Multifunctionality of Urban Green Space

An Analytical Framework and the Case Study of Greenbelt in Frankfurt am Main, Germany

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04.04.2017, in Darmstadt

To My Kitty

Contents

Abstract

This research emphasizes the significance of multifunctionality in urban green space planning practice and builds an analytical framework of multifunctionality for the holistic interpretation of the studied case, the Greenbelt Frankfurt am Main.

Multifunctionality has been widely used in the context of urban green space planning practice and evaluation in recent years. It is considered as a key characteristic in several contemporary concepts like Green Infrastructure, Ecosystem Services and Landscape Planning. However, the applied range and meaning of the term is becoming too broad while the specific definition is still an elusive description. With the spreading of the new concepts and the transition of urban green space planning to a more critical role, the lack of clarification of this term may lead further confusion and misuse.

This research aims at the clarification and application of multifunctionality in the context of urban green space planning practice, as a necessary entry point for the future researches on urban green infrastructure planning. Based on literature review on the development of related topics, this study argues that most component functions of multifunctionality have long traditions in planning history and multifunctionality is more about a new holistic perspective instead of a new term; moreover, the ecosystem services should be seen as the theoretical base for multifunctionality because it provides so far the most rational and overall classification for the component functions as well as multiple analyzing approaches; furthermore, the interactions among functions are the unignorable parts of multifunctionality and distinguish it from only multiple functions. In a word, multifunctionality is a comprehensive status of urban green space and represents the overall performance of the place. Thus it is not comparable between different contexts but can be used as a framework for the holistic understanding of urban green space.

Based on the theoretical study, an analytical framework is built and applied on the Greenbelt in Frankfurt am Main, Germany. The methodology combines both semi-quantitative and qualitative approaches and targets on the analyses in both planning process and land use performance status, to discuss how multifunctionality of urban green space is influenced by planning efforts. The results on urban level analyses illustrate that the spatial distribution of functions in reality is quite uneven while the main planning efforts were made without specific focus. These results together indicate the mismatch of supply and demand of multifunctionality in the Greenbelt. Furthermore, at local level, three cases are used for the in-depth discussion of interactions between functions. They point out the significant role of positive synergy effects on the efficient delivering of multifunctionality,

as well as illustrate possible ways to generate such positive effects. The overall result of case study clearly indicates the advances and potential directions for the future development of Greenbelt.

Multifunctionality is a significant term for the holistic interpretation and systematical analyses of the urban green space. In this study, it has been proved to be a useful framework to understand the functions and interactions from the perspective of human-nature system, as well as to provide insights for the features of current development, which is critical for the future. As a term that has connected multiple topics and has been applied in both theoretical researches and planning practice, multifunctionality has further potential in assisting the development of urban green space, especially in urban Green Infrastructure Planning.

Keywords:

Multifunctionality, Urban green space, Urban planning, Ecosystem Services, Combined approach, Greenbelt

Chapter I. Introduction

1.1 Background of the Research

The sustainability of a city relies a great deal on the healthy and well-functioning natural and semi-natural environment within and surround the city. Clean air, drinking water and healthy food, they are the fundamental elements that support our everyday urban life and directly influence the human well-being and even most economic activities. Nowadays, with the negative examples and decades of public education, most people who live in cities would no longer take these benefits for granted, on the contrary, their demand for the quality and quantity of natural environment has increased tremendously. On the other hand, the upgrade of the planning practices, which could provide or improve the qualified environment, are comparatively slow and restricted by complex conditions. How to meet this demand becomes a primary question for planners and related researchers, thus the attempts like "eco-city", "zero-emission city" and "green city" keep evolving.

Emerging from ecological economics of the 1990s, Ecosystem Services gradually gets high attention world wide, for it represents an evolving concept, dealing with the human-natural relationships, and forming a holistic view of human's dependence and responsibility for healthy ecosystems (Hansen, Frantzeskaki et al. 2015). Ecosystem Services refer to the benefits that human derive from nature (TEEB 2011) and one of the initial aim through the direct monetary valuation of such services is to influence the decision making towards a mutually beneficial status of human-nature dual structure (Costanza, d'Arge et al. 1997, MA 2005). The concept has been further extended and developed as an evaluation method with monetary or non-monetary approaches to the analysis of the existing natural capital.

In the meantime, Green Infrastructure starts spreading from North America to the rest of the world. Though based on the functionalism concept, Green Infrastructure, from a planning perspective, changed the role of green spaces in the urban components, proving they can provide functions like flood protection and water purification, which are equally essential as the urban gray infrastructures (Benedict and McMahon 2012). This point of view is coherent with the definition of Ecosystem Services and Green Infrastructure by the EU, namely as strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (Hansen and Pauleit 2014). Based on this theoretical foundation, the view of Green Infrastructure is further widened in the European context, but at the same time it has become more elusive.

In the past decade of the booming development of the concept related to urban environment, the term "multifunctionality" became more frequently used in both Green Infrastructure and Ecosystem Services, as well as in landscape planning, urban agriculture and other involved research

areas. In the planning of green infrastructure, multifunctionality is considered as a vital feature and a final aim, while in the analysis of ecosystem services, the term is more often used to describe the assemble of multiple services in urban districts. Moreover, for landscape planning, multifunctionality is the co-appearance of five types of functions in urban areas, including ecological, economic, socio-cultural, historical and aesthetic aspects (Brandt, Tress et al. 2000, Selman 2009). Multifunctionality, which originates from agricultural context against mono-functionality of agriculture industry, is now an all-inclusiveness word targeted by every research area.

However, the hotter the term, the less meaningful it works for an actual planning practice. Multifunctionality starts to be entitled everywhere, in every project and plan, as a symbol of the new planning fashion towards greener city. The single mixture of any functions can be called as multifunctional but by doing so the actual aim of a human-nature balance in ecosystem services and green infrastructure is easily lost. Due to the intensive misuse and confusion around the term, some also try to question its specific content and whether it is suitable to be present the feature (Hansen and Pauleit 2014).

More recently, greater efforts have been made on both ecosystem services and green infrastructure concepts to help with the urban planning and decision making, so that the two are not discussed separately. The barriers are obvious: each place has its own planning paradigms and routines in dealing with the ecology-related questions, and the separation of different institutions and departments makes the cooperation hard to proceed (Hansen, Frantzeskaki et al. 2015). Moreover, despite the fact that concepts have been spreading globally, they are still unfamiliar to the landscape and regional planners, who accomplish substantial planning tasks everyday (Albert, Hauck et al. 2014). Nevertheless, multifunctionality as a term with massive acknowledgement and high identifiability, its root in multiple research areas seems to regain its role, starting with the creation of general planning framework and evaluation approaches based on former studies and concepts (Lovell and Taylor 2013, Hansen and Pauleit 2014).

As an urban planner involved in both actual planning projects and theoretical researches, one gets a strong sense of a conflict between the need for fundamental upgrade of new concepts and the old routines inherited as traditions. The vast majority of everyday planning is only influenced by these concepts on a very superficial level and in some cases this results exclusively into the change of the title. On one hand, application of a new concept demands certain conditions in the material and knowledge system; on the other hand, the groups of planners and researchers sometimes just don't speak the same professional language and lack effective communications. In this respect, the study focuses on the term multifunctionality as an intersection connecting both sides, in order to contribute to the bridging of the gap between the two disciplines.

1.2 Forming of Research Questions

The interest for this study topic started with the term multifunctionality due to its broad application, multiple theoretical backgrounds and elusive explanations. It has been an increasingly important term for the planning practices in the urban environment but specific discussions or clarification in this respect were few. Thus, in order to facilitate future studies and practices of urban green infrastructure planning, the core research question of the dissertation is: what is multifunctionality in urban green open space and how is it influenced by the related planning practice?

The first part of the question focuses on the nature and definition of multifunctionality that could be further subdivided into the following categories:

- From which field does this term and its predecessor originate in the urban planning history?
- How has the term been developed and what has changed in its underpinning meaning?
- What is currently the main understanding of the term in the most used cases?
- How to define the multifunctionality in the urban green open space?
- What are the components of the term and how are they being studied?

The second part centers around the relationship between the planning and implementation perspectives of multifunctionality, which were studied separately by different groups.

- How is multifunctionality portrayed in the planning documents?
- How does multifunctionality perform in reality?
- How did the planning practice change the situation?
- What kind of practices can have a positive effect on the multifunctionality of urban green space?

These smaller questions also provide guidance for the dissertation research and help further elaborate on the understanding of multifunctionality step by step.

1.3 Research Aims and Expected Results

The aim of the research is to improve the understanding of multifunctionality as a term, vital for both theoretical and practical planning of urban green space. To be more specifically, the aim is to clarify the definition of multifunctionality and testify its practical application within the case study, which will contribute to the holistic comprehension of the studied case.

This aim is supported by the following sub-divided questions, contributing to the five expected results:

- Establish a definition for the multifunctionality in the context of urban green space, based on the history of its development and description in the related studies, with consideration of its current content.
- Build an analytical framework of multifunctionality, based on the summary of main the research approaches within the related topics.
- Compare the multifunctionality in terms of of planning efforts and implementation at the urban level based on the study case. This will allow to identify the influences of planning practice on multifunctionality.
- Analyze multifunctionality at the local level for the case study with respect to the influence of interactions between functions on the efficiency of multifunctionality. This will help to identify positive planning measurements in order to improve future performance.
- Establish a holistic interpretation of multifunctionality for the case and make rational suggestions for the future developments.

1.4 Dissertation Structure

This chapter outlines general background of the study and lists the research questions as well as the correspondent expected results. In the following chapters the research questions will be answered step by step.

Chapter II and III review literature, which helps set up theoretical base for the understanding of multifunctionality. Chapter II traces the development of multifunctionality to illustrate its deep roots in the urban open space planning and practice, as well as its upgraded meaning, assigned by the Green Infrastructure concept. Thus, the definition and key characteristics of the term are summarized. Chapter III centers around the content and evaluation methods, proving that ecosystem services represent the optimal classification of functions and services for urban green space. Among the widely used assessment approaches for functions and services, the land use-based approach has closer link to planning and lower threshold for data collecting.

In Chapter IV, an analytical framework is developed to use multifunctionality as a holistic approach for the interpretation of urban green space. In the following Chapters V an VI the case study is analyzed, and the elaborated framework is applied to both urban and local levels of the Greenbelt in Frankfurt am Main, Germany. In Chapter V, a semi-quantitative approach is applied to map the spatial distribution of single functions and general multifunctionality of the Greenbelt at the urban level. The qualitative approach is applied to the coding of the Greenbelt planning efforts with the emphasis and vision on multifunctionality. By combining the results from two perspectives, obvious conflicts of the Greenbelt development are identified. Chapter VI continues the analysis of the local level using three typical types of sites. The urban forest, which acts as the area of the highest achievement of multifunctionality at the urban level, is potentially overloaded and may lead

to trade-offs between the functions. While the case of Old Airfield and Hiking Route of Springs serve as positive and negative examples respectively, they also indicate the vital importance of creating synergy effects among functions at the local level, which increase the efficiency of the delivered multifunctionality.

The final Chapter VII concludes the results of the case study, which prove the developed analytical framework is a critical lens for a holistic understanding of the urban green space. Moreover, the Chapter points out current discussions on the development of the Greenbelt as well as possible future improvements.

Chapter II. Multifunctionality: Past and Present

In this chapter, the historical development of multifunctionality is reviewed to show its deep roots and core role in urban open space planning and practice. The section 2.1 traces back to the period before multifunctionality was widely used as a specific term, and emphases how the understanding of "function" evolved over time. In the following section, the origin and development of the term were discussed from the perspectives of two research areas, agriculture and landscape planning, where multifunctionality appeared almost simultaneously. Despite the arguments on the differences, the term was used for similar purpose, in particular, as an alternative against the conventional anthropocentric approach. More recently, as discussed in section 2.3, multifunctionality found its revival as a core feature of the concept urban Green Infrastructure concept which deals with open space. Multifunctionality experiences its upgrade in several dimensions: its content is being directly dockedwith the concept of Ecosystem Services; its range goes into different planning scales; more importantly, it receives wide acceptance as a necessary target in planning and policy of urban open space. Based on the review, key characteristics of the term was concluded to form the definition of multifunctionality for urban green open space; furthermore, the underpinned meanings of the term in different scales are discussed for a better understanding of the term.

2.1 Urban Open Space Planning from the Perspective of Function

2.1.1 Green function at the beginning of modern urban planning

Function, the root of the word Multifunctionality, was a key notion for modern urban planning theories and practices. The function of urban green spaces was one of the reasons for the rethinking of urban industrialization, since the way it was understood always reflected the core value of urban planning of the particular period. Three pioneers of modern urban planning, Howard, Geddes and Le Corbusier, represented different approaches towards how human could form their own city (Fishman 1982). Though Howard has been a profound influence on the future development of planning theories even until now (Parsons and Schuyler 2004); Le Corbusier and his architectural understanding of "functions" for modern city was greatly adopted by many fast industrializing cities and totally changed the outlook of cities in middle age, and has been largely criticized for decades.

Garden Cities of Tomorrow is without a doubt the founder of modern urban planning, though Howard's idea based greatly on social reform over urban form(Ebenezer 1902). His worry of the cities at that time was not only the industrial pollution, but more about the possible fatal disasters under such irrational urban industrialization. So in his ideal city, the combination of advantages in countries and cities was the solution and economic profits was not in his priority. Despite the fact

that he used half of the book to describe the operability of autonomy by local citizen and land finance and management, his diagram got much more attention and distorted: small cities surrounded by permanent agriculture land, plenty of public open spaces and radioactive-shaped rail-transportation organized the ring-form living areas and also connected other similar cities, which altogether formed a loose city-agglomeration on the matrix of vast agricultural land(Howard and Osborn 1965). He set lots of green spaces and avenues inside the city, but his understanding of environment based on human utility and urban-rural connection. Agricultural land, five times as city area, supports the city by agroforestry products as food and source of income; residential area was quite intensive on the contrary(Hall and Tewdwr-Jones 2010). In this way, the city and the country could be reunited and self-sufficient. The small scale, high-density and ring-form arrangement of land promised healthier air and a closer distance with nature. This image provides later scholars with abundant inspiration of the possible form of urban green spaces (Freestone 2002, Parsons and Schuyler 2004) but many concepts is not the original intention of Howard himself. From an environmental perspective, Howard's contribution lies in the rethinking in the functional complementation between built and non-built area, and relating the city to its rural environs physically and mentally (Batchelor 1969).

Inspired by Howard, Patrick Geddes expanded the vision of a city from an isolated island in the unpredictable nature to a system closely connect and react with its surrounding environment (Patrick 1915). As both biologist and urban planner, Geddes combine the language of diagram with the ecological analysis methods. The Valley Section illustrated how people's living type changes according to the gradual change of landscape from mountains, woodland, farmland, to cities. It reveals the importance of geographical context, as well as the contact relationship between human and nature. Geddes emphasized the significance of natural areas in the framework of city planning, to study how the environmental capacity and scale could influence the city layout. He didn't draw any conceptual model of what an ideal city should look like, but he affected the approaches people study on cites and environment and is even considered as one precursor of urban ecology.

The understanding of functions for modern city was put to an extreme by Le Corbusier, while the green functions was greatly oversimplified. In his imagination, "the City of To-morrow should be set entirely in the midst of green open spaces"; people all live in skyscrapers, the vertical streets, so the area of green and open spaces could be increased and that "is the only way to ensure the necessary degree of health and peace to enable men to meet the anxieties of work…"(Corbusier 1987). It's not hard to find that though occupying large areas, the green space is considered a backdrop since there is no specific description for such vast land besides "green grass" "green parks" and "wood". It is not surprising that when his concept spread globally, only the skyscraper part is noticed and replicated. Such emphasis, not based on Le Corbusier's original intention either, is an inescapable reason for the over expansion of "grey cities" and is still used by many developing

cities(Zhang and Lv 2003). The Athens Charter in 1931 further developed the concept of Le Corbusier that the city is a living machine, to announce that residential, work, transportation and recreation are the four basic functions that should not be mixed inside the city. Green spaces, in this way, belong to the recreation function and is weakened to some scattered spots in the form of park. The connection was cut and green space is subordinate and decoration of a city with people in the center of picture.

2.1.2 Function-oriented green planning paralleled with urban planning

The problems of urban green spaces can never be separated with the problems of urban itself (Nilon, Berkowitz et al. 1999). Green planning and design has always been in diverse hands, including urban planners, landscape architects, gardeners, architects and many other experts. To some extent, green topic has developed as a quite independent branch of modern urban planning. It seems to be a quite dissociative theme from the mainstreams of planning debate but when we connect them both, green topics more or less keep together with the urban planning trends in the past century. And more recently, it is merging deeper in to the urban planning ever with the rising discussion and practice of Urban Green Infrastructure Planning, which bring the topic to a new height.

When pioneers of modern urban planning like Howard and Le Corbusier were drawing the prototypes of their ideal city at the end of 19th century, urban parks was already a popular trend in the European and American cities (Schenker 1995, Maruani and Amit-Cohen 2007). Such parks were scattered green open spaces, some formally belong to rich people or kings, now they serve for the recreation and aesthetic appreciation demand by the public, and functioned also as compensation areas for the expanding industrialized city. There was few green planning but rather by chance, like the Central Park in New York. Landscape architecture as a profession became accepted in American thanks to the work of Olmsted, and his follower, Charles Eliot, had great influence on German landscape with his urban and metropolitan park system (Czechowski, Hauck et al. 2014).

The concepts from earlier planners kept brewing and found their place after the wars. Urban planning in European and America entered a new era of development which focused on physical plan and was considered as “architecture writ large”(Taylor 1998). Green planning developed together. “Green space standard for 1000 people” and Greenbelt were typical corresponding ideas. The former one was commenced by Sir Raymond Unwin to form a quantitative frame for urban green open space (Turner 1992); the latter wanted to use green space as fixed boundary of urban development, a physical ring-form stopper of urban expansion. Recreation was still the aim, added on with the purpose of social equity and form integrity. Here we see clear inheritance from Howard’s Garden City. Both concepts were largely spread and criticized but they also provide the possibility

to combine planning with green spaces. So revised versions of them came later, like Green Way to some extent could be understood as a more flexible, recreational priority and nature reservation attached version of Greenbelt (Taylor, Paine et al. 1995, Freestone 2002); and the quantitative consideration of urban green space merged into the master plan, land use plan or zoning in the city level.

Since 1960s to the end of 20th century, planning theories undertook three huge waves of introspection on the decades of physical planning. The first wave change the perception of urban planning from physical design to a rational or system process, or "from art to science"; the second one change the position of urban planner from a technical expert to a communicator between people from different fields; and the third one pushed the modernist planning to the postmodernist era, in which the complexity of a city is recognized and emphasized (Taylor 1998, Taylor 1999).

The first shift redefined a city from a geographical or morphological space to a space of social life, a live space that cannot be determined by a two-dimensional blueprint. Because of this "living" feather, no matter rational or system view of planning, the understanding of process is vital. Quite interestingly is the perception of landscape design from Ian McHarg (McHarg and Mumford 1969) who proposed an alternative approach as Olmsted. McHarg believed that landscape design is not a matter of natural scenery preservation or out of pure human aesthetic appreciation, but should base on the ecological principles and follow the way that the land suits the most. He proved that human need to join the dynamic circle of nature and hold a relatively objective view on the relationship of men and environment, a shift of the main body of green spaces. McHarg received as many followers as objectors, which accused him for ignoring the local and social/cultural characteristics(Corner 1999), but one big step was made, that urban green spaces is not a procession of people, it functions for itself.

This new emerging subject, the nature, could be view as the post-modernist focus of green planning. If we take The Death and Life of Great American Cities and A City is Not a Tree as alarm bells pushed planners to realize the complexity and diversity of a city, then two things could be seen as the turning point for green planning: the rising importance of urban ecology as an independent discipline and a general world-wide recognition of natural reservation and protection. While Mixed-Use of urban land became an alternative to mono-functioned zoning(Rowley 1996), Biodiversity of urban ecosystems found its role paralleled or in some scenarios even in priority of human recreation (Savard, Clergeau et al. 2000). This may be seen as the very beginning of the current known Multifunctionality, for both mixed-use development and biodiversity admit and emphasize the complexity and multi-aspect meanings within one subject, and working on nourishing instead of forcing a prosperous status.

2.1.3 Merging of green function and urban function

Since the end of 20th century, urban planning shows a theoretical pluralism with spatial planning an emerging paradigm (Albrechts, Healey et al. 2003). A more important question now is whether the actions could be taken continuously and successfully in a real context, as the pragmatic culture and communicative rationality has been critical factors for planning(Palermo and Ponzini 2010). Green planning has been more affected by cross-disciplines like geography, ecology, infrastructural concept and new technology. A notable feather is the relationship between green planning and urban planning, which developing from close connected, to integrated together, and further to guide in cooperation as could be found in the topic of Landscape Urbanism and Urban Green Infrastructure Planning(Waldheim 2012, Zaręba 2014). Especially from the discussion of Urban Green Infrastructure Planning, a normative approach, rather than an elusive concept, was frame with consideration of planning phases as well as ecological and social factors (Environment 2012, Hansen and Pauleit 2014). Despite the challenges in institution and implementation, GI for the first time forms a quite complete model for green planning (Kopperoinen, Itkonen et al. 2014, Maes, Barbosa et al. 2014). Furthermore, it bring back, to some extent, the rethinking for the value of design in translating the abstract concept into substantial reality (Czechowski, Hauck et al. 2014), which is also an emerging debate for urban planning(Palermo and Ponzini 2010).

Among the endless emerging terms, sustainability has been an evergreen topic. It has been developing from a simple concept, through the phase of misused buzzword, and now grow to a relatively substantial topic (Bettencourt and Kaur 2011, Kates 2011, Wu 2013). The significance of this term is that it illustrates the nature of cities with basic concepts and forms the platform for greater discussion. It functions on different levels: on a general level, sustainability reveals the vital paralleled role of environment, society and economic, as well as their dynamic constant interactions; on a more specific level, it could also help to organize the growing history and interactions of green concepts.

Different terms and concepts could be understood much clearly if following the traces of how the three pillars of sustainability are considered in priority, and how different topics trying to fix the weak points of its formal predecessors and grow as a more comprehensive concept. For the contemporary topics, whether it is multifunctional/sustainable landscape, green infrastructure or ecosystem services, they are all reach to a stage that all the three aspects are to some extent targeted.

2.2 Forming of Multifunctionality

Addressing to the beginning of using this specific word "Multifunctionality", some would like to contribute to agriculture related study, as a notion opposite to mono-functionality in the industrialized modern farming system (Shi 2013, Peng, Lv et al. 2015); also others argue its political origin as a further explanation of sustainability and as approach against loss of biodiversity (Jones-Walters 2008). However, as multifunctionality grows both in landscape/ecology and agriculture field, its underpinned concept has divergence. Experts of multifunctional agriculture critics the other side as being narrow-sensed to see agriculture as only an economic activity that produce commodity and non-commodity outputs(Wilson 2007, Wilson 2009); meanwhile the side of multifunctional landscape had similar idea to see the other side as a narrow view that mostly exist in EU context (Selman 2009). Nevertheless, in most cases, there is no clear distinguish and multifunctionality is more or less a buzzword for research and policy.

2.2.1 Multifunctionality in Agriculture

2.2.1.1 Origin and development

Urbanization and the fast urban expansion not only affects the life quality inside the city, but also change the agriculture in urban fringe fundamentally. This process of changing regimes could be best described as from "Productivism" to "Post-Productivism" and in the past decade, to a "Multifunctional Agricultural Regimes"(Burton and Wilson 2006).

Farmland decreased in area and fragmented in space due to the conversion for urban purposes; urban demands for foods, on the other hand, increased greatly and thus have direct effects for the industrialization of agriculture. Meanwhile, with the acceptance of urban life style, the perception of environmental and recreational value of peri-urban farmland influenced the traditional production-oriented agriculture which has been the domination in Europe in after middle of the 20th century (Zasada 2011). Beyond pure commodity production, non-commodity demands from urban dwellers like organic food, agricultural experience and countryside tourism helps to modify the industrial farming model (Van Huylenbroeck, Vandermeulen et al. 2007, Yang, Cai et al. 2010, Huang, Tichit et al. 2015); furthermore, ecological consideration add on more pressures with topics like erosion prevention, water quality conservation, climate change mitigation and safeguarding biodiversity (Galler, von Haaren et al. 2015). Therefore, the emerging of multifunctional agriculture in 1990s provide an instant comprehensive pathway to coordinate and manage these demands from multiple aspects; in particularly for peri-urban areas where the potential conflicts among diverse subjects are in tension (Todorova and Ikova 2014).

From a broader sense, the content of multifunctionality in agriculture includes different types of functions provide by agricultural enterprises (Zasada 2011). It is categorized by colors: The white functions refer to the agricultural functions such as food security and safety; the green functions are the contribution to nature, the environment and landscape, for instance the maintenance of landscape amenities and biodiversity, the creation and management of wildlife habitat, improvement of nutrient cycle; the blue functions mean the water-related services provided by agricultural land, like water management, flood control, water quality improvement; the yellow refer to social and cultural services, including rural cohesion, cultural and historical heritage uses, building of local identity and recreational activities like hunting and tourism; sometimes the red functions are added to describe the energy related harnessing in the farms(Van Huylenbroeck, Vandermeulen et al. 2007, Todorova and Ikova 2014).

The multifarious content of multifunctional agriculture makes it hard to give a clear definition, however, most won't object that in the topic of agriculture, multifunctionality is necessary for sustainability (Hediger 2004, Zasada 2011). From an economic perspective, multifunctional agriculture is an economic activity that could provide food and primary material, as well as various non-market output to society (Hediger 2004). It could integrate land uses and functions at spatial and temporal level to reach a certain balance between production function and other functions including aesthetical and recreational through synergy, coexistence or compromise in conflicts (Zasada 2011). It could also be understood as a new model of agriculture which is capable of embedded in local conditions and combine both supply and demand perspectives of agriculture(Van Huylenbroeck, Vandermeulen et al. 2007). In this way, the multifunctionality in agriculture functions as a bridge of the divided rural-urban relationship and posts further breakthroughs for urban planning and policy making.

Policy and planning

Multifunctional agriculture poses a series of challenge for current political and institutional system which react slower as expected. Many arguments point out the lack of regulation framework and common support from EU or national level to local level (Todorova and Ikova 2014), also cause the unequally of development between nations (Rossing, Zander et al. 2007). The UK government, for example, was accused of being unable to turn multifunctional activities into real rural developments, but support mono-functional projects that emphasis on either agro-industrial interests or environmental and amenity focus (Yang, Cai et al. 2010) and such situation is not accidental phenomena but rooted in the sectorial setting (Marsden and Sonnino 2008). This has been a common disadvantage that single sector or department would only count for single aim, and lead to the restriction of multifunctionality in funding plan and management approach (Galler, von Haaren et al. 2015).

2.2.1.2 Practice and limitation

Despite the balanced paradigm multifunctional agriculture is described theoretically, the practical development and public cognition are quite uneven. The visual amenity functions of countryside agriculture, deeply rooted in European context as an integrated part of cultural landscape, has been a dominated perspective for urban visitors; its ecological value is less prioritized or even recognized (Yang, Cai et al. 2010, Zasada 2011).

Moreover, the diverse in the sub-topics and multiple subjects of multifunctionality also cause difficulties in both theoretical development and practical implementation. Related research approaches like market regulation, land-use approaches, actor-oriented and public regulation approaches, have each made certain progress but quite fragmented as a whole (Renting, Rossing et al. 2009). In actually, multifunctionality need to be taken as a multi-scaled hierarchical system which have different level of strength. It should have multi-level standard to cope with the needs in different scale, meanwhile, it should be carried down from nation level to a farm scale, so as to be considered implemented (Wilson 2008, Wilson 2009).

Comparing with an all-inclusive comprehensive approach, practices in complex context show that multifunctional agriculture is not suit for equal measurements. Based on the cost-effective point of view, researches on locating the hotspots, which have larger potential for multiple purposes, would be a more efficient way of allocating resources(Crossman and Bryan 2009). Furthermore, most specific measurements suit for the promotion of different types of functions and only works within the limited scale with right allocation. For instance, land sparing is effective for sensible types while land sharing works better in regular types (Law, Meijaard et al. 2015).

Generally speaking, the topic has been more discussed on the methodological and theoretical development, the following stages, like the solutions for specific problems from subjects, development in simulation and long-time monitoring are not enough. A common result is the excessive concern about economic and abiotic factors on the sacrifice of biotic, landscape and social factors, in which case, the real multifunctional characters of agriculture fall to present themselves (Rossing, Zander et al. 2007). Instead of focusing on filling more gaps in the theoretical settings, the topic in priority and significance would be fulfil the existing knowledge in the practical context.

2.2.2 Multifunctionality in Landscape

2.2.2.1 Origin

There is no strong prove that multifunctional landscape is directly influenced by multifunctional agriculture and the two sides do not show much mutual agreement with each other (Selman 2009, Zasada 2011). In fact, multifunctional landscape in European context has deeper root in two other things, the landscape tradition, and the political advocated and social accepted notions, biodiversity and sustainability.

While Olmsted built the fundamental basis for landscape theories in America, the European path, especially the German path, has not been identical. Olmsted had clear design principles, such as free movement, easy access and free association, that link directly with social purposes and stand outside nature itself but serves only for human demands (Spirn 1996). His concepts were objective, functionalistic-feathered and thus were sometimes criticized for its artificial characteristic, bending nature to mankind's order (Corner 1999). Green functionalism in Germany also aimed at objectifying beauty through functions, but it has another tradition, the cultural landscape, that is a more organic understanding of beauty (Czechowski, Hauck et al. 2014). Relatively speaking, the American parks are not some real existence, but a demonstration and decoration that had no connection with human life; cultural landscape, on the other hand, based on the agriculture tradition and implied the involvedness and meaningfulness of men.

An important driving force is the common acceptance and increasing actions towards more sustainable development in during the last two decades of the 20th century(Jones-Walters 2008). Such traditional cultural practices already sustain certain extent of economic, social and environmental services and under the interaction of the social, cognitive and technical transformation could it then gradually develop as multifunctional landscape. Soon, the Pan-European Biological and Landscape Diversity Strategy in 1995 and the European Landscape Convention in 2000 first formally emphasis the vital role of multifunctional landscape to biodiversity (Jones-Walters 2008, Selman 2009, Peng, Lv et al. 2015). At about the same time, the European-wide concern about the loss of biodiversity and ecosystem functions, and the worry for the fulfilment of sustainable development in early 2000s, triggered a series of systematic studies in related field. The abundant literatures and reports establish and categorize functions and services with reference from related disciplines like ecology and sociology, and formed a fundamental and scientific system for later studies (de Groot, Wilson et al. 2002, MA 2005, de Groot 2006).

2.2.2.2 Multifunctional landscape and planning

The situation of multifunctional landscape is quite comparable with that of multifunctional agriculture: the conceptual and theoretical development keep in evolution (Peng, Lv et al. 2015); evaluation related studies are processing but lack comparative studies between cases (Willemen, Verburg et al. 2008); and appeals for more implementation are emphasized with few actual echo(O'Farrell and Anderson 2010). Sometime the concept has been described as omnipotence and give trouble for the down to the ground practice (Brandt, Tress et al. 2000, Naveh 2001, Tress, Tress et al. 2001).

However, a considerable number of studies has been focused on the performance of ecosystem service in urban landscape, and more recently, to connect ecosystem services with the planning discourses. It is not surprising to find that many single ecosystem services were implied in the past planning documents, especially the ones related with water quality and recreation purposes; more than half of the services were mentioned through time line but lack a clear consistency and systematisms (Wilkinson, Saarne et al. 2013). In recent 5-10 years, more ecosystem services were explicitly used in planning documents, but mostly for informal plans that have less restrictions and maybe also less possibility for fully implementation (Kabisch 2015) but could already be count as a positive sign for further uptakes. And the complexity and trans-disciplinary characteristic of urban planning may be a key reason why planners could adapt new concepts relatively fast.

The current attempt of combining such conceptual term have made certain progress but for real changes, more need to be done in practical aspects. In order to link ecological, social and economic considerations, the planning paradigms and routines need to transform to a more holistic and systematic approach, as well as the shift of administrative coordination between existing sectors (Hansen, Frantzeskaki et al. 2015). The practical context is always complex under such transitioning demand. A case study made in Germany show that, many now common environmental knowledge has close relation with ecosystem services but the most used terms, species and habitat, belong to the old theme of biodiversity. Despite a quite high level acceptance of single ecosystem that could be combine within current planning, the real implementation needs permission from higher-level policy (Albert, Hauck et al. 2014). This explains why cities with earlier national level ecosystem services discourses have more related researches (Hansen, Frantzeskaki et al. 2015). On a more practical level, services could get better allocation in context like Project-oriented planning, public information and regional development, and design capacity as the key phase to translate abstract services into the physical environment, plays a vital role (Ahern, Cilliers et al. 2014).

2.3 Multifunctionality in Urban Green Space Planning

2.3.1 Green Infrastructure

Multifunctionality is officially promoted as a core characteristic in the concept of Green Infrastructure (GI). It originates from the United States about two decades ago and has a revolutionary effect worldwide. GI planning is no doubt a rising paradigm for the holistic planning of urban green space and has been largely discussed by scholars, planners and decision-makers. From a broader definition, GI refers to "… an interconnected green space network, including natural areas and features, public and private conservation lands, working lands with conservation values, and other protected open space, that is planned and managed for its natural resource values and for the associated benefits it confers to human population" (Benedict and McMahon 2012). The word "infrastructure" reveals more of its nature, that it is not isolated green patches that haven't been developed yet, but rather a correlated and interacted system that provide basic and necessary functions for the whole society. That means for the first time, green space is considered to be as vital as the artificial system like transportation or electricity in our built environment. GI goes beyond mere aesthetic appreciation or ecological conservation. It roots on the rethinking of modern US style of urbanization which is built on massive consumption of natural resources, and it seeks for the conception change of traditional green planning since last century.

The stronger link of Ecosystem Services (ES) in the European context provide GI with more ordered and substantial content. In fact, the description of the function of GI was quite vague in the US context like "…that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife" (Benedict and McMahon 2012). This mixture of function, service, benefit and value leave a large space for planners, and lead to possible misuse or exaggeration of the concept that everything could be included in GI. While in the EU definition, GI is "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (Commission 2013). The ES, however, provides a fundamental category that a large range of services the ecosystem provides could be filled into either the Provisioning, the Regulating, the Cultural or the Supporting group (MA 2005). Though this classification is neither perfect nor complete, it further connects ES with other disciplines, like agronomy, ecology and sociology, thus provides clear channel for multi-disciplinary studies.

However, with all the brightness in GI researches, it encounters problems in the mainstreaming process as well as in realization. For starters is the lack of a precise, generally accepted definition of the term or approach in US or EU. It somehow became an all-inclusive, over-expanding idea that covers from trees to environmental friendly structures and stands for both environmental theory and socio-economic policy, which makes the concept corruptible and hard to follow (Wright 2011).

Furthermore, the emphasis on technique is clearly stronger than that on humanistic concern. Partly inherit from the concept of McHarg, GI has paid more attention on being ecologically functional, which may not necessarily equal to comprehensible aesthetic value for residents and the role of design has been underestimated (Czechowski, Hauck et al. 2014). To make it more difficult, GI as an integrated concept ask for cooperation between sectors, across scales and disciplines, which has posed great challenges on most contemporary institutional structure, not to mention the huge funding and maintenance requirement in the long-run. This is probably the main reason of the current limited practices and would not be solved by the efforts of scholars only. Similar situation for multifunctionality, the term is considered equally vague and all-inclusive, so as became popular instead of substantial.

Despite all the obstacles ahead, this GI movement is inspiring, revolutionary and still promising in the foreseeable future. The essential change is the upgrading of values for urban green space. Through the lens of GI, now the green and open space in urban and rural context has been portrayed as a potentially integrated, systematical network that interconnected across the scales and support the natural-social system with multiple functions. This fundamental understanding has greatly promoted the prosperity of urban green space studies, and its underlying connection with urban planning makes GI a future-oriented approach. Currently the GI is still problematic and not mature in many aspects, but the transformation towards such approach is inevitable (Amati and Taylor 2010). What's urgently in need for the development of GI is not inventing new concept, but rather interpretation of existing terms and bring them down to the reality.

2.3.2 Multifunctionality in Green Infrastructure Planning

The planning and practice of urban green space has lasted for over a century, with the changing of aspects, methods and aims. Generally, the targeting functions of green spaces are increasing from aesthetics appreciation to sense of identity; the scale of planned space is expanding, from single park to urban green system and to regional green network; the thinking mode is upgrading, from consumption to preservation and to symbiosis; and the practitioners are growing, from planners, designers to geographer, ecologist and sociologist. Complexity, multi-disciplinary and variety have been the common tags of green planning, especially on urban scale, the medium scale that connects nature and human society. On one hand, urban scale green planning is promising with more possible interactions between these two fields and has the potential of creating new possibilities; on the other hand, urban scale need to deal with both tangible and intangible problems that extended to regional or local scales. The concept of Green Infrastructure (GI) is from such perspectives a promising approach. It provides a wider platform for cooperation between urban planning and related disciplines in the green spaces. It may be one reason of the most criticized vagueness in the definition, but in the meantime it brings with opportunities and deeper understandings.

Comparing with integration, connectivity, multi-scale and multi-object, the other planning principles of GI (Hansen and Pauleit 2014), multifunctionality relates more directly to both tangible and intangible performance of green spaces. In this sense, it has been used as a general evaluation comment in many studies. However, its potential in the above mentioned trends was not paid enough attention and very few argued the value of multifunctionality as an interpretative framework, which could be understand by both planners and ecologists and thus form a common platform in the multi-disciplinary task of improving urban green spaces.

Within the discussion of GI, lots of necessary topics were able to bring multifunctionality to the deeper level. For instance, the scale distinguishes in defining multifunctionality. Ecosystem services perform differently according to scale difference (Andersson, McPhearson et al. 2015). Current studies of multifunctionality tend to focus on a "landscape scale", which differ between regions and have no clear boundary. The multi-scale perspective of green infrastructure planning aimed at the consistency between scales, from individual parcels to community, regional and state, to function at multiple scales in concert (Hansen and Pauleit 2014). The participation of stakeholders forms a vital but less discussed direction. Public participation, especially at a local scale has been a routine for formal planning systems. It has advantages in the use of local experiences (Faehnle, Bäcklund et al. 2014), the quantification of vague concept like Cultural services (Caspersen and Olafsson 2010) and to match the local demand within specific context (Ives and Kendal 2013).

2.3.3 The gap between concept and practice

It has been pointed out by multiple studies that there is an obvious gap between the updating concepts, like GI and ES, and the real practices in urban green space planning, or to be more specifically, the corresponding practices are always weak and much less in numbers than expected (James, Tzoulas et al. 2009, Lafortezza, Davies et al. 2013, Haase, Larondelle et al. 2014). Urban green space has been increasingly discussed for almost half a century and a quite massive amount of theories, concepts and models have been proposed, involving multiple aspects of the green space. It has been linked with ecological concepts, like ecological corridor or network; with economic bases, like ecosystem services and cost-benefit analysis; and with sociological considerations like green justice. More recently, the adaptation capacity of urban green space in the challenges of urban climate change is also largely discussed. It is impressive to see the possibility of multifunctionality in urban green space, to be more specifically, the large amount of functions green space could undertake and how much more value it will bring for human well-being. Meanwhile, since the study of urban green space is receiving attention from many other disciplines, some technique and methods are getting more frequent used like GIS and quantitative analysis that enrich the dimension of green space.

While the conceptual part of urban green space has been kept pushing forward by new challenges, new perspectives and the dissatisfaction of current situation, the practical part seems relatively slow and fragmented, which is the so called "gap" between concept and reality. With perfect plans keep coming out, the realizing is hard to follow(Li, Wang et al. 2005). In fact, only few cities, like New York and Seattle, actually made top-down and radical changes to keep up with new concepts like GI planning. Most other actions that try to implement the concepts are small, individual projects rather than integrated efforts (Young 2011). This could easily lead to a doubtable assumption that the large-scale, all-involved perfect new project are the only best practices. Thus famous cases may be discussed and learned several times internationally with few considerations on real transferability. For example, the Maryland case for urban green infrastructure planning (Weber, Sloan et al. 2006), and the transformation of New York Highway as a classic case of urban green space innovation.

Again, the emerging new concepts are not totally new. As discussed in the second section, multifunctionality grows from biodiversity back in the twentieth century, many sub-topics inside multifunctionality has long being targeted. Though "ecosystem service" has not been formally and explicitly used in past urban green space planning, part of the content, from provisioning to cultural services, has already been the focus in planning documents in many American and German cities (Hansen, Frantzeskaki et al. 2015, Kabisch 2015). There are challenges and asymmetric information at governmental and institutional level, but the actual "gap" may be different.

Moreover, when talking about the lag in the implementation, the life-cycle of urban green space is often ignored. The basic structure of urban green space formed together with the shaping of urban form, after that there could hardly be any big changes but rather gradual trends. The large-scale green space in urban region that intensively used today are usually treasures from decades ago. For many cities, the outdated urban forest, the widely critiqued Greenbelt, or the plainly designed People's Park, functions as the back bone of urban ecosystem without enough attention.

Thus, what does "gap" mean for the theory and practice in urban green space planning? To some extent, the gap is naturally unavoidable for urban green space and even positive for the further development. Because urban green space, a space for both human and natural, need certain nurturing time so the present are results from past. A gap between contemporary concept and long-formed current situation provide possible direction for the future. The more important thing is, from a longer dimension of time, how has the gaps formed, remedied and reborn; and how to describe the current gap explicitly in order to pose accurate moves in the near future. This process of self-comparing and interpretation would probably reveal more fundamental mechanism under a certain context, compare with some general best practices.

Urban green space is being relocated in planning system, from the left place to the place of high priorities and vital roles. But the transition of a general cognition on urban green spaces is still

on the way. It is a dynamic, incremental system with a helix growing trajectory. On one hand, the historical aspect of green space should be emphasized and valued since that is the base of any future changes; on the other hand, the grow of green space need patience and constant updating, to catch up with the gaps that will never be totally fixed. In this way, the gaps are dynamic clues and chances for urban green space, and link the concept and practice from a historical perspective.

2.4 Summary

2.4.1 Characteristics and definition of multifunctionality

In a boarder sense, having multiple functions is the common trend of urban green spaces. However, multifunctionality goes beyond multiple functions, which use Ecosystem Services and landscape functions for references, and includes the possible interactions between functions as well. This term is being increasingly used in the evaluation and discussion of urban green spaces with some leading trends. Firstly, there are still huge barriers between practitioners in different fields, for instance the planners and ecologists, but some already stared to translate and inspirit for each other(Kabisch 2015) and merging the gaps between disciplines. Second, most case studies focus on large scales like municipalities or regions, in which functions were being roughly counted, with few emphasizing the importance of context, localization and everyday uses(Haase, Larondelle et al. 2014). Third, the different corresponding scale of functions led to the imbalance of studies; cultural related functions, limited by scale, method and complexity, were always oversimplified. Last but not least, with the growing capacity of data collection and processing, temporal changes need more attentions to act as the dynamic monitor of human intervention and natural reaction.

