m²	Count	Area m²	Count	Area m²	Count	Area m²	Count	Area m²	Count	Area m²
Groß-Gerau	2012	105	1288057,61	19	703045,83	10	151863,84	7	78970,50	4	54807,35	2	45544,90
Groß-Gerau	2015	112	1299415,05	19	811132,83	12	156085,15	5	60792,61	5	80637,00	2	44514,71
Groß-Gerau	2016	108	1299587,35	18	811894,35	12	158157,62	6	78452,48	5	83024,27	2	44514,71
Groß-Gerau	2017	105	1285315,33	19	703657,93	11	151866,77	7	78970,50	4	54807,35		
Groß-Gerau	2018	105	1288057,68	19	703045,83	10	151863,84	7	78970,50	4	54807,35	2	45544,90
Groß-Gerau	2019	105	1288057,61	19	703045,83	10	151863,84	7	78970,50	4	54807,35	2	45544,90
Change % specific			**0,0000**		**0,0000**		**0,0000**		**0,0000**		**0,0000**		**0,0000**
Change % 41001 and 41006							**0,0000**						
Rüsselsheim	2012	134	1212980,782	17	773752,9177	15	217885,9126	10	246982,2059	35	135897,5753		
Rüsselsheim	2015	133	1200784,67	23	691764,75	18	276634,87	10	246943,29	10	154438,77		
Rüsselsheim	2016	133	1200935,60	22	677249,51	20	285352,54	10	246943,29	15	296783,55		
Rüsselsheim	2017	133	1199579,36	21	677254,04	20	285762,78	10	246943,29	18	302430,87		
Rüsselsheim	2018	123	1110207,85	21	694550,91	31	360178,45	14	275574,82	18	294377,59		
Rüsselsheim	2019	119	1110207,85	20	627292,56	31	360178,45	14	275574,82	18	294377,59		
Change % specific			**-0,0847**		**-0,1893**		**0,6531**		**0,1158**		**1,1662**		
Change % 41001 and 41006							**0,0276**						
		Count	Area m²	Count	Area m²	Count	Area m²	Count	Area m²	Count	Area m²	Count	Area m²
Bad Homburg	2012	51	819907,05	27	754189,88	14	317949,62	12	172405,64	51	281857,44		
Bad Homburg	2015	49	841492,59	24	868852,55	14	341779,00	11	249747,95	16	299762,04		
Bad Homburg	2016	49	841492,59	24	868852,55	14	341779,00	11	249747,95	16	299762,04		
Bad Homburg	2017	49	841492,59	24	868265,68	14	341779,00	11	249747,86	16	299762,13		
Bad Homburg	2018	49	841492,59	24	868265,68	14	341779,00	11	249747,86	16	299762,13		
Bad Homburg	2019	49	840348,00	24	868298,27	14	341740,70	11	249747,86	16	299762,13		
Change % specific			**0,0249**		**0,1513**		**0,0748**		**0,4486**		**0,0635**		
Change % 41001 and 41006							**0,0389**						
Oberursel	2012	111	1393612,66	26	519837,27	15	206637,32	13	191534,30	13	100495,01	24	84102,24
Oberursel	2015	107	1417925,01	23	525169,11	14	209510,71	9	191534,30	11	97009,29	1	84102,24
Oberursel	2016	104	1360326,85	20	461847,94	17	322308,36	9	229577,58	27	152947,82	1	60625,48
Oberursel	2017	104	1360326,85	20	461847,94	17	322308,36	9	229577,58	27	152947,82		
Oberursel	2018	104	1360326,85	20	461847,94	17	322308,36	9	229577,58	27	152947,82	1	60625,48
Oberursel	2019	104	1359265,36	20	461881,20	17	323466,90	9	229577,58	27	152850,12	1	60625,48
Change % specific			**-0,0246**		**-0,1115**		**0,5654**		**0,1986**		**0,5210**		**-0,2791**
Change % 41001 and 41006							**0,0515**						

Land-use change analysis for the towns in which the population and housing stock analysis was insufficient to determine the case town (continued):

Langen	2012	135	1643538,36	16	642143,41	14	252981,85	8	111437,19	5	28909,79		
Langen	2015	126	1638818,71	17	558428,68	14	279577,07	8	112855,58	6	29090,48		
Langen	2016	127	1639895,19	17	556212,01	14	275477,43	8	112855,58	7	49552,12		
Langen	2017	127	1639894,99	17	556212,13	14	275477,43	8	112855,58	7	49552,12		
Langen	2018	127	1639894,99	17	556212,13	14	275477,43	8	112855,58	7	49552,12		
Langen	2019	125	1639894,99	15	613282,02	14	275477,43	8	112855,58	7	49552,12		
Change % specific			**-0,0022**		**-0,0449**		**0,0889**		**0,0127**		**0,7140**		
Change % 41001 and 41006							**0,0099**						
Neu-Isenburg	2012	19	358048,80	5	328052,88	9	121841,91	2	5550,99	7	283541,68		
Neu-Isenburg	2015	18	358048,80	3	302834,37	9	121841,91	2	5550,99	6	283556,64		
Neu-Isenburg	2016	18	358048,80	7	345293,71	9	121841,91	2	5550,99	6	283556,64		
Neu-Isenburg	2017	18	358048,80	7	345293,71	9	121841,91	2	5550,99	6	283556,64		
Neu-Isenburg	2018	18	358048,80	7	345293,71	9	121841,91	2	5550,99	6	283556,64		
Neu-Isenburg	2019	18	358048,80	7	345293,71	9	121841,91	2	5550,99	6	283556,64		
Change % specific			**0,0000**		**0,0526**		**0,0000**		**0,0000**		**0,0001**		
Change % 41001 and 41006							**0,0000**						**0,0157**
Seligenstadt	2012	163	1474382,07	4	84317,1267	21	363103,11	9	184159,41	15	235299,70	2	14775,70
Seligenstadt	2015	158	1461445,89	4	78772,09	21	386533,50	9	184159,41	15	235760,78	2	14775,70
Seligenstadt	2016	158	1461372,43	4	78772,09	21	386533,50	9	184159,41	15	235760,78	2	14775,70
Seligenstadt	2017	148	1415616,35	5	87692,34	21	419426,08	9	162945,25	14	292174,72		
Seligenstadt	2018	148	1415616,40	5	87692,34	21	419426,08	9	150298,96	15	304820,96	2	16922,11
Seligenstadt	2019	148	1415616,40	5	87692,34	21	419426,08	9	150298,96	15	304820,96	2	16922,11
Change % specific			**-0,0399**		**0,0400**		**0,1551**		**-0,1839**		**0,2955**		**0,1453**
Change % 41001 and 41006							**-0,0013**						
Hattersheim	2012	108	1334860,47	15	460429,79	7	61074,54	8	68562,36	18	224295,49	1	5062,78
Hattersheim	2015	114	1453497,89	15	388966,18	10	105337,98	6	67644,93	18	295276,22	1	5062,78
Hattersheim	2016	114	1453497,93	14	388841,81	10	105337,98	6	67644,93	18	291057,48	1	5062,78
Hattersheim	2017	114	1453497,93	14	388841,81	10	105337,98	6	67644,93	18	291057,48		
Hattersheim	2018	114	1453497,93	14	388841,81	10	105337,98	6	67644,93	18	291057,48	1	5062,78
Hattersheim	2019	109	1454405,93	14	388784,59	10	105153,55	7	67074,40	18	291192,51	1	5062,78
Change % specific			**0,0896**		**-0,1556**		**0,7217**		**-0,0217**		**0,2983**		**0,0000**
Change % 41001 and 41006							**0,1172**						
Hofheim	2012	204	1882758,40	8	103859,42	15	202557,70	12	254115,18	18	169711,68	3	26408,43
Hofheim	2015	189	1889249,81	7	103836,25	12	191144,19	13	261785,31	14	169744,68	1	26408,43
Hofheim	2016	189	1886808,77	6	101555,53	13	200471,78	13	272762,31	13	158979,42	1	26408,43
Hofheim	2017	189	1886808,77	6	106582,59	13	200471,78	13	272762,31	13	158979,42		
Hofheim	2018	189	1886808,77	6	106582,59	13	200471,78	13	272762,31	13	158979,42	1	26408,43
Hofheim	2019	189	1887069,44	6	106354,17	13	200711,46	13	272844,75	13	158982,74	1	26408,43
Change % specific			**0,0023**		**0,0240**		**-0,0091**		**0,0737**		**-0,0632**		**0,0000**
Change % 41001 and 41006							**0,0012**						