Based on the literatures, four major characteristics could contribute to the uniqueness and significance of multifunctionality:

1. The combination of multiple functions and services: multifunctionality always appears in a heterogeneous land. The multiple functions that attached to the land could be different functions on the same land at the same time span; or different functions sharing same land but have time difference; or even it could be mono-functional in one land but all together constitute a complex and fragment open space.

2. Multifunctionality emphasis the potential interaction between functions. Synergies between functions are specifically promoted to create an innovative environment for further positive and occasional reactions in such land. In this way, landscape as a whole is more than the sum of its parts, and the massive interactions will provide chances for the generation of self-sustain.

3. Multifunctionality understands the urban landscape not as only scenery, but as an integrated system that balance between functions and changes through time. It shows a more tangible and dynamic image of green sustainability.

4. The social-ecological meaning of Multifunctionality close the tension between urban and rural space. Because of the unity in space, it promotes the shift for the reconnection of urban- rural separation.

Multifunctionality is a term used in multiple fields, each has its own focus, but generally, it refers to a phenomenon, an aim and a framework. The phenomenon aspect described an already existing status, that the coexistence or aggregation of multiple functions within same land and spatial and temporal difference, presents more positive benefits than simple assumption of the parts, which leads to high-efficiency of land use and self-sustain. Thus multifunctionality was set as a dynamic aim for constant pursuing and adjusting through human intervention. However, to achieve such an aim, the primary and vital step is to use multifunctionality as a comprehensive framework, for self-interpreting and target setting, which require the understanding of the term from both theoretical and practical perspectives.

From a theoretical perspective, multifunctionality is taking references from agricultural, landscape and ecosystem services to build as a tangible framework with components from ecological, social and economic aspects, and potential interactions within components. These fields also provide multifunctionality with their tradition of demonstration and analysis. From a practical perspective, though multifunctionality is believed as a key feather of green infrastructure planning, it still needs further understanding from planning dimensions. The scale difference and consistency between scales; the demand/supply budget of function delivering; and the planning circle of concept forming, planning and design, implementation, management and evaluation, are the vital aspects for the building of an adaptive multifunctionality framework.

To sum up, multifunctionality is a term based on different fields and involved in multiple occasions. It has the potential to become a tangible framework of sustainability in urban green space context because of its inclusiveness, adaptability and abundant underpinned connotation. To avoid the term becoming a buzzword, more need to be done to form a more concrete, down to the ground operating environment for the practical use of multifunctionality.

2.4.2 Multifunctionality in three scales

Multifunctionality is critiqued as being too blurring (Hansen and Pauleit 2014) mostly because there is no clear and definite borderline between mono- and multi-functional green space. Tracing the source of the multifunctionality from landscape study, it is argued that every piece of landscape is multifunctional. Landscape is an anthropic definition of non-built area which contains

more than two kinds of ecosystems, it would be impossible to include just one function. A golf course could serve for recreational purpose as well as regulating on micro-climate, just at a higher ecological and financial cost. Similarly, the criticize of mono-functional for conventional or industrialized large-scale agriculture does not mean such kind of land use has no other function beside food provisioning, but rather other requirements rooted on the same space are greatly crippled. Multifunctionality is not something absolute, the judgments depend on the object and range. In the context of planning and base on human perspective, multifunctionality should at least be distinguished from three scales: regional, urban, and local scale.

Multifunctionality is not widely used in regional scale. No matter in the ecological or political sense of "region", the coverage of ecosystem types is board and there is no argument for the existence and interactions of multiple functions at this level. In fact, multifunctionality is not enough for this scale due to its irrefragable anthropocentric feather. Instead, "sustainability" is a general description of a harmonious future in regional development strategy; "biodiversity" holds an equal perspective and values the role play by non-human creatures, with the special "connectivity" and "networking" of open space as preconditions. Even multifunctionality is sometimes used in this scale, it would be better considered equivalent to sustainability, that ecological, economic and social aspects have been under a full-scale consideration (Yang, Ge et al. 2015).

For urban/municipality scale landscape, multifunctionality is a vital and context-dependent term. The urban open space system, which from a border sense include all open spaces from center to sub-urban areas, is a semi-natural system in which anthropic aspects have strong and direct influences. Many types of ecosystems can be find in this system, as well as all potential functions of green spaces present more or less here. Human intervention on this system will immediately or gradually show as the changes of multiple-functions provide by green spaces. From this sense, multifunctionality is quite manageable. However, human activities in urban areas are also constrained by different forces that conflict with each other, which limit the frequency and range of interventions. Furthermore, every city has unique geographical, historical and political conditions which makes the orientation of planning different at the very beginning. Therefore, multifunctionality at this scale is a drifting point within the confines of conditions, but could be improved to a certain extend, like the sustainability in urban reality (Campbell 1996). Most functions could be included but not absolutely balanced between aspects.

In this case, comparisons between context different urban areas may not be that significant, even if they are all called multifunctional. In a Denmark case, urban areas are defined as multifunctional because most ES present the average score of all study units; while in the Stockholm case, the cultural and water related services have obvious better performance (Turner, Odgaard et al. 2014, Queiroz, Meacham et al. 2015). On the contrary, the setting of baseline and the identification of changing trends in the same place could lead to further discussion.

The multifunctionality of local/neighbourhood level green open space is least studied but most appealed in discussions. However, the appearance of the term now constantly accompanied by Urban Green Infrastructure planning and practices. Especially in local GI projects, multifunctionality represents the typological improvement of conventional green space functions, that some other services are combined into or emphasized besides the traditional recreation and aesthetic appreciation purpose (Lovell and Taylor 2013). Benefit from urban GI programs, the fragmentized urban green spaces are organized to function against stormwater, heat weather, polluted air and etc. So as the rising number of community scale urban agriculture, which contributes both in the services and cognition of residents (Dennis and James 2016). Local scale multifunctionality refers to the enhance of efficiency rather than all-inclusiveness of functions. Furthermore, synergy effects among functions would be best observed at local scale, which links directly with human cognition and activities.

The scale difference is a key reason of the sometimes inconsistent expectation on the "multifunctional green space". It may also be seen as an advantage that multifunctionality could be carried out from top to bottom. Regional multifunctional development based on containment of possibility that need policy and strategy with higher capacity; urban level target is a changing point of the socio-natural system that need balance and resilience; local scale tends to be anthropocentric that need add-on values beyond just green sight. Urban level as the center of system, undertakes the necessary responsibility from above, and is affected by the preferences from below. Lots of "landscape multifunctionality" researches have focused on this middle scale, and more are needed in the local and the relationship in between.

Chapter III. Multifunctionality: Content and Interpretation

This chapter centers on two questions: what should be included in multifunctionality and how is it evaluated. Section 3.1 focused on the first question and located the functions back to three origins, the Ecosystem Services, the landscape functions and functions of urban green spaces. The functions in multifunctionality is a combination of all three with Ecosystem Services as the structuring category. Then, the interactions of functions were briefly discussed which reveal the difference between multifunctionality and multiple functions. Widely used assessment approaches were compared in section 3.3, with special attention on the ones has closer link to planning. Cases targeted on more than two types of functions are selected, since few studies used multifunctionality as the evaluation term.

3.1 Content of Multifunctionality

Though all use multifunctionality to describe the combination of multiple ecosystem services and functions, the amount of "multiple" in different scenario varies. About 40 services are defined in theoretical studies (de Groot, Wilson et al. 2002, MA 2005, TEEB 2011), 10-15 left dealing with evaluation in certain practical context (Raudsepp-Hearne, Peterson et al. 2010, Turner, Odgaard et al. 2014, Yang, Ge et al. 2015) and the ones that have been specifically and directly used in a design course are really rare.

Functions are the fundamental content of multifunctionality. In the context of urban area, green open spaces functions could be listed long, but its strongest influence towards its current understanding cannot ignore the enthusiastic discussions of ecosystem functions since 1960s (de Groot 1992), which leads to the recognition of the critical role of natural and semi-natural environment in urban areas. Nowadays, the commonly used functions of urban green open spaces refer to an ambiguous combination of ecosystem functions, landscape functions, agricultural functions, sociological functions and so on. The wide inclusiveness of the term helps to develop the huge potential for planners and designers, but also an identification problem for scholars in different fields (Hansen and Pauleit 2014).

However, with all the criticizes and debates, function is still irreplaceable in terms of open space planning and the importance of multifunctionality is being widely accepted. By the growing trans-disciplinary efforts, the meaning of function in urban green open space planning is being widened and deepened. Like many other concepts in urban planning, the understanding of a multi-dimensional function group also has influences from the three pillar of "sustainability" -- ecology, economy and society. The studies of Urban Ecosystem provide it with the core theoretical ecological

base; the Ecosystem Services connects the intangible function with countable economic value; the context and cultural discussions give function more profound sociological meanings. There may be no final agreement on the definition of function in urban green space, but there is already an abundant content of function for discussion.

3.1.1 Ecosystem services

1) Definition

At the latest in 1970s, the discussions on ecosystem services had been a topic of rising importance (de Groot, Wilson et al. 2002). One of the most influential articles would probably be the one written by Costanza et al. and published in 1997, which is the first approximate evaluation of the global ecosystem services. It reveals the huge economical value provide by ecosystems and its underestimation in policy-making in the era of market-oriented economy (Costanza, d'Arge et al. 1997). Here, the term "ecosystem services" was defined as "*the benefits human population derive, directly or indirectly, from ecosystem functions*" with exclusive of non-renewable ones, and refers to both ecosystem goods (like food) and services (like waste assimilation) together. The anthropocentric nature of ecosystem services was later emphasized again by de Groot et al., that only after the implying of human values could the observed ecosystem functions re-conceptualized as "ecosystem services"; and the relationship between them are not always one-to-one correspondence, but inter-related inside the complex systems (de Groot, Wilson et al. 2002). Studies at this time mainly took place in the field of ecological economy or ecosystem, so as the discussions focused more on the range and classification of content rather than term definition.

In the past decade, the discussing range expanded because of the rising attention on the urban ecology and urban environment. The monumental report of Millennium Ecosystem Assessment brought the concept to multiple fields related with urban studies, urban planning and policy-making and so on. Ecosystem services are "*the benefits people obtain from ecosystems*" (MA 2005), or some express as "*the benefits humans derive from nature*" (TEEB 2011). "Ecosystem" here was defined as "*a dynamic complex of plant, animal and microorganism communities and the non-living environment interacting as a functional unit*", with the size varies from a pond to an ocean and the human an internal part of the system (MA 2005). It is a simpler, broader and more direct explanation to connect human closer to nature, but maybe to some extend also lead to more confusion. Ecosystem functions and services have been seen paralleled (Tzoulas, Korpela et al. 2007), or replaced with each other (Bastian, Haase et al. 2012); or to completely avoid the ambiguous trouble by ignoring the term Ecosystem Function (Wallace 2007); or Ecosystem Services is partly revised and expanded (Burkhard, Kroll et al. 2012). Since the term function was widely used already in many fields and had some underpinned meanings, such vagueness is no doubt problematic.

However, when tracing back to its earlier origin, a clearer relationship between these terms could be drawn with the flow of ecosystem complexity, that the ecosystems process a series of ecological structures and processes, which present as ecological functions; ecological functions, in turn, provide the goods and services to human; the economical or mental benefits that captured by human are the values of ecosystem (de Groot, Wilson et al. 2002, Haines-Young, Watkins et al. 2006). In other words, ecosystem services is the subset of ecosystem functions; the former one is inherently positive and the latter is normally neutral which means that "disservices" also exists. In either situation, "services" is a critical term but cannot be discussed without its correlated functions or its generating context. Furthermore, multifunctionality, roots on but grows beyond functions, is also a particular term that cannot be replaced simply by multiple services (Selman 2009, De Groot, Alkemade et al. 2010, Hansen and Pauleit 2014).

2) Categories

One of the most critical efforts on the classification of ecosystem functions and services would would be the one by de Groot et al., which use "Production", "Regulation", "Information" and "Habitat" as four basic types of ecosystem functions and listed the services responded with them (de Groot, Wilson et al. 2002). The current widely used categories of ecosystem services, as "Provisioning Services", "Regulating Services", "Cultural (and Amenity) Services" and "Supporting/ Habitat Services", have a clear inheritance. The first three are paralleled with each other and have general acceptance and tons of studies. While the Supporting/Habitat services is considered unequal with the others and always got removed from quantitative studies to avoid double counting.

Provisioning Services are services that describe the material of energy out puts from ecosystem, includes food, water, raw materials, biochemical and genetic resources. Regulating Services are the ones that ecosystems provide by regulating the quality of air and soil or providing flood and disease control, like the regulation on climate, disease, natural hazard and water treatment. Cultural Services, which are the non-material benefits people obtain from contact with ecosystems, aesthetical, spiritual or psychological, for instance, cultural diversity and identity, cultural landscapes and heritage values, spiritual services, inspiration (such as for arts and folklore), aesthetics, and recreation and tourism (TEEB 2011). Most provisioning and regulating services have direct indicators and are more suitable for quantitative evaluation; while cultural services are intangible for counting and rely greatly on local context.

Supporting Services refers to nutrient cycling, soil formation, photosynthesis, water cycling and etc. (MA 2005). Critiques on this category centered on that it mix processes (means) for achieving services and the services themselves (ends) within the same classification category (Wallace 2007). One possible modification is to replace Supporting Services with "Ecological Integrity", as the other

three types are "final ES" which are "*components of nature directly enjoyed, consumed or used to yield human well-being*", while Supporting Services are incomplete, intermediate and overlapped with others (Boyd and Banzhaf 2007, Burkhard, Kroll et al. 2012). Another less used classification intended to avoid vague terms and link ecosystem services with human values, ecosystem processes and natural assets (Wallace 2007). The most used TEEB classification replace Supporting services with Habitat Services, which maintain a diversity of plants and animals and includes habitats for species and maintenance of genetic diversity (TEEB 2011), and was developed base on the former studies of de Groot (de Groot, Wilson et al. 2002). The content of this type developed from lifecycle maintenance and gene pool protection (TEEB 2010), to habitat for species and maintenance of genetic diversity (TEEB 2011), which are both hard to evaluate, and maybe better to ignore at this stage of study.

3) Content

It is not possible to detail every classification of ecosystem services due to the vast number and the different explanation. However, trace back based on leading scholars and mainstreamed understanding of the function-service relationship, the similarity and differences between three most cited milestone classifications and two widely used reports, among other literatures, could be clearly found. The references include, on a chronological base, the first widely discussed article to estimate the global economic potential of ES by Costanza et al. in 1997; the origin of the now used classification by de Groot et al. in 2002; the Millennium Ecosystem Assessment in 2005 which brought the topic to multiple disciplines; the updated version by de Groot et al. in 2010 that focusing on bridging the concept with planning and decision making; and the reports of the still on-going TEEB-project (The Economics of Ecosystems and Biodiversity) in 2010 (Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB) and 2011 (Manual for Cities: Ecosystem Services in Urban Management).

The category of Provisioning Services has few changes between times, "food", "water" and "raw materials" keep consistent in all versions which show their fundamental roles. The related ecosystem functions and processes were described a little differently, emphasizing on the "presence" in the more recent description. The "Medicinal resources" was not considered in 1997 version, but used as important services and extended its inclusiveness later. Maybe limited to the condition of "relevant to cities" in TEEB 2011 report, neither "genetic resources" nor "ornamental resources" were selected. In fact, all the latter three services are seldom used in quantitative studies due to data acquisition.

The Regulating Services received most consistency and the slight differences mostly lies in expressions. For instance, "pollination" never changed; "air quality regulation / purification" is just the more common used words for "gas regulation"; "disease regulation" and "pest regulation" means

the similar service as “biological control”. Only the “Nutrient cycling/ regulation” was later removed to supporting category. The TEEB 2011 urban version made some instructive changes, that “air quality regulation” and “climate regulation” were merged together since their functional ecosystems, trees, plants or other type of green spaces, normally providing these services simultaneously. It is the similar situation for “moderation of extreme events”, since floods and storms are the most probable extreme events in urban areas.

Cultural Services varies a lot among the five versions, not to mention in actual evaluations. Starting with “Recreation” and “Cultural” in Costanza 1997, up to 10 services were later derived, split or combined. To avoid being lost in all kinds of such vague distinguished services, the explanation of the two originals were critical. The ecosystem function related to “recreation” service was described as “Providing opportunities for recreational **activities**”; to “cultural” service was described as “Providing opportunities for **non-commercial uses**”(Costanza, d'Arge et al. 1997) or “Variety in natural features with cultural and artistic **values**”(de Groot, Wilson et al. 2002). The services in this category could thus be easier explained following these two types. The type of “possible activities” could be further subdivided into services like “recreational activities”, “ecotourism/ tourism”, and “science/ education/ training”; the type of the intangible “values” could include “aesthetic values”, “inspiration (for culture, art and design)”, “spiritual and religious values/ experience”, “cultural heritage values”, “sense of place” and so on. Of cause each value has its unique definition, however, some values often correlated or co-exist in certain context. It would then be reasonable to merge some pairs in same type together, like “spiritual experience and sense of place” in TEEB 2011, or “recreation and ecotourism” in MA 2005, or even to select according to practical situation.

The “Habitat” category, which mainly follow de Groot et al. 2002, is still the indirect benefit for human well-being but avoid doubt counting as the Supporting services defined in MA 2005. The original supporting services are now more accepted as ecosystem functions, which are the intermediate between ecosystem processes and services. The nursery of “Habitats/ refugia” intended to protect the physical condition for species while the maintenance/ protection of “Gene pool” focus on the processes and outcomes. As mentioned above, it is a still on-going debate and more discussions are necessary before general acceptance (De Groot, Alkemade et al. 2010).

4) Ecosystem Disservices

Not only positive effects can be perceived from ecosystems. The so-called Ecosystem Disservices (EDS) are the negative impacts human perceive from ecosystems, the opposite of ecosystem services(von Döhren and Haase 2015). Similar as ecosystem services, disservice is also a human centered notion and thus especially useful in human intervened conditions, like in urban areas and agricultural areas. It is worth mentioning that EDS may not necessarily be the

consequences of biodiversity loss or negative effects of ecosystem change, but rather the results of normal ecosystem functions that are harmful for human in specific context and conditions (Lyytimäki and Sipilä 2009).

Related discussions of EDS only got attention since about five years ago and mainly focused in urban ecosystem, mostly in Western Europe and USA. There are no widely accepted categories on the types of EDS and some of them are quite subjective. For instance, trees standing close buildings may cause "view blockage" (Gómez-Baggethun and Barton 2013), however, that may also have positive effects on "local climate regulation" and "air purification" which are both ecosystem services. The judgement and inclusiveness of EDS may possibly change due to particular context, which is among the main problems of related studies. Some of the general accepted EDS are listed below (Table 3.1.1). Due to limited total amount of studies and the concentration in developed countries, the current understanding of EDS is limited. Main challenges lie in the further comparable quantitative studies and the integration of EDS in ES approaches (von Döhren and Haase 2015).

Table 3.1. 1 The main urban ecosystem disservices, its correlated ecosystem functions and possible indicators.

Ecosystem functions	Urban Ecosystem Disservices	Description	Indicators
Photosynthesis	Air quality problems	Emissions of volatile organic compounds (VOC), emissions in course of maintenance, concentrations of particulate matter (PM) can decrease air quality	Emission of VOCs
Movement of floral gametes	Allergies	Plants and their pollens can cause allergies or poisoning	Allergenic potential of respective plants
Biomass fixation in roots; aging of vegetation	Damages/ Accidents	Breaking up of pavements by roots; break up of branches falling in roads	Amount of affected infrastructure; number of aged trees
Dense vegetation development	Unpleasant appearances	Extensive or inappropriate management cause unpleasant, ugly or unsafe feelings	Areas of abandoned or non-illuminated parks
-	Displacement of species	The inappropriate allocation of endemic species; the introduction of invasive species	Population of displaced/invasive species

Adapted from former related studies (Lyytimäki and Sipilä 2009, Gómez-Baggethun and Barton 2013, von Döhren and Haase 2015).

3.1.2 Landscape functions

1) Definition

The definition of "landscape" varies a lot due to different perspective, scale and context. From an ecological perspective, landscape is a mosaic of interacting ecosystems, possible in any scale; while from a wildlife perspective, landscape is a heterogeneous distribution of habit (Leitão, Miller et al. 2012). There could be many ways to define landscapes depending on the targeted phenomenon, but the indispensable condition lies in the heterogeneous spatial form and its impact on process, that landscape should composed of at least two functionally linked land units (Bastin, Ludwig et al. 2002). The size of the landscape depends on the study object and could be one single tree to entire region. Nevertheless, the more general "default" landscape scale refer to an area of "several square kilometers" (1,000 to 10,000 hectares, to be more specific) from a practical management perspective, and would be large enough to contain multiple interacting ecosystems and species with certain amount of population.

Landscape function is also a vague term that rely on the demarcation of its corresponding landscapes, which was defined based on targeted study object and specific context. In general, landscape function refers to "the capacity of a landscape to provide goods and services to society" (Willemen, Hein et al. 2010); they are "directly observable from the land cover or are defined by policy regulations" (Willemen, Verburg et al. 2008). In some circumstances landscape function and service are interchangeably used (Gulickx, Verburg et al. 2013) or jointly understood based on their common ground (Bastian, Haase et al. 2012). However, comparing with the obvious economic root of the concept Ecosystem Services, Landscape functions has a stronger natural science base. Functions of a landscape are pre-determined and influenced within a given landscape structure which was defined at the beginning. In other words, a standardized classification of landscape function is not necessary since the definition of landscapes may be diverse and the focus lies more in process. Moreover, the topic of landscape has a longer history in urban planning. The concept of landscape function has been widely applied by European planners in landscape planning, especially in Germany and Netherland (Bastian, Haase et al. 2012). The concept landscape has been an integrated part of spatial planning and the theoretical base for natural preservation or for non-built semi-natural areas.

2) Content

There is no generally used classification of landscape functions. Some categorized them in five groups, as ecological, economic, socio-cultural, historical and aesthetic (Shi 2013). In recent decades, studies of landscape functions and ecosystem services have made cross-references with each other after the fast rising of the latter concept. Landscape function categories, which are production functions, regulation functions, habitat functions and information functions, see its similarity with the ecosystem services classification. Most listed landscape functions could be linked

to a quite transferable or equivalent ecosystem service, with some exceptions like "residential space" is commonly considered as a landscape function that has the "ability to provide areas for residential use" but not included in any classification of ecosystem services.

Few assessments fulfilled the complete list of functions due to data limitation and underpinned emphasis on the process rather than only appearance. On the contrary, a more direct question-oriented function analysis may better convey the site-specific characteristic of chosen landscape. For instance, soil retention, carbon sequestration, water conservation, crop production, and residential space are selected as five key quantifying functions to respond to critical threats at regional level, like vegetation deterioration, soil erosion, water shortage, cultivated land reduction and tight living space (Peng, Chen et al. 2016). And the recreational value as an information function was classified and mapped in seven types to support decision making in land use planning (Caspersen and Olafsson 2010). The variation of selected landscape functions among researches reduce the possibility of comparison, but may also lead to better focus on targeted questions.

3.1.3 Functions of urban green (open) space

1) Definition

Urban green space is used in a general sense by its literal meaning: the green (vegetated) spaces in urban areas. Its inclusiveness allows an intensive use in urban planning, landscape planning and ecology researches, but sometimes it is not explicit enough for either perspective. Like ecosystems and landscape (units), "urban open space" is the more common term in the context of urban planning. "Open space" was originally defined as "any land, weather enclosed or not, on which there are no buildings or of which not more than 1/20 part is covered with buildings, and the whole of the reminder is laid out as a garden or is used for purposes of recreation or lies waste and un occupied" in The 1906 Open Space Act of London, one of the first cities to value the non-built areas in the high cost of urban land (Turner 1992). To be short, open spaces are "the totality of land units with mainly non-built soils"; such soils are the resources and substrate for "biological, hydrological and other functions that constitute the natural components of agriculture, nature conservation, forestry and many other services" (Bomans, Steenberghen et al. 2010). As the contrary and reminder of built environment, urban open space emphasis on the low level of artificial interventions and the maintenance of naturalness (Maruani and Amit-Cohen 2007).

However, "urban green (open) space" is also commonly used and considered the subset of open space which is dominated by natural elements, since specific objects of open spaces relay also on scale and range. At local scale, artificial elements like streets and squares are necessary components of urban open space; while in urban and above scales, the natural elements, like forest,

farmland, river and so on, are the core functional parts. To avoid such confusion, "urban green (open) space" is mainly used in the thesis.

Another category is public and private open space, the two mutually connected and penetrated types. Private gardens and public lawns may be distinguished based on landownership, but they are connected mentally and ecologically. A park could be a public space to meet strangers, and also a personal place to hide away from noise and traffic. In the meantime, parks and gardens regardless of their size, are components of the urban landscape mosaic, as well as unique urban ecosystems.

2) Content

Access to some form of nature as a fundamental human need is the very base of open space (Thompson 2002). However, after more than a century of development, the current functions of urban green open space has become a vague combination of all kinds of functions, services and benefits/values of related ecosystems (De Groot, Alkemade et al. 2010). The content has been increasing with the upgrading of open space planning models from single points to complex networks, as well as the changing of service object from a bunch of people to both society and nature. The relevant personnel started with urban planners, soon added with landscape architects and now also with ecologists and more others.

Most requested functions of green open space in early times belong to "cultural services" or "informational functions". For instance, the "public walk", a purpose of the allocation of public open space in the middle of 19th century in London, could be translated into the function or service of "recreational activities" and "aesthetic appreciation". Some demanded functions also related to the "regulating services", like "public health" is the benefit people would get from "Air purification" and "waste treatment". Some functions were already used but may be excluded out of urban areas, like "food provisioning" which came back to urban context in recent decades. Some functions only exist after the the planning object has shifted from "human-centered" to "society-nature system". Many green functions have influences from conservation biology, like green networks/webs will benefit for "genetic diversity" and "Habitats for species" (Turner 1992).

Some traditional green functions and demands are complicated and not easy to classify. "Equity" has been the topic at the beginning of open space planning, and could be reflected by the still used "urban green standard", which try to achieve relatively equal accessibility (maybe also quality) for everyone by regulating the service range, population and minimum area of public open spaces (Turner 1992). In the past decade, "environmental justice" attract more attention again and over-quality of open space may lead to "green gentrification" (Campbell 1996, Wolch, Byrne et al. 2014). Another case is the "segregation" function used by planners. Street trees could "reduce noise", service for "air purification", "local climate regulation", "carbon sequestration", and as disservice

to “block view”(von Döhren and Haase 2015). From a larger scale, the green structure is not planned for ecosystem only, but play a vital role in the formulation of urban and regional development.

3.1.4 Summary

One key question of this section is, what/which functions should be included when talking about the multifunctionality of urban green open space? It is clear the ecosystem services, landscape functions and functions of urban open space have different focus and background, but they are not distinct with each other. Fundamentally, they have basically the same physical base, the non-built use of land. The advantage of landscape functions lies in its long study history and strong connection with natural science; the urban green open space linked directly towards land use and planning, focus on the improvement and balance with built environment; the concept of ecosystem service is better described as “the missing link” between nature-centered and human-centered perspectives (Bastian, Haase et al. 2012), and unified multiple perspectives in its widely accepted categories (Fig 3.1.1).

From a planning perspective, for which drawing lessons from other disciplines is part of the work, a practical joint view and a combination of the various approaches would be a better option to complete and supplement existing shortages towards better future. The included functions of a multifunctional urban green open space must draw inspirations from all useful sources and further test in real application.

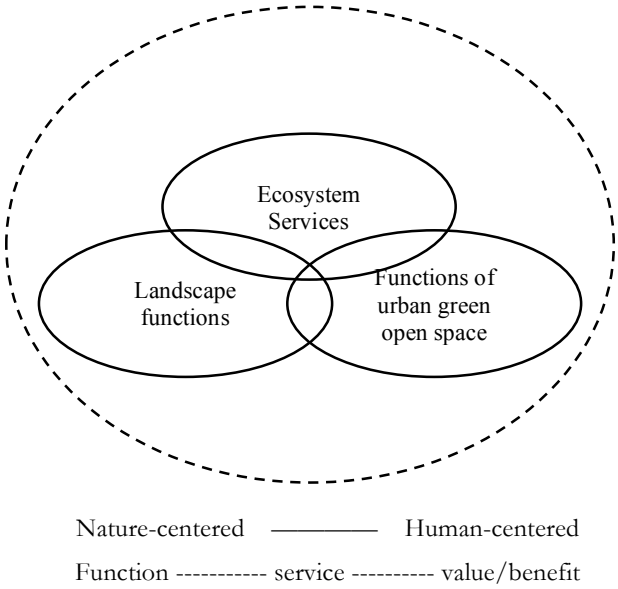


Fig 3.1. 1 The different focuses of concept, dashed ring refers to the possible maximum range of multifunctionality. Based on Andersson 2015 and others and draw by author.

Another critical condition is the scale or context suitability hidden in the definition. Scale refers to the multi-layer spatial network of urban green space. As pointed out by GI concept, it is a system consists of elements from any scale and scope, from small patches to community garden or the national conservation area. However, green spaces are spatially continuous but functionally differed depend on scale and context. For instance, most cultural services matter more on local scale, while provisioning services could be scalable or more meaningful on regional scale (Andersson, McPhearson et al. 2015). Moreover, different methods should be applied on different scales, like some argued that city level analysis on ES should focus on the generation and distribution, for which the ecological analysis could be used; while on local level, it is important to trace the consideration of actors and specific contextual limitations, using ethnography, interviews and archival methods (Ernstson 2013). By doing this, the smaller scale is not simply amplified from a larger one, but more details will be added to the whole picture and helps the in-depth interpretation. In this way, scale will be the leading dimension to understand functions (from an objective aspect) and aims (from a subjective aspect) at different level.

By using the broader definition of ecosystem as above, ecosystem services in either MA or TEEB report should be considered as a general collection of all possibility. For instance, ecosystem services in urban areas will pay more attention on the ones directly related to human well-being, like air filtering, micro-climate regulation, noise reduction, rainwater drainage and so on(Bolund and Hunhammar 1999). Some studies applied the full package of all services for policy or planning analysis (Wilkinson, Saarne et al. 2013, Hansen, Frantzeskaki et al. 2015); most quantitative evaluation selected about 10 to 15 services due to local conditions and mostly the availability of data (Raudsepp-Hearne, Peterson et al. 2010, Turner, Odgaard et al. 2014, Yang, Ge et al. 2015); only few considered weight or used certain algorithm for grouping(Koschke, Fuerst et al. 2012).

3.2 Beyond Functions

3.2.1 Relationship between functions

Multifunctionality is more than simply addition of multiple uses but consist different types of integration between functions, with spatial and temporal changes. Spatially, most landscape functions have strong attachment with land use and land type, and two or more functions could co-exist as a basic level; beyond this location-sharing, multifunctionality emphasis the interaction between functions (Lovell and Taylor 2013), especially different types of functions; furthermore, based on intensive interactions, synergistic effects could be captured and encouraged, which is one critical feather of multifunctional landscape (Selman 2009). More advantages could be bring by such positive synergies, for instance, it brings more benefits to the public; it also enhances the land

use efficiency (Gulickx, Verburg et al. 2013); upon these, a more complex relationship network between users could be built and it also give chance to a better comprehensive management (Tank 2008).

Through the temporal scale, diverse functions could be realized on the same substantial land simultaneously or successively (Selman 2009); the present of functions may also changes or being re-adjusted through time (Rodríguez-Loinaz, Alday et al. 2015). These spatial and temporal interactions between functions give multifunctionality an image of a dynamic balance between topics, which makes it a substantial expression of sustainability in green spaces (O'Farrell and Anderson 2010).

In recent five years, many quantitative researches noticed a specific phenomenon that ecosystem services in a given landscape show certain patterns of synergies and trade-offs among each other because of their underpinned connectedness or interdependence, which is the so-called ecosystem services bundles or clusters Interestingly, the distribution of such bundles always strongly coupling with the social-ecological gradient and reveal deeper roots of human-modified nature of urban landscape. In fact, such bundles are exactly the reflections of multifunctionality at different level and scale.

Normally only 10-15 ecosystem services are chosen for the bundle researches, within which Supporting or Habitat services are often ignored and Cultural services left only 1-2 due to the hardness in locating suitable indicators (Haase, Larondelle et al. 2014). Instead of using natural boundaries like river basin, municipality boundary or spatial grids are used to engage with social process and municipal data. The actual bundles are not always clearly diverse with each other but has varies with social-ecological gradient, it was artificially divided into typical types. A common category is urban related bundles, Exurban/ Destination Tourism/ Mega-city/ Urban perform higher Cultural services, average Provisioning services and medium to low level of Regulating services; the agriculture/ corn-soy/ feed-lot group has obviously better food related Provisioning services but acts not ideal in other services. Many such bundles are land use based, or resource-oriented, like recreational forest/ lake/ coast attract local and foreign tourism and are favourable places for activities like hunting and hiking, thus have Cultural services than other places (Raudsepp-Hearne, Peterson et al. 2010, Turner, Odgaard et al. 2014, Queiroz, Meacham et al. 2015, Yang, Ge et al. 2015).

Since there is no common division method, the specific classification varies and few trends could be summarized. The Stockholm case (Queiroz, Meacham et al. 2015) shows no obvious trade-offs between Provisioning and Regulating or Cultural services, while the Denmark case (Turner, Odgaard et al. 2014) and Chinese case (Yang, Ge et al. 2015) confirms a negative relation between Provisioning and other services, but such trade-offs could be reduced in certain land type through better management (Xue, Li et al. 2015). Similarly, Denmark case show a dispersal of Cultural

services, which concentrate surround urban area in Stockholm case. Generally, the services across different cases show a clear non-random, but context specific, geographic patterns with several gradient. In this way, the bundles is a graphic information of social-ecological relationship on site, which could be a useful reference for multifunctionality.

The status of an ecosystem services is influenced not only by its provision but also by the related human demand (Paetzold, Warren et al. 2010). Agricultural discussion intensively involves the topic based on its commodity production nature, but for landscape scenario it is relatively new. The ecosystem services supply is the natural resources and services that currently could be used, not the maximum or potential situation; the demand refer to ecosystem services that are being used, but it may not necessarily be local because of the globalization reality; based on such perspective, the budget and foot print could be calculated to present the necessary total amount of services and corresponding areas that needed to generate the services (Burkhard, Kroll et al. 2012, Willemen, Veldkamp et al. 2012, Palacios-Agundez, Onaindia et al. 2015). Such approach further connects practical problems like "mismatch" in the allocation of services and has profound effects for planning perspectives.

3.2.2 Multi-disciplinary influences

The developing of multifunctionality in landscape helps the traditional deep-rooted aesthetic-oriented artificial space growing out of its limit and forming a bigger unity with the adding concepts from other fields. Disadvantages naturally would be a confusion in the randomness of its current use but on the positive perspective, this enlarging process give the term more substantial content and methods. Ecosystem services, giving assistance to the construction of an applied framework for landscape multifunctional analysis, have strong roots not only in urban ecology, but more essentially in economic. The trend of monetization and commodification of ecosystem services helps to capture the attraction of political support and involve market logic for environmental problems (Gómez-Baggethun, De Groot et al. 2010). The production perspective in multifunctional landscape, which may have influence from cultural landscape and peri-urban agriculture, merged the former exclusive topics like food production and agro-biodiversity into the unity, and thus have positive effects for the relocation and reconnection of rural-urban relationship (Selman 2009, Lovell, DeSantis et al. 2010). By fixing this traditional rural-urban divide, urban landscape expand its range and became a continuous matrix that docking more easily with planning system (Lovell and Taylor 2013). Besides, public participation as another factor give the chance of multifunctionality to embedded in local context (Otte, Simmering et al. 2007).

3.3 Interpretations of Multifunctionality

The co-existence of multiple functions is already considered in most landscape-scale evaluations as multifunctionality, while the interactions between functions are less discussed in details. These assessments of functions/services in multiple ecosystems have to put major efforts on the "translation" from phenomenon to performance of artificially regulated terms. Past such case studies have accumulated a vast set of examples for imitation, interpretation and value transfer to similar cases. The breakthrough on methodology and approaches have been inspiring especially in past five years, pointed out the theoretical possibilities on the future mainstreaming into formal planning instruments.

The assessments and mappings of multiple ecosystem services are the main objects discussed in the section. But cases aimed at economic value assessment are excluded since the interpretation of functions rather than specific results is the main concern. The quantitative and qualitative refer to the core data collecting and analysing methods, however, they are in a large member of studies combined or co-existed. Beside the dividing of methods used for mapping, as listed below, the types of chosen functions, data sources and spatial scale are the focus of attentions.

3.3.1 Quantitative assessment

The range and type of chosen ES directly affects the methods and depth of researches. Studies that evaluate ES in more than two types normally use models based on the well-known causal relationships between environmental variables, and apply mostly on regional scale (Martínez-Harms and Balvanera 2012). On the contrary, sometimes very limited number of ES are used in order to engage in more complex methods, models or data sources (Roces-Díaz, Díaz-Varela et al. 2015, Xue, Li et al. 2015, Peng, Chen et al. 2016). For the types of mapped ES, regulating services was the most applied, followed by provisioning and cultural services; the supporting services are least mentioned due to the wide query on its rationality, but the discussion on habitat functions are quite high, based on the general approval on the role of biodiversity from multiple aspects (Haase, Larondelle et al. 2014). Due to several systematic reviews, the most assessed ES are climate and air regulation, carbon sequestration, and water regulation. These are typical "old" functions of green open space but gain re-intensification in past two decades as a response to climate change and environmental crisis. Nonetheless, in quantitative mappings that involved three or all categories of ES, some services were always ignored. Apart from food, water and raw materials, the other half of provisioning services were basically never chosen for mapping purpose. Natural hazard mitigation, pollination and biological control received similar results. Not to mention some cultural services like "inspiration for culture, art and design" or "spiritual and religious inspiration" which are complicated to quantify even with intricate data collecting methods (Table 3.3.1). Furthermore,

though context specificity has been long argued, almost all studies choose equal weight for all selected ES.

Table 3.3. 1 Services used in related quantitative mappings.

Country and sources of case study / Targeted services	Food	Water	Raw materials	Air purification	Climate regulation	Carbon sequestration	Natural Hazard	Water regulation	Waste treatment	Erosion prevention	soil fertility	Pollination	Biological control	Aesthetic	Recreation	Tourism	Education	Cultural heritage	Habitats for species
China (Yang et al. 2015)	4	1				1	1			1					1	1	1		
Sweden (Queiroz et al. 2015)	4		1						2		2	1		1	5				
Denmark (Turner et al. 2014)	2	1				1			1		1			1	3			1	
Germany (Koschke et al. 2012)	1	1	1	1	1	1		1		1				1	1				
Germany (Haase et al. 2012)	1				1	1									1				1
Canada (Raudsepp-Hearne et al. 2010)	3	1				1					2			1	3	1			
Spain (Rodríguez-Loinaz et al. 2015)	2	1	1		1	1		2	2	1	1					1			2
Netherlands (Van Oudenhoven et al. 2012)	1			1		1		1					1		1		1		1
Spain (Felipe-Lucia et al. 2014)	1		1	1	1						2				3		1		1

Number refers to the indicators used for the service.

The selecting of indicators or proxies for targeted ES is also a subtle process, often greatly restricted by limitations in reality, like time and manpower in obtaining the information. Secondary data like administrative statistics and institutional reports have been the main data source (Seppelt, Dormann et al. 2011). It is a reasonable choice for many studies that deal with urban/ regional scale and above, or cover a larger spectrum of ES. Local scale analysis is rarely found according to the normal applicable range of secondary data. Few studies give satisfying reasons in choosing indicators, and it is not always comparable between cases. Some argue the necessity of systematic selecting criteria to evaluate the usefulness of indicators, including flexible selection process, consistency, comprehensive, sensitive to changes in land management, temporarily explicit, spatially explicit, scalable and credibility (Van Oudenhoven, Petz et al. 2012), which has not received enough feedbacks.

Many indicators in one case swings between state indicator and performance indicator. The former indicates "what ecosystem process or component is providing the service and how much", while the latter emphasis on "how much of the service can potentially be used in a sustainable way" (De Groot, Alkemade et al. 2010). Moreover, the collected indicator values don't necessarily have a reasonable range, or in another word, the baseline or the demand perspective is ignored. In these case, most such mappings show the standardized extend of a certain service, or the extend compared with its adjacent municipalities or other landscape units. Few past studies set an acceptable range for each indicator based on literatures, but an increasing number has made clear distinction with capacity, supply and demand (Rodríguez-Loinaz, Alday et al. 2015, Wolff, Schulp et al. 2015).

Despite the accomplishment in the translating and locating of ES, some results of quantitative studies are disappointing. In many cases, the rough approach of data collecting and mapping only lead to common and general conclusion. The higher population density a municipality is, the more concentrated could the cultural services gather (Queiroz, Meacham et al. 2015); agricultural areas only show high performance in provisioning services but go below average in all other types(Turner, Odgaard et al. 2014); forest domain districts always present highest comprehensive ES performance (Rodríguez-Loinaz, Alday et al. 2015). These mappings are sometimes the visual version of status with new terms but limited new inspiration for planning and policy making.

Furthermore, the scale of evaluated units could have stronger influence than others. Urban district could be low (Raudsepp-Hearne, Peterson et al. 2010) or average (Turner, Odgaard et al. 2014) or high (Yang, Ge et al. 2015) in the present of total ES value, and the term "multifunctionality" would be used here. The seemingly contradictory result normally could be traced with the actual range of urban district used in the study. The general performance is low due to low percentage of open space in certain municipalities and high because of the large included natural and semi-natural areas. Similarly is the phenomenon that the larger the scale is, the more synergies rather than trade-offs would appear, which in fact rooted in the diverse types of land use at a larger scale. How the ES mapping could lead to interpretations other than another expression of the ecological and socio-economical gradients is the key problem.

In a word, quantitative mappings of more than two types of ES on regional scale have been exploratory examples for the wider application of ES concepts. Spatial variation of ES performance are valuable information for planning and management. More improvement is expected to dock with practical needs, some of which have been pointed out like temporal changes, localization, visualization, and transferable framework.

3.3.2 Qualitative assessment

From the perspective of urban development, the final aim of any rising concept is to improve the dissatisfied current situation. Starting with the Millennium Ecosystem Assessment, scientists

and experts have pushed the concept from eye-opening to interpretation and indicated the advantages of ES in the holistic understanding of environment. Ideally, the concept need to be mainstreamed into planning system so as to support practical improvements in reality. However, one of the most mentioned challenges is that there is no ready-made tool for the in-depth integration of the concept into the already mature system of planning, management and decision-making, which has been traditionally centered on land use and land cover pattern or strongly sector-oriented (De Groot, Alkemade et al. 2010).

Policy assessment provides with an alternative way of understanding the relationship between ES concept and planning. In fact, concept of ecosystem or landscape services and functions are upgraded rather than brand-new idea in the history of urban planning. Reflection on the relationship in socio-natural system has always been a non-negligible voice across the whole 20th century and reached its peak since 1960s. Many sub-topics, though not organized as a system, have been long adopted into the planning strategies. Instead of adding ES into planning, Wilkinson et al. first used an inverse way to examine in what ways an ES approach has been addressed in past strategic spatial planning (Wilkinson, Saarne et al. 2013). Using a designed coding protocol, 39 ES based on MA 2005 and related literatures were examined on how they were considered in eight planning documents of Stockholm and Melbourne dated back from 1930s to 2010s. Though only water purification and recreation were constantly targeted in the documents, two third of the ES has been mentioned at least once. The term ecosystem services were specifically used in most recent planning, as a response to the high attention on the topic. Nevertheless, the way ES appears functions more like go with the tide and critical questions like land use related trade-offs and equity have not been clearly defined.

Similar approach was used in some other cities includes Berlin, New York and Seattle, which have always been in the front line of urban open space planning. 14 out of the 21 selected ES (based on TEEB category) were identified in three depths as acknowledged, indirectly elaborated or elaborated in more than half of all planning documents (Hansen, Frantzeskaki et al. 2015). Habitats for species and recreation services have been paid top attention in most cases, followed by other cultural services and most of the regulating services. In general, many individual ES have been formal targets brought by many past ecological moves, like the core role of biodiversity promoted by European Union, or the urban stormwater management emphasized by EPA. As a result, planning documents gradually formed its own means of expression and practical implementation. From this perspective, the practices may also have certain advantages to complement the concept. In fact, cities like Berlin already go further to describe the dependency of human to urban nature, which is beyond the mere obtain of named services. This wide application of ES in different urban contexts already indicates a new ecological approach to urban planning.

The assessment of ES application in planning documents highlight the further mainstream possibility of the concept. With the current wide adoption of individual ES, it is promising that the concept merge into current system and helps in the plan structuring as a platform that could address common interests from different background. Furthermore, independent in-depth ES study could also be a supplement to existing plans. Nation level policy, as well as the historical open space strategies, has great influence on promoting the related ES. But more challenges may lie in further implementation and management. Limited financial capacity and priority, lack of experts and professionals, as well as the inadequate communication efficiency between actors are all potential obstacles (Kabisch 2015).

Another significant qualitative approach focus on the cognition and reaction of the concept among related stakeholders. Sociology research methodology are greatly applied under the topic, with interview, questionnaire and field investigation the most used method in data collection. Most cultural services are specially favoured in this approach, as they are always neglect or oversimplified in quantitative ecological studies, while are traditionally among the topics of urban sociology. Some provisioning services and land use related services are also frequently discussed with qualitative approach, since these services are built above the long-time living experiences that the public has the power of discourse.

Qualitative approaches could provide interpretation and abundant structural context, as an assist of the existing quantitative results, or even fundamental base for policy making in complex and data-poor urban environments. For instance, low-income residents tend to choose non- or indirect-use cultural services, which is not included in current plan (Vollmer, Prescott et al. 2015); land tenures in fact have stronger influence on land use preference than protected area designation (Hausner, Brown et al. 2015). Alongside with these supplement to the blind area in practice, the perspective from practitioners may also be optimistic. Many ES related environmental knowledge has been a common sense for planners in Germany, especially the ones related with biodiversity; many individual ES suit in project-oriented planning though the concrete implementation may need some further push and approval from higher level (Albert, Hauck et al. 2014). These studies demonstrate a both rough and promising nature of the application of this scientifically great concept, and in return, provide with direction and chances of improvement.

However, qualitative methods do need longer time and more manpower in data collecting, could be longer in data analysing. A regular semi-structure interview alone takes approximately one hour, but the preparation, transcription and coding process need days or weeks. Another difficulty lies in the objectiveness and reliability of the results and the root cause is the intangibility of cultural services themselves. Human perspectives are naturally heterogeneous even in same local area and the identification of the inner connection be ES value perceive and physical landscape characteristics would help to most effectively transfer the value to similar situations. Furthermore, more modern

data collecting methods have been developed to a mature level so as to be widely adopted, like the Public Participatory GIS (PPGIS) applied in multiple cases (Brown, Helene Hausner et al. 2015). In a word, qualitative approaches show its unique advantage in human related perspective, as well as in complementing and maximizing quantitative results.

In fact, some studies pointed out that not all functions have to be either synergy or trade-offs with each other. More frequently, there exist a middle status that some functions or services could simply co-exist without interactions, or under certain conditions some functions tend to appear simultaneously, which is called as a "bundle" (Raudsepp-Hearne, Peterson et al. 2010, Turner, Odgaard et al. 2014). However, the identification of such relationships require a great amount of samples in regional scale, while not much empirical studies have been done on local scale with mature analyzing method.

3.4 Summary

Multifunctionality is used in green space when multiple functions/services/values are presented. Among the three reviewed concepts, the Ecosystem Services concept received general high acceptance for its unified and standardized classification, reflected by the booming quantity of related studies. Though the full package of this system is seldom used, its basic four categories are approved and the terms of function/services have a trend of adopting the settings or complement the system by adding few others. And these categories, from the perspective of open space planning, indeed present a simplified, united and relatively complete way of summarization to include the majority of past discussion topics. The researches on the relationships between functions, the synergies and trade-offs, are comparatively not enough. But the increasing discussions on bundles and services providing units could be an alternative approach to identify the complex interactions. In a word, Ecosystem Services has the potential to be the core concept in the studies of social-ecological system (Niemelä 2014).

However, the unification in categories has not been achieved in assessment approaches. Evaluations of cultural services tend to choose qualitative methods, while for the other types are the quantitative indicators widely used. Besides, indicators/proxies for state or performance are constantly mix used, and the attentions on demands and capacity is unbalanced. Furthermore, the future-oriented and state-oriented studies have few communications. These segregations in studies between different backgrounds are the current barriers of its further application in planning.

Multiple studies have devoted to explore the application in planning system. The land use based approach shorten the distance between abstract services and physical land in urban areas; the use of administrative boundaries provide possibility on further human-social analysis; multi-criteria approach intends to minimize the objective and subjective errors led by different data sources; and

the coding of planning documents is a bridge between the two language systems. Nevertheless, the gaps between practice and concept are still large. The focus on landscape scale partly solve the demand of unification in approach at the cost of weaken the role of cultural services and interactions among functions, as well as the oversimplification on weight among functions. There are too many limitations starting with the data sources, few options are available for studies using secondary data, not to mention a set of constant statistics for every indicator throughout years. The static mapping result of regional behaviour is not a sufficient assessment for urban planners or policy maker.

Obstacles and opportunities lies together in the integration of contemporary concepts with urban open space planning, management and decision-making, because the final aim is the actual transformation of everyday open spaces which are most influenced by planning tools. Merging and combining the advantages in various approaches, scaling down and localizing with the specific context, balancing and weighting between functions and tracking dynamic interventions and reactions are foreseeable research focus to fill the gaps.

Chapter IV. The Construction of an Analytical Framework

The aim of this chapter is to built an analytical framework as well as a specific andfeasible research methodology to use multifunctionality for the holistic interpretation of urban green space. Section 4.1 points out the current gap in using different approaches in the evaluation of functions and services, that not enough attention has been paid on the land use which is the center of current theoretical structure and links directly with urban planning; moreover, the interlinks between different scales and planning processes are often ignored which lead to the fragmentation of evaluation results that cannot be easily applied for planning analyses; Thus a theoretical framework is built on trying to built a bridge over this gap. Section 4.2 illustrates a detailed methodology in applying of the conceptual framework and further listed the needed research methods for data collection and analysis in the specific case study.

4.1 Conceptual Framework

4.1.1 Locating the gap

Multifunctionality has been a vital term for our living environment in multiple scales. It has a long history in multiple related fields and got its revival in past decade for several reasons. First is the strong representativeness of multifunctionality within Green Infrastructure concept, especially in the context of urban planning, multifunctionality illustrates the imagination of a well-balanced mutual-beneficial open space system for both human well-being and ecosystem integrity. Second, the multi-dimensional interpretations of multifunctionality as a common root. From an ecological perspective, the term is a merited feather of any healthy natural ecosystems; when it is used more often as an anthropocentric term, it in fact refers to the extend of efficiency for human-involved system to imitate healthy natural system. The differences of multifunctionality in three scales (see 2.4.2) are actually about responding to three extend of human intervention. Last but not least, multifunctionality has the potential to be a public platform for multiple disciplines, especially structured by the widely accepted concept Ecosystem Services. These qualifications allow multifunctionality to be a promising analytical framework for urban green space interpretation, instead of being just an adjective.

There is no final perfect state of multifunctionality, but it is rather a direction which keeps fine adjustments according to the changing demands. Multifunctionality at city level is the core of three scales, that it directly deals with conflicts of interests, land use planning and policy making. It is formed in a great part by regional structure, and interacted with local practices. From a practical perspective, urban level multifunctionality could be simplified as the magnitude and quality of

presented functions/services, as well as the spatial and temporal dynamic; local level need to focus on the specific performance of and interactions between involved functions/services, as well as how local level situation affects the efficiency of urban level. Nevertheless, few researches have been found on the exploration of integrated approaches for the such assessment of multifunctionality in urban green space. With the limited studies that covers a wider range of functions/services, it mostly deals either with mapping the status quo of services provided by certain combination of land use / land cover; or with identifying services from past planning. It is still not clear, as descript in the research question of the dissertation, how is the multifunctionality of green space affected/ formed/ changed by planning practices?

Based on the Millennium Ecosystem Assessment (MA 2005) and later works like The Economic of Ecosystems and Biodiversity (TEEB 2010) and others (De Groot, Alkemade et al. 2010, Burkhard, Kroll et al. 2012), frameworks to link and demonstrate relationships between human society, policy decision and biophysical entities have been developed and improved. The famous Cascade Model (Haines-Young and Potschin 2010) provides for most of the current comprehensive framework with the fundamental relationship chain, that ecosystem structures and processes are presented as ecosystem functions; within these functions, the ones that could sustain human well-being are named ecosystem services and the ones have negative effects called disservices; services lead to benefit which is defined from the human perspective, with the social percept parts known as ecosystem value. Land use/ land cover and planning / policy-making were identified as being vital for a framework of ecosystem services (De Groot, Alkemade et al. 2010) and began to find its location in the center only in recent studies (Van Oudenhoven, Petz et al. 2012). Anthropocentric value presented as demand on related spatial planning strategy and related policy, which have direct and strong influences on the change of land use / land cover and ecosystem integrity. Land use / land cover changes as a reflection of human value, will furtherly influence the delivery of ecosystem services. With potential other factors, these objects that covers three systems structured a inter-related loop (Fig 4.1.1), which could includes the majority of related studies.

This framework also indicates the methodologies underpinned, which normally divided as the grey shadows shown. The left part centered with ecosystem structures, processes and functions, and deals with mainly three interactions. Its research approaches rooted in ecological principles and are carried mostly within the field of natural science and by ecologists. In contrast, the right part is closely related with social science and rely a lot on sociological methods. Human perception, social cognition, identity formation and so on are the study focus, while ecosystem services could be served as a way to reach the deeper core. Studies within either these fields are numerous and methods are basically mature. The accumulation of more empirical studies, among other methodological gaps, is a critical direction to expand existing knowledge range, especially in social perception.

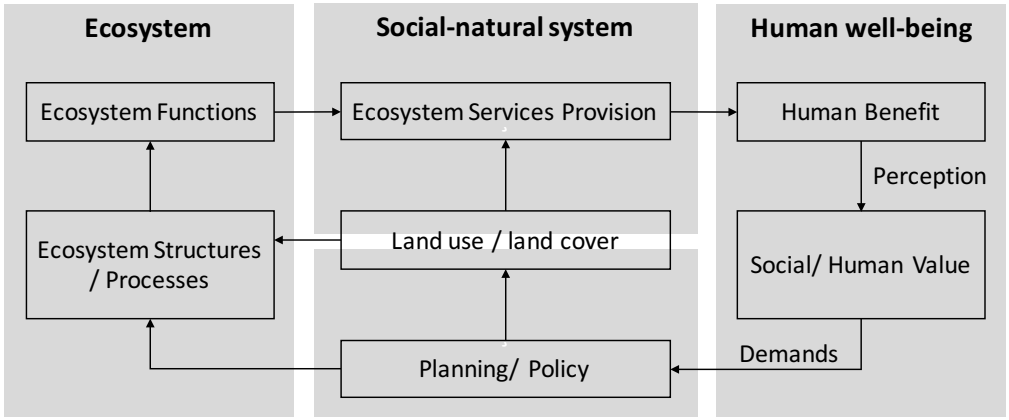


Fig 4.1. 1 Conceptual framework linking land use/ land cover, ecosystem properties and functions, human benefit and value. Drawn by author and based on (De Groot, Alkemade et al. 2010, Haines-Young and Potschin 2010, Burkhard, Kroll et al. 2012).

There is no surprise that the middle field has been a "hotchpotch". No simple scientific foundation can be directly applied here, so as in the history of open space planning. In order to go deeper, studies in this range further divided into smaller patches which may follow either the left approach or the right, or sometimes take the advantages from both (see section 3.3). Many heterogeneous questions are being discussed, for instance, how many services can be provided within certain range; how certain services always show as bundles; how services provisions changes with land use or social gradient; how much compromises could residents make for certain services; how do residents understand the value of ecosystems and so on. However, relationship between the dynamic of ecosystem services and open space planning practices, more importantly within urban areas, is still a field with few discussions and rare empirical studies. It is where the research question directed, which is to trace the comprehensive "effects" of planning practices from the perspective of green space multifunctionality. It's not only about trends of open space performance but what has lead to the a better or worse situation.

4.1.2 Conceptual framework and components

Following the common accepted former works, as illustrated in Fig 4.1.1, a conceptual framework for the analysis of this dissertation was built (Fig 4.1.2). This framework goes further within the middle part of Fig 4.1.1, the "social-natural system", and based from the perspective of planning processes. In the former framework, the course from planning/policy to land use/ land cover and then to the supply of ecosystem services seems simple and direct. However, it is not what usually happens in reality. Even ignoring how all kinds of contradictory demands and requirements from diverse stakeholders have to go under selection and compromise, it is still a long way from a fixed plan until the provision situation of services, both amount and quality, finally changed. The actual necessary process would at least include three phases: planning, implementation/ management, and actual changes in land use and land cover which will reflect as the transformation

of ecosystem services status. To make it more complicated, this process lasts a long time and effects multiple level. Here only two scales are focused.

1) Urban level

Urban is a general term refers to built-up and populated areas. Here by urban scale emphasis its spatial extent in which the planning and management of open space system is made on an official platform (Willemen, Veldkamp et al. 2012). It would mostly be a city or municipality or some similar area under similar administration, at which level the decisions of human intervention on natural and semi-natural lands would be balanced outcomes of social demands and ecological needs. It is a practical level since it normally would possess its own database and context, from socio-economic statistical data, land use and land cover change, to historical and cultural traditions.

Changes of the distribution of ecosystem services forms an open loop as shown in the upper left shade in Fig 4.1.2. Starting with the Ecosystem Services (ES) provision Scenario 01, its shortages would be a part of the demands, which is a critical background for the developing strategy of urban open space in a certain time range, normally one or several decades. The target and priority of each related ES would be first implied in this plan, then concretized, detailed and probably more or less altered in a series of specific implementations, after that maintained by everyday management, and finally present as the changes on land use / land cover which is the matrix providing services. This provision of ES, the Scenario 02, response to the initial demands after a considerable long time when new demands may come up and begin the new loop.

On this level, the multifunctionality of green space could be better conceived as the "**stock**" of all ES, including their effective amount and quality. The changing of the multifunctionality stock is a dynamic process follows the pattern of human intervention, and sometimes the natural disasters. This dynamic thus records the results of related planning practices from a socio-natural perspective.

2) Local level

ES as defined are services benefit for human well-being. Though different services have diverse range of response scale, local level relates to the specific location at which the majority of services are supplied (Willemen, Veldkamp et al. 2012). For instance, most cultural services matter the most at local level where human perception and interactions can be captured, and this type of services could be conveyed through smaller patches like trees, gardens and parks; temperature regulation of green space could formulate a regional scale or urban scale effect, while its function may differ at local level based on idiographic settings and context (Andersson, McPhearson et al. 2015). Same services at different levels would lead to distinguished study focus.

Local level follows a similar path, just simultaneously or successively on multiple smaller and separated locations. Each location has its own initial former scenario and latter one, which is effected by the specific project. These projects or action plans are the further materialization of urban level implementation, adding with localized demands and adjusting according to local situation. Likewise, the stock of green space multifunctionality dynamic with the patter of these actions. Distinction is local level stock includes also the interactions between ES and more information of certain services like the cultural ones.

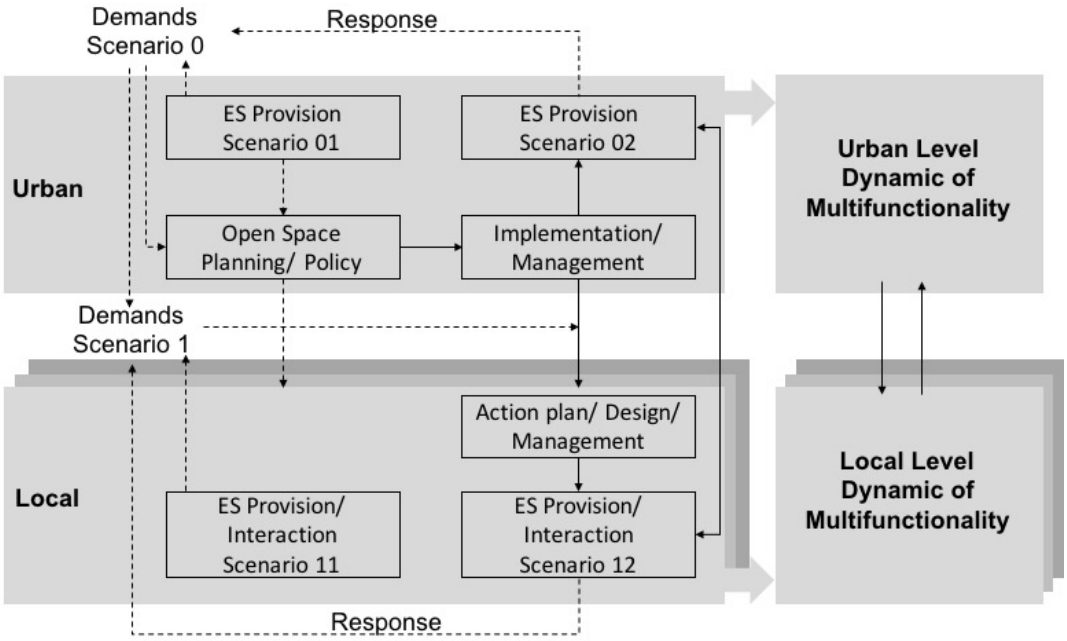


Fig 4.1. 2 An conceptual framework of relationships between the planning processes and ecosystem services provisions and their interaction between urban and local level, by author. From a simplified perspective, the demands on urban green space will influence the targets set by planning polices; these plans turn into implementation and lead to changes of green space functions, the changes will response to the demands and start another loop. This dynamic process and the co-exist functions presented all together forms the multifunctionality at urban level. Similarly, on local level, specific plan/design and management are made under the complex influence from above master plan as well as local conditions. This plan will also affect the performance of both the functions and the interactions. The dynamic performance makes the multifunctionality at local level. And the combination of both level forms the multifunctionality in urban green space, which represent a holistic status describes the quality, distribution and potential interactions between multiple functions.

Generally, urban level dynamic of multifunctionality is more or less an estimation, its core function is the comprehensive status which may support related planning making. Absolute accuracy is not possible, and not necessary either. However, with sufficient data, time and manpower, each local level dynamic of multifunctionality may be detailed captured, but not a probable choice for every patch of space. Urban level stock provides a basic matrix for the generating of local stock; local stock has a more intricate content and could serve as the revising source for upper level, or an anchor into deeper comprehension. In either way, these two levels have strong inter-connection.

Through analysing the key boxes in the framework, which each is a record of status in the dynamic system, critical nodes of multifunctionality stock would be portrayed, which helps to illustrate the causality between multifunctionality dynamic and planning practices.

4.2 Methodological Approach

4.2.1 Research methodology

The essential problem lies in how to transform the data to a comparable and direct readable form. To be more specific, in the urban level, in order to connect the dynamic of multifunctionality with planning practice, there are three steps: first is to describe the initial past status; second is to summarize the human intervention, the planning practices, under the same structure; third is to describe the final status of this time period. The results of the three steps need to be in the same framework with relatively close elaborate degree, meanwhile, a mapped result is necessary to illustrate direct changes. However, the aims determined that the absolute accuracy of data is not in top priority but it is acceptable with secondary data or value transferred data.

The proposed approach used a combined methodology in both data collection and analysis. There has been a lots of examples exploring possibility of ES assessment methods and this approach takes a relatively flexible attitude in combining them, with the principle of data availability and results comparability. Nevertheless, two approaches were constructed to deal with the two situation: plan-based or reality-based. These two approaches are structurally similar but distinguished in core data analysing methods.

1) Plan-based approach

In urban level, the second and third phases of the process is not yet fully real, but rather the anticipation of changes which is carried by related plans and policy. The fundamental problem is the “translation” from text description and land use planning, to a spatial distribution of functions. This plan-based approach contains three steps as shown in Fig 4.2.1.

Step 1: Preparation

The full pack of ES, according to reports and studies, contain 25-30 services which may not applicable to all context, and their occurrence frequency is not the same. Normally if more than ten of these services exists in one study, it is already quite comprehensive (see chapter 2). In this way, a selection of targeted ES is necessary, as it directly affect the complexity of later work. ES need to be selected based on the conditions and limitation of chosen case, importance in the context and also the reference from other studies. Related planning and land use data of the case also need to be searched.

Step 2: Document interpretation

Qualitative coding method is the fundamental one used in the second step to analyzing and categorizing textual data according to the meaning of selected services. The referring of services in planning documents need to be ordered into four group, elaborated use, indirectly used, with potential correlation or not mentioned. The priority of ES could be either based on documents or through other approach like expert interview. In this way, how multifunctionality is planned would be extracted and summarized as diagram.

Step 3: Spatial projection

Furthermore, based on the correlation between services and planned land use type, as well as the strength or weight of each service, a preliminary spatial distribution of planned multifunctionality and be projected. It is not an accurate mapping but rather used to illustrate hotspots and ignored points of the plan, in order to make this non-reality based process on similar expression with others.

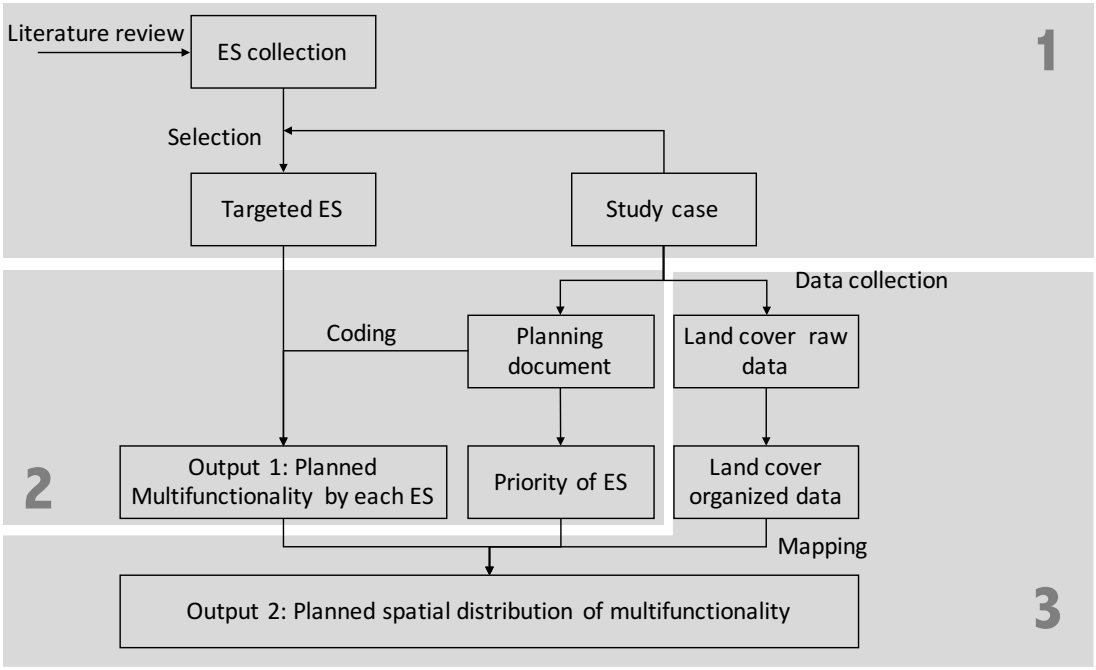


Fig 4.2. 1 The plan-based approach, by author.

2) The Reality-based approach

There are similarly three steps contained. The first step is basically the same and the selected ES need to keep insistent among all (Fig 4.2.2).

Step 2: Standardized distribution of individual ES

In reality-based approach, some ES have the potential to be quantified, or at least use equivalent data. Multiple studies have tried on a range of indicators as intermedium for the quantification and services can be divided into two types according to the characteristic of required data. The left group refers to services with "complete delineation" (Willemen, Verburg et al. 2008) whose indicator data could be directly connected with land cover or based on certain regulations. Food, raw material, drinking water provision and cultural services belongs to this type. However, most regulating services are not so directly connected with one type of land cover. Statistic data related normally is monitored and collected on larger levels. In this case, equivalent data need to be found as a replacement. It could either through value transfer or expert-based valuation. Since different methods naturally have different errors, it is vital to keep one method within one service. The results of individual service need to be normalized before being compared or mapped respectively.

Step 3: Revising and overlapping

The results of step 2 show the relationship between individual service and certain type of land use. Even if some data may come from local statistics, it is still common that this relationship may be quite universal. This step tries to use "add-on" information contained by local land use and land management to revise this problem. In specialized planning and regulations, extra data can be extracted. For example, conservation area refers to higher level protection of "habitats for species" and human facilities like roads and benches lead to higher potential of aesthetic appreciation and recreation. Also there is potential disadvantages in some circumstances, like the fragmentation of roads lower the "maintenance of genetic diversity" and bring with higher pollution. The overlapping of these information, transformed as positive or negative changes in percentage, give the universal result a tailored revising.

The interactions especially the synergies among services at local level will mostly investigate through qualitative methods and present in narrative ways. Other parts of the local level could follow same but simpler approaches as descripted above.

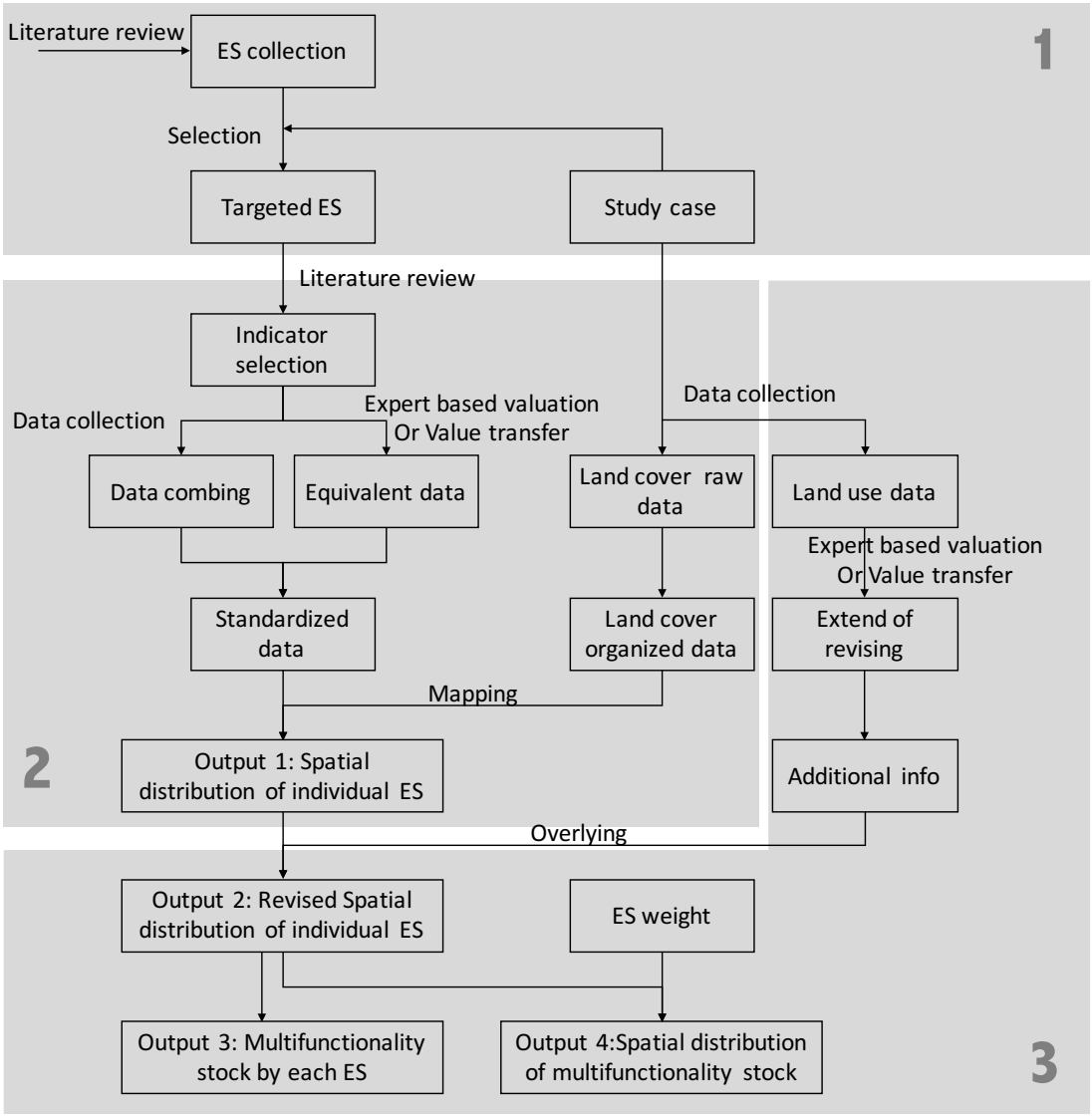


Fig 4.2. 2 The Reality-based approach

4.2.3 Data collection and analysis methods

Literature review

Literature study codified common sense, a refinement of ways that might be used to describe and explain aspects of related research. It is particularly valuable as means of gathering comprehensive evidence on a particular question. It provides a key source of evidence-based information to support and develop practices. In this study, the review of literatures helps to trace the complex development of multifunctionality as well as its different emphasis within the diverse concepts which are the base of the conceptual framework.

Moreover, literature study is also applied in the Reality-based approach as a pre-study of the expert-based evaluation on land cover and land use. In order to get better communication and more substantial information, the land use evaluation matrix is first prepared according to the results from other similar studies, especially that in European and Germany where the geographical conditions are similar with that in the studies area. In this case, experts don't need to evaluate from nothing, but based on an average results of others which could greatly increase the accuracy. Similar step is done for the coding of planning documents, which have taken references from former researches for the coding protocol.

GIS method

Geographic Information System (GIS) technologies are computer tools for analyzing landscape by collecting, storing, retrieving, transforming and displaying spatial data. It can quickly access a large amount of data to link different datasets and analysis their relationships and connections. GIS mapping is often necessary to establish the distribution and coincidence of resources to demonstrate functions of green open space. It has been widely applied in related studies especially in the quantitative evaluation of multiple ecosystem services distribution.

In this study, GIS method plays a vital role in the semi-quantitative approach of the mapping of services and functions in the study area on urban level. The analyses are carried based on the detailed local land use and land cover data, the 4th version Biotope Type Map made by the project group of the Senckenberg Research Institute, which provides with detailed land use and land cover information, as well as the usage status in certain type. The basic expert evaluation results can be then added in the information system for further spatial analyzing. The additional information from other sources are also re-edit to combine with this dataset for the revising of spatial distribution.

Interview

Expert interview as a research method typically involves the researcher asking questions and hopefully receiving answers from selected participants. The interview denotes an unstructured or semi-structured approach. In an interview, the person interviewed is altered much more flexibility of response. The interviewees may provide highly relevant and insightful comments during the process. Also, interviewers can depart significantly from their schedule or guide. They might ask new questions that follow up interviewee's replies and can vary the order and even the wording of questions.

In this study, expert interview is used first of all as an approach to get into the background of the case since the author is not native. It is not the main information source for the study, but rather

a guidance to further documentation and a direct way to understand the back stories behind formal records. Also due to the limitation of time and conditions, interviews are taken in a selective and extensive way and using the semi-structured approach. For all the interviews (Appendix 4.1), normally three parts are taken in sequences: first, a brief introduction of the main study aims and interview purpose by the author, including necessary illustrations of pre-studies; second, prepared questions to the interviewee due to their expertise or professional experiences; third, further extended questions due to the answers in the second part. These interviews help to get access to the core documents of the case study, especially the GIS dataset and internal reports of the study area; moreover, through institutional structure is not the center of the study, the explanation of experiencers help to understand the real problems in actual practice.

For some of the experts, an additional part is taken into interview, which involves the discussion with the experts on how each land use type would typically performs for each ecosystem function; as well as how each function is relevant for the district (section 5.2.1).

In this study, expert interview is used in both semi-quantitative and qualitative approaches. The former one is structural interviews involves the discussion with experts on how each land use type would typically performs for each function or services; the latter one is more complex and is taken in a semi-structure way. The interviewees based on their working focuses are being asked from the general development stories to the specific local problems. Due to research limitation, this method is not used as the main information source but the assisting part to compare with the table analyses.

Chapter V. Multifunctionality of Greenbelt on Urban Scale

This chapter studies Multifunctionality of urban green space at the urban level and is mainly focused on the discussions of its functions and services. Using the Greenbelt Frankfurt as the case study, the core question of the chapter is how does multifunctionality, as a set of functions, is being considered in the related planning and later translated into practive, as well as how these two stages relate and affect one another. The following four sections are used to illustrate the question: the first section explains reasons of choosing the Greenbelt in Frankfurt am Main, as well as the related background of the city and the Greenbelt; the second section discusses and selects Ecosystem Services with relevance of the Greenbelt, and clarifies the data used for analysis; the third section uses semi-quantitative method to map the distribution of each relevant Ecosystem Service and the general performance of the entire Greenbelt in 2010, and conducts preliminary comparison to identify the changes within Greenbelt from 1991 to 2010; the forth section uses qualitative method to interpret the Greenbelt plans as to how relevant Ecosystem Services were considered in planning practice. Finally, a conclusion is made to highlight the characteristics of the multifunctionality in Greenbelt, as well as the main contradictions between the planning efforts and reality of Greenbelt.

5.1 Introduction of Studied Case

5.1.1 Criteria and limitations of the studied case

The case study chooses the Greenbelt of Frankfurt am Main, Germany, for three main considerations. First is the complete and maturity of the case, that after the provision of different functions by original designs, multifunctionality of urban green open space needs to be tested by users and to sublimate from a green “space” to a green “place” with time (Coleman 2014). Also, every fresh plans of urban landscapes have their uniqueness and purposes, but the ones lasted have stronger proofs deeply rooted in the particular contexts. In this way, the “age” range of the case was set to be older than one decade, which allows the natural and artificial alternation.

Second, the scale range was set from medium to large city with relatively complete economic structure. Modern city is a complex collaborative system consist of multiple components, with environmental issues only one aspect of the question. Small or tourism-relied cities, though may have outstanding urban green spaces, are not replicable to most cases due to differences in natural resources and priority of green policy. Contrarily, best practices of urban green space in larger cities would reveal improvement after balanced consideration and in limited conditions.

Last but not least is the availability of key documents, which is the decision problem. The potential cases included two Chinese and two German cities at the beginning. However, the first Chinese case, Shenzhen, has a city history of only 20 years and still in-built green network which is not suitable for expected analysis; the other Chinese case Tianjin was eliminated due to the unattainable land use data (most such data is closed to the public). Frankfurt am Main is in this way most suitable for purpose, and the Greenbelt is further defined as the study objective for its clear physical range, independent working group and relatively intact documentation.

However, one limitation is unavoidable, that the cultural context of the case could be a little distant for foreigners. Three measures are made to minimize the disadvantage: firstly, the main part of the analysing process rely on objective data like land use map and local plans acquired from official sources; then expert interview was used as supplement materials for results analysis; furthermore, field research was taken but used as reference and correction of map data. The purpose of the case study is the application of the methodology for future revise and studies. Moreover, a such international perspective could also have its advantage as a new lens of local problems.

5.1.2 Case description

5.1.2.1 Frankfurt am Main

Frankfurt am Main (Frankfurt for short) lies along the Main river in the western part of Germany (Fig 5.1.1), the fifth largest city in Germany by population. The city administrative boundary of Frankfurt am Main contains 724,486 inhabitants and covers 248.3 km2 area (Statistik 2016). It lies in the north end of the Upper Rhine Plain, one of the warmest region in Germany. There is no large mountain in Frankfurt and the highest point is 212m in the northeast. Generally, Frankfurt has a quite mild climate but also threatened by global climate change. In 2015, the precipitation is 430.8 mm and the annual average temperature reached 11.6 °C, almost one degree more than that in the past two decade.

Frankfurt is not the capital city of Hessen State, but the largest and the actual core city of FrankfurtRheinMain metropolitan region which has more than 5.5 million people and extend an area of 14,800 km2 (Statistik 2016). The city has set its core standing as an international financial centre, “the European Manhattan”, not only with its impressive skyline, but more with its strong economic competitiveness. 201 credit institutions and headquarters centred here with approximately 75,000 employees of financial and insurance activities. Besides, about 11% of the work are from production industries. The high opportunities attract the people from whole region, that about 64.7% are commuters. Consequently, Frankfurt has the highest population growth rate in State of Hessen (FrankfurtRheinMain 2013), with the accompanying problem of increasing housing shortage in this dense city.

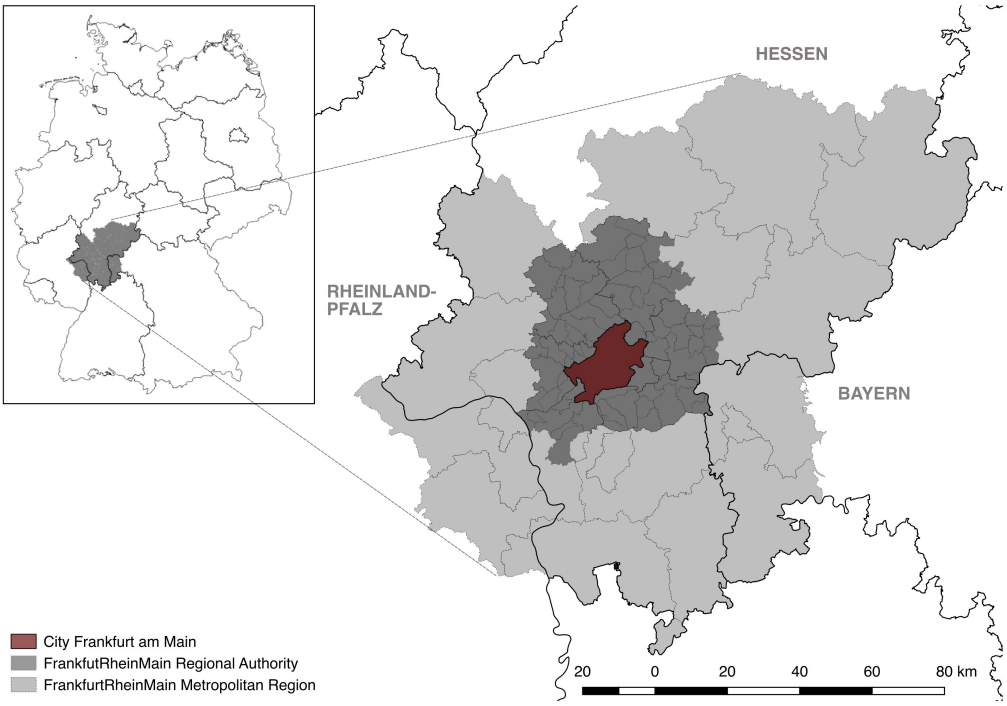


Fig 5.1. 1 The location of FrankfurtRheinMain Metropolitan Region and City Frankfurt am Main, made by author.

The geographical location also makes Frankfurt for a vital transportation hub of European countries from several aspects. It contains the one of the largest airports in the world; its central train station as a pivot point serves the European wide train lines; it has one of the most used highway cloverleaf junction, as well as the biggest public transportation network of Europe (FrankfurtRheinMain 2013). Altogether 20.9% of the urban land was used for traffic purpose (Statistik 2016). This multidimensional transportation system helps sustain the large commuter group and the economic structure. Likewise, it sharpens the environmental problems like loud noise and pollution from motor vehicle.

However, Frankfurt has another side beneath this well-known modern cosmopolitan image, that it is from many aspects a quite green city. 52% of the total city area are set aside as green and open spaces like urban forest, parks, farmland, orchard meadows, grassland, allotments and hobby gardens (Fig 5.1.2). Moreover, Frankfurt was shortlisted as finalists in the 2014 competition cycle of European Green Capital. It was rewarded as European City of Trees in 2014 for its over 200,000 implemented city trees. Nevertheless, more than 500,000m^2 green spaces are added to the existing 40 parks in the past five years, within the limited money which taken up less than 5% of the total budget (Frankfurt Green City).

Despite all the "green data" and governmental efforts, the image of "a city with many parks and green spaces" is not the main perception of Frankfurters, but rather "banks and trading centres",

"international city" and "transportation hub", which were agreed by more than three forth of the interviewee. Comparatively, Leipzig which has similar open space rate was most labelled as "green city" (Projektbüro 2010). Furthermore, the general degree of satisfaction for urban green open space in Frankfurt is much less than Munich, which has only half of the open space per capita as in Frankfurt. In this way, Frankfurt is not so "green" a city as it seems to be.

To sum up, Frankfurt is a big city with strong economic attractiveness, moderate climate and geographical conditions, as well as willingness of being "green". It's not the "best practice" in urban environmental development, but rather a typical example of many less famous cities which straggled between multiple targets in everyday life. After all, environmental consideration is for most cities less prioritized. Conflicts between green open space and housing, pollution from heavy transportation, limited available land and budget are all common problems after green concepts meet with reality. From this sense, Frankfurt makes an interesting place for its potential representativeness, especially in the Greenbelt which covers the majority of its urban open space and has been developed for 25 years with ups and downs.