Appendix D – Open space type

(Source: Dettmar, 2018)

1. **Public open spaces - free access without restriction**

   General open public spaces:

   1.1. Parks: diverse types
   1.2. Forests
   1.3. Green corridors and connectors
   1.4. Streets: diverse types: play streets, residential street
   1.5. Squares
   1.6. Pedestrian zones

2. **Purpose-dependent open public spaces (with a dominant function)**

   2.1. Playgrounds
   2.2. Sports fields (ones with free access, e.g. amateur soccer field)
   2.3. Cemeteries
   2.4. Nature protection areas (publicly accessible)
   2.5. Streets including roadside green
   2.6. Parking lots

3. **Conditionally accessible open spaces (semi-public)**

   3.1. Botanical gardens, show gardens
   3.2. animal parks, zoos
   3.3. leisure and amusement parks
   3.4. swimming pools, entertainment pools
   3.5. sports areas of associations
   3.6. open spaces of public organizations: schools, daycare centers, hospitals, administration buildings, churches, etc.
   3.7. green areas of densified residential construction: green buffers
   3.8. community gardens: communal areas and pathways
   3.9. agricultural fields: farm track, agricultural road
   3.10. nature protection areas: access only with permission or with guides

4. **Private open spaces (not publicly accessible)**

   4.1. gardens (garden of a house, garden in a community garden area, rented gardens etc.)
   4.2. terraces, balconies, roof gardens, courtyards
   4.3. cultivated areas of agriculture, horticulture, tree nurseries
   4.4. open spaces of industry and trade areas
   4.5. brownfields: industry, trade, transport, gaps between buildings, brownfield gardens
   4.6. construction site (added by author)

Appendix E – Land-cover type

Classified according to generic and detailed examples in combination with the ATKIS classifications (Source: Gill, 2006; Lehmann et al., 2014):

Ecological value	Generic land-cover types according to Gill 2006 p. 92	Urban vegetation structure types according to Lehmann et al. 2014	ATKIS vegetation and water land-cover types	Emerging category in this study
None	Building	1- Residential sites, mixed-use sites as well as industrial, commercial and specialized sites	31001, 31002, 51001, 51009, 53001, 53009	Buildings
	Other impervious	2- Transport facilities and infrastructure	42000 Verkehr	Transport and other impervious surfaces
Low	Bare soil / gravel	13- Open sites	43007 Unland/vegetationslose Fläche	Surfaces without vegetation
	Rough grass, mown grass	7- Grassland	-	Rough grass, mown grass
	Cultivated	6- Agricultural fields	43001 Landwirtschaft	Agriculture, conventional (pesticides, machinery etc.)
	-	11- Waterside zone with little or no vegetation	44000 Gewässer (all subcategories, but mostly 44003 Kanal, 44005 Hafenbecken)	Waterside zones with strong anthropogenic influence
Medium	Shrub	8- Trees, shrubs, bushes	43003 Gehölz	Shrubbery
	Cultivated	6- Agricultural fields	43001 Landwirtschaft	Agricultural, ecological (community gardening etc.)
High	-	10- Near-natural wetlands	43005 Moor 43006 Sumpf	Near-natural wetlands
		12- Arid grasslands, heathland	43004 Heide	Heathland
	Tree / forest	-	43002 Wald	Forest
	Water	11- Waterside zones	44000 Gewässer (mostly 44001, 44006)	Near-natural waterside zones

Appendix F – Question catalogs

Question catalog from CityStrength Diagnostic Tool – Optional Sectoral Module Environment (Source: World Bank, 2018b, 2018a):

Topic	Guiding Question	Relationship to Resilience Quality	Applicable Resilience Quality
Institutional capacity	Who manages and protects the environment, natural resources and ecosystem services* in the city? If there are several agencies, are they well-coordinated in terms of management, environmental planning and implementation of environmental requirements? With which agency/department does the main responsibility lie?	Close coordination among agencies responsible for environmental protection facilitates better management of natural resources and ecosystem services, exchange of data and information, environmental planning and enforcement of environmental regulations. Having a responsible agency for environmental protection allows for better coordination of activities and accountability.	Coordinated
Institutional capacity	Have environmental considerations been formally mainstreamed into relevant city departments? Are there systems for evaluation and accountability?	Efficient planning of environmental assets relies on alignment of environmental concern with the plans, programs and actions of institutions that drive sectoral development in the city. Systems for evaluation and accountability help ensure that departments meet predetermined environmental objectives and learn lessons for improving their environmental performance.	Coordinated; Reflective
Institutional capacity	Does the city have baseline data about the environment? Does the city regularly assess and monitor land use changes and other development activities impacting the environment?	Cities that have environmental baseline data and regularly monitor changes to the environment are able take early action to prevent environmental deterioration.	Reflective
Institutional capacity	Does the city staff participate in regular training and knowledge-sharing events about environmental challenges, and how these relate to climate change?	Climate change has numerous impacts on the environment (e.g., increasing occurrence and severity of floods, droughts and forest fires; sea level rise; heatwaves) - depending on the region. City staff that regularly draw upon the expertise of in-house environmental agencies and/or external experts are better able identify appropriate coping strategies to deal with current and future environmental challenges within their own departments.	Robust
Finance	What are the funding sources for environment and nature management? To what degree are funding sources and uses coordinated across agencies?	Reliable funding allows for sustained and up-to-date environmental and nature resource management. Coordination among agencies (both public and private) helps improve environmental planning	Robust

		and implementation of environmental regulations.	
Finance	Does the city have an environmental contingency fund set aside to clean up and restore the environment after manmade (e.g. pollution; hazardous waste etc.) and natural disasters?	An environmental contingency fund covers unexpected release of hazardous materials into the environment and impacts of natural disasters on the environment (unless these natural disasters are adequately covered by other funds). A contingency fund could also help overcome sudden changes in demand for environmental control and management due to rapid urbanization.	Redundant
Planning	Is environmental planning and environmental management coordinated with urban planning? Do land use plans indicate where development is permissible and where it would be damaging for the environment? Are land use plans enforced?	Integrated environmental and urban planning facilitates consistent land use development. For effective environmental protection, land use plans must include legally binding indications on where development is (not) permissible. Effective environmental protection depends on the protection of environmental zones outlined in land use plans and enforcement of zoning laws.	Coordinated
Planning	Are there environmental licensing requirements for new developments? Who manages and approves environmental licenses for new development in the city?	License requirements are put into place to make sure that a specific activity, especially construction, is consistent with the intended land use – as defined in the area's zoning plan, and development on sensitive/at risk land is being prevented.	Robust
Planning	How well integrated are the city's disaster risk management policies, strategies and implementation plans into existing environmental development, natural resources, and ecosystems management plans?	Disasters can have significant impacts on natural resources and their effective management. Natural resources and ecosystems can also be used to help manage the impacts of disasters (e.g., water retention ponds, mangroves, etc.).	Coordinated
Urban Growth	Have the city's settlement patterns shifted recently? Do new settlements pose threats to the environment and the balance of the urban ecosystem? Are the new settlements vulnerable to natural hazards and adverse climate change impacts?	Land use change, from natural vegetation to built-up areas, is often the main cause of environmental degradation and loss of biodiversity. New developments can disrupt the balance of the urban ecosystem and exacerbate impacts of natural disasters.	Robust
Regional Impacts	Are there any regional environmental problems that impact liveability in the city (i.e. air pollution, pollution of rivers and coastal areas, etc.)? Are there any urban activities that have environmental impacts beyond the city's administrative boundaries (e.g., ecological disruption and resource depletion)? To what extent are the environmental management	Environmental impacts are rarely contained within administrative boundaries – pollution from the outside can affect life in the city and pollutions/natural resource depletion within the city can have regional consequences. Local and regional governments need to collaborate with governments beyond their own administrative boundaries to	Coordinated