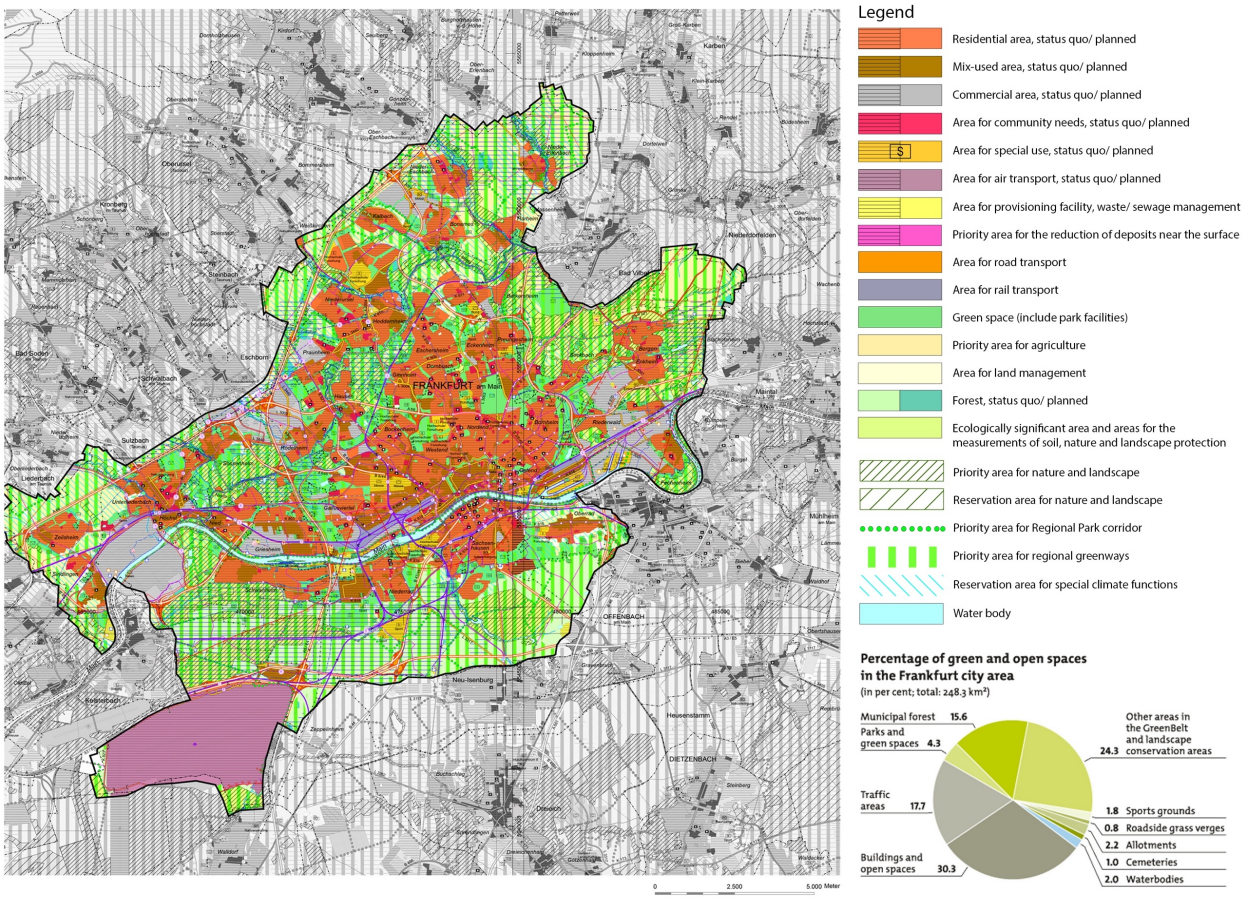


Fig 5.1. 2 The land use of Frankfurt (above, redraw and translate by author based on the Regional Land Use Map of FrankfurtRheinMain Verband 2010) and percentage of green and open spaces(right below, from Umweltamt 2009)

5.1.2.2 The Greenbelt

1） General description

The Frankfurt Greenbelt (GrünGürtel) is an 8000-hectare 70km-long strip around Frankfurt city and accounts for one third of the city area (Fig 5.1.3). The Greenbelt was founded by Frankfurt City Council in 1991 with a special law, the Greenbelt Charter (GrünGürtel Charte 1991), to protect the whole area from future construction. Soon after the founding of the belt, the entire area was included into the landscape protection zones (Landschaftsschutzgebiete). Together with this two protection laws and measurements, there is no land loss in the past 25 years despite the growing demand of housing and great shortage of land for construction in Frankfurt.

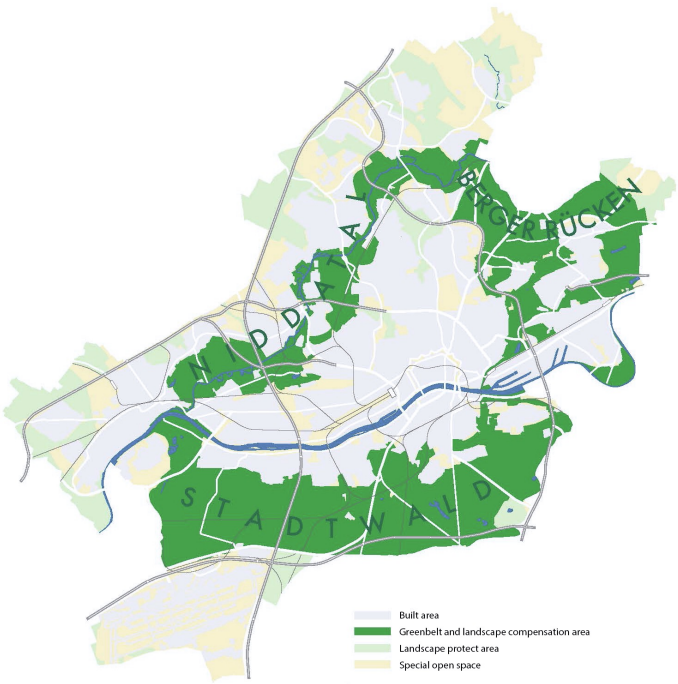


Fig 5.1. 3 The location of Greenbelt Frankfurt, from Umweltamt 2011.

It is not a typical “Greenbelt” as in the Britain context, but a combination of many popular contemporaneous green concepts like greenbelt, greenway, public parks and wild parks, as well as a long-term landscape development plan for the metropolitan area. Now it is an exhibition of local landscapes, like farmlands, vineyard, orchard meadow, streams and ponds, parks with histories and vast forest. It also serves for the biodiversity of fauna and flora, inherit traditional planted herbs, helps sustain the drinking water sources and provide opportunities for the nature education of the youth, as well as providing playground and leisure facilities to the public. It is from many aspects a successful case and was awarded by the United Nation as a positive example of sustainable urban development in 1996.

The Greenbelt is not as “intact” as it sounds to be. At the beginning, it was a C-shape strip with the east part near the Main river bank occupied by industries; this breaking point only closed since 2012. Furthermore, there are many “holes” in the plan, most of which are private residential areas, nevertheless, most agricultural land is also private owned. The tortuous and complicated boundary line indicates the forming of this Greenbelt is not fully planned ahead of time but rather use the “left land” after a certain degree of urban expansion. In order to deliver the perception of a Greenbelt full of natural beauty and leisure value for every citizen, despite its imperfect shape, a large proportion of the work were about publicity. Comparatively, land use change inside the boundary was quite incremental and small-scaled. Most of the land remains it main use type with certain adding of new meanings or components.

The Greenbelt and shaped the fundamental structure of the open space in Frankfurt, and functions as a vital buffer zone for the region. In fact, this Greenbelt is the third open space belt of Frankfurt. The first green belt, the Wallanlagen, is a continuous C-shape open space built on the location of the old city wall which was tore down in 1910. The second green belt was a wide boulevard which gradually taken by urban construction. This third belt as a real Greenbelt, not only fulfilled the green structure of the city, but also serves as the end point of ecological corridors that stretched across the Rhine/Main region and connected with the regional park (Fig 5.1.4). With the improving of paths and roads in between, Frankfurt Greenbelt also becoming a destination of the whole region. The significance of this ring of open space also rises from a single potential ecological hub to a critical part of the whole regional ecological network.

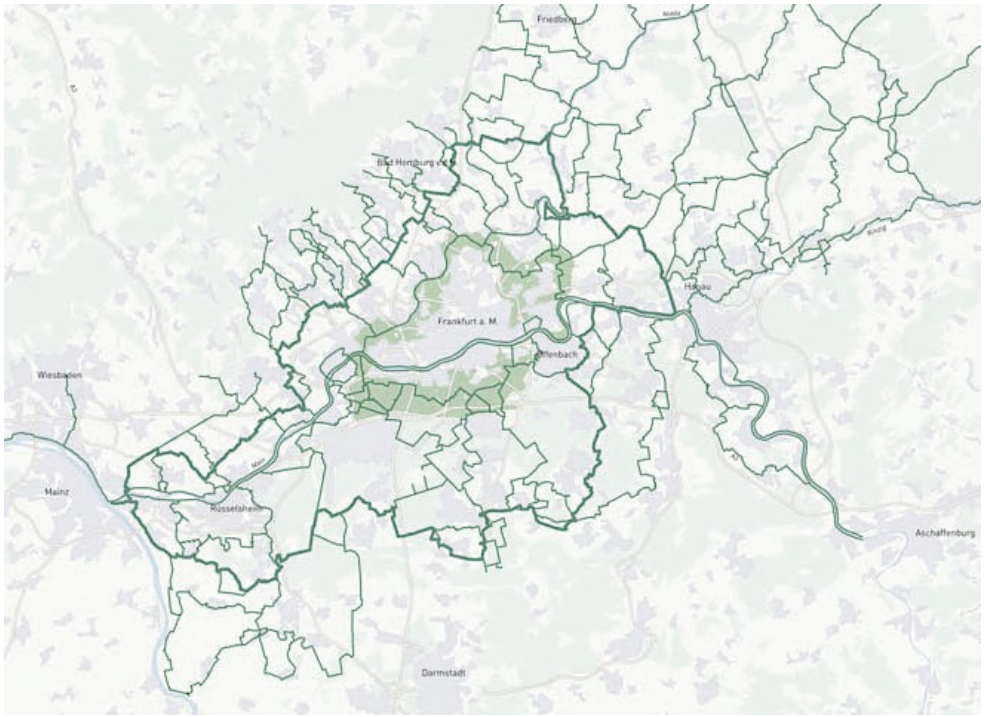


Fig 5.1. 4 The green network of Regional Park RheinMain centred with Greenbelt, from Umweltamt 2011.

2) Developing history of Greenbelt Frankfurt

The Greenbelt didn't exist in reality until 1991, while the concept had been developing by several predecessors since decades ago. The developing history could be divided into five critical stages, each of which had its outstanding leader. From this sense, the Greenbelt was built firstly thanks to these people.

Stage I: Sprouting of early concept (since 1920s)

Among all place in Greenbelt, the urban forest (Stadtwald) in south of the city is the oldest. It covers about 14% of the urban land and was bought by city Frankfurt in 1372, when Frankfurt was much smaller a city than it is today. It is still the biggest urban forest in Germany and it set tones for the later urban open space development in a certain way, that such a vast area of pure historical green space is owned by the city.

Two other actions had made more direct impacts on forming the concept of green belt open space, the first and second Greenbelt. The former Frankfurt city, which is now the area of inner city, set in the north bank of the Main river and was secured by a typical star-shaped medieval fortress in the north. A moat went surround the wall and connected the Main. In 1806, the fortress was demolished and land auctioned as a garden land with the requirement to make the outer edge available to the normal citizen. This beloved open space ring was protected against any construction according to the "Wallservitut" which was authenticated by Emperor William II in 1907 (Wichert 2012). It was later enlarged and redesigned three times, and became the First Greenbelt of the city.

The fast growth of Frankfurt in the 19th century demand the upgrading of existing road system. Enlightened by the successful first greenbelt, a second Green Ring was established to combine the ring road and urban scenery. The original idea did sound perfect, that a second enlarged greenbelt would function together as a wide tree-lined avenue as well as the central ring road that connected existing road network. The real estate near the ring road did booming at that time. However, the urban development didn't stop at this ring. This avenue got frequently cut by other radial roads and was upgraded and expanded in order to carry the increasing traffic demands like personal vehicles and city tram lines. The promised avenue transformed to city fast roads with wider green space in the middle(Behrens 1988).

Between the development of the first and second green belts, a more fundamental plan, the actual footstone for the third and largest Greenbelt, was forming by urban planner Ernst May and landscape architect Max Bromme. They together had the first idea to preserve the River Nidda and its surroundings as a green open space between the city center and new residential districts outskirts, which called "the greenbelt of river Nidda" (Grüngürtel Niddatal). Ernst May was the student of Raymond Unwin, the vital inheritor of Howard's Garden City concept. When May was hired as the Baustadtrat of Frankfurt, his concept of decentralized urban development met with the opportunity

of flourishing housing demand, and led to the master plan "New Frankfurt". New semi-independent well-equipment residential quarters were built a distant away from the crowded city center, providing fresh developing direction and saved precious open space in between. May only worked in Frankfurt for five years (1926-1930) and focused on residential construction, but his legacy left behind further possibilities besides simple urban expansion.

Stage II: Forming of concept (1970s-1980s)

The post-war II Frankfurt experienced massive urban construction and expansion without master plans, created economic miracle and then met with crisis and critiques in 1970s. Public complained about the jammed traffic, disordered city lives and polluted urban environment. Till Behrens, architect and designer, development his first general concept of a third greenbelt and green river bank as a comprehensive solution of the current urban problem in 1970. He later went further into the concept and published as his doctoral dissertation titled "Greenbelt- Growth oriented urban policy and coherent green spaces" (Grüngürtel - wachstumsorientierte Stadtpolitik und zusammenhängende Grünräume) in 1988. He was the first to realize the potential of the urban structure from May era and look at the open space from the perspective of urban level development policy.

Behrens notice the non-material basis of forming a third greenbelt, the first and second green rings. Especially the success of the first greenbelt had quite positive influence on citizens for such a shape related urban open space. Also, he identified the "left space" north of the city during urban expansion which was the gift traced back to May. He believed that with the rest land along the Nidda River, the vast urban forest in the south, as well as the potential of the river Main which cross the city in the middle, all together these elements could be shaped as a third ring of open space with the bank of Main as a clip pined in the middle (Fig 5.1.5). As long as these unbuilt areas were no longer treated as some forgotten space but positive urban green space, their value could be realized and left space became green popular public space. Especially, he pointed out the future possibility of the water front of Main river, which was at that time occupied by many industrial constructions, that they could be the urban recreational center with cultural, educational and leisure facilities.

Furthermore, Behrens realized that such an urban level open space plan would benefit for both the environment and development of the city and region, a valuable chance to reverse the image of Frankfurt from a noisy "American style" skyscraper gathering city to a livable pleasant place. He composed a green radial network to sustain not only the city but also the nearby countryside. In this network, the Wallanlage, the ring avenue and the Greenbelt served as three basic skeletons, green connections should be built between these three rings and stretched further into the country. Inside these green grid there were many parks functioned for daily recreation and ensured lowest walking distance for citizens to go into natural space. Behrens also considered the

necessary conditions of creating such a greenbelt, including planning methods from organizational level and social level, basic expenses for ecological restoration and compensation for agricultural land, and possible construction steps.

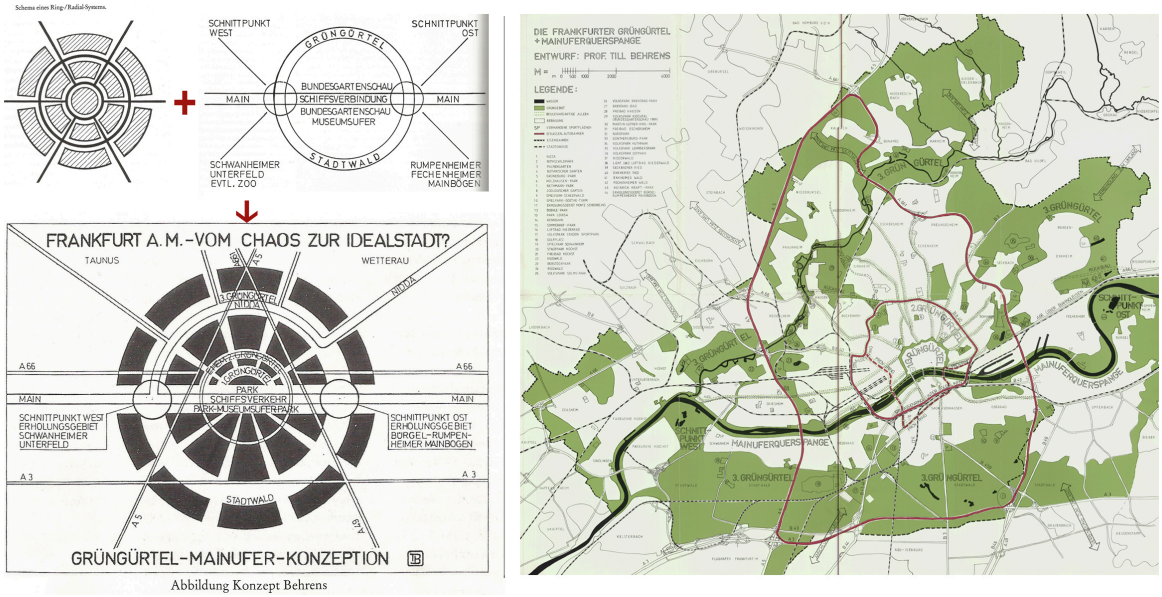


Abbildung Konzept Behrens

Fig 5.1. 5 The concept forming of Behrens (left), a radial urban structure with an open space structure made of green ring and blue connection; the Greenbelt Plan of Behrens (right) together with a comprehensive re-organization of main urban traffic, from Behrens 1988 and 2006.

This open space plan had a relatively comprehensive consideration over many contemporary urban problems and was a vital foundation for the later Greenbelt Plan. But many of his contestation were too aggressive for that time. For instance, he thought the current water front of Main river was terribly built, the rest green spaces were neither continuous nor green enough. Many buildings along the Main must be teared down to keep both sides free as public space. Also, he believed the current road system had caused too many crossovers of open space and certain lines should change course to avoid disturbance. These were real questions but not the right time to have rush changes. Theoretically, urban infrastructures are interrelated and the sustainable of open spaces greatly rely on its appropriation within the urban physical and social structure. But in the 1970s-80s Frankfurt when economic development was the first priority, open spaces was still considered less important. Behrens was not satisfied that his plan was not fully taken, together with other reasons, he didn't attend in the later planning work, which may be a loss for the Greenbelt.

Stage III: Pragmatizing of concept (1989-1991)

Another critical politician, Tom Koenigs, pushed forward the Greenbelt from concept to substantial project in 1990s. Despite the numerous criticism and rethink on the negative influences of unordered urban expansion, and new concepts like Behrens to change the dissatisfied track of

urban development in Frankfurt since 1970s, there were few actions taken to deal with the urban environment crisis and loss of natural resources in the rapid settlement construction. Frankfurt was at that time a city with top urban infrastructure but much less considered from the landscape perspective. The turning point came after the political social-ecological alliance. In 1989, Tom Koenigs, the new leader of the Department of Environment, Energy and Fire Protection, saw the opportunity of this alliance for the realization of May's idea. He started to collect information and contacted with scholars like Behrens for their support. With these efforts, the Frankfurt City Council decided to start a "project year" to define the objectives and areas of the Greenbelt. In fact, a large scale development plan in Seckbach-Nord was stopped, because the site was a sensitive point for urban climate protection and inside the range of Greenbelt plan (Dan 2007). This place stays green and is still farmland for about 1,600 residents.

The Greenbelt Project Year began in March 23rd 1990 and ended in March 1991, all events responsible by the Greenbelt Project Office (Grüngürtel-Projektbüro). Besides Tom Koenigs as the head, three experts were in charge of different aspects, that Peter Lieser for space and society, Peter Latz for landscape and ecology, and Manfred Hegger for organization and general control. The commission was given by the Department of Environment to work on the concept of a greenbelt based on the current free land and to deal with the relationship of urban development and natural reservation in the urban fringe (Dan 2007). Clearly the radical part of Behrens' plan was from this time excluded, like the reforming of certain part of the urban expressway or the demolishing of buildings along the Main, since the Department of Urban Planning was not so involved into this project. The whole project year was divided into four phases, each of which lasted for three months and had one central event. At last, the final results include the Greenbelt Charter, a strategic plan for Greenbelt development and the first detailed plan (Grüngürtel-Projektbüro 1991).

The first quarter from March to early June was used mainly as preparation phase for the entire area. In the second phase, an intensive workshop was taken to gather ideas from international best practices and experts. About 20 of the participant were professionals from local and regional institutions and administrations, some equal numbers were national and international experts from different related disciplines. Together they explored the critical focus points and designed the guidelines for the future planning and development of the Greenbelt, as well as assignments for the coming phase.

The core event of the third quarter was the Greenbelt Summer Academy in September 1990. In this two-weeks-long academy, 20 involved design teams from eight countries were given the assignments for the design of the four parts of Greenbelt. The event was host by Goethe University as a competition, with a fruitful result as designs of the different parts of Greenbelt from cooperated experts. At the same time, the Department of Environment hosted a citizens' competition (Bürgerwettstreit) to collect the ideas from citizens on this project. At the end of this phase, the

project furtherly established eight workgroups centered on different topics and specific subjects. In the last phase, all the related results were presented to the City Mayor and administrators in Dec. 17th and 18th, the winner of the citizen competition was awarded, the full-scale steps and progresses of this project year were collected, organized and exhibited (Fig 5.1.6). The project year closed in March 23rd 1991.

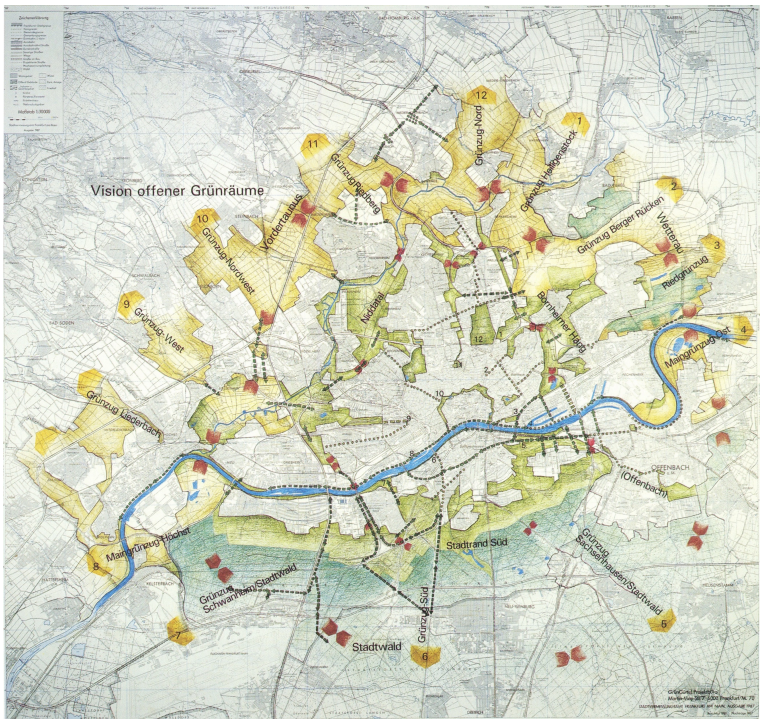


Fig 5.1. 6 The vision of a networked green structure for Frankfurt, from Koenigs 1991.

The Greenbelt Project Office only existed for this one year but numerous and substantial works were done with high public awareness and involvement. There were intensive public relation works, like local press, citizen information, citizen competition, public sight seeing tour and intensive on-the-spot discussions with local councils. Not to mention the workshops and summer academy that brought the contemporary new ideas together for the production of a non-traditional urban open space. They give the project a solid foundation.

In Nov. 14th 1991, the Greenbelt Constitution (Grüngürtel-Verfassung) received the full agreement by the City Council. This included four parts, the Greenbelt Charter which summarized the special impact, ecological values, social benefits and planning principles; a public legal protection for the safeguarding of the area, principles for design, procedures for planning, and plans for maintenance and development; the Land Use Plan which was the basis of the decision-making process (Fig 5.1.7); and a Greenbelt Plan (1: 10,000) of the current situation and future development (Stadt Frankfurt am Main 2003). Further more, there was a budget plan of 300 million DM (approximately 150 million Euro in 1999) with programs for sponsors, guidelines for further urban

land replacement, recommendation for a foundation, and financial and organizational measurements for the next ten years(Dan 2007). The Greenbelt Constitution was an innovative form of governmental agreement with basically no precedent. It represented the understanding and respect of urban open space as an independent component instead of the appending of built area.

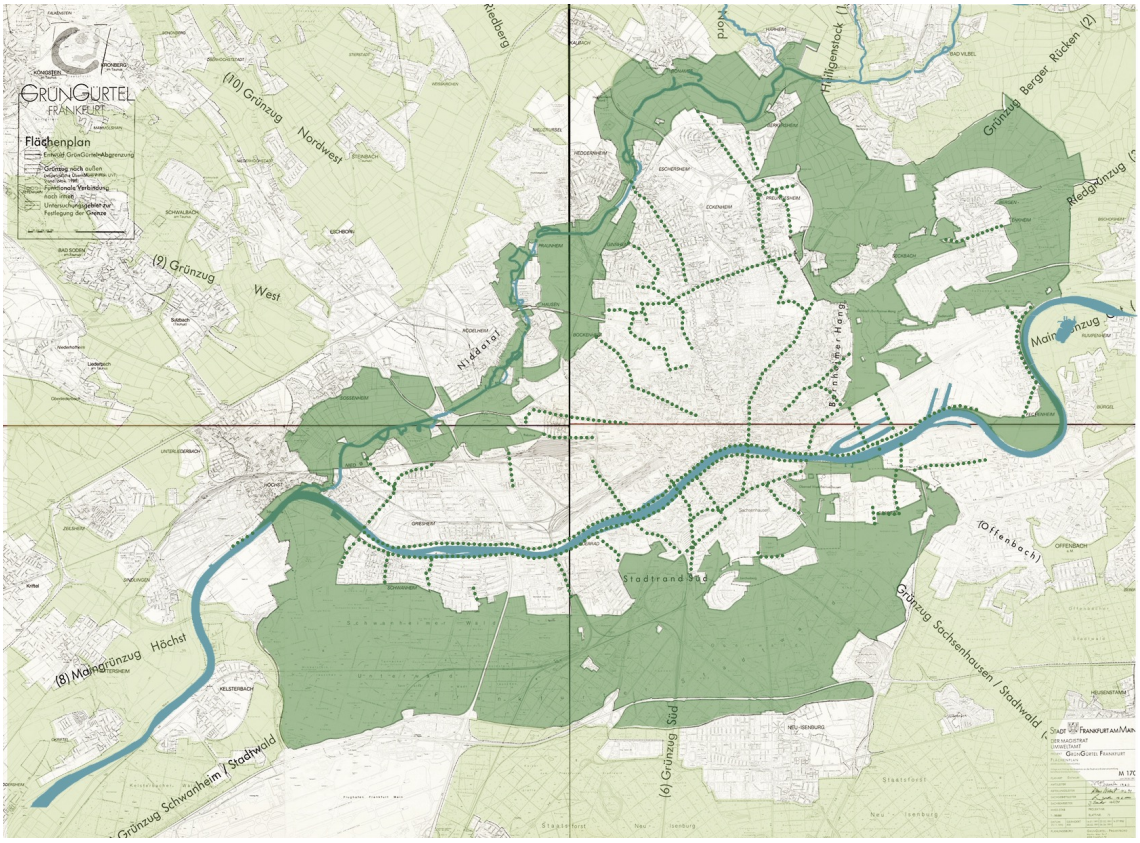


Fig 5.1. 7 The Greenbelt Land Use Plan 1991, re-edit by author based on Greenbelt Constitution 1991.

Stage IV: The Greenbelt GmbH (1992-1996)

After the project year there was a short transitional period and the Greenbelt working group was led by Klaus Wichert of the Department of Environment. Then one year after the Greenbelt Constitution was agreed and executed, the Greenbelt Frankfurt GmbH was built based on the former Federal Garden Show (Bundesgartenschau) GmbH. It started operations in November 1992 and began the project implementation in 1993. Leading by Professor Peter Lieser and Dietmar Vogel, together with the involvement of several responsible departments and authorities, the GmbH established a series of planning and implementation steps for the following five years. The main operational sections were set as 1994 for the floodplains especially the Nidda Valley, 1995 for the hills and 1996 for the forest. The related opportunities, potential and tasks were illustrated as examples. The whole project of Greenbelt was estimated with a time frame of 30-50 years.

Simultaneously, the legal status of this area was carefully affirmed and reinforced within different level of laws and regulations. After the agreement of the Constitution, the Greenbelt area

was thoroughly examined with the land use plan and local development plans to deal with potential conflicts. In 1994, the Government Bureau Darmstadt identified the whole Greenbelt as Landscape Protection Area and in 1995, the Greenbelt was included as the central part of the RheinMain Regional Park (Umweltamt 2016). Now it is secured on five legal levels: self-sufficiency parliament, the commune of building authority, land use plan-surrounding area, landscape conservation regulation-Regierungspräsident, regional spatial planning plan of State Hessen (Dan 2007).

However, the GmbH had several internal and external problems which led to its final disbandment. Firstly, soon after the GmbH was in operation, the city Frankfurt met with serious financial shortage and the investment (Paul 2000). The project year already spent 2.6 million DM and in the four years time of GmbH about 3 million DM were spent (Stadt Frankfurt am Main 2011). The money was primarily invested in the planning process including public relations, and many original ideas became much too costly for the government. Due to this constrained financial situation, not all plans could be fulfilled, like nothing could be done to the heavy traffics that stopped people from the water front of Main, and some parts were influenced greatly by investors' intention. Another problem was the institutional setting, that the GmbH didn't have any concrete commissions beside implementation work and it was led by experts not officers who were familiar with the governmental process, but the implementation work required sufficient assistance from several governmental departments which all had their own assignment and priorities. Complains and dissatisfaction gradually accumulated, but the gratitude for the positive results were easily forgotten, and the increasing financial difficulties was the last straw. The GmbH formally dissolved in May 1996 according to the decision from the majority of municipalities.

Nevertheless, the GmbH have made some achievements in this four years and set a good start for future works. Besides the further planning work, they were account for the construction of the "Streuobst" educational trail in Sossenheim, the reconstruction of the North Park Bonames with artists and children, the City Park Höchst and Nied, the path from the Nidda old river arm to the settlement, and etc. Some of their objectives failed because of the resistance from other city departments.

Fig 5.1. 8 The Greenbelt Logo

One of the best achievements done by the GmbH was the publicity of Greenbelt to the citizens (Fig 5.1.8). From 1990 to 1995, the activities in and about Greenbelt was extensively and positively reported by medias. Also, they designed the Greenbelt Leisure Map and gave out to the public for free. This map contains walkable trails and interesting destinations inside the Greenbelt and the overall circulation reached 600,000 from 1992 to 2011. Another book "Kreuz und Quer" published later which recorded the

complex Greenbelt, local maps in detail and the different kinds of landscape portraits, as well as related knowledge and culture (Stadt Frankfurt am Main 2011). These public works helped to engrave the idea of the Greenbelt as a public open space on the citizens' mind. From this perspective, the millions of investments were worth it, even the GmbH failed, the Greenbelt was unlikely to disappear.

Stage V: The Greenbelt working group (1997 until now)

A new Greenbelt Project Group (Grüngürtel-Projektgruppe) was built in 1997, with the task to further develop and implement the Greenbelt. The experiences from GmbH were carefully learned, that this new group is a cross-border cooperation of multiple governmental departments. Head of this group was Klaus Hoppe, also the director of Department of Environment; his deputy was Stephan Heldmann, and later Heike Appel, both from the Department of Green Space. There are nine members of the project group, which besides the mentioned two departments also from the Department of Urban Planning and the Urban Forestry Bureau (was included in the Department of Green Space). Some other departments or offices are involved when required, like Department of Transportation, urban drainage office and authorities of nature conservation (Unter Naturschtzbehörde), and etc. The group is not a fixed office like a department, in fact, every member has his own task in his original department but serves for the Greenbelt at the same time. All members have regular meetings together and are clear of each other's responsibilities and working range. In this way, these people undertake the duty of communication between departments naturally and smoothly.

The advantages of such a project group setting should not take away from the fact that the financial retrenchment didn't leave much choice for the Greenbelt. Members of the group joined in the principle of free will and did take more jobs than not. But these predecessors were quite motivated and innovated in the building of Greenbelt. Since 1997, the yearly budget for Greenbelt was about one fifth as that in GmbH period, that 200,000 Euro was used for investments like new construction or basic renewal green facilities and objects or renovation works, another 125 Euro was used for planning, publicities and educational programs. To cope with this situation, projects inside the Greenbelt became smaller, more independent, more attractive and flexible, so as to bring in other sources of investment beside Frankfurt government, like the European Union, the Regional Park, the Planning Association, Nature conservation compensation, big companies and even independent sponsors and citizens (Stadt Frankfurt am Main 2011). The hardness and complexity of fund gathering for each project did limited the power of the group, but also an approach to open to more perspectives and achieve multiple benefits.

Many successful small projects were done under the organization of the project group. Most favorable projects including: the wooden boarding road built inside the nature conservation area

Schwanheimer Dune in 1999; the renovated Goetheruh area in 2000; the redesigned former American military airfield in 2004; the new walkways through the Greenbelt; renewed parks and so on (Umweltamt 2016). In 2012, the old airfield project won the international Green Good Design Award, and the educational program "Discover, Research and Learn in Greenbelt" which started since 2004 has been awarded by UN three times in 2005, 2008 and 2010. The Greenbelt is becoming more heterogeneous by these small steps, which still goes on today.

This concept of an incremental implementation approach with small projects suited the Greenbelt situation well but it was not completely new. The IBA Emscher Landscape Park in the Ruhr Region had created and successfully applied the approach. They had met with more severe problem like the vast contaminated land but with small projects perfectly finished one by one, confidence was gradually built among the public and the sponsors. The project itself in this way became its own publicity. The project group of Greenbelt Frankfurt, as an organization with much closer relationship with the government and smaller scale than that in the Ruhr case, tried to create something more besides these attractive projects. Some even smaller projects were designed to keep all different brilliant projects together under the union of the Greenbelt logo. Benches, stele and the Greenbelt logos was set and printed long the main walking and cycling routes; 75 places with historical or cultural significance were introduced on the nearby steles of their values; all interesting destinations, service points and necessary information were drawn on the Leisure Map and gave out free; the group also organize in summers public walks with explainers and open to the all people; and seasonal activities gives old place new enjoyment. The fulfillment in publicities saved the Greenbelt once during the budget cutting, and continuous nurturing the project with non-material power.

5.1.2.3 New environmental strategies

As a part of the 20-year anniversary program, the Department of Environment and the Greenbelt Project Group took a quite exhaustive project in 2010 to review the loss and gain of Greenbelt Frankfurt in the past 20 years and made guidelines and strategies for future development. The review project included: discussions with related stakeholders and activists involved in Greenbelt; on-the spot interviews with citizens for their opinions; questionnaires online and off-line to get first-handed information on the usage and suggestion of the Greenbelt; further more, a special external team consist of architects, landscape designers, urban planners, sociologists and other related disciplines, was built and made further studies based on field researches, workshops and expert discussions (Projektbüro 2010). In this report, the results of the former questionnaires were included and the Greenbelt was reviewed from five aspects, the spatial structure, the infrastructure, the ecological, the social and economic problems. Based on this report, and with consideration of current urban problems like climate adaptation and social communication, the

Büro Friedrich von Borries helped made a Development Guideline 2030 for the open space system of Frankfurt, and a further planning strategy of Greenbelt named “The Spokes and Rays” (Speichen und Strahlen) (Umweltamt 2016).

The development guideline has its strategies simplified as “Connecting - Accentuating - Activating” (Fig 5.1.9) and involves the networking of the open green space, the adaptation with the expected warming as a result of climate change, as well as to increase the participation of population from all ages to secure the foundation of Greenbelt. “Connecting” refers to the enhance of linkage and accessibility of the Greenbelt, the inner city and the surrounding countries. In fact, both the Behrens version and 1991 constitutional Greenbelt Plan had settings of such green connections to make the urban green structure a networking place, but due to complex realities, the Greenbelt had been developed more as an entirety itself and the connections which were dotted lines in the Greenbelt Plan were mostly ignored. “Accentuating” highlights the value of aesthetic landscape design. The current Greenbelt is constantly crossed and cut by traffic and infrastructures which made some places less attractive. High quality design would be a solution to expand the possibilities of natural experience and strengthen species diversity. “Activating” points out the importance of the social communication, which is also the initiating point of the project director, Dr. Manuela Rottmann, the former leader of Department of Environment, that the Greenbelt needs fresh blood, needs the activities of the younger generations with different background. Greenbelt should play its social role in responding to urban challenges such as demographic change, migration and social inequality, and become a place that different lives and social communication co-existed.

The Connecting concept of the guideline was further developed into the planning strategy of Greenbelt, namely the Spokes and Rays (Fig 5.1.9). The spokes refer to the connections from the Greenbelt to the city center, the first green ring, so it would look like the spokes of a wheel; the rays are the links from the Greenbelt to the range of the city and connect with other existing open space or green corridors, like rays of light that lighten to the region. These seven spokes and six rays have their own specific functions. The Northwest two connections have the main purpose for the urban climate, that these areas are in the upper reach of urban prevailing winds, thus are critical areas for the generation of cold air to mitigate the hot city center. Connections along the Main river are the future key areas for developing creative open space. Currently, there are already some green spaces and public leisure facilities along the river banks, and the continuity of open space as well as types of activities should be enhanced and encouraged, especially sports places for the young and recreational places for the old need to be both considered. The other connections focus on the mobility pressure that has bring the Greenbelt with too much noise and disturbance. More green travel alternatives, like express fast bicycle roads and higher proportion of public transportation lines, would be provided for nearby commuters.

This strategy focuses on the potential development approach of Greenbelt in the coming decades, and restore some existing problems in the mean time. However, the implementation after the plan has been really slow despite the remarkable concepts. First of all, there has been a political change right after the plan making, that the proposer of the plan left the group and the new leader is not quite interested in the large scale strategic urban green space planning (Interview Frau Specht). But this plan, as well as the Greenbelt Plan, is a political idea that needs to be carried forward with strong support. Second, the plan targets on climate, open space and transportation at the same time. All three are critical urban problems but not possible to be solved simultaneously by one ruling party. This plan so far has involved with too many departments, environment, green space, urban planning and transportation, and asking for "environment first" everywhere is not realistic. Too make things harder is the financial limitation, that this plan, even worse than the already poor Greenbelt Group, has no budget of its own. It furtherly weakens the influences on other independent department and left the environmental consideration with no priority. It is still too early to judge the results, but comparing with the history of Greenbelt itself, the chance of real changes according to this plan is quite low if no other support would be found.

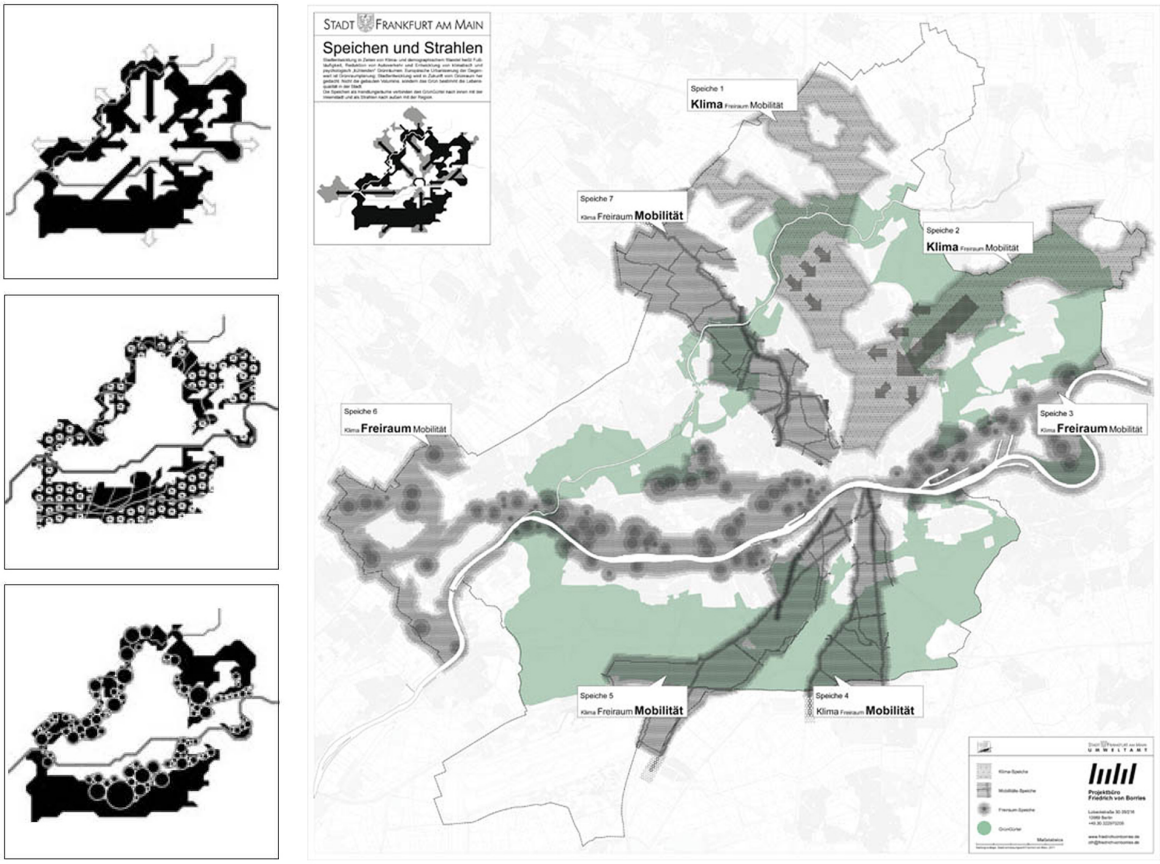


Fig 5.1. 9 Guideline of Further Development: Connecting - Accentuating – Activating, from Department of Environment Frankfurt (Left) and The Spokes and Rays strategic plan (right), from Umweltamt 2011.

In November 2016, Greenbelt Frankfurt had its 25-year anniversary. Its achievement is undeniable, that it reshaped the spatial structure of the city and conceptual cognition of the citizens. Frankfurt becomes a literally greener city and shows certain advantages in air pollution level comparing with similar big cities. But the Greenbelt remains an unknown project. It is understandable that the Greenbelt, unlike the Emscher landscape park, is a pure municipal project that targets on local and regional residents (Paul 2000), and the funding has been too poor to support long-time research and spread out stronger influences. In the past five years, many former members are leaving and debates are increasing about the strict no-construction regulation inside Greenbelt due to heavy housing pressure. The Greenbelt is probably in a critical changing point like it has been twenty years ago.

5.2 Range and Material of Case Study

5.2.1 The relevance of ES in Greenbelt Frankfurt

The discussion of the relevance of each ES in studied area is the first and necessary step. As discussed in the last two chapters, the content of multifunctionality in urban green open space could be concluded into two parts, the quantity and quality of relevant ES as a whole, and the efficiency of interactive multiple ES at local level. For the study in this chapter which will focus on the level of the whole Greenbelt, the former is the main concern. And as pointed out in some researches (Koschke, Fuerst et al. 2012, Kopperoinen, Itkonen et al. 2014) among quantitative studies, whether and to what extend an ES matters for the targeted area have direct influence on the results. Because the existence and performance of ES relies on its corresponding ecosystems which are to a certain extent, site specific.