	strategies coordinated across administrative boundaries?	effectively manage environmental effects.	
Accessibility	Are all residents able to use and benefit from the city's natural resources, ecosystem services, and recreation areas? Does the city have programs for improving accessibility and knowledge about effective use of ecosystem services for all segments of the population?	Equal access to the city's natural resources, ecosystem services, and recreation areas is a prerequisite for social cohesion and equal opportunity. Accessibility and knowledge about effective use of ecosystem services (e.g. agriculture, fisheries and/or water accessibility) can be a method for reducing food scarcity and improving livelihood options among the poor.	Inclusive
Participation	To what degree do civil society organizations and citizens participate in the restoration, protection, and sustainable management of ecosystems services?	In many cities, uncontrolled urban growth and encroachment has a deteriorating effect on the environment. When restoration, protection and management of ecosystem services is done in consultation with affected communities and civil society groups, solutions are more robust because they include the nuanced needs of affected communities and the general public.	Inclusive
Participation	To what degree does the private sector participate in the development of environmental, natural resources and ecosystems management plans in the city?	A city's environmental planning, natural resource and ecosystem management is more robust when it includes the economic dependencies (e.g., natural resources that are necessary for current industries) and environmental risks (e.g., pollution) of the private sector.	Inclusive

Interview guide for the semi-structured, in-depth interviews in this research:

Thema		Frage	Mögliche Folgefragen
Stadtwachstum	Bevölkerungs-entwicklung	Wie haben sich Entscheidungen und Strategien in der Entwicklung von Siedlungsflächen und in der Ausweisung von Bauland im Zeitraum von 2008 bis heute verändert? Wie wächst die Stadt zurzeit?	Innenentwicklung: Spielt LEP-definierte Dichtewerte einzuhalten eine Rolle? Gibt es noch Potenzial in Baulücken oder sind sie schon zum gewissen Teil geschlossen/gebaut? Außenentwicklung: Planen Sie mehr Neubauflächen als bereits im regionalen Flächennutzungsplan festgelegt ist? Kombination: Wird versucht, Siedlungsentwicklung in Innen- und Außenbereichen durch Wachstums- und Schrumpfungsreserven auszugleichen?
	Bautätigkeit	Was sind die Umweltherausforderungen bei der Entwicklung neuer Siedlungsflächen (z.B. Überflutung, Dürre, Hitzewelle, Waldbrand, Umweltverschmutzung, Kontamination usw.)?	Gibt es sensible Flächen, die für Siedlungsentwicklung nicht geeignet sind? Hat man hierbei aus Erfahrung gelernt?
Raumplanung	Integrierte Stadtentwicklung	Sind Siedlungsentwicklungspläne und -prozesse in Freiraum- und Infrastrukturkonzepte in einem entsprechenden Verfahren, wie z.B. einem integrierten Stadtentwicklungskonzept (ISEK) integriert?	Was sind/wäre die Vorteile? Glauben Sie, dass dies z.B. Innenentwicklung erleichtern könnte? (Potenziale im Innenbereich genauer zu erkennen, durch umfassende Berücksichtigung der Auswirkungen auf die gebaute und natürliche Umwelt) Hat sich Ihre Kommune mit dem Konzept „doppelte Innenentwicklung“ beschäftigt oder wurden Maßnahmen vergleichbarer Wirkung angewendet?
Regionale Wirkungen	Wirkungen über die Grenzen hinweg	Was war die größte Änderung in Bezug auf Flächenversiegelung seit 2008? Welche Auswirkungen hat diese Änderung auf Grünflächen in oder um Ihre Kommune bewirkt?	Welche Maßnahmen wurden zum Ausgleich möglicher negativer Folgen ergriffen?
Finanzierung	Ressourcen, Rücklagen	Gibt es finanzielle Ressourcen, um die Qualität und Quantität des Stadtgrüns zu erhalten oder zu steigern und/oder Schäden (z. B. Überflutung, Dürre, Hitzewelle, Waldbrand, Umweltverschmutzung, Kontamination usw.) zu beseitigen?	Inwiefern unterstützt dies der Bund oder das Land mittels z.B. Förderprogrammen?
Zugänglichkeit	Gleichberechtigter Zugang	Wie hoch ist Ihrer Meinung nach, die Akzeptanz für Nachverdichtung unter der Bevölkerung?	Glauben Sie, dass aufgrund von Nachverdichtung die Rolle der öffentlichen Grünflächen (Rekreation, Klimaanpassung, ggf. Produktion von Nahrung usw.) für einen gleichguten Zugang - unabhängig vom Einkommensniveau - zu Stadtgrün zunimmt? Waren der Zustand der Infrastrukturauslastung, Parkmöglichkeiten, Lärm usw. in der Innenstadt schon ein Thema in Politik?
Institutionelle Kapazität	Monitoring Evaluation	Nutzen Sie das jährlich vom Regionalverband FrankfurtRheinMain veröffentlichte Monitoring und die Evaluation oder andere Tools wie z.B. Baulückenpotenziale?	Werden diese Dienstleistungen für eine nachhaltige Stadtentwicklung in Ihrer Kommune genutzt? Gibt es Verbesserungspotenzial?

	Koordinierung	Inwiefern vertragen sich die Ziele der Bundes- und Landesebene mit denen der Kommune in Bezug auf Wohnraumversorgung und Umweltschutz?	Was sind die wichtigsten Instrumente, um die Strategien der Bundes-/Landesebene auf kommunaler Ebene umzusetzen? Wo gibt es Konfliktpotenziale?
Beteiligung	Mitverwaltung	Wer sind die wichtigsten Akteure im Stadtentwicklungsprozess? Wie erfolgt die Zusammenarbeit?	Wie ist der aktuelle Aufbau der Interessenvertretung auf kommunale Ebene in Bezug auf die Verhältnisse zwischen staatliche Einrichtungen, Privatunternehmen und Bürgerinitiativen? Wie hoch ist der Einfluss der Medien? Gibt es die Möglichkeit für Wissensaustausch unter den Kommunen, um voneinander zu lernen?