To clarify the significance of each ES (the 24 collected ES are listed in Table X) in the context of Greenbelt Frankfurt, the following questions are proposed:

1) What strong is the historical and recent development related to this ES?

2) What is the level of significance of this ES and its related topics? How intensively is the ES demanded by local population?

3) For some kind of ES, which group of citizens are the potential beneficiary?

4) What are the related land use and land cover of each ES?

Based on these questions, a preliminary documentation research is made, and then discussed with related experts. According to the extent of importance of the second and third questions, a final level of relevance is decided and all ES classified into four groups: High, Medium, Low and Not relevant within the studied area. The first three groups will later represent the different weight in mapping process, and ES in last group will not be quite discussed in the study.

5.2.1.1 Provisioning services

Food products derived from plants, animals and microbes out of artificially managed agro-ecosystems. Food production is traditionally an important function for the city. In Frankfurt am Main, there are approximately 3700 ha agricultural land in total which covers 15% of the city land especially in the north and west part. About 1700 hectares' agricultural land lies inside the boundary of Greenbelt and constitute the second largest land use type (21%). The natural conditions in Frankfurt is favorable for farming, with fertile soil and mild climate. Therefore, this famous European banking center is also called by local people as "largest village in Hessen".

About 80% of the agricultural land are crop field with the most demanding crops like wheat and sugar beet. Two types of cultivation are vital besides crop, the orchard meadow (Streuobstwiesen) and special types of herbs for the making of Frankfurt green sauce (Grüne Soße). Pastures, on the other hand, is rare in the city. There are some farms raise pigs around Harheim and very few dairy farms in Bergen-Enkheim. One interesting type of livestock is horse breeding pension (Pensionspferdehaltung), that the owners of horses authorize local farmer to take care of the horses.

The importance of food production inside greenbelt is not so high as it was hundreds years ago, but still take its place in citizens' lives. Agricultural parcels inside greenbelt now tend to be smaller than that in the outskirt of the city, but the types of crops more diversified. It is not the optimal condition for large scale automation of agricultural production. Meanwhile, due to its close distance to the city center, many farms started in-situ markets and agricultural tours, which provide new incomes. In this way, the cultural value increased and give more abundant possibilities to traditional farming. The heft of local food production changes its way but still plays an important role.

Raw materials refer to wood, biofuels and plant oils that are directly derived from wild and cultivated plant species. About half of the Greenbelt, approximately 4000 hectares, is urban forest and count for the major place for raw material productions. The majority of forest is in the south of city, with some smaller separated patched on the northwest and northeast. The forest is made up by a mixture of deciduous and coniferous trees aged from 40 to 60 years, with Oak (29.9%), Beech (25.0%) and Pine (21.9%) the most common types (Zwilling, 2016). Timber production was a vital economic activity in the past, and reached its peak after wars. Nowadays, this function is more like a by-product of forest maintenance, with more diverse use of wood, from large timber for furniture manufacturing, burning wood for household, to small branches and barks for souvenirs and art works. The timber production is eco-friendly and eco-first, which means a smaller amount of raw materials than economic forests.

The drinking water of Frankfurt comes predominantly from ground water and spring water. Now about 17% drinking water is directly obtained inside the city boundary. In order to protect the

provisioning and quality of water, some activities, like contamination, changes with negative affects or threats, are restricted or prohibited in the "drinking water protection areas" (TWS, Trinkwasserschuztgebiet). Such areas are furtherly divided into three zones depending on the distance and groundwater flow velocity to the extraction points. There are four such areas in Frankfurt, with the biggest one in urban forest. Since the majority of the city drinking water comes from outside Frankfurt, the importance of this provision is not the highest.

The other three services, the medicinal, genetic and ornamental resources, are seldom discussed in former spatial analysis. However, there is a small number of plant nurseries in the area of Greenbelt, owned by private firm or the Forestry Bureau (Stadtforst) of city Frankfurt. They count for the ornamental uses in the city, like flowers and Christmas trees. They are profitable small companies with the exception of the Forestry Bureau and thus the service is of lower relevance to local people. The medicinal and genetic resources are not quite discussed in the area; they are either hard to locate or may lead to double counting.

5.2.1.2 Regulating services

Regulating services have stronger dependence on the quality and type of land use. Urban forests are the most valuable assets for the regulation of air quality, local climate and carbon sequestration. The capacity of fruit trees, shrubs and grassland is not as strong as forest and mostly rely on specific site situation. Besides, agricultural areas also have but a limited contribution on the themes and differed by cultivation methods. Air pollution was a top problem for the city when the Greenbelt Plan was made. Now Frankfurt has an impressive level of air pollution considering its large daily traffic, mainly due to the continuous attention on air quality.

Built along the Main river, Frankfurt has always close connections with water related functions and services. However, flood is not the main threatened urban extreme event, despite the floods happened in 1995, 2003 and 2011. The flood in Main river normally didn't cause death, through millions of economic loss is unavoidable. Another river Nidda had worse hydrologic condition in 1970s due to massive river channelization, but the situation relieved a lot after the re-naturalization began in 1990s. The identification of flooding areas based on the statistic of the hundred-year flood in Nidda also show a high rate of open space in the potential water retention zones, which indicate lower risk.

On the contrary, extreme heat events are recent topic under the urban climate change adaptation strategy, which should be better simultaneously considered with local climate regulation. Urban climate map was made and updated by DWD to support related studies and policies. The adaptation and mitigation of urban climate, related to local climate regulation and carbon sequestration, have been taken on top priority with Greenbelt a main buffer zone.

With the majority land inside Greenbelt the permeable and vegetated surface, water regulation is a basic service provided to the whole city. But based on the mild climate of the region, this service is not in urgent demand but had a good record in history. The diverse vegetation, especially forest, forms substantial riparian buffer for the water purification in the Main, Nidda and other 90 rivers, streams and abandoned meanders, as well as lakes, pond and pools of the city.

Nosie regulation is another vital service of the urban forest because of the busy international airport which lies in the southwest of the forest. The laud noise of plains was lowered down to under 55 dB at the interface of forest and built area in the south of the city. In the meantime, the noise is causing certain damage in the health status of tree species.

However, the rest three services are not the priority. Only part of the agricultural land in Heiligen Stock faced a medium to high potential erosion caused by water (Potentieller Bodenabtrag durch Wasser) and even less possibly by wind. The protection of Flora-Fauna-Habitat may bring positive effect for the pollination and biological control in the area, but they are not the primary goal.

5.2.1.3 Habitat functions

The preserving and improving of habitat function is one of the top priority for Frankfurt greenbelt, as well as the city-wide environmental protection. The whole area of greenbelt is safeguarded by state law as landscape protection area, which furtherly divided into two zones, zone 1 is for recreational use and zone 2 for the reservation of local landscapes, like forest, water meadow, orchard meadow and agriculture. Moreover, there are six nature protection area and five Flora-Fauna-Habitat which count for about 1/8 of the greenbelt. So far over 1800 plant species have been detected as wildly grown, a relatively high number compare to that in other cities. In the meantime, about 500 species are on the red list.

5.2.1.4 Cultural services

Looking for aesthetic appreciation and inspiration in greenbelt has been the most common reason for citizens in Frankfurt, in this case, most open public space inside greenbelt is qualified for such requirement. However, some provide owned land, like some farms or allotment gardens, only served for small number of people, means a low contribution to the public; on the contrary, vista points special types of landscape and facilities provide better chances for the perception of natural beauty. Recreation, mental and physical health is another main objective of the greenbelt plan delivered by parks, nature reserves, designed route for pedestrian and bike riders, as well as special place for recreational activities like barbecue. Nevertheless, this area is mostly used by local people instead of foreigners and tourism is not the purpose or actual use.

The greenbelt has been used as a huge green classroom for the children and families to get closer look and understanding of the nature, specialized programs funded by local government were provided to the public since 2003. Besides, the abundant natural resources also attract scientific studies from universities and institutions.

Greenbelt itself is not a heritage but history and culture leave traces in this complex landscape, like the Berger Warte which stands since the Middle Ages to frightened the intruders. Many such places are identified and propagandized with signs on the spot and free brochures. New spots with cultural meanings are adding, like some art devices installed in succession. However, spiritual and religious values are not normally included.

5.2.1.5 Summary

To conclude, 20 out of the 24 potential ES are relevant for the study area. However, their significance is clearly not equal, especially the regulating services due to local context.

Table 5.2. 1 Relevance and related land use of ES in study area, by author

No.	ES	Sub-class	Relevance	Related land use and land cover	Other related information
P1	Food	Crop, fruit, herb	High	Farmland, orchard	Soil quality rating data
P2	Raw materials	Timber, Fuel wood	Medium	Forest	
P3	Fresh water	Drinking water	Medium	Water body and riparian	Drinking water protection area
P4	Medicinal resources	-	Not relevant	-	
P5	Genetic resources	-	Not relevant	-	
P6	Ornamental resources	-	Low	Plant nurseries	
R1	Air quality regulation	-	High	Forest and green space	
R2	Local climate regulation	-	High	Forest and green space	Urban climate map
R3	Carbon sequestration and storage	-	High	Forest and green space	
R4	Moderation of extreme events	Flood	Low	River riparian	Potential over-flooding areas
R5	Water regulation	-	Low	Wetland, permeable surfaces	
R6	Water purification and waste treatment	-	Medium	Wetland, permeable surfaces	
R7	Erosion prevention& maintenance of soil fertility	-	Low	Green space	Soil erosion potential
R8	Pollination	-	Medium	Nature reserves near crop field	
R9	Biological control	-	Low	Nature reserves near crop field	
R10	Noise regulation	-	High	Forest	
H1	Habitats for species	-	High	Nature reserves	FFH, Nature protection area

No.	ES	Sub-class	Relevance	Related land use and land cover	Other related information
H2	Maintenance of genetic diversity	-	High	Nature reserves	Habitat integrity
C1	Aesthetic appreciation & inspiration	-	High	Public green space	
C2	Recreation, mental and physical health	-	High	Public green space	Route, facilities, activity sites
C3	Tourism	-	Not relevant	-	
C4	Science and education	-	High		Education project sites; scientific research sites
C5	Cultural heritage values	-	Medium		Cultural/heritage sites
C6	Spiritual and religious values	-	Not relevant	-	-

5.2.2 Data collecting

The case study of the multifunctionality in Greenbelt Frankfurt have two main analyzing process, the semi-quantitative mapping and qualitative coding. The first part of mapping focuses on the visualization of the spatial distribution of each ES and general performance of Greenbelt; the second part of coding focuses on the reorganization of existing main planning documents into the same framework.

The first part of the case study is to produce the spatial distribution of ES capacities in the studied area. In this process, the main applied methodology is A semi-quantitative land use based GIS mapping which was first proposed and used by Burkhard, and later others (Burkhard, Kroll et al. 2012, Koschke, Fuerst et al. 2012, Lovell and Taylor 2013, Kopperoinen, Itkonen et al. 2014). The core concept lies in the grading matrix for each kind of land use on their general performance according to related experts. Comparing with other pure quantitative approaches, it is more convenient for non-ecologists and directly gets closer connection with land use and land cover, the critical object in urban planning. But it could also be too general and lack local information. A later case who mainly used local policy related data, like natural reserves and protection zones, give more particularity in the case but hard to apply on different cases without equal information (Kopperoinen, Itkonen et al. 2014). Both these approaches were used on regional/watershed scale and have better inspiration for regional planning strategies.

In this study, as described in the methodology chapter, a combined approach is used here to take advantages of both. First of all, the land use data is graded as the former approach, but with urban policy-related information as added on data to keep both tangible and intangible data of the studied area. Second, more detailed data sources are used. Most former works used the CORINE land cover data (Coordination of information on the environment) and correspondingly mapping

on the regional scale. CORINE land cover is strong in its wide coverage and unified standard due to its initiated organization, the European Union; in the meantime, the in total 44 classes of land cover and the scale of 1:100 000 indicates that it could be insufficient for urban green space which are in the classification oversimplified. In this way, the 1:2000 Biotope Map of Frankfurt was applied in the study, as well as some additional information was add to different type of ES based on city-wide policy and special plans. In this way, the Biotope Map of the studied area is the critical data for ES mapping of year 2010.

1) The Biotope Type Map of Greenbelt

The Botany Department of Senckenberg Research Institute started the extensive mapping of the biotope types throughout the Frankfurt city since 1985, under the commission from the city council. One main focused research location of the Senckenberg Research Institute is the metropolitan area of Frankfurt and the flora and fauna of the region have been documented in the collections of the Senckenberg association for nature research (Senckenberg Gesellschaft für Naturforschung, SGN) for nearly 200 years. The working group of the Biotope Map is led by Dipl. Dirk Bönsel from the beginning. The filed surveys normally involved a group of master students but the organization work was done by the three group members who are all researchers of the institution. It was a small group and shorthanded for the survey area, however, a unified standard can be better followed within the group.

The map is not stable but under constant revising. The first version of Frankfurt Biotope Type Map finished in 1990. At that time, the main focus was the urban area, with exceptions in the nature reserves, the urban forest and large industrial facilities. Since then, revision maps have been carried out every five years to correct changings and complement the gaps. In the mapping section 2001-2005, an indicative instruction handbook which originated in 1997 was more formerly and strictly developed based on many related biotope mapping studies, and the whole map was digitalized by the City Surveying Office (Stadtvermessungsamt) simultaneously. The digital map was available within the intranet of the municipal authorities and is functioned as a main database for related urban works (Bönsel 2007).

The 4th revision mapping (2005-2010) restricted to the non-developed area and the Greenbelt. And the latest version (2010-2015) has focused on the main changes along the Nidda river. This version (data recorded until 2014) is used as base map of the ES spatial distribution in 2010s. According to the distribution of time dated (Fig 5.2.1), the majority of the data is dated between 2007 to 2012, thus could serve the purpose well.

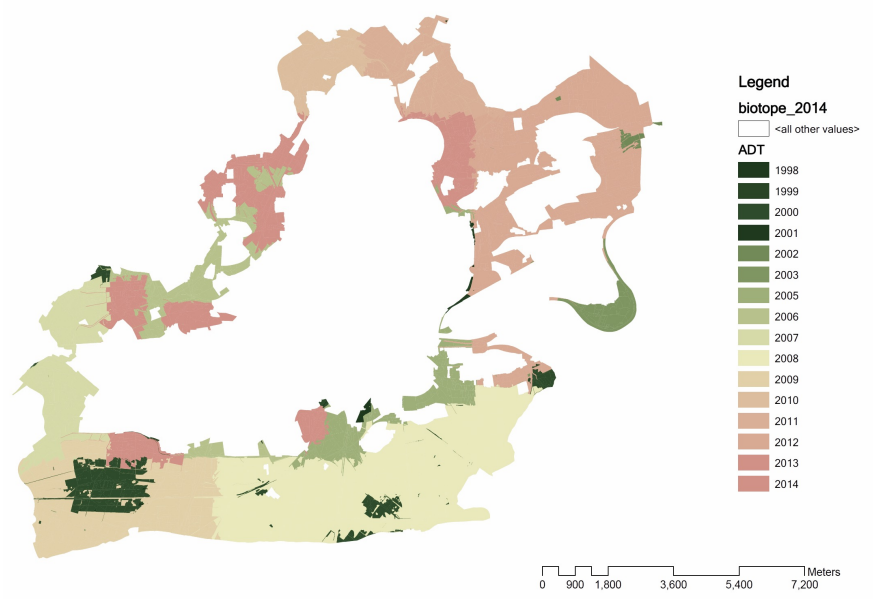


Fig 5.2. 1 The spatial distribution of revising year of the Biotope Map in studied area, draw by author, origin map from Department of Environment, Frankfurt.

The biotope mapping is demarcated on the aerial image and also with the help of the 1:2000 urban ground map, and carried out in the field for surveying. Then the biotope map is drawn in a 1:2000 scale and other data, including name, date, type and additional information, are recorded in the excel and digitalized with the graphic information to form the database. The minimum area size for the mapping is defined as 5m * 5m. The classification system of biotope types is a hierarchical structure which allows the space to be captured in a detailed sharpness. The biotope types used generally three levels, the Main Group, the Subgroup and the Main unit. A fourth level, the Subunit, is also applied since it is quite meaningful for further differentiate for example the degree of sealing and utilization. This fourth level has each a more detailed explanation made with indications on characteristic plant societies and species. In order to achieve as detailed results as possible, the mapping is carried out at lowest present level and normally at least until the third level, the Main Unit. If an encountered habitat type can not be assigned to a Subunit, the next higher level would be used. Besides these types, some additional information is added like the nature reserves Flora-Fauna Habitat (FFH in short) (Bönsel 2007).

This biotope map is valuable not only for the institution but also for many other related studies of the area. Since the founding of the working group in 1985, more other detailed flora-fauna investigations have been carried out in selected areas of Frankfurt known as “specific mappings”. These helps to the complex topics such as landscape facilities, species inventory, nature conservation, and also in some independent and comprehensive projects like Frankfurt 21, the Urban Forest and Airport project. After the extensive digitalization and update of mapping procedure based on newest progress in 2005, the Biotope Map could better catch the current

requirement in a wide range and provide much more information beside the map. The case study here only uses the very preliminary level of the database.

2) Historical land use map

To understand how multifunctionality in the study area have changed in a certain time period, the searching for how it was before could be necessary. However, there are no digital land use data for the 1990s. The most comparable map for the newest Biotope Map of 2010s would be the first version Biotope Map finished in 1990. But this map has not been digitalized yet due to the staff shortage of the group. Though the paper version is well kept in documentation, the amount of work is not possible to be done by author alone. On tracking with urban land use data, two paper historical maps were available from the Frankfurt Institution of City History, the Land Use Plan of 1988 in scale 1: 50 000, and the Land Use Plan of 1984 in scale 1: 25 000. But these two also have disadvantages that they are made mainly for built areas and the land use type inside Greenbelt were quite simple.

Shifting the thinking of a complete comparison, preliminary and approximate location of changes seems to be a reasonable approach. The comparison is taken between the changes on the Greenbelt Leisure Map 1992 and 2011, the first and latest version of the map. This pair of maps have three advantages for the case study. First of all, the two maps both focused on Greenbelt and other open space in the city, instead of the built area. The aim of the map is to provide citizens with available possibilities in open spaces, with necessary public transportation and road information, the buildings in the city are just a background. Second, the maps have same content. Open spaces inside and outside Greenbelt were classified as forest, public green spaces and parks, cemetery, small gardens, sport areas, grassland and agricultural land (public open space and cemetery were merged as one type in 1992 map). It is more detailed than that in urban land use types and directly comparable with the Main Group of the classification of Biotope Map, which means the same evaluation standard. Last but not least, the timing of maps fits the study purpose. The Leisure Map 1992 was made during the transitional working group of Greenbelt and the beginning of the Greenbelt GmbH, when the range of the belt was settled but no substantial works done. This map served as a status quo for the beginning of Greenbelt, while the 2011 Leisure Map were filled with destinations, route and lines, facilities as well as new landscapes. They most closely captured the changes of the area.

These two maps were drawn both in scale of 1: 20 000, which is much smaller than the Biotope Map. So the maps were compared under the same range but only the different parts are marked and digitalized, then import into GIS with same coordinate and range. In this way, these less accurate changes will be mapped and present to show the main differences in the two decades.

In second part of the case study, the efforts from the planning process are discussed, with same focused ES. This involved planning documents and policies since 1990. The process is divided into three steps, the first is the Greenbelt planning in 1991 which involved the documents from the Greenbelt Project Year 1990 and the documents of the Greenbelt Constitution in 1991. The second part is the gradual implementation process, mainly focused on the Project Group since 1997, including documents like project planning, open information, experts' reports and investigation from third company. In the last part, the planning documents, the analyzing report and recent pilot projects are used to identify the main purposes and actions after 2010s.

5.3 Multifunctionality in the Present and Past

This section applies the GIS mapping under the framework of multifunctionality, to present how the supply of each ES performances and what is the overall potential of all ES, which could be understood as the multifunctionality at urban level. Three steps are taken to illustrate the questions, the first is the mapping of single ES based on the status around 2010; the second step is the analyzing of the overall performance, especially the hotspots on the general mapping; the last step is a short analysis on how the multifunctionality of Greenbelt may have changed after the Greenbelt Plan in 1991 due to land use and policy changes. All together, these three steps try to unveil part of the "reality" of multifunctionality of urban green open space in the studied area.

5.3.1 Multifunctionality in 2010s

5.3.1.1 The mapping process

The mapping of multiple ES distribution in Greenbelt Frankfurt followed the land use based approach (Burkhard, Kroll et al. 2012) and revised with local policy and planning. It is a semi-quantitative approach which to be more specifically has three following steps.

First step is the making of a ranking matrix containing each of the 20 chosen ES (section 5.2.1.5) to the different classification of Biotope Map, according to the supplying capacity of ES for certain biotope type. There are seven levels defined in this study, from "+3" to "-3", "+3" represent the biotope type is "very favorable" to the targeted ES, "+2" as "favorable", "+1" as "slightly favorable", "0" for neutral impact, "-1" for "slightly harmful", "-2" for "harmful" and "-3" for "very harmful". This ranking system followed the more recent study (Kopperoinen, Itkonen et al. 2014) and could better represent both positive and negative capacity comparing with the "+5" to "0" evaluation system, which the positive effects are too elaborately described but the negative sides are neglected. At regional scale, the latter one is acceptable since the built area would generally be considered as a large block. But at the city scale as in the Greenbelt, urban infrastructures like transportation systems are interweaved with green open space, which indicates unavoidable disturbance and demand a ranking system with negative descriptions.

This approach has been carried out by some studies and principally based on existing case studies and interviews with local experts. This study considered mainly the experiences of European cases, especially the ones in Germany (Koschke, Fuerst et al. 2012, Potschin and Haines-Young 2013, Burkhard, Kandziora et al. 2014). Though this study used Biotope Type instead of CORINE data in most other cases, the latter one is from a certain extent transferable to the former one (Appendix 5.3.1). The CORINE system has three levels, five main groups, 15 subgroups and 44 main units; the Biotope Map has four levels, 9 main groups, 50 subgroups, 167 main units and numerals subunits. The 44 main units of CORINE are comparable with the majority of the 50

subgroups of Biotope or the main units in certain situation, while the further detailed classes actually provide more information to correct some of the evaluation in CORINE system. For example, forests are categorized in three types in CORINE, the 311 Broad-leaved forest, the 312 Coniferous forest and 313 mixed forest. While in the Biotope Types, broad-leaved forest is divided as in dry area and in humid area, coniferous forest which grows in sandy soil is identified and protected forest areas with fewer disturbance of human activities are marked, and etc. Some of the detailed units are indeed redundant information for this study, but a great deal of them provide with specific local information which may need extra huge amount of field researches in other case.

However, not each main group of the biotope classification is taken equally detailed consideration, since their proportion in Greenbelt varies a lot (Table 5.3.1) and the amount of evaluation would be too much for either the author of the interviewed experts. Greenbelt is an urban level open space around the city center, which is naturally dominated by none-built area like forest, agricultural land and parks. The majority of built areas is unattached and scattered houses and limited public or commercial buildings. Therefore, three levels of detailed further classification in the making of the ES matrix is considered in this part. For main groups that account for less than 1% of the land in Greenbelt, like B6 and B0, there is no need for further classifications. For main groups that account for 1% to 5% of Greenbelt, only particular subgroups, which represent properties with large difference, would be partially revised based on the group character. This level includes B1, B2, B5 and B9, which are the subordinate land use types for Greenbelt. Only the rest four main groups are detailed discussed in their subgroups, main units and, even in certain conditions, their subunits. These four groups, namely the land for transportation, green spaces, agriculture and forest, cover 87.5% of the Greenbelt and are the main contribute for ecosystem services and disservices.

For the expert interviews, this study also takes a simplified approach due to time limit and shorthanded. In the study, three experts were being consulted for the evaluation, each of them represent a type of expert, the ecologist/botany, the designer/planner and the manager of the project. They have the judgement from their own perspectives, and their understandings were combined together by author into final result. It is worth mentioning that each expert would have their opinions based on their own experiences and preferences, it may not be an absolute accurate and objective concept. When more time and funding available, multiple experts would provide with results closer to neutral, but the corresponding costs also need to be balanced.

Based on both literature and expert interviews, the evaluation matrix made showing how each selected ES could be suppled by different type of land use and land cover (Table 5.3.2). Considering the properties of each biotope type and the amount of correspondent land, all the land use types were classified into 56 groups. B8 which covers 40% of the Greenbelt was divided into 12 smaller groups while B6 with only 0.2% proportion was kept as one group. Type B8-3, which

refers to the Broad-leaved forest plantation used for forestry production, hit the highest score of all, and the B3-1 reached the lowest score below zero since it contains all the heavy and transit traffic cross Frankfurt.

Table 5.2. 2 The proportion of each main group in the Greenbelt

No.	Main groups in Biotope Map category	Total area*/ ha.	in Greenbelt %
B1	Mixed built area	382.5	4.1%
B2	Industry and commercial area	311.4	3.4%
B3	Land for transportation	1020.8	11.0%
B4	Green spaces, parks and recreational area	1561.0	16.9%
B5	Inland waters	213.6	2.5%
B6	Weed and vegetation in periodically drought sites	19.7	0.2%
B7	Agricultural land	1771.9	19.2%
B8	Trees, bushes and forests	3732.2	40.4%
B9	Fallow field, ruderal areas, construction sites and special sites	163.5	1.8%
B0	currently no data	51.1	0.6%

*Areas are counted based on the GIS Biotope data.

This matrix is the fundamental base for the mapping. Worth noticing is, not every ES could be directly and sufficiently evaluated by its land use type and condition. Eight ES, marked with # in the table, will need other additional information to form a better presentation of the status, which will be carried out in the following step. One ES, the "Biological control" (R9) is not determined by land use only, but also locations and relationship with other land type. It will be also counted in the second step.

The second step is the overlapping of additional information on single ES. After the first step, each ES could be already mapped in GIS. However, it only represents the properties provided by different biotope types, critical but may lose information from the human side of experience as urban open space. Especially for cultural services, the forest or park is only a necessary part for the delivering of aesthetic appreciation (C1), some artificial facilities and policies, like convenient roads for pedestrians and resting locations are sometimes decisive for users. In this way, some ES are mapped by the overlapping of two layers, the score based on biotope types and on other information.

The third step is the counting of weight. As shown in the table (section 5.2.1.5), the ES means differently for the targeted area and they are demanded differently. When all ES are considered simultaneously, a weighting process is necessary for a comprehensive consideration. According to the relevance of each ES for the studied area, namely High, Medium and Low, their weight is set into three levels and calculate in GIS. The final mapping would then be produced showing the distribution of contribution of all ES in the area, which would be the basis for further analysis and essential for the multifunctionality of the Greenbelt.

Table 5.3.2 The Evaluation matrix of the ES supply in Greenbelt.

	Ecosystem services	Provisioning				Regulating										Habitat		Cultural				Statistics		
Type	Content of biotope units	Food	Raw materials	Fresh water	Ornamental	Air quality regulation	Local climate	Carbon sequestration	Moderation extreme	Water regulation	Water purification	Erosion prevention	Pollination	Biological control	Noise regulation	Habitats for species	Genetic diversity	Aesthetic	Recreation	Science and education	Cultural heritage values	Total score	Referred area/square meter	Proportion in Greenbelt
		P1	P2	P3#	P6	R1	R2#	R3	R4#	R5	R6	R7	R8	R9#	R10	H1#	H2#	C1	C2#	C4#	C5			
B1-1	B112; B113, B131; B1132; B114;B1141;B1142; B1151; B1152; B1161; B1162							-1		-1												**-2**	678552	0.73%
B1-2	B1143; B1153; B1163																					**0**	342907	0.37%
B1-3	B1171-1173, B1191; B131; B133; B141	1						-1	-1	-1							1	1	1			**1**	1932327	2.09%
B1-4	B118; B1192; B1193; B1194					1		1									1	2	1		1	**7**	630992	0.68%
B1-5	B1212; B122; B123; B124	2				-1		-1		-1												**-1**	204270	0.22%
B2-1	B21, B211, B2111-2114, B2121-2124, B221, B2221-2224, B2234, B23, B231, B233, B235, B237					-1	-1	-2	-1	-1					-1		1					**-6**	3011023	3.26%
B2-2	B2231, B2232 and B2233							-1	-1										1			**-1**	103369	0.11%
B3-1	B3211-3215, B3221-3225					-2	-2	-2	-2	-2				-2	-3	-2						**-17**	3388773	3.67%
B3-2	B3132-3134, B3141-3144, B3151, B3231-3235					-1	-1	-1	-1	-1				-1	-2	-1	1		1			**-7**	1513313	1.64%

	Ecosystem services	Provisioning				Regulating										Habitat		Cultural				Statistics		
Type	Content of biotope units	Food	Raw materials	Fresh water	Ornamental	Air quality regulation	Local climate	Carbon sequestration	Moderation extreme	Water regulation	Water purification	Erosion prevention	Pollination	Biological control	Noise regulation	Habitats for species	Genetic diversity	Aesthetic	Recreation	Science and education	Cultural heritage values	Total score	Referred area/square meter	Proportion in Greenbelt
		P1	P2	P3#	P6	R1	R2#	R3	R4#	R5	R6	R7	R8	R9#	R10	H1#	H2#	C1	C2#	C4#	C5			
B3-3	B3241-3244, B3251-3255					-1		-1	-1				1		-1		1		1			**-1**	1086261	1.17%
B3-4	B3111-3114, B3152												1				1		1			**3**	1057116	1.14%
B3-5	B3261-3263, B3271-3275								1				1				1	1	2			**6**	2240732	2.42%
B3-6	B3216, B3226, B3236, B3256,						1								1			1				**3**	232646	0.25%
B3-7	B3281-3284, B35, B33, B34																					**0**	630145	0.68%
B4-1	B411, B4111, B4112, B4115, B4121, B4122, B4125					1	1	1		1	1	1	1	1	1	1	2	3	2		1	**18**	1706881	1.85%
B4-2	B4113, B41143, B4123, B4124							1						1		1	1	2	1			**7**	953759	1.03%
B4-3	B4131					1	1	1		1		1		1	1	1		3	2		3	**16**	8876	0.01%
B4-4	B431-436					1	2	1		1		1		1	2	1	1	2	1		1	**15**	771243	0.83%
B4-5	B441-445	1			2		1	1				1	1	1		1		1	2			**12**	8537482	9.23%
B4-6	B45				3	1	1	1		1		1	2	2	1	2	2	2	2		1	**22**	45229	0.05%
B4-7	B4141, B4142, B4145, B4152, B4161, B4162, B4165, B4171, B4172, B4175					1	1	1		1			1				1	1	3			**10**	575220	0.62%
B4-8	B4163, B4164, B4173, B4174, B4181, B4182, B419, B4191, B4192							1					1				1	1	2			**6**	1040691	1.13%
B4-9	B42, B421-429							-1										2	3			**4**	1941097	2.10%

	Ecosystem services	Provisioning				Regulating										Habitat		Cultural				Statistics		
Type	Content of biotope units	Food	Raw materials	Fresh water	Ornamental	Air quality regulation	Local climate	Carbon sequestration	Moderation extreme	Water regulation	Water purification	Erosion prevention	Pollination	Biological control	Noise regulation	Habitats for species	Genetic diversity	Aesthetic	Recreation	Science and education	Cultural heritage values	Total score	Referred area/square meter	Proportion in Greenbelt
		P1	P2	P3#	P6	R1	R2#	R3	R4#	R5	R6	R7	R8	R9#	R10	H1#	H2#	C1	C2#	C4#	C5			
B5-1	B5311-5314			2			1		1	1	1			2		2	2	2	2			**16**	42520	0.05%
B5-2	B5321-5326			2			2		2	1	2			3		3	3	3	2	1	2	**26**	21289	0.02%
B5-3	B541-545	1		3			2		2	1	2			3		3	3	3	2	1	3	**29**	1482089	1.60%
B5-4	B521-526, B551-556, B56, B58			1			1		1	1				1		1	1	2	1			**10**	461202	0.50%
B5-5	B5111-5113, B5711-5726			2			2	1	1	1				2		2	2	3	2	1	2	**21**	308478	0.33%
B6-1	B6					1	1	-1	3	1	2			3		3	3	2	1			**19**	196632	0.21%
B7-1	B7131, B7132, B7212, B7214, B7513, B7523, B7533						1		1	1				1		1	1					**6**	1917333	2.07%
B7-2	B722,B7221, B7222		1		3	1	1	1	1					1		1	1	1				**12**	363831	0.39%
B7-3	B731-733	3					-1		-1	-1				1		1						**2**	146691	0.16%
B7-4	B7111	3				1	2	1	1	1	-1	-1	1	1		1	1	1				**12**	8926180	9.65%
B7-5	B7213	1	1				1	1		1				1		1	1	2	3		2	**15**	13097	0.01%
B7-6	B7211	3	1			1	1	1	1	1		1	3	2		2	2	2	3			**24**	60573	0.07%
B7-7	B7521, B7531, B754, B7551	3					1	1	1	1							1	1	1			**10**	761518	0.82%
B7-8	B7522, B7532, B7552	2					1	1	1	1		1		1		1	1	1	1			**12**	225570	0.24%
B7-9	B7412-7416, B7421-7426	2	1		1	2	2	1	1	1		1	2	2		2	2	3	2		2	**27**	2045250	2.21%
B7-10	B7121, B7122	2					1	1	1	1		1	1	2		2	1		1			**14**	153422	0.17%
B7-11	B714	1	1				1	1	1	1	1	2		2		2	2	1	1			**17**	33481	0.04%
B7-12	B761-765						1		1	1							1					**4**	131878	0.14%

	Ecosystem services	Provisioning				Regulating										Habitat		Cultural				Statistics		
Type	Content of biotope units	Food	Raw materials	Fresh water	Ornamental	Air quality regulation	Local climate	Carbon sequestration	Moderation extreme	Water regulation	Water purification	Erosion prevention	Pollination	Biological control	Noise regulation	Habitats for species	Genetic diversity	Aesthetic	Recreation	Science and education	Cultural heritage values	Total score	Referred area/square meter	Proportion in Greenbelt
		P1	P2	P3#	P6	R1	R2#	R3	R4#	R5	R6	R7	R8	R9#	R10	H1#	H2#	C1	C2#	C4#	C5			
B8-1	B8721-8724		1			3	3	3	2	2	3	3	3	3	3	3	3	3	3	1	1	**43**	392093	0.42%
B8-2	B8711-8714		3			3	3	3	2	2	2	3	2	3	3	3	2	2	3			**39**	6763509	7.32%
B8-3	B8731-8733		3			2	2	3	2	2	2	2	2	2	2	2	2	2	1			**31**	11420460	12.35%
B8-4	B821, B831, B851					1	2	1	1	1	1	1	1	2	1	2	2	2	2			**20**	1608798	1.74%
B8-5	B8751		3			3	3	3	2	2	2	3	2	3	3	3	2	2	3			**39**	6082400	6.58%
B8-6	B8752					2	1	2	2	2	2	3	3	3	2	3	3	3	3	2	3	**39**	5038	0.01%
B8-7	B822, B832, B852					1	2	1	1	1	1	1	1	2	1	2	2	2	2			**20**	19274	0.02%
B8-8	B8741-8743		3			2	2	3	2	2	2	2	2	2	2	2	2	2	1			**31**	7300252	7.90%
B8-9	B876, B8771-8774, B878, B879					3	3	3	2	2	3	3	3	3	3	3	3	3	1			**38**	1277156	1.38%
B8-10	B824, B833, B834, B853-855, B861-863					1	2	1	1	1	1	1	1	2	1	2	2	2	2			**20**	1720849	1.86%
B8-11	B841-843						1	1	1	1			1	2		2	2	2	1			**14**	693502	0.75%
B8-12	B81																	3	1			**4**	38230	0.04%
B9-1	B91, B92, B93, B94								1													**1**	1425817	1.54%
B9-2	B95, B97					-1	-1	-2		-2		-1										**-7**	100804	0.11%
B0	B0																					**0**	511033	0.55%

1. Blank cell refers to "0" score in the evaluation.
2. ES with # refers to "other data needed for a full evaluation"
3. The total score only represents the potential capacity since many ES needs other information to complete.

5.3.1.2 The distribution of single ES

5.3.1.2.1 Provisioning Services

The distribution of provisioning services (Fig 5.3.1) shows strong attachment with land use and land properties, especially in P1, P2 and P6, whose contribution areas rarely overlay with each other.

P1 Food provision

In Greenbelt, 2726 ha land (29.48%) contribute to food provision at different level (Fig 5.3.1-a). Among them, the intensively cultivated crop land alone covers 9.65%, which is the second largest biotope subunit in Greenbelt. Other productive agricultural lands have much smaller areas, like the orchard meadow (2.21%), the grassland (1.06%) and extensively cultivated crop land (0.17%). These agricultural lands lie mainly in the Berge Rücken (from Bergen-Enkheim district to Berkersheim), part of the Nidda river meadow (from Harheim to Nied), the relics of Main river meadow in Schwanheimer Unterfeld, and the arch of Main river in Fechenheimer. Another leading type is the small gardens which reaches 9.23%, includes small gardens facilities and leisure time gardens. Food production is not the main purpose in such gardens, but growing own food with and for families or friends has been a new popular trend.

Though food provision could be more precisely mapped using the crop yield data in previous years (Rodríguez-Loinaz, Alday et al. 2015), the approach applied here has proved to have enough accuracy for urban level analysis. The biotope classification system provided detail enough information in this main type, include cultivation intensity (intensive, extensive, lie fallow), land type (crop, vegetable, horticultural plants, vineyard, orchard, mixed, grassland or wild) and surface properties (permeable, impermeable). But more data are necessary considering the large percentage and scattered location.

Food production is a highly land-dependent services that mainly provided by certain type of land. For the Greenbelt, the one fifth agricultural land has been a vital and characteristic part for the abundancy of land use type and inheritance of traditions. However, such land is not so “public” as other types. The agricultural land is owned either by persons or companies. 80 active farms are responsible for food production, a quarter of them cultivate vegetables, fruit and herbs. These farms are not totally fenced toward visitors but intensive agriculture activities are no playing ground for leisure time. The small gardens belong also to persons or clubs with strict access control, that citizens who are not members or renters of such places are completely locked out. Moreover, the private landownership also leads to the lack of official statistic data in the area, which is indispensable for further studies.

P2. Raw materials

Over 3400 ha land (37.29%) are involved in the production of timber in Greenbelt, the main contributor belongs to the urban forest (Fig 5.3.1-b). Among the productive area, more than half of them is broad-leaved forest like beech, oak and some non-local types, 19.27% is coniferous forest and 23.12% is mixed forest. Some special types like the broad-leaved forest in moist to wet land (B8721) or the historical sand pine forest (B8752) are identified as endangered biotope types which are under carefully monitoring than forestry use.

The entire Frankfurt urban forest, 6000 hectares all together, was acquired by the city administration in 1372 and is still the biggest municipal forest in Germany. Timber production has been a traditional industry in Frankfurt, but the expansion of forest from pure economic to recreational purpose started ever since the 18th century. Now the logging was taken in a sustainable way with considerations of the biotope and tree types protection. The timber production was certificated by PEFC (Programme for Endorsement of Forest Certification) since 2001 and approved by FSC (Forest Stewardship Council) in 2014 (Zwilling 2016). Generally, less amount of wood is cut than grown and the purpose of urban forest is no longer about profit chasing. For instance, in 2009, the productivity of usable forest was 5 cubic meter per hectare, while about 3.5 cubic meter per hectare was logged.

P3. Fresh water

The provision of fresh water is mapped from both biotope map and local policy (Fig.5.3.1-c). Based on the biotope types alone, only 2.5% of Greenbelt is relevant for the provision of fresh water. These areas are the potential sources of surface water, include the Main river, the Nidda river and several small lakes, ponds and springs. The ground water source area, which cannot be identified from biotope map, is mapped based on the "Drinking water protection area" (Trinkwasserschutzgebie, TWS) inside Greenbelt which covered approximately the whole urban forest.

The TWS is protected by the related policy of Hessen and managed under the Untere Wasserbehörde. There are four such areas in Frankfurt and only the urban forest TWS (ordinance of Nov. 11th 1997) lies inside study area. Depending on the distance and groundwater flow velocity to the extraction points, the TWS are divided into Zone I to Zone III to restrict or prohibit certain activities. In this way, the impurities and disadvantageous changes, threats in the area of the extraction plants and the catchment area of the drinking water protection areas are excluded.

P6. Ornamental resources

Nursery gardens, seedling areas and private small gardens provide with ornamental resources for the region (Fig 5.3.1-d). These fragments intersperse in the Greenbelt with commercial nursery gardens a very tiny proportion (0.39%). The main contributor is still the private hobby-related small gardens. Similar problem like in P1 is the exclusiveness of the such lands to the majority of visitors, especially in the east part where these land are collected together.

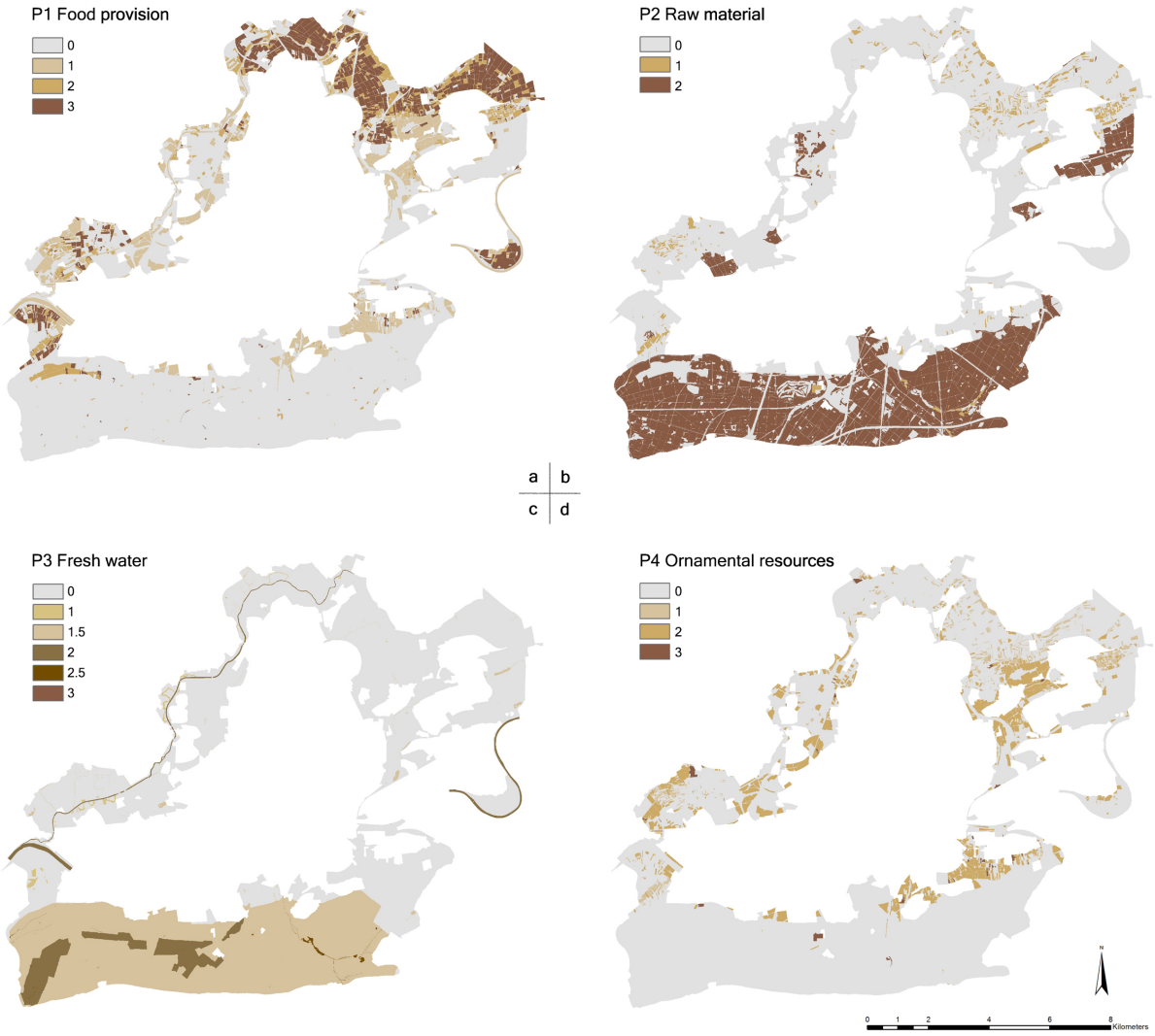


Fig 5.3. 1 The spatial distribution of Provisioning Services, by author

5.3.1.2.2 Regulating Services

Regulating services relies in most cases the quality and location of green spaces, which in the mapping present as the dominant position of forests in the majority of functions (Fig 5.3.3 and Fig 5.3.4).