Appendix G – Green space parameters

Green space amount in the entire town (Source: OpenStreetMap):

BAD HOMBURG Total area: 51,14 ha, population: 54.227			
Layer	Area (m²)	Percentage cover (%)	Per person (m²)
41008 Recreation	2178253,018	4,2593919	40,1691596
41009 Cemetery	178812,4075	0,349652733	3,297479254
SUBTOTAL	**2357065,425**	**4,609044633**	**43,46663885**
43001 Agriculture	13704595,57	26,79819235	252,7264198
43002 Forest	21368496,35	41,78431043	394,0563991
43003 Woods	150418,2588	0,294130346	2,773862814
44001 Flowing water	259605,4447	0,507636771	4,787383493
44006 Standing water	28665,7669	0,056053514	0,528625351
TOTAL	**37868846,82**	**74,04936804**	**698,3393294**
BAD VILBEL Total area: 25,65 m², population: 35.553			
Layer	Area (m²)	Percentage cover (%)	Per person (m²)
41008 Recreation	1605685,193	6,252668198	45,16314216
41009 Cemetery	83017,9996	0,323278815	2,33504907
SUBTOTAL	**1688703,193**	**6,575947013**	**47,49819123**
43001 Agriculture	13210247,48	51,44177368	371,5649166
43002 Forest	1719776,607	6,696949403	48,37219382
43003 Woods	114126,8836	0,444419329	3,210049324
44001 Flowing water	606487,4912	2,361711414	17,05868678
44006 Standing water	13654,7215	0,053172592	0,384066647
TOTAL	**17352996,38**	**67,57397343**	**488,0881044**
HATTERSHEIM Total area: 15,80 ha, population: 28.940			
Layer	Area (m²)	Percentage cover (%)	Per person (m²)
41008 Recreation	575267,2536	3,640931985	19,8779286
41009 Cemetery	75532,1565	0,478051623	2,609957032
SUBTOTAL	**650799,4101**	**4,118983608**	**22,48788563**
43001 Agriculture	8007227,805	50,67865699	276,6837528
43002 Forest	476090,6855	3,013232187	16,45095665
43003 Woods	60247,8071	0,381315235	2,081817799
44001 Flowing water	721278,8514	4,565056022	24,92324988
44006 Standing water	44876,9365	0,284031244	1,550688891
TOTAL	**9960521,496**	**63,04127529**	**344,1783516**
LANGEN Total area: 29,12 ha, population: 39.214			
Layer	Area (m²)	Percentage cover (%)	Per person (m²)
41008 Recreation	688543,8377	2,364504937	17,55862288
41009 Cemetery	85017,3768	0,291955277	2,168036334
SUBTOTAL	**773561,2145**	**2,656460215**	**19,72665922**
43001 Agriculture	4517083,602	15,51196292	115,1905851
43002 Forest	14779916,03	50,75520613	376,9040655
43003 Woods	65820,5618	0,226032149	1,678496501
43006 Marsh	4093,8297	0,014058481	0,104397146
44001 Flowing water	95453,2216	0,327792657	2,43416182

44006 Standing water	996553,42	3,422230151	25,41320498
TOTAL	**21232481,88**	**72,91374271**	**541,4515703**
MAINTAL Total area: 32,41 ha, population: 41.417			
Layer	Area (m²)	Percentage (%)	Per person (m²)
41008 Recreation	1021965,667	3,1532418	24,67502879
41009 Cemetery	93971,3797	0,289945633	2,268908412
SUBTOTAL	**1115937,047**	**3,443187433**	**26,9439372**
43001 Agriculture	14701473,13	45,36091678	354,9622891
43002 Forest	5586405,524	17,2366724	134,8819452
43003 Woods	652014,9803	2,011770998	15,74268972
43005 Moor	22037,7631	0,067996801	0,532094625
43006 Marsh	5927,9344	0,018290449	0,143128049
44001 Flowing water	706820,0776	2,180870341	17,06594098
44005 Harbor basin	20222,2416	0,062395068	0,488259449
44006 Standing water	261515,6323	0,806897971	6,314209921
TOTAL	**23072354,33**	**71,18899824**	**557,0744943**
RÜSSELSHEIM Total area: 58,29 ha, population: 65.788			
Layer	Area (m²)	Percentage cover (%)	Per person (m²)
41008 Recreation	814057,6258	1,396564807	12,37395309
41009 Cemetery	169062,8248	0,290037442	2,569812501
SUBTOTAL	**983120,4506**	**1,686602248**	**14,94376559**
43001 Agriculture	1680238,686	2,882550499	25,54020013
43002 Forest	2916659,057	5,003703992	44,33421075
43003 Woods	8358,1712	0,014338945	0,127047048
44001 Flowing water	538701,8967	0,924175496	8,188452251
44006 Standing water	42215,8904	0,072423898	0,641695908
TOTAL	**6169294,152**	**10,58379508**	**93,77537168**

Green cover in the spatial focus area:

BAD HOMBURG SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Area (m²)	Percentage cover (%)
41008 Sports, leisure, recreation	312128,727	9,935658985
SUBTOTAL	**312128,727**	**9,935658985**
43001 Agriculture	315272,4653	10,03573023
43003 Woods	380,538	0,012113258
44001 Flowing water	27470,478	0,874438262
TOTAL	**655252,2083**	**20,85794074**
BAD VILBEL SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Area (m²)	Percentage cover (%)
41008 Sports, leisure, recreation	279897,9564	8,909691434
41009 Cemetery	30461,8748	0,969660188
SUBTOTAL	**310359,8312**	**9,879351622**
43001 Agriculture	625044,4666	19,8963701
43002 Forest	10302,1658	0,327937794
43003 Woods	4367,7474	0,139033818
44001 Flowing water	89571,2172	2,851224485
44006 Standing water	830,0809	0,026423075
TOTAL	**1040475,509**	**33,12034089**
HATTERSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Area (m²)	Percentage cover (%)
41008 Sports, leisure, recreation	302802,8613	9,638798704
41009 Cemetery	4276,1624	0,136118491
SUBTOTAL	**307079,0237**	**9,774917196**
43001 Agriculture	572007,5486	18,20810277
43002 Forest	73958,344	2,354236639
43003 Woods	4168,9303	0,132705087
44001 Flowing water	24527,108	0,780745122
44006 Standing water	1273,2362	0,040529562
TOTAL	**983014,1908**	**31,29123638**
LANGEN SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Area (m²)	Percentage cover (%)
41008 Sports, leisure, recreation	77219,102	2,458032851
SUBTOTAL	**77219,102**	**2,458032851**
43001 Agriculture	71225,2301	2,267236355
43002 Forest	99903,6009	3,180124173
43003 Woods	4287,7893	0,136488598
44001 Flowing water	1741,877	0,055447302
44006 Standing water	6329,8867	0,201492494
TOTAL	**260707,486**	**8,298821773**
MAINTAL SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Area (m²)	Percentage cover (%)
41008 Sports, leisure, recreation	225013,462	7,162612192

41009 Cemetery	1910,4705	0,060813958
SUBTOTAL	**226923,9325**	**7,22342615**
43001 Agriculture	421499,9608	13,41715616
43002 Forest	220680,1113	7,024673287
43003 Woods	32081,2478	1,021207952
44001 Flowing water	26928,845	0,85719704
44006 Standing water	55864,9261	1,778288273
TOTAL	**983979,0235**	**31,32194886**
RÜSSELSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Area (m²)	Percentage cover (%)
41008 Sports, leisure, recreation	137680,5683	4,729862727
SUBTOTAL	**137680,5683**	**4,729862727**
43001 Agriculture	79725,1952	2,738870371
44001 Flowing water	102829,2615	3,532584861
TOTAL	**320235,025**	**11,00131796**

Distribution of green cover in the spatial focus area, edge density:

BAD HOMBURG SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Edge Length (m)	Edge density (m/ha)
SUBTOTAL	**13245,2187**	**42,16208404**
41008 Sports, leisure, recreation	13245,2187	42,16208404
43001 Agriculture	13805,1203	43,94435875
43003 Woods	162,951	0,518704441
44001 Flowing water	7313,5112	23,28031577
TOTAL	**34526,8012**	**109,905463**
BAD VILBEL SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Edge Length (m)	Edge density (m/ha)
SUBTOTAL	**12825,5287**	**40,82612987**
41008 Sports, leisure, recreation	11830,4934	37,65874073
41009 Cemetery	995,0353	3,167389145
43001 Agriculture	28884,0272	91,94342575
43002 Forest	970,1845	3,088284259
43003 Woods	457,2624	1,455554353
44001 Flowing water	8437,4099	26,85790196
44006 Standing water	128,6572	0,409540665
TOTAL	**51703,0699**	**164,5808369**
HATTERSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Edge Length (m)	Edge density (m/ha)
SUBTOTAL	**19634,4458**	**62,50022537**
41008 Sports, leisure, recreation	19324,8578	61,5147471
41009 Cemetery	309,588	0,985478275
43001 Agriculture	18750,9447	59,68787108
43002 Forest	2068,5694	6,584655101
43003 Woods	868,082	2,763272322
44001 Flowing water	5724,5411	18,22231768
44006 Standing water	185,914	0,591800095
TOTAL	**47232,497**	**150,3501417**
LANGEN SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Edge Length (m)	Edge density (m/ha)
SUBTOTAL	**10372,9089**	**33,01896833**
41008 Sports, leisure, recreation	10372,9089	33,01896833
43001 Agriculture	5764,9797	18,35104154
43002 Forest	3582,4335	11,40357632
43003 Woods	1211,9003	3,857712239
44001 Flowing water	975,7837	3,106107592
44006 Standing water	559,7916	1,781924558
TOTAL	**22467,7977**	**71,51933057**
MAINTAL SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Edge Length (m)	Edge density (m/ha)
SUBTOTAL	**10399,5968**	**33,10392106**
41008 Sports, leisure, recreation	10399,5968	33,10392106
41009 Friedhof	226,6133	0,721353812

43001 Agriculture	21793,2055	69,37197358
43002 Forest	9234,5251	29,39527328
43003 Woods	4395,9255	13,99307815
44001 Flowing water	12638,1967	40,22981601
44006 Standing water	2685,9906	8,550025784
TOTAL	**61374,0535**	**195,3654417**
RÜSSELSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)		
Layer	Edge Length (m)	Edge density (m/ha)
SUBTOTAL	**7883,9532**	**25,09614261**
41008 Sports, leisure, recreation	7883,9532	25,09614261
43001 Agriculture	5438,5886	17,31207576
44001 Flowing water	2903,0714	9,241035811
TOTAL	**16225,6132**	**51,64925418**

Connectivity of green cover in the spatial focus area:

BAD HOMBURG SPATIAL FOCUS AREA (r=1.000 m around train station)			
Connectivity categories	Number of hexagons (R=100m)	Percentage, overall	Percentage, within connected
0 - not connected	1	0,00	0,00
1 - Very low connectivity	7	0,01	0,03
2 - Low connectivity	21	0,04	0,08
3 - Medium-low connectivity	59	0,11	0,23
4 - Medium-high connectivity	64	0,12	0,24
5 - High connectivity	45	0,09	0,17
6 - Very high connectivity (median)	66	0,13	0,25
Total	262	0,51	n/a
All hexagons in SFA	517	n/a	n/a
BAD VILBEL SPATIAL FOCUS AREA (r=1.000 m around train station)			
Connectivity categories	Number of hexagons (R=100m)	Percentage, overall	Percentage, within connected
0 - not connected	1	0,00	0,00
1 - Very low connectivity	3	0,01	0,01
2 - Low connectivity	18	0,03	0,06
3 - Medium-low connectivity	52	0,10	0,17
4 - Medium-high connectivity	76	0,15	0,25
5 - High connectivity	57	0,11	0,18
6 - Very high connectivity (median)	104	0,20	0,34
Total	310	0,60	n/a
All hexagons in SFA	517	n/a	n/a
HATTERSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)			
Connectivity categories	Number of hexagons (R=100m)	Percentage, overall	Percentage, within connected
0 - not connected	3	0,01	0,01
1 - Very low connectivity	5	0,01	0,02
2 - Low connectivity	27	0,05	0,10
3 - Medium-low connectivity	36	0,07	0,13
4 - Medium-high connectivity	76	0,15	0,27
5 - High connectivity	37	0,07	0,13
6 - Very high connectivity (median)	102	0,20	0,36
Total	283	0,55	n/a
All hexagons in SFA	517	n/a	n/a
LANGEN SPATIAL FOCUS AREA (r=1.000 m around train station)			
Connectivity categories	Number of hexagons (R=100m)	Percentage, overall	Percentage, within connected
0 - not connected	4	0,01	0,03
1 - Very low connectivity	21	0,04	0,13
2 - Low connectivity	35	0,07	0,22

3 - Medium-low connectivity (median)	36	0,07	0,23
4 - Medium-high connectivity	29	0,06	0,18
5 - High connectivity	17	0,03	0,11
6 - Very high connectivity	19	0,04	0,12
Total	157	0,30	n/a
All hexagons in SFA	517	n/a	n/a
MAINTAL SPATIAL FOCUS AREA (r=1.000 m around train station)			
Connectivity categories	Number of hexagons (R=100m)	Percentage, overall	Percentage, within connected
0 - not connected	0	0,00	0,00
1 - Very low connectivity	10	0,02	0,04
2 - Low connectivity	19	0,04	0,07
3 - Medium-low connectivity	37	0,07	0,13
4 - Medium-high connectivity	65	0,13	0,23
5 - High connectivity	30	0,06	0,11
6 - Very high connectivity (median)	119	0,23	0,43
Total	280	0,54	n/a
All hexagons in SFA	517	n/a	n/a
RÜSSELSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)			
Connectivity categories	Number of hexagons (R=100m)	Percentage, overall	Percentage, within connected
0 - not connected	1	0,00	0,01
1 - Very low connectivity	12	0,02	0,09
2 - Low connectivity	21	0,04	0,16
3 - Medium-low connectivity (median)	27	0,06	0,21
4 - Medium-high connectivity	25	0,05	0,20
5 - High connectivity	19	0,04	0,15
6 - Very high connectivity	24	0,05	0,19
Total	128	0,27	n/a
All hexagons in SFA	482	n/a	n/a

Proximity of green space in the spatial focus area:

BAD HOMBURG SPATIAL FOCUS AREA (r=1.000 m around train station)		
	Total coverage of all buildings (m²)	coverage of buildings within 300 m zone of green spaces larger than 1.000 m² or 500 m zone of green spaces larger than 10.000 m²
Area (m²)	816991,5941	550119,1169
Percentage (%)	26,00641713 (of spatial focus area)	67,33473403 (of total coverage of all buildings)
BAD VILBEL SPATIAL FOCUS AREA (r=1.000 m around train station)		
	Total coverage of all buildings (m²)	coverage of buildings within 300 m zone of green spaces larger than 1.000 m² or 500 m zone of green spaces larger than 10.000 m²
Area (m²)	527782,9459	472383,6744
Percentage (%)	16,80034843 (of spatial focus area)	89,50339871 (of total coverage of all buildings)
HATTERSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)		
	Total coverage of all buildings (m²)	coverage of buildings within 300 m zone of green spaces larger than 1.000 m² or 500 m zone of green spaces larger than 10.000 m²
Area (m²)	552428,9085	549018,3411
Percentage (%)	17,58487692 (of spatial focus area)	99,38262329 (of total coverage of all buildings)
LANGEN SPATIAL FOCUS AREA (r=1.000 m around train station)		
	Total coverage of all buildings (m²)	coverage of buildings within 300 m zone of green spaces larger than 1.000 m² or 500 m zone of green spaces larger than 10.000 m²
Area (m²)	599521,7984	521901,1679
Percentage (%)	19,08393438 (of spatial focus area)	87,05290938 (of total coverage of all buildings)
MAINTAL SPATIAL FOCUS AREA (r=1.000 m around train station)		
	Total coverage of all buildings (m²)	coverage of buildings within 300 m zone of green spaces larger than 1.000 m² or 500 m zone of green spaces larger than 10.000 m²
Area (m²)	461438,9878	429667,307
Percentage (%)	14,68849237 (of spatial focus area)	93,11465185 (of total coverage of all buildings)
RÜSSELSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)		
	Total coverage of all buildings (m²)	coverage of buildings within 300 m zone of green spaces larger than 1.000 m² or 500 m zone of green spaces larger than 10.000 m²
Area (m²)	823557,8556	740532,6944
Percentage (%)	28,29241376 (of spatial focus area)	89,91872148 (of total coverage of all buildings)