R1 Air quality regulation

Air quality regulation, also known as air purification, is one of the first services identified and emphasized in urban environment (Bolund and Hunhammar 1999). In Greenbelt, this services involved approximately 70% of the land and positive effects are the dominant (Fig 5.3.3-a). The urban forest, as proved in other studies (Baró, Chaparro et al. 2014), is the key contributor while the massive transit transportation cross the forest and agricultural land are the main source of air pollution. The air

purification capacity is extremely low along the west side of Nidda river, as well as in the east part along the Main river, where this service almost disappeared.

R2 Local climate regulation

The identification and mapping of local climate regulation capacity combined two considerations. The first part is the properties of land cover in providing better microclimate, this depends on the land use and land cover type. For instance, experiments have confirmed that the temperature in a park is on average 0.94-degree cooler in the day, and larger parks or those with more trees have better effects (Bowler, Buyung-Ali et al. 2010). Reflected directly by the biotope map, forests have the strongest positive effect and other green areas, depending on the percentage of tree canopy, have less effects. The areas for wide roads with sealed surface and large traffic, are the main heat sources in the Greenbelt.

The second part is the location of green spaces considering its significance in urban ventilation corridors. Based on the climate map of Frankfurt (Fig 5.3.2 left), the critical fresh air corridors inside Greenbelt include the areas along the Main and Nidda river, and the core dynamic effective areas for the generation of cold fresh air lie in the north and north-east part of Frankfurt, as well as in the east part of urban forest (Fig 5.3.2 right). The maintenance of high quality and continuous open spaces in these areas has higher priority and importance than in other place, vice versa, the disturbance here also have negative effects for the whole city. Overlapping with the two factors, the final mapping present as a comprehensive consideration on both the city climate and local micro climate (Fig 5.3.3-b).

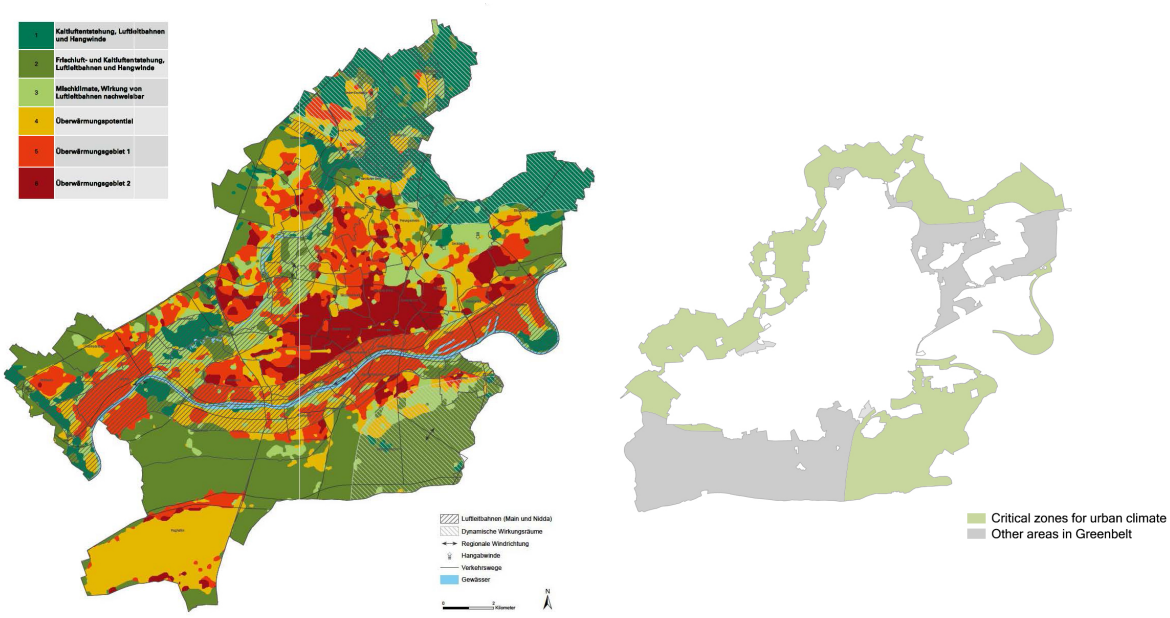


Fig 5.3. 2 Left: The climate map of Frankfurt, from Umweltamt; Right: The critical zones for urban climate in Greenbelt, draw by author based on the climate map.

R3 Carbon sequestration and storage

Generally, urban green space are natural carbon sinks and human activities lead to the emission of greenhouse gas. In Greenbelt, the forest is the top absorber of carbon while transportation areas are responsible for carbon emission (Fig 5.3.3-c). Agricultural areas sequestrate carbon as yearly harvest, while the tillage on soil also lead to the release of greenhouse gas in soil organic matter, which in total limits the capacity of this land use type (Paustian, Six et al. 2000). Wetland, on the other hand, is the potential greenhouse gas source due to the methane emission during the degradation of organic matter. To be more accurately, intensive managed and used green space have relatively less carbon storage capacity, but this difference is ignored in the study due to inadequate information provided alone in biotope type classification.

R4 Moderation of extreme events

The main targeted extreme events in Frankfurt is the flood, which is no more the top threat in recent years. Similar calculation method like R2 is taken here to combine both location and land properties (Fig 5.3.3-d). Land properties as evaluated in the Table 5.3.2, considers the potential of the biotype in creating buffers against natural disasters, which makes the wetland the most capable type and the built area the least one. Moreover, the main related area would be near the water courses, in this case the Main and Nidda river. Thus the areas in the 200-meter buffer zone are considered relevant for the services (Rodríguez-Loinaz, Alday et al. 2015).

R5 Water regulation

Like R1, R2 and R3, the majority of Greenbelt contributes to the water regulation service and urban forest still counts the most (Fig 5.3.3-e). This service could be quite adequately evaluated based on the land cover and properties described by biotope classification, include the surface water permeability, vegetation type and percentage, as well as soil water content. Continuous built area with sealed surface is considered pushing on negative influences.

R6 Water purification and waste treatment

Ecosystems can help in different extent to filter out and decompose organic wastes brought into inland waters and assimilate and detoxify compounds through soil and subsoil (MA 2005). This process dependents on the vegetation and biota in soil retention as well as the natural soil formation and regeneration(De Groot, Alkemade et al. 2010). The more accurate approach of assessing this service need specific indicators like the average soil denitrification efficiency or N-export with seepage water (Koschke, Fuerst et al. 2012); while the more approximate proxies were also applied like the cover of riparian forest in river margins or the just the cover of forest in certain area (Rodríguez-Loinaz, Alday et al. 2015). Based on existing information, the disturbance of human activities, the condition of water body and surrounding vegetation and the condition of forest are the main reference of the mapping (Fig 5.3.3-f).

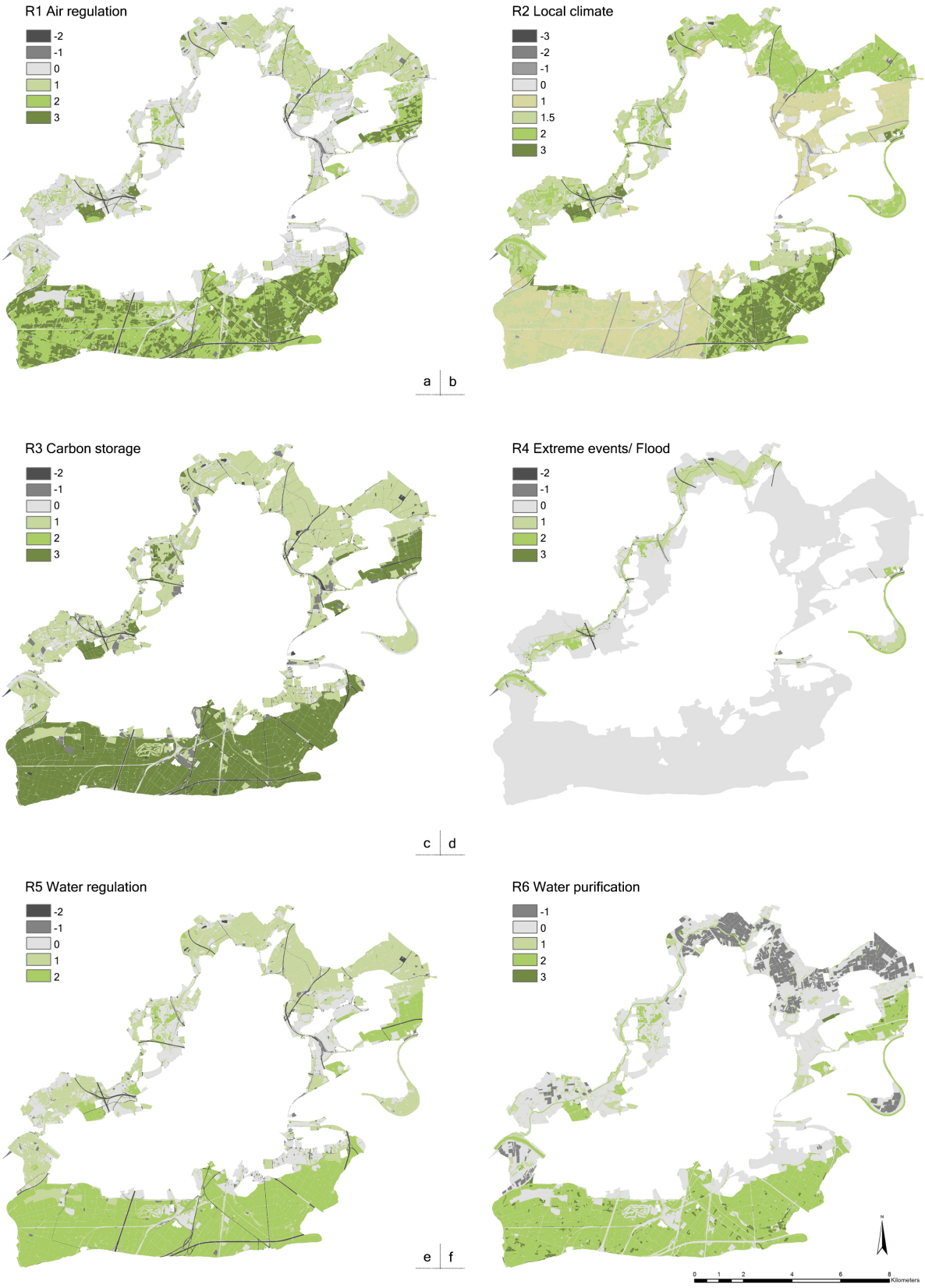


Fig 5.3. 3 The spatial distribution of Regulating services (From R1 to R6), by author.

R7 Erosion prevention and maintenance of soil fertility

Soil erosion is a key factor in the process of land degradation, desertification and hydroelectric capacity. Soil fertility is essential for plant growth and agriculture, and well-functioning ecosystems supply soil with nutrients required to support plant growth. Based on the national investigation on the risk of soil erosion through water (BGR 2007), only the agricultural land in the north part of Frankfurt is in potential risk due to intensive tillage. Other green spaces theoretically have positive effect on the service. In this way, the mapping based on biotope is sufficient as a general assessment (Fig 5.3.4-a).

R8 Pollination

Pollination is vital for the sustainability of flora and fauna in Greenbelt. Two criteria are considered in the mapping, the abundant habitats for pollinators and the promoting of wind. The orchard meadow as a local traditional landscape, is relatively favorable for pollination due to the combination of fruit trees and herbaceous plants under the trees, include pasture, herbs and crops. The forests, especially the ones with less human activities and higher soil water content, are natural habitats for small pollinators. Some local roads due to its use by human also help in the short distant migration of seeds (Fig 5.3.4-b).

R9 Biological control

Ecosystem regulate the pests and diseases through the activities of predators and parasites, like birds, bats, flies, wasps, frogs and fungi (TEEB 2010). Thus the habitats for these natural predators are the critical source of the service and the interface between crop field and predator habitats are the key areas for biological control (Kontogianni, Luck et al. 2010). In this way, the mapping focuses on the suitable habitats within a buffer of 200-meter from crop production areas and defines the value by land cover and land use (Fig 5.3.4-c).

R10 Noise regulation

The vegetation barriers, especially thick vegetation like dense forest, can absorb the sound waves made by human activities. In total, over 70 km transportation go across the Greenbelt and makes the service significant. Based on former filed investigation, a 300-meter distance to the main road is the minimum in order to bring down the noise to under 65 dB, the number is smaller to about 100-meter for urban traffic. Thus the buffer is made accordingly to select serviceable area and make evaluation based on vegetation density (Fig 5.3.4-d).

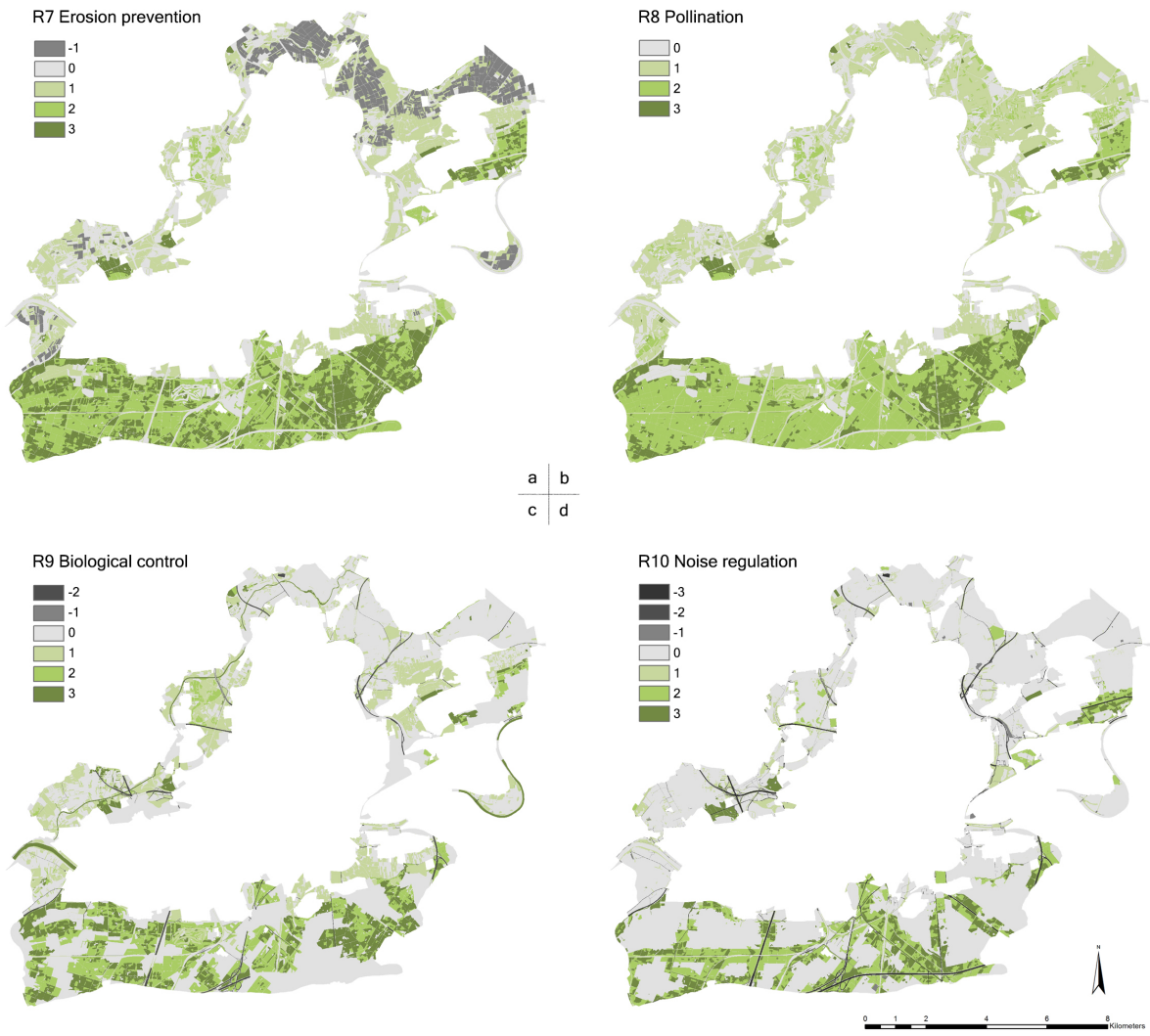


Fig 5.3. 4 The spatial distribution of Regulating services (FromR7 to R10), by author.

5.3.1.2.3 Habitat Functions

H1 Habitat for species

Habitat provide individual plant or animal with food, water and shelter which are essential for a species' life cycle (TEEB 2011). For migratory species like birds, fish, mammals and insects, the suitable habitats and corridors between destinations are critical for their movements. The mapping of this function also considered two aspects, similar proxies was also used in former studies (Rodríguez-Loinaz, Alday et al. 2015). The first is the abundance of a given area as habitats, which can be preliminarily estimated through the detailed classification and description in biotope map, whose main purpose is to keep record of information for regional biodiversity.

The second part was get from the additional explanation in the biotope type introduction, the endangers biotope types and the FFH protected areas which were recorded in the GIS database respectively. Table 5.3.3 show the related biotope type in Frankfurt, protection condition, endangered condition and the evaluation for mapping. This list based on the latest version of the Biotope type red

list in Germany. Three threaten levels are marked as 1 (under the threat of complete destruction), 2 (highly endangered) and 3 (endangered). The following column show the classification of regenerability as four types: K for hardly regenerable biotope types whose regeneration in historical periods is not possible; S for biotope types difficult to regenerate, which means the regeneration is only likely in long periods from 15 to 150 years; B means conditionally regenerative types whose regeneration is likely in short to medium term for about 15 years; X refers to no classification useful. Furthermore, there are two levels of legal protection for these types, the Federal Nature Conservation Act (Bundesnaturschutzgesetz, BNatSchG) and the Hessen Nature Conservation Act (Hessischem Naturschutzgesetz, HENatG) (Bönsel 2007). The FFH, Flora and Fauna Habitats, are also selected out as critical areas. Based on above information, the related areas of endangered and protected habitats are identified as most favorable places for H1(Fig 5.3.5-a).

Table 5.3. 3 The endangered and protected biotope types in Greenbelt

Code	Biotope type	Threaten level	Regenerability	Legal protection	Area in Greenbelt/m²
511	Ungefasste Quellen	1-2	K	§ 30, BNatSchG, § 31 HENatG	256
52	Gräben und grabenartige Bäche	3	X	-	136862
532	Bäche mit strukturreicher Gewässermorphologie	1-2	K	§ 30, BNatSchG, § 31 HENatG	21289
54	Flüsse und Ströme (naturnahe Ausbildungen	2-3	S		1482089
55	Altarme und Altwässer	1	S	§ 30, BNatSchG, § 31 HENatG	201802
56	Tümpel und temporäre Gewässer,	2	B	§ 30, BNatSchG, § 31 HENatG	19254
57	Teiche, Weiher	2			308222
58	Bagger- und Abgrabungsgewässer	2-3			103284
611	Schilfröhricht	3	S	§ 30, BNatSchG, § 31 HENatG	129704
615	Sonstige Röhrichte	3	B	§ 30, BNatSchG, § 31 HENatG	951
63	Goßseggenriede	3	S	§ 30, BNatSchG, § 31 HENatG	17098
712	extensiv genutzte Äcker	1	B	-	153422
713	Ackerbrache	1-2			828266
7421	Flächiger Streuobstbestand, UW trockenes oder mageres Grünland	2	S	§ 31 HENatG	182675
7422	Flächiger Streuobstbestand, UW mesophiles Grünland				473283
7423	Flächiger Streuobstbestand, UW intensiv genutztes Grünland				522751
7424	Flächiger Streuobstbestand, UW Acker	2	S	§ 31 HENatG	2349
7511	Grünland frischer Standorte, extensiv genutzt, artenreich	2	S	-	535338
752	Grünland wechselfeuchter Standorte	1-2	S	§ 30, BNatSchG, § 31 HENatG	51117

Code	Biotope type	Threaten level	Regenerability	Legal protection	Area in Greenbelt/m²
7531	Grünland feuchter bis nasser Standorte, extensiv genutzt, artenreich	2	S	§ 30, BNatSchG, § 31 HENatG	71690
7533	Grünland feuchter bis nasser Standorte, brachliegende Bestände	3	X	§ 30, BNatSchG, § 31 HENatG	25901
761	Sandtrockenrasen	2	S	§ 30, BNatSchG, § 31 HENatG	66580
Total					5334183

H2 Maintenance of genetic diversity

Genetic diversity refers to the variety of genes between and within species population. It distinguishes different breeds or races from each other and providing the basis for locally well-adapted cultivars and a gene pool for developing commercial crops and livestock (TEEB 2011). The habitat integrity is one of the essential conservation problems, that the fragmentation and destruction of habitat could directly effect the maintenance of the general genetic diversity. Habitat integrity was suggested to be evaluated by the minimum critical size for targeted species, however, at urban scale and with general conservation aims, the targeted species are hard to fix, not to mention the results of fragmentation experiments varied largely due to specific condition (Debinski and Holt 2000, De Groot, Alkemade et al. 2010). Thus only the relative size is considered in the mapping to identified the existing patches. After excluding of the artificial infrastructures inside Greenbelt, like the buildings, roads and sport areas, the rest patches have a median area of 2.6 ha. Then four groups are divided based on patch area, that area under 2.6 ha is marked "0", for the patches over 2.6 ha, the top one third is marked as "3", the medium as "2" and the rest as "1" (Fig 5.3.5-b). It is not a precise dividing way, but could present clearly the area difference and distribution.

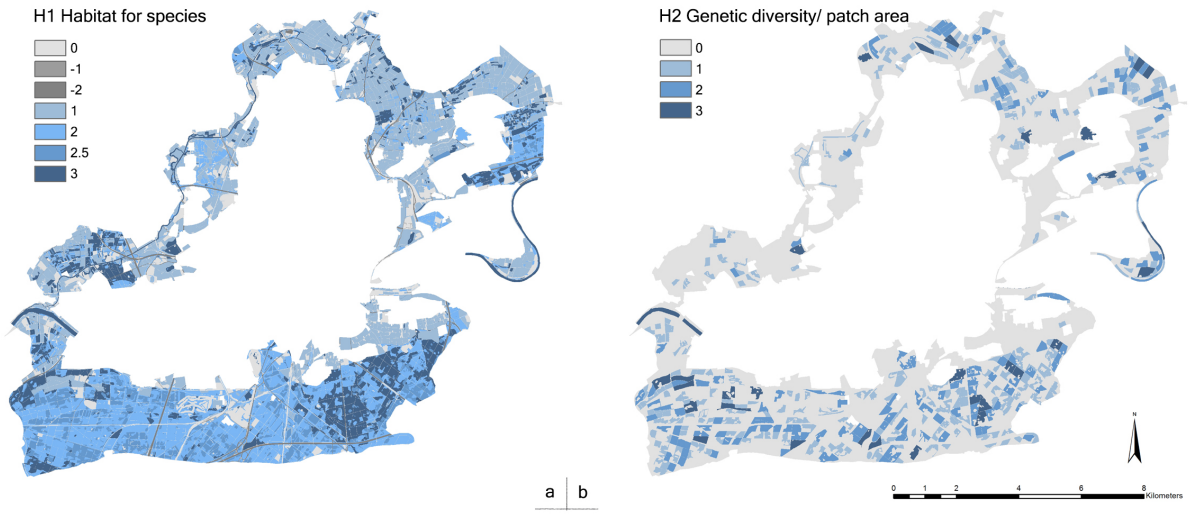


Fig 5.3. 5 The spatial distribution of Habitat functions, by author.

5.3.1.2.4 Cultural Services

C1 Aesthetic appreciation and inspiration

Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture and advertising (MA 2005). The mapping of this service (Fig 5.3.6-a) is mainly decided by the richness of landscape features as well as the uniqueness of the landscape for the city and the region, both rely on experts' perspectives which would unavoidably carried with subjective opinions.

C2 Recreation, mental and physical health

The role that green space plays in maintaining mental and physical health is increasingly becoming recognized. Walking and playing sports in green space is a good form of physical exercise and helps people to relax (TEEB 2011). This service (Fig 5.3.6-b) is especially vital for Greenbelt since one of the initial targets of the plan was to provide citizens with more recreational possibilities. Besides the evaluation of potential capacity of each biotope type, the several existing routes for walking and cycling are projected into the map as a vital additional information for the service. These routes provide not only suitable road surface for pedestrian and bikers, but also basic facilities like benches, road signs, and sometimes introduction boards to historical and cultural sites. Moreover, these routes are better maintained and have better connection with favorite destinations and built areas.

C4 Science and education

Ecosystems, as well as their components and processes, provide the basis for education in many societies (MA 2005), and the potential opportunities for formal and informal education or training have been increasingly emphasized in recent years. In Greenbelt, the formal educational programs for children and families started in 2004 and received huge success. There are 12 learning stations set inside the Greenbelt to provide green classes and outdoor activities. Besides, the informal educational value based on biotope types were also added to form the distribution of this service (Fig 5.3.6-c).

C5 Cultural heritage values

Frankfurt is not a typical historical and tourism city and not a lot of heritages can be found in Greenbelt. However, many cultural landscape types are identified and protected in the area, such as the Orchard Meadow, the once channeled and now renaturalized Nidda river and so on. These areas could be located directly through the description in biotope database to form the mapping of the service (Fig 5.3.6-d).

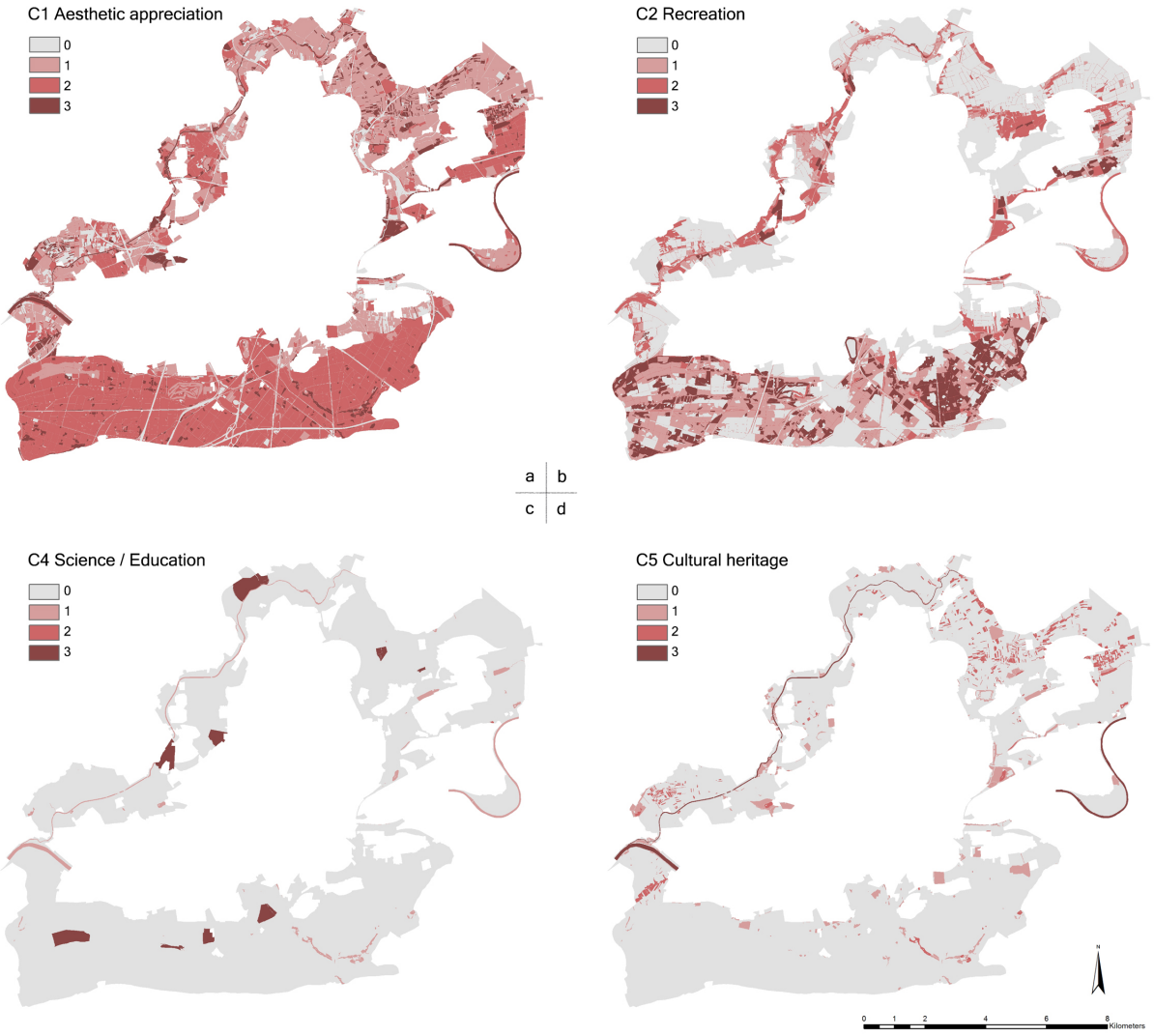


Fig 5.3. 6 The spatial distribution of Cultural services, by author.

5.3.2 The multifunctional hot spots

Based on the performance of each single ES, the general performance of Greenbelt in each type of the ES was counted through the overlaying of single ES with their weight. The weight of each ES in its group of services used the relevance level shown in Table 5.2.1, that those ES with "high" relevance are counted as the first level by weight, while the "low" relevant ones are the last. In this way, the performance of each ecosystem type could be calculated and mapped (Fig 5.3.7).

The spatial distribution of each type of ES show quite distinct features and each type present different dimension of the multifunctionality. The general performance of provisioning services not only shows the land involved in agricultural production, but also a sign for the exclusiveness of land. In Greenbelt, this type has a quite homogeneous character, that the majority part of the whole Greenbelt is productive, except the areas along the Nidda river and in the east part near the city center (Fig 5.3.7-a). The north-east part are traditional agricultural zones produce mainly crops, the south forest is the timber

producing area, and the rest small patches are small gardens where planting and horticulture are leisure time hobbies of citizens. The urban forest is the only area that carries out two types of products, the timber and the groundwater. For other producing land, normally only one type of production is provided because of the strong land use dependency rooted in this type of ES. However, it is still not quite normal for an urban green space to have such massive productive areas.

The regulating services could generally reflect the quality of green space from the ecological perspective(Paetzold, Warren et al. 2010). In Greenbelt, the forests contribute much more than other types of land use due to the natural large range of capacity in the vast stretches of trees (Fig 5.3.7-b). The south-east part of the forest, where the soil is wet and trees are mature, is clearly the hotspot among all, while the transit traffic roads have been the negative elements for the area. The farmland has limited regulating capacity due to massive and intensive tillage, however, the barely satisfactory on open space along the Nidda river suggest that the quality of green space in these areas may need further improvement.

Habitat functions represent similar but more fundamental feature of a given area, that how is the potential capacity and sustainability of the area to support other kind of services in the long run (Tzoulas, Korpela et al. 2007). The actual specific algorithm and field investment approaches are much more complicated while this study only captured the very first steps. Taking overall consideration of the properties of land use and land cover, the size of an undisturbed patch, and the habitats that are under formal legal protection, the south forest is the optimal area for this type of services (Fig 5.3.7-c). Especially valuable is the concentration of large patches in the center of the forest, whose sizes vary from 8 ha to 18 ha. It is a pity that these larger patches are separated constantly by roads and even heavy railway traffic, which may completely stop certain animals from moving between the patches. The poor performance along Nidda river in the west indicates not only the quality of green space but also the quantity and patch size of the area is worth improving. The re-naturalization work of the old channeled river has been a good start but further work is needed to ensure a better environment for both visitors and other creatures.

Cultural services are normally considered as non-land-dependent and intangible(Yang, Ge et al. 2015). However, the actual performance relies on the quality of both tangible and intangible works, as well as how these two aspects are combined. The relatively evenly distributed situation, like the score of “0.5” or “1” in light rose color, indicates the lack of efforts rather than the equally good performance (Fig 5.3.7-d). The score of such areas comes from the land property alone, which means the landscapes have the value for aesthetic appreciation but few could be captured since no other facilities are possible. The darker colors represent the combination of both sides, like in the educational sites, that a beautiful landscape is specifically prepared to be illustrated to visitors.

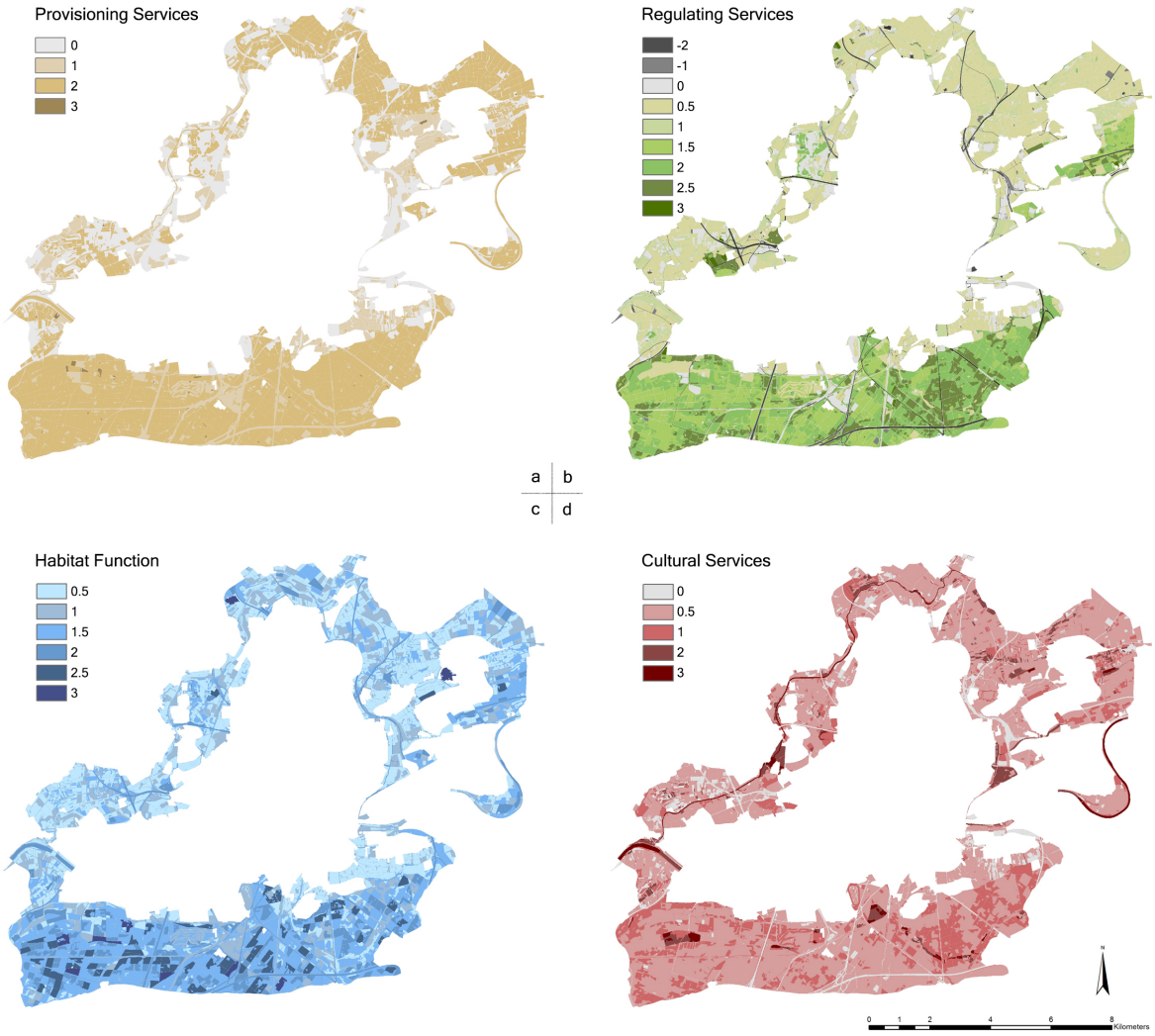


Fig 5.3. 7 The performance of each ES type, by author.

Using the same weighted overlay method, all the 20 involved ES were mapped together to show the comprehensive performance, which in urban scale could be understood as the multifunctionality of the studied area (Fig 5.3.8). The spatial distribution is divided into six levels. The lowest show a negative score and belong to the heavy transportation areas, where the roads are impermeable, wide and loaded with traffics that bring with polluted air and create interdiction to animals. The second part marked in light grey indicate the neutral result, that its contribution could more ore less offset the negative effects it brings. The third and forth levels distribute the most, they have certain extend of benefits but limited by its land properties or way of use. The last two levels represent the most multifunctional areas in the Greenbelt, they provide multiple services in a large amount and are the core functional parts in Greenbelt, or to be called as the “hot spots” of multifunctionality in the area.

The most obvious hot spot lies in the east of urban forest. This area has displayed from medium to high in all four types of ES and has extreme advantage in regulating services. This site is formed by medium to old aged forests in the moist or wet soil, a naturally optimal location for vegetation. The activities of the site are quite abundant, including timber producing, Greenbelt school, forest museum,

art devices, as well as roads for pedestrians and bikers. Furthermore, a group of endangered and valuable flora and fauna habitats located in this place, provide with potential genetic diversity as well as unique landscapes. The west side of the urban forest, through also present as high value in general, is too spread around the whole area without a clear center. In this way, the area performs more as a base area.

Some small patches of forest make up of the second group of hot spots. These areas, like the Enkheimer forest, the Fechheimer forest, the Nied forest and the Bieg forest, they separated in the vally of Nidda river or behind the small hills of the north and services as high quality recreational center. Sports areas and recreational facilities were set in the outer part of the small forest and the routes could easily access the place.

The third group of hot spots includes parks and some special agricultural lands. These areas don't present as the highest in score comparing with the urban forest, but they are the remarkable high point of the area and could attract visitors nearby. This includes the Volkspark, the old airfield, the Lohrberg and Heiligen Stock, all of which site in the north part of the Greenbelt and have higher cultural quality.

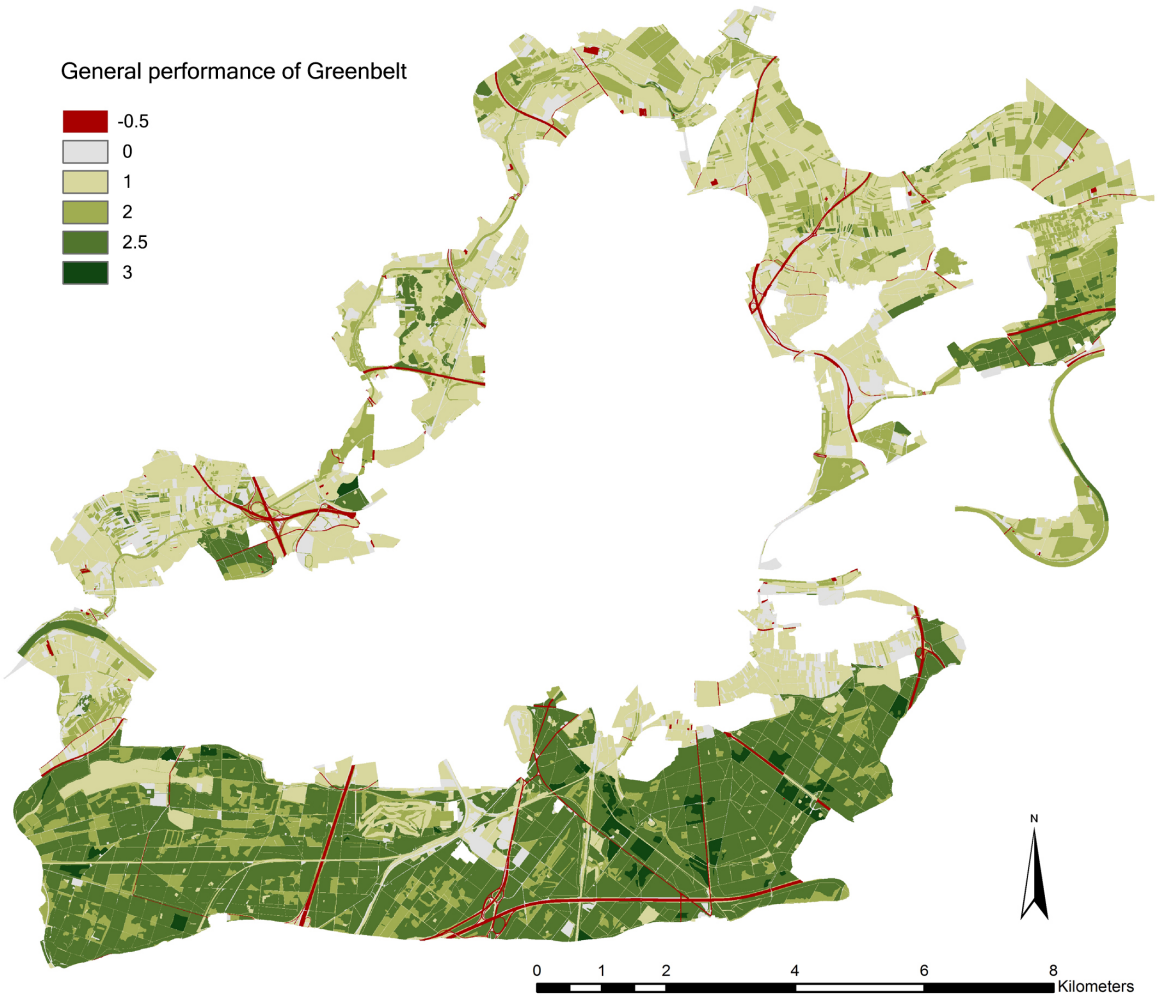


Fig 5.3. 8 The general performance of the multifunctionality of Greenbelt, by author.