Appendix H – Field visit documentation

BAD HOMBURG SPATIAL FOCUS AREA (r=1.000 m around train station)							
ID#	Open space category		Social value	Fits criteria	Ecol. value	Land-cover type	Observation
1	1.8	Sports fields (with free access, e.g. amateur soccer field)	high	1, 2, 4, 5, 6	low	Rough grass, mown grass	sports field (soccer)
2	3.3	Cultivated areas of agriculture, horticulture, tree nurseries	medium	1, 5, 6	low	Agriculture, conventional (pesticides, machinery, etc.)	Gartenlandschaftsbau
3	1.1	Parks: diverse types	low	3, 5	medium	Shrubbery	park
3a	2.9	Agricultural fields: farm track, agricultural road	none	-	low	Agriculture, conventional (pesticides, machinery, etc.)	agricultural field
4	2.9	Agricultural fields: farm track, agricultural road	none	-	low	Agriculture, conventional (pesticides, machinery, etc.)	agricultural field
5	1.11	Streets including roadside green	low	2	medium	Shrubbery	green field, alongside traffic
5a	2.2	Animal parks, zoos	high	1, 2, 3, 5, 6	low	Rough grass, mown grass	equestrian facility (Pferdehof)
5b	1.11	Streets including roadside green	low	2, 3	medium	Trees with rough grass, mown grass	green alongside walkway
6	1.3	Green corridors and connectors	low	2, 3	medium	Shrubbery with waterside zones with strong anthropogenic influence	Stream; diverted
7	1.11	Streets including roadside green	none	-	medium	Shrubbery	green alongside walkway, separating private properties from street
8	1.8	Sports fields (with free access, e.g. amateur soccer field)	high	1, 2, 3, 5, 6	low	Rough grass, mown grass	soccer field, continuation of Schlosspark
8a	1.7	Playgrounds	high	1, 2, 3, 4, 5, 6	medium	Shrubbery	playground / park
9	1.3	Green corridors and connectors	medium	2, 3	high	Forest	inner-city forest with limited access
9a	3.2	Terraces, balconies, roof gardens, courtyards	n.a.	-	n.a.	-	inaccessible, most likely courtyard
10	1.1	Parks: diverse types	high	1, 2, 3, 5	medium	Shrubbery with mown grass	park alongside walkway
11a	1.11	Streets including roadside green	none	-	medium	Shrubbery	small green patch accompanying walkway
11b	3.5	Brownfields:gaps between buildings	none	-	medium	Shrubbery	private property with green cover

11c	1.12	Parking lots	none	-	low	Shrubbery with transport and other impervious surfaces	parking lot with some green
11d	-	-	n.a.	-	n.a.	-	does not exist on the field, may be already densified
12	1.1	Parks: diverse types	medium	2, 3, 5	medium	Mown grass with shrubbery	large green cover, park
12a	1.11	Streets including roadside green	high	n.a.	high	n.a.	flowerbeds for insects: social-ecological value in raising awareness
13	3.1	Gardens (of a house, in a community garden area, rented gardens etc.)	none	-	medium	Shrubbery	small green patch in front of private property
14	1.1	Parks: diverse types	high	1, 2, 3, 4, 5, 6	high	Shrubbery with mown grass and water components	Kurpark / Kurgarten, one of town's landmarks
14a, 14b	3.2	Terraces, balconies, roof gardens, courtyards	n.a.	-	n.a.	-	inaccessible, most likely courtyard
15	2.6	Open spaces of public organizations: schools	high	1, 2, 4, 5, 6	low	Surfaces without vegetation	schoolyard
BAD VILBEL SPATIAL FOCUS AREA (r=1.000 m around train station)							
ID#	Open space category		Social value	Fits criteria	Ecol. value	Land-cover type	Observation
1	2.6	Open spaces of public organizations: schools, daycare centers, hospitals, administration buildings, churches, etc.	medium	1, 2, 5, 6	none	Transport and other impervious surfaces	schoolyard
2	1.11	Streets including roadside green	none	-	low	Transport and other impervious surfaces (with bushes)	walkway alongside bushes
3	1.1	Parks: diverse types	low	2, 5	low	Rough grass, mown grass	does not exist on GIS, found by chance. small park at street crossing
3a	3.2	Terraces, balconies, roof gardens, courtyards	n.a.	-	n.a.	-	inaccessible, most likely courtyard
4	1.3	Green corridors and connectors	high	1, 2, 3, 5, 6	high	Near-natural waterside zones	park alongside the Nidda river
5	1.11	Streets including roadside green	none	-	medium	Shrubbery	green alongside railway tacks
6	3.5	Brownfields: gaps between buildings	none	-	low	Rough grass, mown grass	fenced private property

7	3.6	Construction sites	none	-	low	Agriculture, conventional (pesticides, machinery, etc.)	large agricultural area partially new housing being built
8	2.5	Sports fields of associations	high	1, 2, 3, 5, 6	none	Buildings with transport and other impervious surfaces	sports campus with various facilities, dominated by impervious surfaces (on GIS: green space)
9	3.3	Cultivated areas of agriculture	none	-	low	Agriculture, conventional (pesticides, machinery, etc.)	large agricultural fields
10	1.1	Parks: diverse types	high	1, 2, 3, 5, 6	high	Near-natural waterside zones with shrubbery	park alongisde Nidda, continuation with sports fields
11a	1.7	Playgrounds	medium	1, 2, 5	low	Buildings with transport and other impervious surfaces	New development mostly complete. Social value only refers to the playground.
11b	3.3	Cultivated areas of agriculture	none	-	low	Buildings with transport and other impervious surfaces	agricultural field adjacent to 11a as seen on photos
12	1.11	Streets including roadside green	none	-	medium	Shrubbery	green cover
13	3.3	Cultivated areas of agriculture	none	-	low	Agriculture, conventional (pesticides, machinery, etc.)	smaller agricultural field
14	1.1 / 1.12	Parks: diverse types / Parking lots	low	2, 5	low	Rough grass, mown grass	green field with parking lot (Festplatz)
15	2.8	Community gardens: common areas, pathways	high	2, 3, 4, 5, 6	medium	Agriculture, ecological (community gardening etc.)	community garden
16	1.1	Parks: diverse types	high		high	Near-natural waterside zones with shrubbery	park alongisde Nidda, continuation with walkways and bikeways
17	1.1	Parks: diverse types	low	2, 3, 5	medium	Shrubbery	small green patch
18	1.9	Cemeteries	high	1, 2, 3, 5, 6	high	Forest with shrubbery	Jewish cemetery, adjacent forest
19	2.8	Community gardens: common areas, pathways	medium	1, 2, 3	medium	Agriculture, ecological (community gardening etc.)	private gardens
HATTERSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)							
ID#	Open space category		Social value	Fits criteria	Ecol. value	Land-cover type	Observation
1	1.9	Cemeteries	high	1, 2, 3, 5, 6	medium	Shrubbery	cemetery