5.3.3 Changes of multifunctionality in the past twenty years

The result of section 5.3.1 is a detailed and static portrait draw under the framework of multifunctionality. This section will make a preliminary discussion on how the studied area have changed since the Greenbelt project has been carried on for more than twenty years. The result of this section would give some clues on the dynamic portrait of Greenbelt.

5.3.3.1 The comparing process

Due to the limitation of digital data, the comparing process between the land use changes are taken manually using the two Greenbelt Leisure Maps published by the Frankfurt city council in 1992 (the first version) and 2011 (the latest version). The purpose of the maps is to point out the vast possibilities in Greenbelt in order to encourage more citizens in realizing and using the Greenbelt as an everyday green space. Thus the land use types are divided from the perspective of use. For example, forest is labelled all together, ignoring the type (broadleaf, coniferous or mixed), soil condition (dry, moist, wet) or usage (timber production, ornamental use, reserved forest), since all these types have little difference for recreation purpose. Another types like the small gardens and sport areas are on the contrary specifically identified to promote more visitors. It is not an ideal map for a complete comparison of land use changes, but it reflects the aspect of supply to recreational uses.

Also, considering the slight differences between the two versions, the “cemetery” in 2011 is merged into the “public green space”. Through “grassland” was not a category in 1992, it was kept in the map in case of changes. In this way, six types are under comparison, which are the forest, the public green space, the sport area, the small gardens, the agricultural land and the grassland.

Using the same boundary from the GIS data, the original maps was clipped out the areas outside the boundary (Fig 5.3.9) and divided to approximately 30 smaller blocks according to the crossing main roads. Each of the divided block was compared with each other in the smallest patch one by one. Any changes between the two maps were marked and draw in the AutoCAD file. Finally, the comparison was double checked to avoid personal mistakes.

5.3.3.2 Changes caused by land use

The land use changes between these two maps are totally fragmented and small in single site (Fig 5.3.10). The majority of changes distributed along the Nidda river in the west part of Greenbelt, gathered near the Lohrberg or near the banks of Main river. The urban forest in the south basically remains the same, as well as the Heiligen Stock and Gisisberg in the north-east, where the large-scale intensive agricultural industry has been stable for decades.

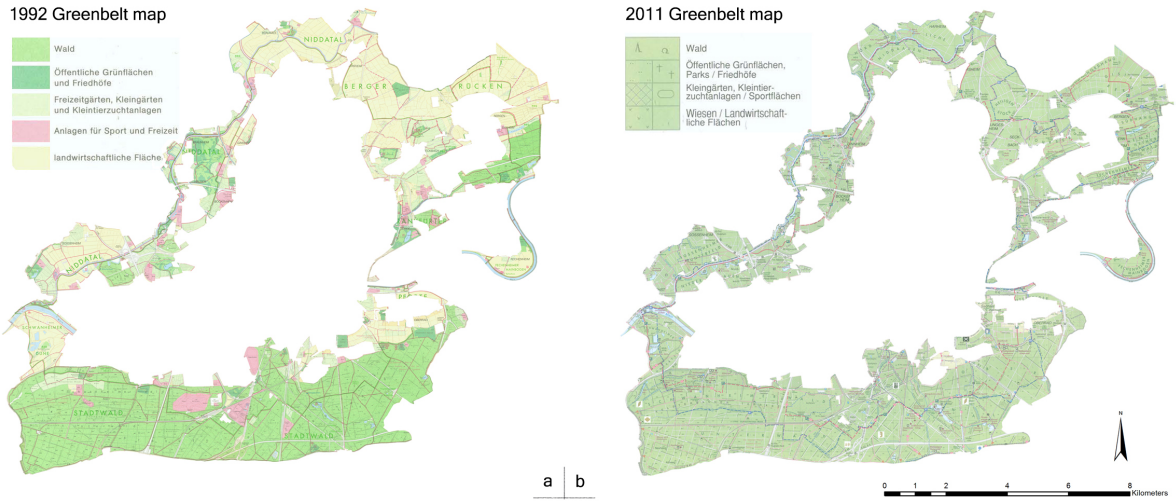


Fig 5.3. 9 The Greenbelt Leisure Maps, in 1992 the first version (Left) and in 2011 the latest version (right), reproduced by author based on original files from Frankfurt Institute of Urban History.

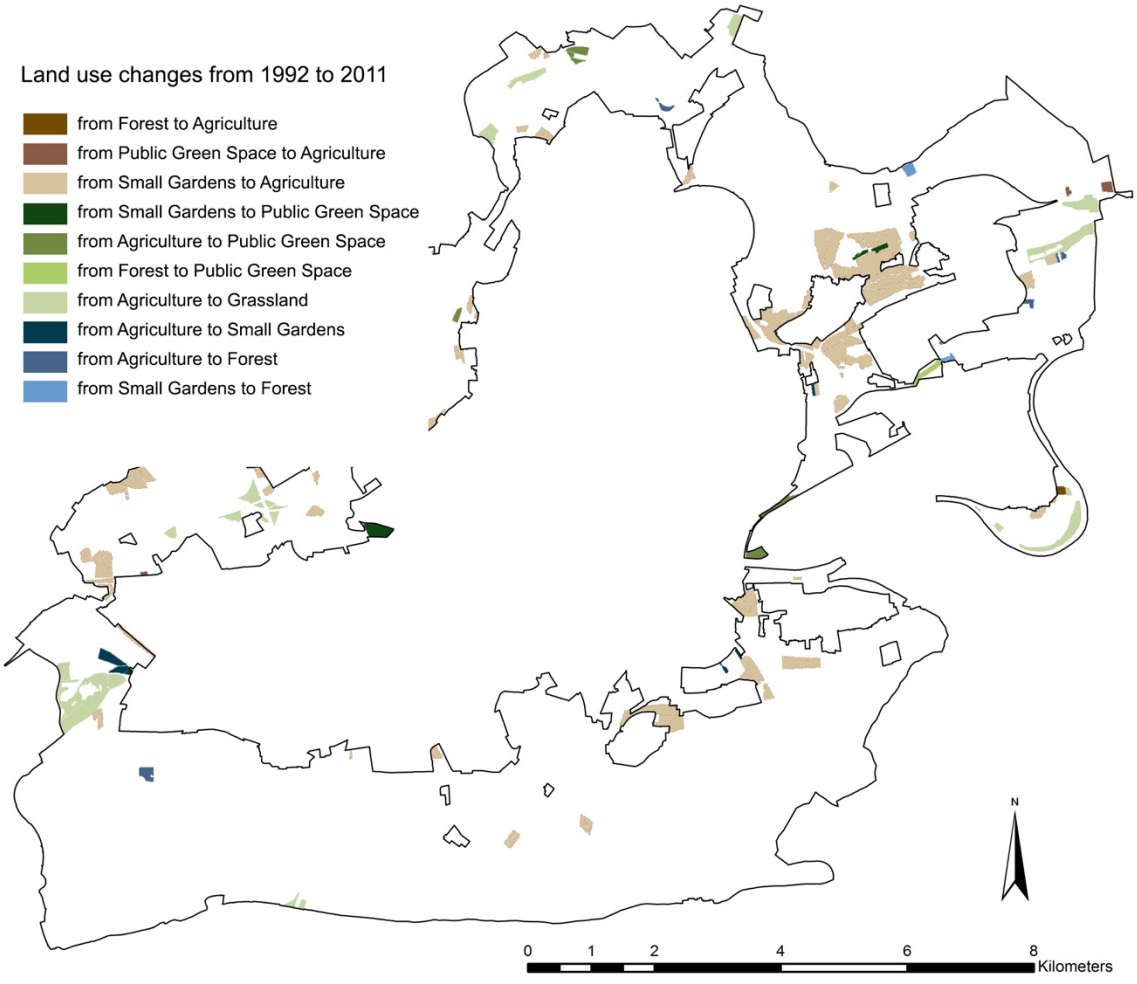


Fig 5.3. 10 The land use changes, land use status 2011(1992), draw by author based on Greenbelt Leisure Map 2011 and 1992.

Land convert from small gardens to agricultural use has been the most common type of land use change. A typical location of such changes lies in the Lohrberg (Fig 5.3.11-a), which has been a favorable location for the view of the whole city because these area has a generally higher altitude with the highest point of 212 m. The open spaces in the north-east of the Seckbach district used to be vast stretches of small gardens arranged along the contour lines, with the Lohrpark in the center and top of the small hill. In the map of 2011, most of the small gardens become large scale agricultural area, left only two small patches in the down hills. In the mean time, the "Main Appel Haus" opened for the recreational picking of apples and fruits, as well as for educational purpose to families and schools. The non-vehicle connections for pedestrian and bikers also improved due to the map.

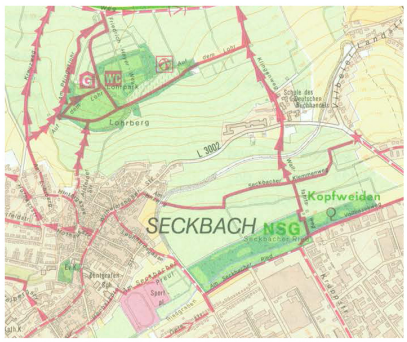
Another obvious change is the grassland, especially in the Schwanheimer Dune (Fig 5.3.11-b). In 1992, only the center of this particular landscape is included in the National Reservation Area (NSG). In 2011 map, the protected area as FFH has increased more than three times to include a large pond inside the area. The whole place, whose vast area were agricultural land before, is now fenced for better protection, but it remained open to the public through a special wooden route in order to keep the historical dune and pine forest intact. Small gardens and parking lot also appeared near the location and provide better facilities for the area. Other converting into grassland are generally much smaller, some are the protective green lawn under the huge road intersections.

In Bonames, the north-west park along the river Nidda, there is a small changed grassland of about 5.6 ha (Fig 5.3.11-c). It was the old airfield of American army but was long abandoned in the 1990s, so was generally counted as agricultural land with its surrounding farm land in the 1992 map. After the reconstruction project stared in 2004, the whole area has become a public space with the return of vegetation and small animals. It was not quite specific to include the area as grassland, since its characteristics have attracted massive visitors and functions even more than normal parks.

A critical but easily ignored change of grassland could be found in the north river bend of Main in Fechenheimer (Fig 5.3.11-d). Due to the large curve of the river flow around the area, this place has a unique view but also endangered with flood. Basically the whole area was agricultural land according to the 1992 map, with only a small strip of sport area in the west. In the 2011 map, the area along the water course became grassland with a width varied from 30 m to 170 m. According to the new plan, this area was furtherly redesigned to suit the flooding scenario and provide better landscape view for the historical route along the river.

Other land use changes are even more scattered and less obvious than these ones, however, all these gradual incremental changes have the potential to alter the micro environment step by step so as to have influences for the whole area in the long run. Nevertheless, considering the time span of 20 years, these changes on land use, which in total counted for less than 8% of the Greenbelt, seems to be too small. Especially some changes like the ones between agriculture and small gardens, are not fundamental turns. Evaluated from their contributions on the ES, both these two types have higher provisioning services, limited regulating and habitat functions and don't perform well in cultural

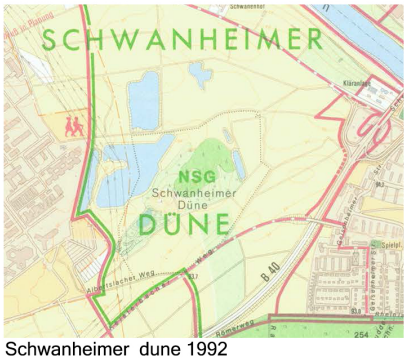
services since such areas are exclusive to the non-members. In a word, the changes of land use based on the 1992 and 2011 leisure maps have some shining points but in general quite limited.



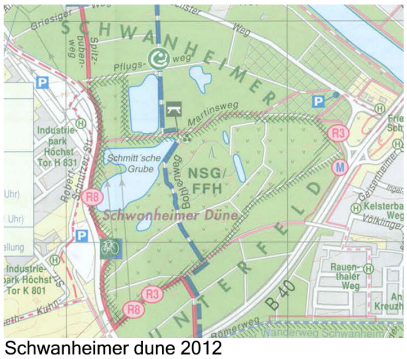
Lohrberg 1992

Lohrberg 2012

a

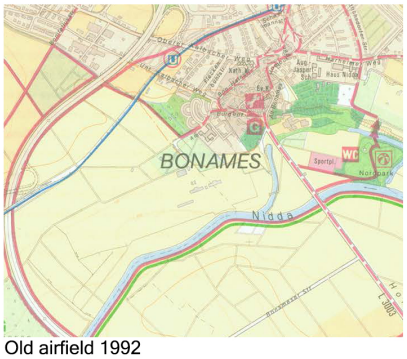


Schwanheimer dune 1992

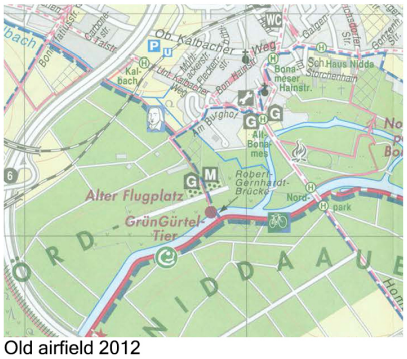


Schwanheimer dune 2012

b

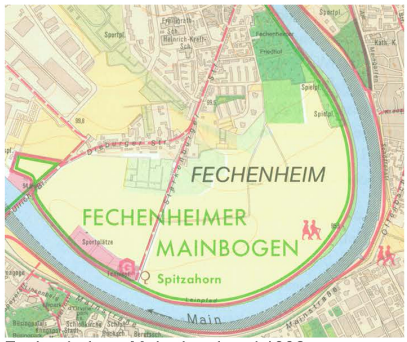


Old airfield 1992

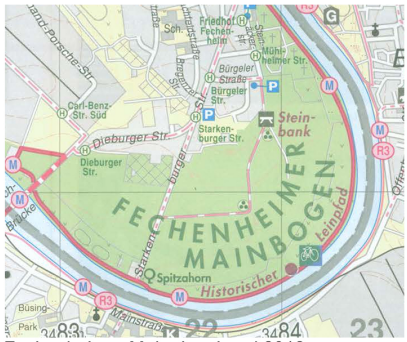


Old airfield 2012

c



Fechenheimer Main river bend 1992



Fechenheimer Main river bend 2012

d

Fig 5.3. 11 The typical changing spots in Greenbelt, by author.

5.3.3.3 Changes in the distribution of ES

Besides the tangible changes on land use types, the no-material changes on policy and planning also have considerable influences on the usage and maintenance of a certain space. Comparing on the new-added policies and measurements in Greenbelt from the four categories of ES, the most affected aspect is the cultural services, while the intended efforts on regulating services seems to be the least.

The Greenbelt Plan and implementation has limited power on the provisioning of food and ornamental resources due to the private land ownership. However, a critical act is taken for the fresh water provision, that is the definition of Groundwater Protected Area in urban forest which went in operation since Nov. 17th 1997. According to the guideline of protection, many actions like the overuse of fertilizer is prohibited in the area and some precautions are specially taken to prevent any potential damage, for example, the zone I area is normally fenced and off limits to visitors.

The FFH and the Protection Area for birds (Vogelschutzgebiet) are similar protection and definition approach taken after the 1991 Greenbelt Plan. These areas contain species and habitat types that are particularly vulnerable, for which special protection measurements need to be taken. The FFH areas are compiled primarily under the criterion of protections for the species and habitats follow the Federal Nature Conservation Act (BNatSchG). Moreover, all the FFH areas are included in the project "Natura 2000", which is a European network of coherent protected areas. There are in total 10 such areas in Frankfurt, and seven of them site inside the Greenbelt (Fig 5.3.12). These areas are rounded by fence or wall in order to keep human intervention completely out during certain time period in the year, and some also in the night.

Fig 5.3. 12 The FFH areas in Frankfurt and within Greenbelt, re-edit by author based on document from Stadt Frankfut am Main.

Much more works were done through the Greenbelt project in the shaping of this huge open space, from some distant urban outskirt into a continuous urban green space for public activities. The building of a green image full of possibilities has been a main approach. For instance, on urban level, about 60 destinations were defined and marked on the Greenbelt Leisure Map by the project group to emphasis potential sites of aesthetic appreciation and recreation for citizens (Fig 5.3.13). Two full round routes for pedestrian and cyclists are high lightened and partially reconstructed for recreational purpose. The Educational Program "Discover, research and learn in Greenbelt" has push forward this effort to a new level. Families and small children, who are the future users of Greenbelt, are presented by experts with the beauty of nature and the landscapes of cultural and historical meanings. The intangible value of Greenbelt is thus being greatly spread and comprehended, which is not possible with the beautiful scenery alone. Furthermore, numerous signs, instructions and benches with Greenbelt logo have been added into the area along the years to enhance the integrality of Greenbelt. Comparing the ways of drawing the Greenbelt Leisure Map in 1992 and 2011 (Fig 5.3.9), the clear message of Greenbelt as a whole is much better delivered in the latter map.

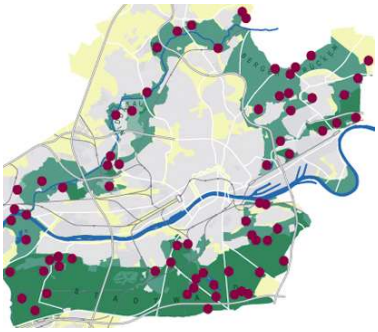


Fig.5.3. 1 The destinations of Greenbelt, from Umweltamt Frankfurt.

Despite the limitation of the data being compared, the changes of Greenbelt in its two decades of development could be preliminarily captured. Changes on the land use and land cover are scattering mainly in the west and east part of Greenbelt. They are small in scale and lack of traceable connections, however, some of the small changes are critical for the wellbeing of its located area. Changes on the non-material aspects of the Greenbelt centered in cultural services and aims at reshaping the image of Greenbelt as a whole, on the contrary, legal protections on the natural resources of Greenbelt are relatively loose and lack of joint efforts with the cultural aspects. In general, the physical and non-material changes in Greenbelt during these 20 years are small, fragmented and isolated with each other, with the only exception of the intangible ones. But the latter aspects are hard to measure and could also be difficult to describe without subjective judgments.

5.3.4 Summary

Based on the current status in the section 5.3.1 and 5.3.2, Greenbelt preformed fairly well from the perspective of urban level multifunctionality and the majority of land contribute positively to multiple ES. The massive traffic made the main transit roads the only negative contributor. The urban forest in the south has been the most multifunctional area in all types of ES, while the west and east parts of Greenbelt preformed only an average level or even below average in certain aspects. Nevertheless, according to the preliminary analysis in section 5.3.3, the fragmented small changes of Greenbelt in physical spaces mainly happen in the west and east parts, while the non-material changes are generally even for the whole area with certain greater attention on the forest in legal protection. To sum up, based on the framework of multifunctionality, urban forest has presented with the highest capacity in Greenbelt with only few changes in past twenty years; the areas along the Nidda river and the east Greenbelt have had multiple scattered land use changes, but their current general capacities are still quite limited; the north part has been the stable provider of food since continuously, with basically no changes.

5.4 Multifunctionality in Planning Efforts

This section use multifunctionality, as one of the many potential clues, to link the performance of urban green space to the planning efforts made on it. To be more specifically, same framework will be applied to examine how each ES had been considered in planning and strengthened in implementation.

5.4.1 The coding process

A qualitative approach was used to interpret the planning efforts of Greenbelt Frankfurt. The approach included three steps: the collecting of related planning documents, the setting of the Coding Protocol, and the coding of related documents. Related data are collected on two scales, the city scale which deal with the Greenbelt as a whole and the local scale in which dozens of projects were formed and implemented. At the city scale, four phases, namely the original plan, the implementation, the status and the new plan, could be detected as key points for Greenbelt Frankfurt. The first is the phase of concept forming and original plan making, with Greenbelt Constitution (Stadt Frankfurt am Main 2003) the final document and other publications as explanations. The second implementation phase still continuous so the review of Greenbelt from 1991 to 2011(Stadt Frankfurt am Main 2011) together with records of single projects of the same period were gathered. In third part the reports made by authorized institutions(Projektbüro 2010, Projektbüro 2014) for the analysis of current status in Greenbelt. The fourth phase based on the planning documents of the new Spikes and Rays Strategies (Speichen und Strahlen, 2012), which is the development guidelines of Greenbelt in the future 20 years. Besides, interviews and field survey were used as validation method to reduce gaps and excessive packaging of above documents. Interviewee are experts in related field or operators and managers who still work for the projects.

The data quality and quantity of local scale has always been an obstacle of related studies. The specialty of Greenbelt is that it used an incremental implementation approach to realize the original goals by small projects, which step by step link the abstract plan into complex reality. Such small projects provide an opportunity for analysis in closer distance and in site-scale. To simplify the process and reduce repetition, projects were chosen and classified into 9 project series (Appendix 5.4.1), each contains projects with similarity in type, theme or location. Some single projects or the ones without enough data were left outside.

The first Coding Protocol was used by Wilkinson in the analysis of Melbourne and Stockholm cases (Wilkinson, Saarne et al. 2013). This section followed the similar approach and made necessary changes. In the study, 20 ES are considered relevant (section 5.2.1) according to the context of case study and they are separately mapped in section 5.3. However, considering the differences between a semi-quantitative mapping and a qualitative coding process, a slight change is added on the 20 ES to make the coding more accurate. To be more specifically, five of the 20 ES is further divided into smaller groups to catch the distinctions inside. “food provision” (P1) is divided to two indicators, the crop and

wild food provision; “aesthetic appreciation and inspiration” (C1) will be differentiated between aesthetic values and inspiration, the former refers to the beauty found in natural systems and the latter emphasis the inspiration for art, symbols, architecture or advertising. Similarly, “recreation/ mental and physical health” (C2) partitioned to recreation/ecotourism like picking garden and health for outdoor activities; “science and education” (C4) to scientific research and educational values; “Cultural heritage value” (C5) to cultural heritage preservation and cultural diversity promotion. The detailed ES, mostly in cultural services, will translate the information of documents in a more precise way, but it is not quite possible for mapping which based mainly on the land use and land cover data.

Based on the preliminary readings of related documents, a refined Coding Protocol for this study is set (Appendix 5.4.2), and further distinguish the coding between two levels of “targeted” ES to clarify the intension of plans since the historical documents were made when above concepts are less known. One level is the “clear target” refers to an explicit similar description of certain ES in the content of planning document; the other is the “potential benefited target” to describe the situation of some policies which do not directly aim at certain services but could benefit for a better achievement by side effects, for example, “Green spaces” would contribute to “local climate regulation” without specific targeting. Also, this refined Coding Protocol helps in the interviews since practitioners of related government department haven’t formed a clear understanding of the related concepts.

Through Ecosystem Services is a young concept which booming in recent decade, its content is not all brand new but with the majority the old topics since 1970s with the emphasis of ecological value in urban environment. Besides, urban planning is naturally a multifunctional task that aimed at balancing between conflict demands. In this case, even to a concept as old as Greenbelt, its multifunctionality is to be expected. To answer the question of how is multifunctionality considered in different phases of Greenbelt cross twenty years, document analysis aims at identifying related description in planning files using the Protocol. Unlike the work of Kabisch in Berlin (Kabisch 2015), a “clear target” in this paper may not necessarily use the explicit term in Ecosystem Services but rather fit with the definition; and a “potential benefit” could be even more ambiguously formed. The balancing and interactions among ES rely on content analysis and in some case the interviews with operators. The question of time changes could be answered by comparison between the four phases to describe the fulfilment of target and direction shift. The same framework was used again on the local level project series.

5.4.2 Greenbelt planning process

The Greenbelt concept has been brewing for decades and revised by several scholars before the Greenbelt Constitution got fully approved by the City Council. Thanks to the international workshops during the Greenbelt Project Year, the contemporary new concepts of urban green space planning from different countries and districts were exchanged together. The acknowledgement of “sustainable development”, which was an emerging idea in 1980s, was quite accepted by planners of the Greenbelt.

In this way, the Greenbelt Plan at the beginning had already targeted on different aspects, which were described as ecological, social and aesthetic goals. It is not an outdated plan even for today.

The implementation process had been more intricate due to its two working forms, the GmbH and Project Group. The coding process here focused rather on the actual works done and made analysis based on official records, than on the complicated process and management. In the implementation for two decades, especially during the Project Group since 1997, the goals of Greenbelt Plan were disassembled and carried out slowly by numerous projects. The coding here marked if an ES was ever targeted in any project instead of the frequency. Same analysis was made for the plan "Spike and Ray" in 2012 by the working group led by Professor Dr. Friedrich von Borries. This plan is a pilot part of the 2030 planning strategy and could also be seen as an "add-on" plan on the old Greenbelt plan. Besides, the report on the current situation of Greenbelt was also studied within the same framework. Though this report was not a plan, it was a relatively objective assessment made by scholars outside the Greenbelt and carried with abundant information. Table 5.4.1 shows the result of detailed content analysis of which ES were considered in Greenbelt Frankfurt in the four chosen phases.

Overall among the 25 analyzed ES items, four of them (16%) were clear targeted in all three phases from 1991 to 2012, namely "local climate regulation" (R2), "recreation/ ecotourism" (C2a), "Health" (C2b) and "cultural heritage" (C4a). Three ES (12%) were never clearly targeted and all of them belong to regulating services. The "moderation of extreme events / flood" (R4) and "Biological control" (R9) were considered of low relevance and they are mostly local and limited problems; the "pollination" (R8) is of medium importance but could always be benefited by other purposes. There is no totally forgotten ES in the analysis, which reflects the necessity of preliminary selection of ES based on studied area.

Considering from the four categories of ES, the habitat functions and cultural services have received full attention in the planning and implementation; the efforts on previsioning services is decreasing and regulating services in all time depends more on co-benefits from other purposes. The reasons are diverse. Biodiversity has been a political and academic topic since 1980s especially in European context and greatly affected the later term multifunctionality (Jones-Walters 2008). However, a majority political attention is paid to climate mitigation and adaptation nowadays. This helps to explain the fact that "Habitat for species" (H1) and "Maintenances of genetic diversity" (H2) was no longer the top priority in the 2012 new plan, despite the fact the attention and funding are never enough; and climate related ES, R2 and R3 which are climate adaptation and mitigation respectively, were the few targeted regulating services, though they already performed beyond average. Most other regulating services are much less mentioned. "Water purification and waste treatment" (R6) and "Erosion prevention and maintenance of soil fertility" (R7) were once vital in the fear of environmental crisis in 1980s, but no longer top agenda in the new plan. "Noise regulation" (R10) emerged as a new urban problem only in recent years due to fast growing transportation of the city. In total, 70% regulating services were not included in the report or New Plan and mostly considered low to medium relevance.

Provisioning services, due to the agricultural tradition in Frankfurt, generally received fair attention and assessment. Half of these ES were explicitly targeted at the beginning and most of them were implemented by projects. But non was included in the new plan 2012 despite the general high relevance. Cultural services were from the beginning the top targets and still caught the planners' eyes in new plan since the Greenbelt was made "for the people" from the beginning (Paul 2000), while the citizens and surveys didn't have all positive feedback.

Besides the listed ES, the Report 2011 also pointed out other notable situations. For instance, social equity or socio-environmental justice was indistinctly mentioned in the 1991 Plan that the Greenbelt should be a place formed by all kinds of life styles, a place where all citizens could participate. It was an advanced topic at that time but too vague to achieve through physical open space. The necessity of using public open space as communication area for all people only got attention in recent studies in other districts (Kabisch and Haase 2014). The report identified the crowd differentiation in the use of Greenbelt that elder people and families are the main groups while not enough younger people take Greenbelt as a first choice, although there are many collage students gathered in Frankfurt. Considering the high migration rate in Frankfurt, this differentiation may bring problems in the future.

Table 5.4. 1 Consideration of ES in different plans and report of Greenbelt Frankfurt

No.	Service/Function	Greenbelt Plan 1991	Implementation 1992-2011	New Plan 2012	Report 2011	Relevance
P1a	Food/crop	●	○	○	▽	High
P1b	Food/wild	-	●	○	-	High
P2	Raw materials/ Timber & Fuel	○	●	-	▲	Medium
P3	Fresh water	●	●	-	▲	Medium
P6	Ornamental resources	●	●	○	-	Low
R1	Air quality regulation	●	○	○	▲	High
R2	Local climate regulation	●	●	●	▲	High
R3	Carbon sequestration and storage	○	○	●	-	High
R4	Moderation of extreme events/ Flood	○	○	-	-	Low
R5	Water regulation	○	●	○	-	Low
R6	Water purification and waste treatment	●	●	-	-	Medium
R7	Erosion prevention and maintenance of soil fertility	●	●	-	-	Low
R8	Pollination	○	○	○	-	Medium
R9	Biological control	-	○	-	-	Low
R10	Noise regulation	-	○	●	▽	High
H1	Habitat for species	●	●	○	▽	High
H2	maintenance of genetic diversity	●	●	○	▲	High

No.	Service/Function	Greenbelt Plan 1991	Implementation 1992-2011	New Plan 2012	Report 2011	Relevance
C1a	Aesthetic values	○	●	○	▽	High
C1b	Inspiration	-	●	●	-	High
C2a	Recreation/ ecotourism	●	●	●	▽	High
C2b	Health	●	●	●	▲	High
C4a	Scientific research	-	●	○	-	High
C4b	Educational value	○	●	●	▲	High
C5a	Cultural heritage	●	●	●	▲	Medium
C5b	Cultural diversity	●	○	●	▽	Medium
	In total	13● 7○	17● 8○	9● 10○	8▲ 6▽	

In first, second and third column, ● represents for a clear target and ○ refers to a potential benefit in the analysed documents. In the fourth column, ▲ states for the satisfaction in reports and ▽ means the problematic or most complained topics, the undiscussed topics are marked with -.

General trend of cohesion and changes through the stages could be clearly seen from the Fig.5.4.1. Both Plan 1991 and Implementation have emphasis the Habitat Functions. In documents it was formulated as "to protect rare and endangered types" and to promote "diversity of habitat and biologic". The 1991 Plan had already addressed half the ES in the framework and the attention paid in Provisioning, Regulating and Cultural services were similar. The Implementation exceeded the original goals and covers all topics, especially on Provisioning services had a great increase, but the majority of Regulating functions were still targeted in an indirect way. However, the New Plan in 2012 show limited consideration other than cultural ones. Its emphasis on mostly response to the global discussion of urban climate change mitigation and adaptation, as well as the local demand of a greener urban image setting. The new plan tried to be a turning point of the development in Greenbelt, from the infill process to the out-connecting approach. The name of the new plan "Spokes and Rays" could also help to objective this transition. However, based on the multifunctionality framework, the former infill process still need more works.

Furthermore, each line of the Table 5.4.1 shows how each ES has been understood by different group of people in different time, the planners/designers, the researchers and the experts, which are three aspects of the questions. Take "food/crop" (P1a) and "food/wild" (P1b) for instance, the Greenbelt plan 1991 valued the farmlands inside Greenbelt and wanted the place to be "a dialogue between the city and agriculture" and to "supply Frankfurt with fresh local farm products"(Stadt Frankfurt am Main 2003). For the experts of Greenbelt, the importance didn't change even for now, as it was still identified as high relevance (interview Bönsel). However, few has been done for the topic by manager/officer of the project. The clear target for P1b came from the apple picking garden project like "Main Apple House" in Lohrberg, whose success mainly rely on non-profit associations rather than Greenbelt project. The concern of P1a in the 2011 report was mainly about the 5% low rate of ecological cultivation (Projektbüro 2010), which showed no difference as agriculture out of this natural protection area. But

the hands of the project group are tied due to private landownership and low special funding for larger moves. It is then reasonable that the new plan no longer focused on the provisioning services.

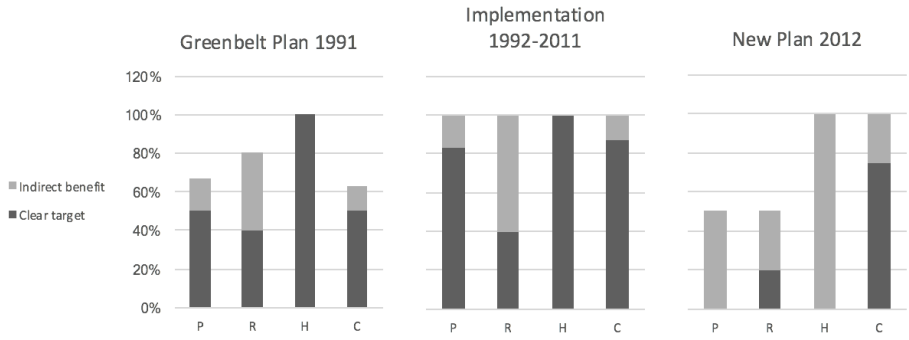


Fig.5.4. 1 The consideration of the four types of services and functions, namely Provisioning (P), Regulating (R), Cultural services (C) and Habitat functions (H), in the Greenbelt plan 1991, the Implementation 1992-2011 and New Plan 2012, draw by author.

Though the report 2011 didn't initially targeted on every ES, its results reveal some further problems together with other columns. First of all, all evaluated items were also identified as either high or medium relevance, which shows the consistency between practices and researchers. All the satisfied functions are included, at least mentioned, in the Greenbelt Plan 1991, and all are explicitly implemented in specific projects. However, explicit target is not a sufficient condition. Among the six dissatisfied ones, R10 is the only dissatisfied ES that was not payed enough attention before, while all others have been explicitly targeted. The "aesthetic values" (C1a), "recreation/ecotourism" (C2a) and "cultural diversity" (C5b) received almost full attention all the time but considered not good enough according to questionnaires on citizens (Projektbüro 2010). Similar situation happens between H1 and H2, that with the seemingly same performance on the plan and implementation, H1 was considered less satisfied by experts. According to the report, though the biodiversity level in Greenbelt is quite high from across the country, many typical regional forms of landscape, as well as traditional habitats, are losing. The targets in plan and projects means higher priorities and more opportunities, but not necessarily high quality in the long time run.

More clues are hidden under these contradictory results and pointed out the fact that the enough attention on urban planning level is vital but not sufficient. There could be some potential explanations of the phenomenon. For example, comparing with P1, the fine condition of P2 (raw materials/ timber & fuel) may greatly rely on the centralized management of the Department of Urban Forestry and the city owned forest land. It maximized the capacity of managers and researchers and avoided many divarication from the beginning, like the chasing of profit and maintenance of ecological properties. The "education value" (C3b) is not an initial target of Greenbelt, but it captured the rising trend and possibilities and acted creatively. In a word, the coding based on the unified framework provide a new lens for interpretation, which helps to understand the relationship between planning and reality.

However, the analysis on urban level also shows more questions and directions for the searching of further possible explanations.

5.4.3 Greenbelt implementation

With the results from the coding of urban level related documents, a further part of the study is targeted on the more specific process of the implementation in Greenbelt. Strongly influenced by Emscher Landscapes Park in Ruhr area, the Frankfurt Greenbelt was set at the beginning to be a continuous green program rather than just a fixed plan. The Greenbelt Plan was also descripted as "a vision of urban open space" (Koenigs 1991) and there left certain space for the later translation of the plan within the principles. This concept was kept through the GmbH and the Greenbelt Group, the latter one had it further enlarged to cope with the changing situations in funding and demands. Numerous small projects have been applied, with both success and failure. About 50 typical ones were organized according to their type and content, and summarized into 9 project series (Appendix 5.4.1). Each series include several smaller projects that were planned towards similar aims or on the same location. Using these 9 project series as objects, the same framework was applied again for analysis, to examine the direct targets and co-beneficial functions as in the section 5.4.1 (Table 5.4.2).

Table 5.4. 2 Consideration of ES in different project series of Greenbelt Frankfurt

	Classification	I		II				III					
No.	Service Function/ Project series	Device and	Public activities	Marks	Round Routes	Program	Education	Old Airfield	Parks and cemeteries	The orchard meadow	Nature reservation		In total
P1a	Food/crop												
P1b	Food/wild									●			1● 0○
P2	Raw materials/ Timber & Fuel										○		0● 1○
P3	Fresh water										●		1● 0○
P6	Ornamental resources								●				1● 0○
R1	Air quality regulation							○	○	○	○		0● 4○
R2	Local climate regulation			○				●	●	○	●		3● 2○
R3	Carbon sequestration and storage							○	○	○	○		0● 4○
R4	Moderation of extreme events/ Flood										●		1● 0○
R5	Water regulation										●		1● 0○
R6	Water purification and waste treatment										●		1● 0○
R7	Erosion prevention and maintenance of soil fertility							●		○	●		2● 1○
R8	Pollination				○			○	○	○	●		1● 4○
R9	Biological control							○			●		1● 1○

	Classification	I			II			III				
No.	Service Function/ Project series	Arts and Device	Public activities	Marks	Round Routes	Program	Education	Old Airfield	Parks and cemeteries	The orchard meadow	Nature reservation	In total
R10	Noise regulation							○	●		●	2● 1○
H1	Habitat for species						○	●	○	●	●	3● 2○
H2	maintenance of genetic diversity						○	●	○	●	●	3● 2○
C1a	Aesthetic values					●	○	●	●	●	●	5● 1○
C1b	Inspiration	●		●	○	●	●	●	●	○		5● 2○
C2a	Recreation/ ecotourism	○	●	●	●	●	●	●	●	●	○	7● 2○
C2b	Health		●	●	●	○	○	○	●	○	○	4● 4○
C4a	Scientific research					○	●				●	2● 1○
C4b	Educational value		○	○	○	●	●			●	○	3● 4○
C5a	Cultural heritage	○		●	○	○	○	○	○	●	○	2● 6○
C5b	Cultural diversity	○	○		○	●	○	○	○	○		1● 6○
	In total	1● 3○	2● 2○	4● 2○	3● 5○	4● 6○	9● 8○	7● 7○	7● 8○	13● 7○		

● represents for a clear target and ○ refers to a potential benefit in the analysed documents.

In the table, two total numbers were calculated on the right column and bottom row, represent the total attention paid on each ES and the range of targeted ES in each project series, respectively. Though these 9 chosen objects are not all the projects done in the period, they had been most frequently talked in Greenbelt publications and many are considered main achievements. However, the distinctions between different types of ES are amplified comparing with that in urban level. Only three project series involved provisioning services but none ignored the cultural services which in general reached a 76% referring rate, though they are subdivided into smaller types. 54% of the mentioned regulating services and habitat functions are co-benefited from certain moves, while explicit targets could only rely on specific natural reservation projects which are a small part of the Greenbelt work.

Considering from single ES, the targets of projects, same as in urban planning document analysis, didn't always means the capacity to meet the demands, especially in cultural services. C2a and C1a received highest focus but were considered dissatisfied by users. Especially the C2a which are directly targeted in seven out of the nine projects, but 62% of the interviewee ask for more frequent cleaning job and more than half believe there need to be more control on the safety in use and more quiet environment for sitting and resting (Projektbüro 2010). By contract, C4b was not the top priority and only appeared in certain projects but received high appraises. Nevertheless, direct and explicit targets are necessary condition for the better performance of ES in other categories. R1 and R3 could be beneficiated when green projects could bring with the increasing of the quality and quantity of green space. While R4, R5 and R6 rely greatly on specific ecological restorations.

Based on the number of referring ES categories, the 9 project series are classified into three groups. Group I includes projects of “Arts and Devices” and “Public Activities” which only contribute to Cultural aspect. The successfulness and public awareness of such projects seems to rely mainly on the capacity of expressiveness of themselves. For instance, some art works like “My Monument” (Ich Denkmal) are highly appreciated as a result of artistic creation and popular location; some others like “The Giant Baby Acorn” (Monsterkinder) can hardly be noticed, not to mention to be inspiring for visitors. “Public activities” refers to the publicities of the Greenbelt program, includes brochures for destinations, the Greenbelt Leisure Map, exhibitions and seasonal activities. They are the appendant of other projects but their functions in the intangible aspects are unneglectable.

Group II includes “Greenbelt Marks”, “Round Routes” and “Education Program”. This group aimed at bringing elements together and could combine targets of two aspects. The Greenbelt Marks tried using certain type of tree groups as an identification of the Greenbelt project. Most these tree groups can hardly be distinguished from other trees without the information sign, thus some experts consider this projects as failed ones. However, it did create more natural places for recreation and communication. The Education Program is also a trans-disciplinary attempt, in which certain parts of the Greenbelt are set as permanent bases of nature education and activities center for children and families.

The third Group are projects that combined the majority types of the framework. They present a higher level of complexity in which different types of functions have potential interactions inside. The “Old Airfield Reconstruction” is one of the most famous and favored site in Greenbelt and it combined 9 functions explicitly as well as benefited 8 others. The design concept of letting the nature taken over the artificial place was a key attribute factor. The process of achieving certain ecological purpose, like “Erosion prevention and maintenance of soil fertility” (R7), “Habitat for species” (H1) and “Maintenance of genetic diversity” (H2), were intentionally highlighted and present to the visitors. This presenting process also combines multiple ES, like C1a, C1b, C4a and C4b, as methods of conveying the philosophy of nature to human beings. Another case is the “Nature Reservation” projects which includes multiple projects from river restoration to typical landscape protection. In such specific projects which lead by ecologists, the cultural aspects are not in priority. However, a healthy, sustainable and well-protected local or traditional landscape combined with simple but creative artificial facility, could already form a good environment for the communication of human and nature.

Despite the classification of projects, there is no preference among them. In fact, the reality is more complicated and there is interdependency among different types. For instant, the “Education Program” make use of multiple other projects like the “Orchard Meadow” and Parks. They inter-related together on the level of the whole Greenbelt and form together the different levels of multifunctionality in green spaces. The complexity of referring ES in each project series could be more directly seen from the “Function Palette” (Fig 5.4.2). In each palette, the directions refer to the categories of ES and the

covered areas refer to a direct target or an indirect benefit. Single project will show fewer coverage in limited directions; while completed project series will present a balanced high coverage of the ring.