2	1.11	Streets including roadside green	none	-	medium	Shrubbery	walkway alongside bushes, does not exist on GIS.
3	1.12 / 1.7	Parking lots / Playgrounds	medium	1, 2, 3, 5	none	Transport and other impervious surfaces	mostly private parking with small playground
4	3.1	Garden (private)	none	-	medium	Shrubbery	private garden, back side of the City Hall
5	3.2	Terraces, balconies, roof gardens, courtyards	n.a.	-	n.a.	-	inaccessible, most likely courtyard
6	3.2	Terraces, balconies, roof gardens, courtyards	n.a.	-	n.a.	-	inaccessible, most likely courtyard
7	3.2	Terraces, balconies, roof gardens, courtyards	none	-	none	Transport and other impervious surfaces	private parking lot; accessed via driveway
8	1.1	Parks: diverse types	high	1, 2, 3, 4, 5	medium	Shrubbery	Kelten Park; continues as pedestrian street to inner city
9	1.1	Parks: diverse types	high	1, 2, 3, 4, 5	high	Shrubbery with water components	large urban park (Stadtpark)
9a	2.10	Open spaces of public organizations: elderly care	low	5, 6	medium	shrubbery	green space of senior's center, private, no access
10	1.7	Playgrounds	medium	1, 5, 6	low	Surfaces without vegetation	playground adjacent to schoolyard
11	1.11	Streets including roadside green	none	-	medium	Shrubbery	Walkway with park-like characteristics
12	1.1	Parks: diverse types	medium	2, 5, 6	medium	Shrubbery	park alongside railway tracks
13	2.5	Sports fields of associations	high	1, 2, 3, 4, 5, 6	low	Rough grass, mown grass, impervious surfaces	sports campus with sports fields and buildings
14	1.3	Green corridors and connectors	none	-	high	Shrubbery with waterisde with strong anthropogenic influence	Stream; diverted (Schwarzbach)
15	1.11	Streets including roadside green	none	-	medium	shrubbery	green at road crossing, bikeway underground
16	3.3	Cultivated areas of agriculture	none	-	low	Agriculture, conventional	large agricultural field
17	1.12	Parking lots	none	-	none	Transport and other impervious surfaces	elevated parking lot between housing blocks
18	1.7	Playgrounds	high	1, 2, 3, 4, 5, 6	medium	Shrubbery	agricultural activity adjacent to playground

19	2.8	Community gardens: common areas and pathways	high	1 ,2 ,3 ,5, 6	medium	Shrubbery with agriculture, ecological (community gardening)	community gardening within large green patch
20	1.8	Sports fields (with free access, e.g. amateur soccer field)	medium	2, 3, 5, 6	medium	Shrubbery with rough grass, mown grass, trees	sports fields within green space
21	1.7	Playgrounds	medium	1, 2, 5, 6	low	Surfaces without vegetation with rough grass, mown grass	playground
22	3.6	Construction sites	high	1, 2, 3, 5, 6	none	-	mosque construction almost finished
23	3.5	Brownfields: industry, trade, transport	none	-	none	Transport and other impervious surfaces	private property, conversion potential
24	2.2	Animal parks, zoos	high	1, 2, 3, 4, 5, 6	high	Shrubbery with water components	Tierpark Hattersheim e.V.
24a	3.6	Construction sites	none	-	low	Surfaces without vegetation	Torn down, new construction about to start
25	3.6	Construction sites	none	-	none	Buildings	"Urbansmühle" residential construction
26	1.11	Streets including roadside green	none	-	medium	Shrubbery	green alongside sidewalk
27	1.7	Playgrounds	high	1, 2, 3, 5, 6	medium	Shrubbery, trees, surfaces without vegetation	Playground
28	3.3	Cultivated areas of agriculture	none	-	low	Agriculture, conventional etc.)	Conventional agricultural field
29	3.3	Cultivated areas of agriculture	none	-	low	Agriculture, conventional with Rough grass, mown grass (for groundwater wells)	Conventional agricultural field, industrial construction observed in distance
LANGEN SPATIAL FOCUS AREA (r=1.000 m around train station)							
ID#	Open space category		Social value	Fits criteria	Ecol. value	Land-cover type	Observation
1	3.4	Open spaces of industry and trade areas	none	-	low	Rough grass, mown grass	does not exist on GIS
2	3.4	Open spaces of industry and trade areas	none	-	low	Waterside with strong anthropogenic influence	rainwater retention basin
3	1.11	Streets including roadside green	none	-	medium	Shrubbery	small green between railway and highway
4	3.6	Construction sites	none	-	none	Building	does not exist in GIS, industrial constr. going on, included in city map

4a	3.5	Brownfields: gaps between buildings	n.a.	-	n.a.	-	inaccessible, industry-residential buffer
5	1.2	Forests	medium	1, 3, 4, 6	high	Forest	forest
5a	3.5	Brownfields: gaps between buildings	n.a.	-	n.a.	-	inaccessible, industry-residential buffer
6	1.11	Streets including roadside green	none	-	medium	Shrubbery	green alongside walkway
7	1.1	Parks: diverse types	medium	1, 2, 3, 5	medium	Shrubbery	park
8	1.12	Parking lots	none	-	none	Transport and other impervious surfaces	mostly parking lot
9	1.11	Streets including roadside green	none	-	low	Rough grass, mown grass	green alongside walkway
10	1.8	Sports fields (with free access, e.g. amateur soccer field)	high	1, 2, 3, 5, 6	medium	Shrubbery with rough grass, mown grass	sports field
11	1.11	Streets including roadside green	low	2, 3	medium	Trees with rough grass, mown grass	green alongside walkway
12	1.1	Parks: diverse types	low	2, 3	medium	Trees with rough grass, mown grass	park-like continuation of #11
12a	-	-	n.a.	-	n.a.	-	doesn't exist on the field
13	1.7	Playgrounds	high	1, 2, 3, 4, 5	low	Rough grass, mown grass	playground
14	1.1	Parks: diverse types	low	2, 5	low	Rough grass, mown grass	small green patch
15	1.5	Squares	medium	1, 2, 6	none	Transport and other impervious surfaces	train station area
16	1.11	Streets including roadside green	none	-	low	Rough grass, mown grass	green alongside railway
17	1.1	Parks: diverse types	high	1, 2, 3, 4, 5	medium	Shrubbery	large park
18	1.12 / 1.8	Parking lots / sports field	high	1, 3, 4, 5, 6	low	Rough grass, mown grass	parking lot ot sport field
19	1.1	Parks: diverse types	-		low	Rough grass, mown grass	small green patch with no use value
19a	-	-	n.a.	-	n.a.	-	does not exist
19b	3.2	Terraces, balconies, roof gardens, courtyards	n.a.	-	n.a.	-	most likely courtyard (no access due to street)
20	3.5	Brownfields: gaps between buildings	none	-	low	Rough grass, mown grass	inaccessible, fenced private empty land
21	1.11	Streets including roadside green	medium	2, 3, 5	low	Rough grass, mown grass, surfaces without vegetation	green separating street and walkway, small square

22	2.6	Open spaces of public organizations: schools	high	1, 2, 4, 5, 6	low	Transport and other impervious surfaces	schoolyard
22a	-	-	n.a.	-	n.a.	-	no green space (photo missing)
22b	-	-	n.a.	-	n.a.	Building	no green space; potentially already densified (photo missing)
23	1.7	Playgrounds	high	1, 2, 3, 4, 5	low	Rough grass, mown grass	playground
24	1.7	Playgrounds	high	1, 2, 3, 4, 5	low	Rough grass, mown grass	playground
25	1.7	Playgrounds	high	1, 2, 3, 4, 5	low	Rough grass, mown grass	playground
26	1.5	Squares	high	1, 2, 3, 4, 5	low	Surfaces without vegetation	open public space
27	1.7	Playgrounds	high	1, 2, 3, 4, 5	low	Rough grass, mown grass	playground
28	1.12	Parking lots	none	-	none	Transport and other impervious surfaces	elevated parking lot
29	3.6	Construction sites	none	-	low	Rough grass, mown grass	in the process of development / conversion
30	3.6	Construction sites	none	-	low	Rough grass, mown grass	in the process of development
MAINTAL SPATIAL FOCUS AREA (r=1.000 m around train station)							
ID#	Open space category		Social value	Fits criteria	Ecol. value	Land-cover type	Observation
1	1.11	Streets including roadside green	none	-	medium	Shrubbery	green, no walking for pedestrians
2	3.5	Brownfields: gaps between buildings	none	-	none	Buildings	not marked on GIS, used to be garden, currently under densification
3	1.9	Cemeteries	high	1, 2, 3, 5, 6	medium	Shrubbery	cemetery
4	3.2	Terraces, balconies, roof gardens, courtyards	none	-	low	-	private garden, most likely courtyard
5	3.5	Brownfields: gaps between buildings	none	-	none	-	not marked on GIS, used to be a green cover, currently under densification
6	1.1	Parks: diverse types	high	1, 2, 3, 4, 5, 6	medium	Shrubbery with rough grass, mown grass, trees	park and playground
7	3.3	Cultivated areas of agriculture	none	-	medium	Agriculture, conventional	Horticulture
8	2.8	Community gardens: common areas and pathways	high	1, 2, 3, 5, 6	medium	Shrubbery with agriculture, ecological	community gardening adjacent to, but not directly in SFA

						(community gardening)	
9	1.2	Forests	medium	2, 3, 5	high	Forest	Forest
10	2.5	Sports fields of associations	high	1, 2, 3, 5, 6	medium	Shrubbery	"Fitnesspark Olympia" own green space
11	3.6	Construction sites	none	-	low	Rough grass, mown grass	Former open sports fields currently in preparation for new housing development
12	2.5	Sports fields of associations	high	1, 2, 3, 5, 6	none	Transport and other impervious surfaces	tennis courts, private
13	2.7	Green buffers	low	2, 5	medium	Shrubbery with rough grass, mown grass	green cover between railway tracks and settlements in front of retail
14	1.10	Nature protection areas (publicly accessible)	medium	1, 2, 5	high	Shrubbery with rough grass, mown grass with water components	green patch in between large streets frequented by pedestrians and bikers
15	2.4	Swimming pools, entertainment pools	high	1, 2, 3, 5, 6	high	Shrubbery with waterside zones with strong anthropogenic influence	Maintalbad as part of large green cover
16	3.1	Private garden	none	-	medium	Shrubbery with waterside zones with strong anthropogenic influence	private green patch with shrubbery and pond, no access
17	1.2	Forests	medium	2, 3	high	Forest	Forest
18	1.10	Nature protection areas (publicly accessible)	medium	1, 2, 5, 6	medium	Shrubbery with rough grass, mown grass	relatively large green cover with walking and cycling, adjacent to settlements
19	2.8	Community gardens: common areas and pathways	high	-	medium	Shrubbery with agriculture, ecological (community gardening)	community gardening between a major road and settlements
20	3.6	Construction sites	none	-	medium	Rough grass, mown grass with water	green cover, supposedly with a stream, no pic of the stream could be made
RÜSSELSHEIM SPATIAL FOCUS AREA (r=1.000 m around train station)							
ID#	Open space category		Social value	Fits criteria	Ecol. value	Land-cover type	Observation
1	1.1	Parks: diverse types	low	2, 5	low	Rough grass, mown grass	small park
2	1.1	Parks: diverse types	medium	1, 2, 3, 5	medium	Shrubbery (and trees)	large park

3	-	-	none	-	none	Buildings	already densified
4	1.12	Parking lots	low	2, 5	none	Transport and other impervious surfaces	mostly car parking place with little grass
5	1.1	Parks: diverse types	high	1, 2, 3, 5, 6	medium	Shrubbery	a large city park at the Main river
5a	1.6	Pedestrian zones	medium	1, 2, 3, 5	medium	Near-natural waterside	(does not exist on GIS) flood-proofing alongside Main, pedestrian. Multifunctional.
6	2.8	Community gardens: common areas and pathways	none	-	medium	Agriculture, ecological (community gardening etc.)	privately-owned, no data
7	1.5	Squares	low	5	low	Surfaces without vegetation, trees	an axis formed by several trees in town center
7a	1.5	Squares	high	1, 2, 4, 5, 6	none	Transport and other impervious surfaces	weekly market
8	1.1	Parks: diverse types	high	1, 2, 3, 4, 5	medium	Shrubbery (and trees)	park
9	1.1	Parks: diverse types	low	2, 5	low	Rough grass, mown grass	small park
10	1.7	Playgrounds	high	1, 2, 3, 4, 5	low	Surfaces without vegetation	playground
11	3.1	Gardens (garden of a house, garden in a community garden area, rented gardens etc.)	none	-	n.a.	-	privately-owned, no data
12	-	-	none	-	n.a.	-	does not exist
13	1.1	Parks: diverse types	low	2, 5	medium	Shrubbery	small park
13a	1.11	Streets including roadside green	none	-	medium	Shrubbery	(exists on GIS, photo not taken) small green cover
14	1.11	Streets including roadside green	none	-	low	Rough grass, mown grass	small green cover
15	-	-	none	-	none	-	already densified
15a	1.12	Parking lots	none	-	low	Rough grass, mown grass	(does not exist on GIS) mostly car parking place with little grass
16	2.5	Sports fields of associations	high	1, 2, 3, 5, 6	none	Transport and other impervious surfaces	sports center, car parking space
17	1.11	Streets including roadside green	none	-	low	Transport and other impervious surfaces	bikeway with green cover alongside

18	1.11	Streets including roadside green	low	2, 5	medium	Shrubbery	tree line separating street and sidewalk
19	1.7	Playgrounds	high	1, 2, 3, 4, 5	low	Surfaces without vegetation	playground
20	1.12	Parking lots	none	-	none	Transport and other impervious surfaces	parking lot with some green
20a	1.11	Streets including roadside green	low	-	medium	Shrubbery	green between buildings and street (no photo)
21a	3.4	Open spaces of industry and trade areas	low	6	low	Surfaces without vegetation	swimming pool, mostly without vegetation
21b	2.4	Swimming pools, entertainment pools	high	1, 2, 3, 5, 6	low	Rough grass, mown grass	swimming pool
22	3.6	Construction sites	none	-	low	Surfaces without vegetation	bare soil, most likely in process of densification
23	1.12	Parking lots	none	-	none	Transport and other impervious surfaces	parking lot with some green
24	1.11	Streets including roadside green	low	2, 5	low	Rough grass, mown grass	green separating street and sidewalk
25	1.1	Parks: diverse types	none	-	low	Rough grass, mown grass	small green cover
26	3.4	Open spaces of industry and trade areas	medium	2, 5, 6	medium	Shrubbery, waterside zones with strong anthropogenic influence	Greenspace and pond in front of Opel HQ
27	3.4	Open spaces of industry and trade areas	none	-	medium	Shrubbery	no access; fenced
28	1.1	Parks: diverse types	low	2, 5	low	Rough grass, mown grass	park/grass cover