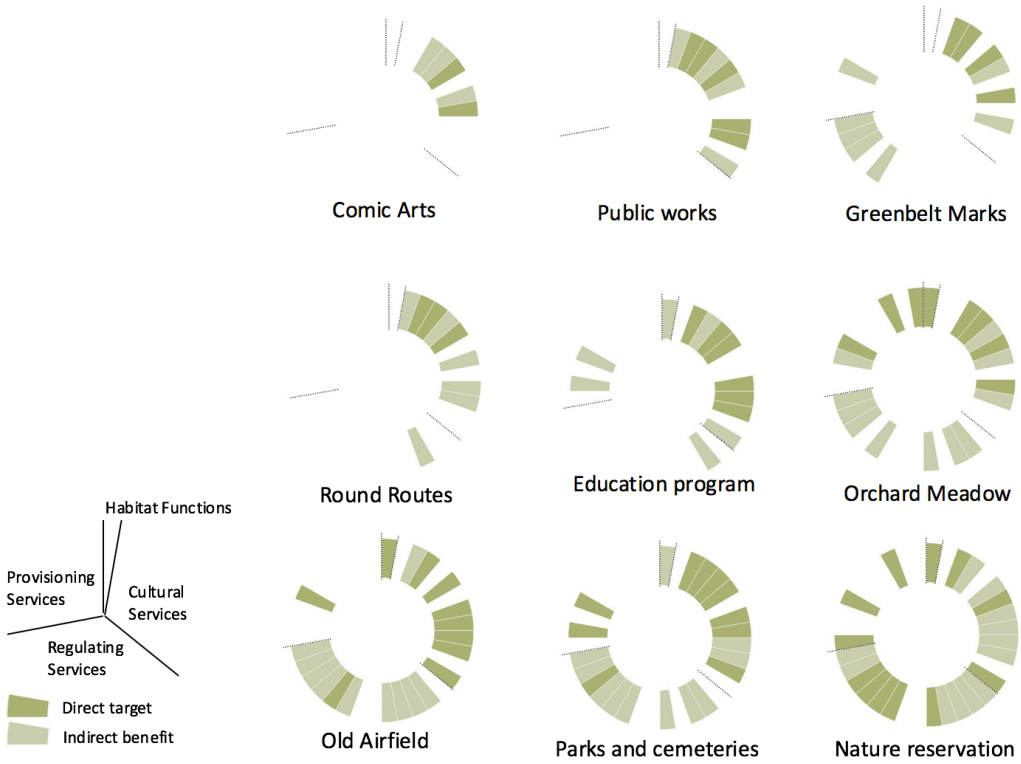


Fig.5.4. 2 The Function Palette for the 9 project series, draw by author

5.4.4 Comparison and connection between two levels

Using the same framework, the results of the above two sections (5.4.2 and 5.4.3) emphasized different aspects on the topic of urban green space multifunctionality at the city level (The Greenbelt as a whole) and local level (small projects inside Greenbelt). At city scale, analysis could concentrate on the ratio of involvement, the cohesion of functions and the balance among types. Thus the discussion on this scale normally was used for policy-making and similar context. At local scale, the extent of implement, the preference and neglecting of functions and the interaction between functions could get a closer understanding. So this scale was mostly connected with design and stakeholders' opinions. These two scales were often discussed separately due to above difference. However, this case provides a chance to connect the two level into one platform. And the status report functioned as a feedback for the system to interpret the cohesion and contradiction between the results of the two scales.

Based on Fig 5.4.1, multifunctionality in the scale of the whole Greenbelt showed the combination and balance among different types of targets, the general plan, though written 25 years ago, still seems to be a well-produced guideline for the development. However, being equally targeted didn't mean the same in its lower level. Through the distribution of Table 5.4.2, how each listed function was

emphasized in the selected different small projects could be seen clearly. Comparing with Table 5.4.1, Table 5.4.2 is not balanced at all but shows that cultural aspects are the actual emphasis and extensive actions of implementation in Greenbelt. It was paid with more direct attention within more projects. Though not all the projects implemented were used here, the randomness and lack of attention in provisioning aspect is quite obvious. Regulating and Habitat aspects synergies with each other but within certain types of projects. Higher level of multifunctionality like that in Group III only happened in quite limited projects, which are separated sites inside the vast Greenbelt. Combining the results on both city and local scales, the multifunctionality of Greenbelt Frankfurt could be portrayed as culturally prioritized and spatially non-homogeneous place, meanwhile, great potential lies in the further combination among cultural and non-cultural aspects.

The time frame of the different kinds of projects could give another dimension to the understanding. Not every series existed on the founding of the Greenbelt and several important projects, like the Education Program, the Old Airfield Reconstruction and some favorited sites of the Orchard Meadow, began approximately since 2003. Since that time, the combination between different types of projects were more intensively considered. The New Plan in 2013 turn again the emphasis to the connectivity of Greenbelt and its surrounding green networks, inside towards the city center and outside reaches the Regional Park Rhein-Main, as well as the utilizing of Greenbelt as a huge natural capital to respond to contemporary popular urban topics, like social equity and urban climate adaptation. However, only considering from the content of the plan, it may be more popular than straight to the point. Without substantial projects under this new guideline, the real changes are hard to imagine.

5.4.5 Summary

The aim of section 5.4 is to interpret from the provisioning perspective, how different ES were targeted by planners in the planning practice. Though the coding and analyzing of related documents, the same analytic framework was applied in both city and local level, to catch the actual purposes behind the rhetoric planning documents. With this lens of multifunctionality, the main findings of the planning efforts of Greenbelt Frankfurt can be concluded as follow.

First of all, the majority of ES was already included in Greenbelt Plan 1991 in a quite balanced way. It proved the suitability of this framework to be applied on urban open space planning within a large time span. Though there had been shifting of political emphases and international interests, the main demands for urban green space hasn't changed much, but rather adding with some new topics. Based on the analysis, the concept of Greenbelt Frankfurt as a large continuous green open space was advanced at the time, and its long living need to be credited to the founders.

Second, the Greenbelt implementation is not that balanced in functions considering its specific projects. There was barely much work done by the Project Group on the improving of provisioning services, despite that agricultural land occupied 21% of the Greenbelt. Regulating services mainly benefited from the projects which lead to the increase of green areas. The directly targeted Regulating

services, as well as Habitat functions, were mostly natural reservation related and the locations were separated in the Greenbelt. The Cultural services were the actual focus of attention throughout time.

Third, based on the Report on Greenbelt, regulating services and habitat functions have better feedback than the other two type, especially than the cultural aspects. It helps to pointed out the dissimilar nature of the cultural services with others. Other types of ES could normally follow the rule that the more works done, the better results get. Thus the ignored ones like food/ crop provision was not in a satisfied situation, while the climate related ES got positive feedback due to being frequent direct and indirect targeted. On the contrary, the most targeted cultural services have not so good feedbacks, like the aesthetic appreciation and recreation. A reasonable explanation is cultural services generally have lower dependency level on land occupation but high dependence on design and intangible conditions.

Last not least, the successful and favorable projects, mostly in recent decade, always combine the cultural services with others in harmonious, and thus maximize both capacities. But how these interactions between functions are planned and synergized need further discussion.

5.5 Summary: The Efforts and Results of Multifunctionality in Greenbelt

In this chapter, multifunctionality is used as an analytical framework for the interpretation of both current status and planning efforts. The aim is simple, that is to find the hidden connections between these two kinds of analysis which were unintentionally separated due to the two groups of people in different research focus. The two parts of analysis use semi-quantitative and qualitative approaches respectively, but their results could be directly connected due to the same analysing language.

The multifunctionality of Greenbelt in current status show a clear uneven distribution, and this inequality is probably being increased through time. The advantage of the abundant natural resources in the urban forest is a fair reason, but the considerable big gap between the forest and Nidda river banks indicates the fact that the latter area should use much more efforts from other aspects which have less dependency on natural conditions. However, the cultural services have been distributed quite evenly with rarely identified hot spots, or any emphasis on Nidda river either. Moreover, agriculture in the north has been too stable to be an urban green space, and the habitat functions are worth concern for the fragmentation and disturbance.

The multifunctionality of Greenbelt planning efforts from the urban guideline perspective is satisfying, that despite the old age of the original Greenbelt Plan, it covered the majority of content that are now included into the framework of multifunctionality. Nevertheless, digging into the specific projects during implementation, the efforts are actually quite uneven. The majority of official resources have been put on the cultural services, while the others due to the financial restrictions are in fact opportunistic. Cultural services are added into every single project, but in most time, maybe in a way that is not essential and closely combine with the core aims. This kind of massive but low-efficient efforts in cultural services may explain the dissatisfactory of many citizens. Provisioning services are mostly forgotten in most projects, and habitat functions also constantly being a co-beneficial option.

Putting the above two results together, two contradictions are thus to be concluded: the mismatch of efforts and the lack of synergy between different categories. The natural condition in Greenbelt already provide with uneven situations, so that planning efforts need to be more to the point. Cultural services in this case, should be a regulating measure to create hotspots instead of just follow the original settings and aggravate the differences. For instance, the Nidda area is restricted in land and newly re-naturalized, but its recreational and aesthetical potential have not been fully realized.

The synergy between the four types of ES may rely more on institutional settings. The approach of small projects in the 1997 had saved the existence of the Greenbelt, but after 20 years of small steps, the central aims become dim and the easier small success on uncoordinated patches are not enough. Many forgotten but huge areas, like agriculture and habitat protection, haven to be put together to avoid potential conflicts and ignorance.

Chapter VI. Multifunctionality of Greenbelt on Local scale

In Chapter V, multifunctionality is used as a framework for the interpretation of Greenbelt on Urban level as a whole. Base on these analysis, the hotspots of multifunctionality and the main conflicts between plan and reality are highlighted. Follow the above results, this Chapter focuses on how multifunctionality is delivered to users at local level. Three locations are chosen for the analysis: the urban forest (east part) as the hottest spot of multifunctionality in the whole Greenbelt; the Old Airfield as a favorable spot for local people and a best practice in ecological rehabilitation and landscape design; and the Hiking Route of Springs as a route to link many small scenic spots in the north-east of Greenbelt. This three cases are respectively three typical elements made up the vast Greenbelt, which are the area, the spot and the line, and they are quite representative for each type. Moreover, the relationships and interactions between different functions at the same location are preliminarily discussed under two questions, that to what extent could a place be multifunctional and how could the concept of multifunctionality help to better convey higher green space quality at local scale.

6.1 The Multifunctional Urban Forest (east part)

6.1.1 History and management of the Frankfurt urban forest

The urban forest has in fact a longer history than the Frankfurt city and has been relatively independent in management since the beginning. Through the city brought the forest from the Emperor, it was the later leaders and experts of the forest who protected, researched and furtherly developed the forest from the king's forest to the citizens' forest.

The main body of Frankfurt urban forest locates in the south of city and extends 15 km from Offenbach in east to Kelsterbach in west, and 6 km from Sachsenhausen in the north to Zeppelinheim in the south (Fig 6.1.1). Among this area, only the forest in north of the road A3 is included inside the Greenbelt. Besides this huge continuous area, some other smaller patches of forests like the Niedwald, Biegwald and Fechenheimer Wald which all lie inside the Greenbelt, are also called urban forest and under same management.

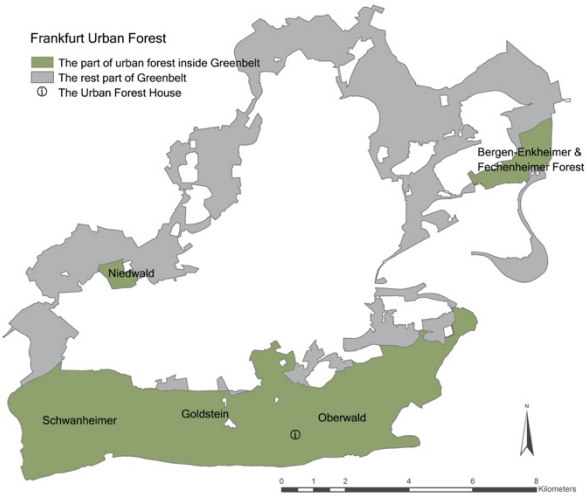


Fig 6.1. 1 The Urban Forest and Greenbelt, by author.

The forest was a part of the historical wildbannforst of Dreieich owned by the emperors of

the Holy Roman Empire of Germany. Its boundary reached to the city Bad Vilbel, Aschaffenburg, Pfungstadt and Mainz. The oldest evidence of human activities in the area was the stone equipment to make fire, could be traced back to about 6000 years ago. About 4000 BC, people built the fist fire and live near the river bank, later the Celts and Germans came and inhabited here. The Romans colonized parts of this area around the new era and established bases and trading centers in the later discovered settlements.

In the middle of the third century, the Alemanni people came but was soon defeated and expelled by the Frank people in 469 AD, which stated the actual history of this forest. The kings of Frank secured the hunting activities in the entire Dreieich through the establishment of a system called Wildhuben. They were villages in which about 50 acres of land was left to a free man called the Wildhubener. The responsibility of this man was to secure the forest and wildlife. Altogether 36 such Wildhuben were distributed in the area, included the current districts like Sachsenhausen, Bockenheim, Griesheim, Kelsterbach, Schwanheim and Offenbach. In the course of time, the majority of this emperor's forest was pardoned by the emperor as a fief, only the northern part near Frankfurt remained under the name of "King's Forest". In the beginning of the 14th century, the forest got connected under the Empire office of Mayor in Frankfurt, which was a position similar like a military commander and tax collector who represented the crown, also included the forest. Thus Frankfurt was dependent on the German Empire.

The Emperor Karl IV (1347-1378) was constantly in fiscal difficulties. He borrowed money from Landlord Ulrich III in Hanau and the pledge was the Empire office of Mayor and the king' forest. In 1363, under the consent of the Emperor, a wealthy Frankfurter named Siegfried used 2200 guldens to redeem the pledges from Ullrich and lent another 1000 guldens to the Emperor. Later in 1372, the Mayor of Frankfurt persuaded the Emperor Karl IV, to allow Siegfried's pledge be redeemed for the city. A certificate showed that in the February of 1372, the forest and the rights attached were brought by the city with 8800 guldens, a price that exceeded the previous pledge amount. After that the Emperor Karl IV, who stayed mainly in Böhmen, showed less interests in the king's forest. For Frankfurt, the Empire office of Mayor was at that time more essential than the forest. Moreover, without the Emperor, the Frankfurt city cannot decide anything about the forest. Frankfurt slowly became a free Empire city and stayed this way until 1806, however, it was put back to the old status in 1813. From the former free city Frankfurt or after the later integration with Prussia since 1866, the urban forest had managed itself independently. Even until today, the State Hessen has only regard to forestry supervision in the forest districts of Frankfurt.

After the acquisition of the urban forest, the each of the two ongoing mayors would designate a forestry director for one year. In order to give the new forestry directors an opportunity to get to know the forest thoroughly, their term was later extended based on their ability, and two deputies were given to help. However, this was not a satisfied solution. The destruction of woodland for pasture and timber production had upgraded into frightening forms. Thus a New solution was issued by Emperor Karl VI

in 1726, that a well-earned and honest man should be hired as a riding chief for the management of Niederrad, since it was in the middle of the urban forest, and to make the work and duty easier and more convenient. In this way, the manager of forest shifted from council members to forestry specialists.

Among the 13 previous directors of forestry, some made special contributions. Johann D. Klotz (director 1734-1763) built the Forestry House Hinkelstein in 1739 to protect the border of Kelsterbach and Schwanheim. Philipp Vogel (director 1798-1828) carried out a new survey, mapping and estimation of the wood stock during 1802-1882. This valid executed operation was one of the oldest forestry operating regulations. Professor Dr. Schottenstein (director 1840-1887) established the mixed forest character of Frankfurt urban forest. He reorganized the forestry office and set up precise economic plans, which regulated woodcutting, cultural foundations, path construction and etc. Carl Hensel (director 1887-1901) developed the first recreational forest facility. Dr. Hans Jacobi (director 1927-1940) started to develop the urban forest into a recreational area, with his representative works like Jacobi Pond and Goethe Tower. Kurt Ruppert (director 1940-1972) replanted the bare land left from the last war, and his management concept of a recreational forest, especially the Forest Play Parks, were examples for the whole Frankfurt. More recently, Werner Ebert (director 1973-2002) mixed large parts of Ruppert's pine forest with beech, as well as turned the pure conifers forests into mixed ones. He furtherly expanded the area for recreation and built the Urban Forest House, a modern information center integrative with playing facilities.

Today the urban forest has six areas, each named after their associated urban districts, the Oberrad, Sachsenhausen, Niederrad, Goldstein, Schwanheim und Fechenheim. The leaders of these six areas are under the director of the Department of Urban Forest, which associated to the Department of Green Space since 2003. Now the entire Department is run by about 35 people includes 8 officers.

6.1.2 The undertaken functions

6.1.2.1 The undertaken functions at urban level

The overlapping of all ES in section 5.3.2 and Fig 5.3.8 shows the general performances of the entire Greenbelt. Bases on this result, it is quite clear that the south urban forest, especially the east part the Oberwald, has been the most multifunctional site in the whole area. Through a closer look on the performance of the east part of urban forest in each ES (Fig 6.1.2), it could be concluded that the multifunctionality of this forest is still high in the absolute value, since the majority of this area is counted as "very favorable" in 80% of all ES. Only the food provision (P1), the ornamental resources (P6), the moderation of flood (R4) and the cultural heritage value (C5) find this area with almost no contribution. According to the significance and distribution, the rest 16 ES are classified into four groups, each has its own underpinned reasons.

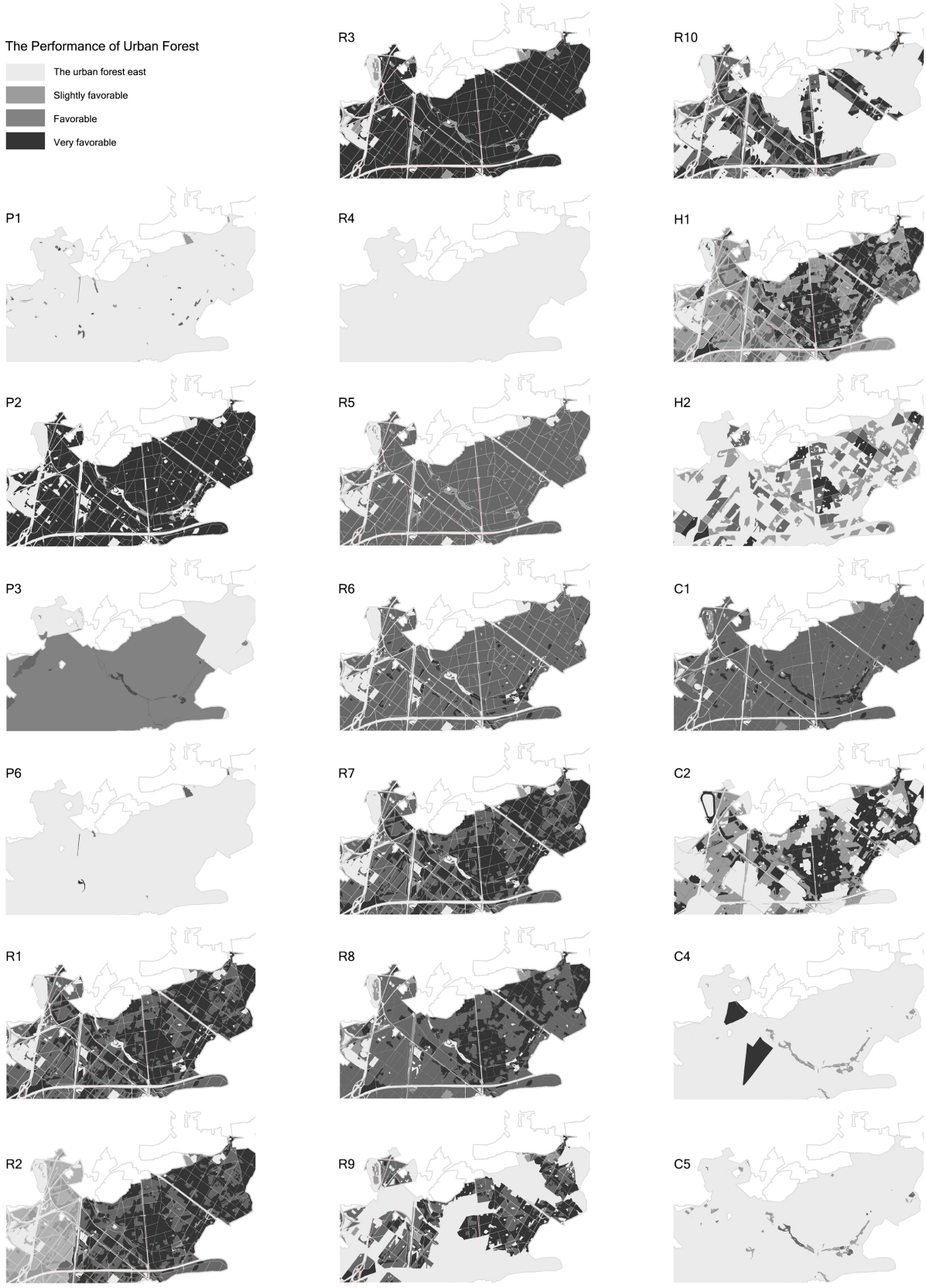


Fig 6.1. 2 The performance of urban forest in each ES, by author. (The negative effects from roads are ignored in this part of analysis)

The first group includes the raw material provision (P2) and carbon sequestration and storage (R3) which present as homogeneous essentiality in the whole area. The timber production in the whole forest has been taken in an evenly distributed and sustainably counted approach, with very few endangered and valuable biotope types stay in the undisturbed condition; the carbon sequestration may vary due to soil type and tree age, but show no significant difference in this scale. These two services rely less on the specific conditions and types of trees, which thus reflect in a three-level evaluation system as equally "vary favorable".

The second group has a similar condition with the first one but presents as equally medium importance for the corresponded ES. The fresh water provision (P3), water regulation (R5), water purification (R6) and aesthetic appreciation and inspiration (C1) all belong to this group. R5 and R6 is given to medium importance since land use types like wetland, which is very rare in the Greenbelt, performs as most significant for this kind of functions. Nevertheless, the evenly performed C1 can be partly attribute to the insufficient information at urban level.

The third group illustrates a medium to high but heterogeneously distributed functions, like the air quality regulation (R1), local climate regulation (R2), erosion prevention and the maintenance of soil fertility (R7), Pollination (R8) and habitats for species (H1). The distribution characteristics of these five ES show great resemblance, that the high value sites center in two places, the middle of Oberwald on the east of Darmstädter Landstrasse and the north-east of Oberwald near the Babenhäuser Landstrasse. These areas are generally of higher ecological value, for example the large and mature broad-leaved forest with a soil type of higher water content, thus function more effectively in the natural process of air, climate, soil regulation and provide better habitat for species.

The forth group shows patchy and mosaic feature, since they are mostly site-dependent. Biological control (R8) matters more in the areas around farmland and pastures; Noise regulation (R10) functions by the dense trees along both sides of heavy traffic; recreation for mental and physical health (C2) is counted on the urban level by the density of specifically signed and maintained paths as well as the natural value of the site. The maintenance of genetic diversity (H2) mainly assesses the size of the patches and the presented scattered sites are the ones with above average size of Greenbelt. The science and education value (C4) on urban level relies mostly on the facilities and policy which currently is represented by the appointed sites for children's educational program.

Urban forest, as a tree-dominated open space, has generally the highest capacity and potential among all urban green space types in the provisioning of ecological services and functions, not to mention its functions for the reshape and integration of urban green structure (Rydberg and Falck 1998, Konijnendijk, Sadio et al. 2004, Konijnendijk 2010). The above four types of results and their reasons in common may indicate the fact that, from a certain point of view, the urban forest may always present higher multifunctionality than other types. With reasonable conditions, like the tree-age, certain management and health rate, all urban forests would have fine performances in the first and second group of ES, which may already exceed the capacity of normal agricultural land or urban parks.

Thus, the main differences between forests depends on the third and forth groups of ES. To increase better performance in these groups, some measurements are to be taken, like to improve the inherent quality of the forests, to better combine the forests with other land use types, to decrease unnecessary human disturbance and to keep up with the cultural demands. In this way, the sites with higher value and the relevant area could be both extended.

However, this results, which is made in urban scale of Greenbelt as a whole, do not show enough level of representativeness for the cultural services when the range is limited to one part of the Greenbelt. The different dependency of ES concerning the scale has been pointed out before but most large scale studies chose a simpler way to minimize and simplify the cultural services (Hein, van Koppen et al. 2006, Andersson, McPhearson et al. 2015, Yang, Ge et al. 2015). This study has added additional information on C2 and C4 at urban level to balance the weight between four ES types, and the results are acceptable. Nevertheless, when the range is zoomed to a local scale like part of the urban forest, more cultural information is necessary for further analysis.

6.1.2.2 The additional information at local level

To complete the cultural services at local scale, some more information is considered to illustrate the complexity in the uses of this forest district. Fig 6.1.3 indicated the typical non-vehicle paths with specific purposes. Six kind of routes are maintained and guided with special signs for specific groups of users. Besides the round route for pedestrians and the round rout for cyclists which run across the whole Greenbelt and thus are mapped at urban level, the other local routes include, the learning paths for children and school teams, the sport paths for nearby citizens, the riding route for horse riders and horse buddy, as well as other non-vehicle and impermeable paths for recreational uses. The cycling paths along the motor-vehicle roads are not included. These paths densely cover the entire area and constantly overlap or go cross with each other.

Besides, some useful locations that provide with services for forest users are also marked in Fig 6.1.3. These sites include the art devices which are specially designed to be exhibited in the nature, the cultural sites like historical remains, the information and education center the Urban Forest House, the resting places with benches or wooden pavilions, the restaurant or coffee shop, the locations with bicycle reparation services, places with sport facilities and parking areas. These services sites distribute along the paths and especially centered near the Jacobi Pond, probably due to its aesthetic value.

Furthermore, the forest is not only for people but also for all species. Fig 6.1.6 maps the location of endangered species listed in Table 5.3.3 as well as the FFH of the area. All these areas are vital habitats for valuable species and animals. They are critical areas for the biodiversity of the entire region, and contribute a great proportion in the Habitat functions.

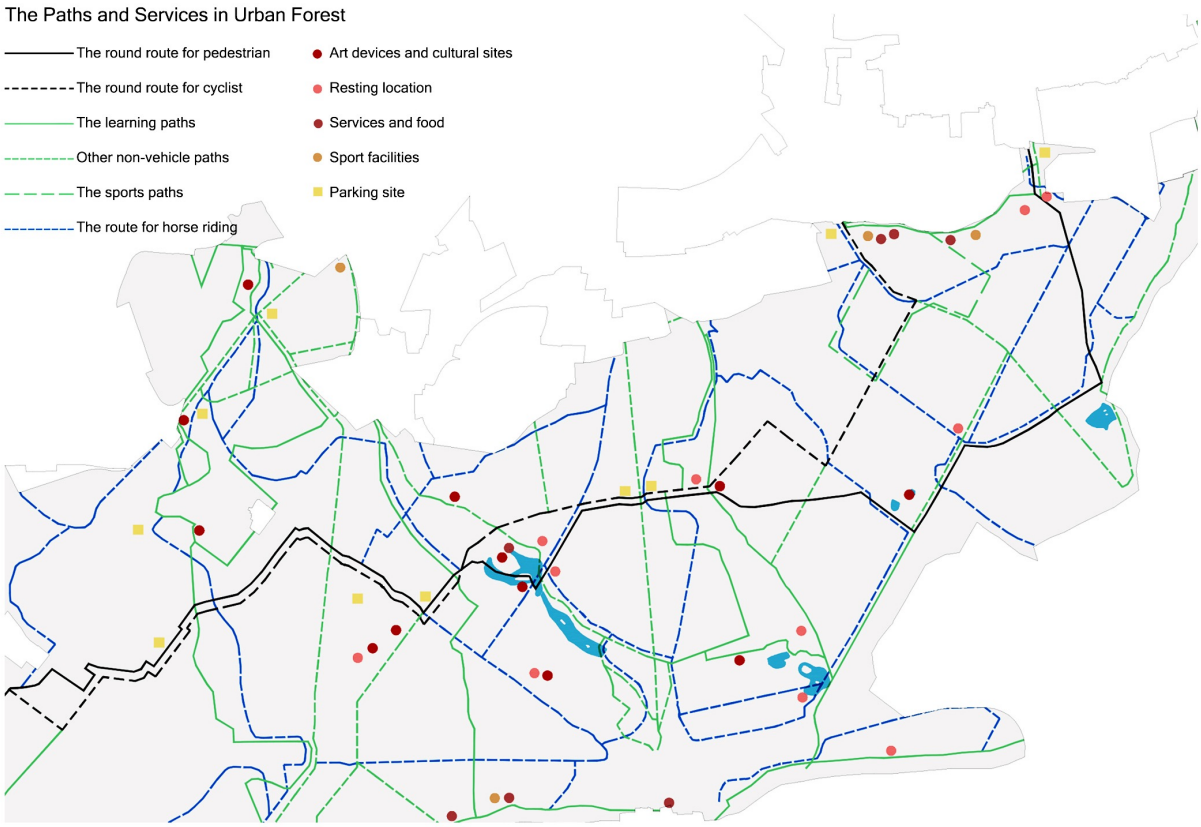


Fig 6.1. 3 The paths and services in urban forest east, draw by author based on the Greenbelt Leisure Map from Umweltamt and Urban Forest Hiking Map from Grünflächenamt/ Stadtforst Frankfurt.

Fig 6.1. 4 The endangered and protected biotope types and the FFH area in the east urban forest, draw by author.

Among the recreational routes, horse riding and buddy is the most unique one. Through the animal husbandry takes a comparatively small proportion in the agriculture industry in the entire Frankfurt, the horse breeding has been a special and modern existence, that farms in the countryside keep the horses in the open spaces for their owners. This niche market is targeted by some local farms or companies and based on the diverse demand of the huge metropolitan area, since the urban forest as a vast and high-quality open space near a large city, provide peerless chance for such special interest. However, horse riding is permitted on the marked trails only and the pedestrians should always have the priority on mix-used paths.

The cultural services are more diverse and active in local scale than that is estimated and calculated at urban level. The urban forest is indeed much more alive than a typical imagination of a deep forest. Besides the recreational and educational possibilities, this area is cut through by several highways, as could be clearly noticed in Fig 6.1.2, and furtherly divided by a road grid of about 250 meters, which is denser than the recreational paths. Those small paths without clearly marked recreational purposes are used by the workers for logging and routine maintenance. Thus the left patches are normally quite small, with the largest recorded patch of about 18.5 ha.

6.1.3 Relationships between functions

Relationships among ES is critical for ecosystem-based management and is manifested as trade-offs and synergies (Yang, Ge et al. 2015). Trade-off refers to the situation that one service increase at the cost of reducing the provision of another service, while synergy refers to the situation that the sum of multiple services is enhanced than that of single services (Rodríguez-Loinaz, Alday et al. 2015). Selman provided a more detailed classification, that synergies of multiple ES in same space could be either in the same time or have a successive occurrence; moreover, besides synergy and trade-off, a third relationship is even more common that the ES may just co-exist without much influences on each other (Selman 2009).

All these relationships are inherent parts of a multifunctional urban green open space and affect the efficiency of services deliverability (De Groot, Alkemade et al. 2010). For a healthy and sustainable urban green space, to increase synergies and avoid trade-offs is a necessary part in planning practices, especially on the local and practical level. In scientific researches, synergies and trade-offs have been detected in regional scale using quantitative analyzing method, however, few analyses have been taken on smaller scales due to the dependency of large amount of relatively accurate statistics demand by the method. Thus the discussions of synergies and trade-offs in this chapter are conducted based on the results of other studies and the observation of this case.

Functions of same category normally show the same type of internal interaction. Regulating services, for instance, that all based on the natural ecosystem processes and functions, are thus in most time co-existence or synergy with each other. The abundant natural resources of the forest provide

remarkable conditions for the well-performing of all relevant regulating services, with carbon sequestration the most outstanding one. Cultural services perform with more synergy effects (Turner, Odgaard et al. 2014). The planned routes and paths link the potential cultural services together and promote chances of synergies through the mix of targeted user groups. Among them, the educational services have contributed the most, that by offering children's programs, all family members get the chances of aesthetic appreciation and recreation. Similarly, habitat functions are two different aspects of the same core of biodiversity, thus present as typical synergy with each other.

Provisioning services normally show mutual exclusiveness due to their dependency on land and vegetation type, however, the timber production and groundwater provision have been sustained by local managers in a paralleled and co-existence manner. The forest counts mainly for the timber production and groundwater provision in a subordinate pattern. The top priority in for the forestry office is not economic interests but the habitability of the forest and the prosperity of functions. Thus the logging work is done in a quite sustainable or low productivity approach, that about 14,000 cubic meter per year, which is less than 3 cubic meter per hectare, is cut down for wood production. Moreover, the logging work focuses on the maintenance and monitoring of the age and type of trees, that in order to keep the forest healthier and more resilient, logging locations as well as re-planting works are carefully selected based on age and type (Fig 6.1.5). In this way, the timber production generally has no conflict with the protection of this area for underground water system, as long as the logging approach keeps as it is now.

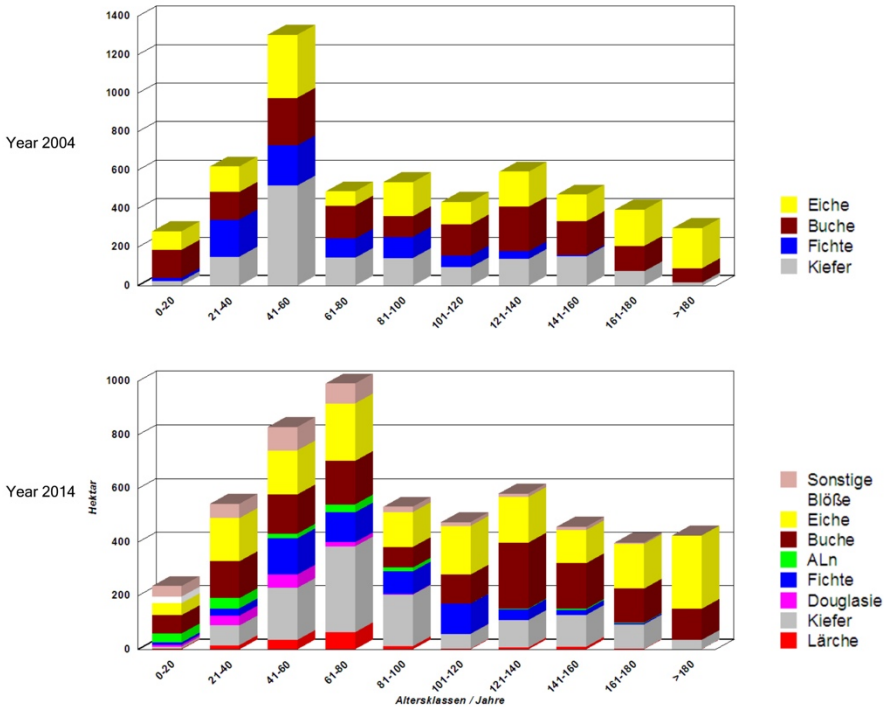


Fig 6.1. 5 The changes in the types and age groups of the trees in urban forest from 2004 to 2014, from Stadtforst.

A common type of trade-off lies between some provisioning and regulating services, like the expansion of food and fiber production often causes notable decrease in carbon sequestration and water

quality(Laurance, Sayer et al. 2014). Such trade-offs also happen between food production and habitat functions. However, in urban forest, this kind of trade-offs have the potential to happen but would be in a neglectable way due to the sustainable logging approach. Under the low productive logging and the simultaneous replanting, the regeneration of forest is kept in a comparatively stable level, thus the majority of regulating services would stay unaffected, with carbon sequestration a regular decrease but less influence in the long run. The fresh water provision, which refers the groundwater protection in the entire forest, has synergy effect with regulating services as well as habitat functions. Forests naturally function like a storage with huge filter to clean the water and supply for springs and rivers. Because of this protection, many potential damage on the soil and vegetation are prohibited from legal level, which provide better environment for the generating of regulating services. In addition, natural biotopes formed in the area of artificially constructed ponds, which have created new habitats for many insects, amphibians and other animal species that contribute to the genetic diversity of the area.

The relationship between cultural services and other types in regional scale diverse greatly to case context and chosen indicators (Raudsepp-Hearne, Peterson et al. 2010, Brown, Helene Hausner et al. 2015, Queiroz, Meacham et al. 2015). This type has been the evaluating difficulty in quantitative regional studies, since neither the proxies nor enquires are equally reliable as the indicators used in other ES. Moreover, cultural services are heterogeneous even in local level, which is suggested to be the most suitable scale for data collecting and analyzing(Andersson, McPhearson et al. 2015). However, based on both urban level and additional information, the cultural services have been described in a relatively sufficient way for the scale of urban forest, so as for a preliminary discussion on the interactions.

The regulating services are generally synergy with cultural services, with the exception of the certain negative effects on air pollution and greenhouse gas emission bring by the traffic of visitors. However, too much human activities post a potential influence on the habitat functions, especially how multiple routes have already been arranged in a crisscross pattern (Fig 6.1.3) that greatly go across the endangered or valuable habitats (Fig 6.1.4). Moreover, the entire Oberwald set in the critical functional area where cold and fresh air generate and help for the urban climate in city center. The result would be a domino effect if the ecosystem quality is impacted in the area.

6.1.4 The maximum capacity in multifunctionality

The urban forest, especially its east part, is no doubt of highly multifunctionality in urban as well as local scale (Fig 6.1.6). This multifunctionality orients from its incomparably abundant natural resources. As a vast continuous forest near city center and has a history longer than the city itself, its advantages in regulating services and habitat functions are to be expected. In the meantime, the large and deep forest provide people with a stable and quiet feeling as well as the sense of being immersed in

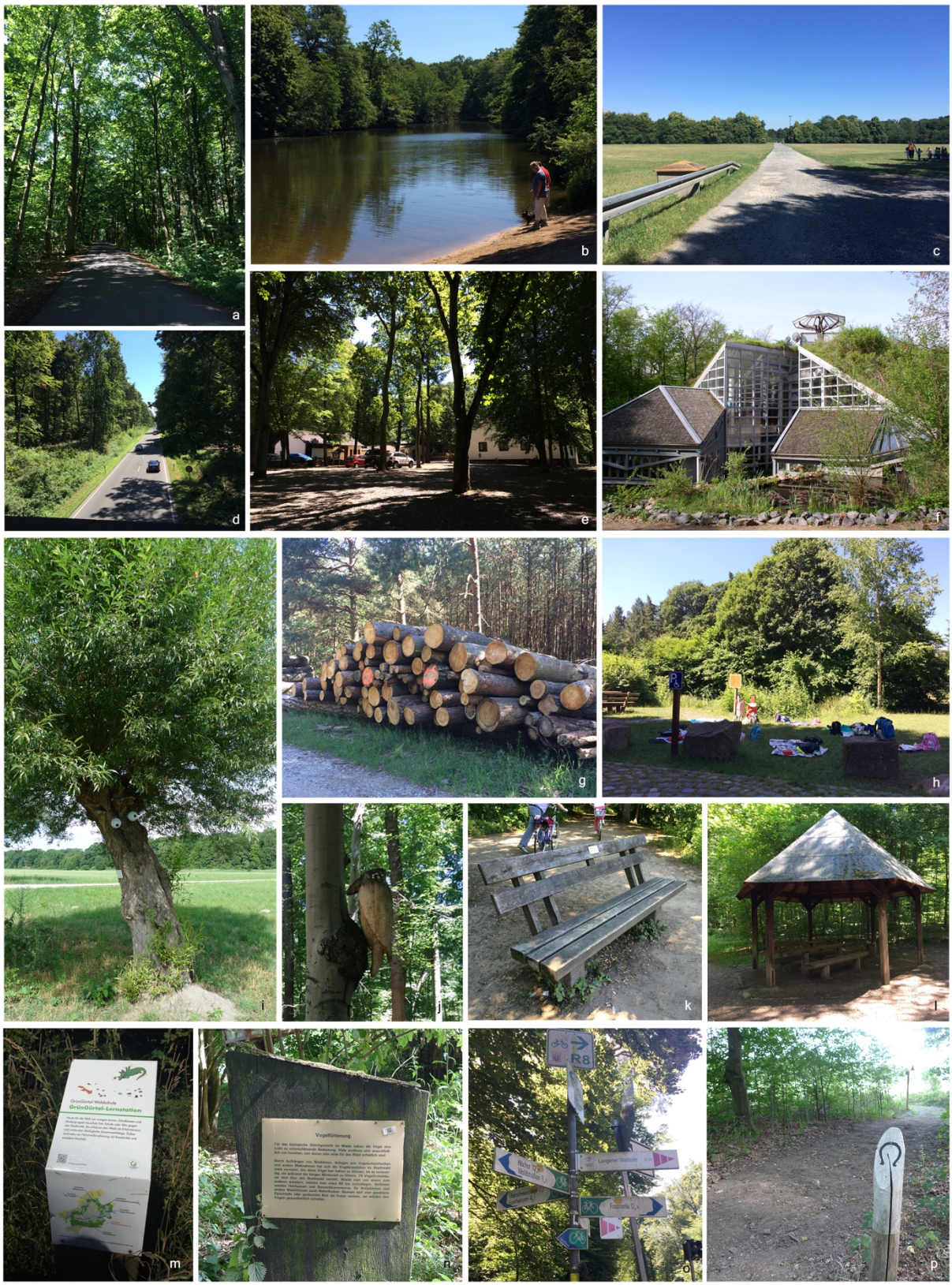


Fig 6.1. 6 The multifunctional urban forest. a, route pedestrian inside forest; b, the Jacobi Pond; c, grassland; d, local traffic; e, a historical restaurant near the pond; f, Stadtwaldhaus; g, logging in urban forest; h, one outdoor site for children's program; i, art device; j, art device; k, bench; l, wooden resting pavilion; m, sign of learning station; n, sign of bird protection; o, signs for different routes; p, sign and route for horse riding. Photo f from Stadtforst, other photos taken by author.

the nature, which are the most valued experience for urban green spaces(Tyrväinen, Mäkinen et al. 2007) and promotes the development of cultural services. Under the multiple synergy effects and co-existence of all types of functions, complex goals, like being a multifunctional urban green space serves for people with diverse demands, could be better achieved.

Nevertheless, the hottest spot of multifunctionality could also be the potentially endangered spot. The forest has been fully and evenly loaded with functions of all types, even the ones have been detected as trade-offs with each other, find a way of cooperation and co-existence. This must greatly contribute to the people working and managing the place who have carefully control the functions. However, such balanced situation is not that stable, any changing of conditions may lead to big problems. In another word, this forest, that greatly contributes to 80% of all services, is approaching its capacity limitation within the current supports from financial and institutional aspects.

It has not been taken enough attention that multifunctionality has its own limit especially at local scale. The more the better is not a rule for multifunctionality of urban green space despite some subconscious expectation underpinned in urban open space planning. Moreover, the limit of multifunctionality has no rule to locate generally, but is dynamic and context-related which need to be captured from certain signs. For example, report indicated that 45% of the urban forest stay in a less healthy condition (Projektbüro 2010); less wild animals are observed in the east than that in the west of forest; forest managers complain about the plan of adding new recreational paths. The extensive way of simply adding new functions to forest need to be adjusted and future actions in this area must be taken in great caution.

6.2 The Old Airfield Reconstruction Project

6.2.1 Development of the Old Airfield

The Old Airfield lies in the north of the Greenbelt by Nidda River (Fig 6.2.1). It was the former US Air Force Base of Frankfurt and now a comprehensive recreational and educational center for citizens, especially children and families, after the reconstruction project mainly operated in 2004. The Old Airfield is a small place with the center site of approximately 7.7 ha, which is less than 0.1% area of the entire Greenbelt. Meanwhile, it is so far the largest project of Greenbelt and costed more than 2 million euros (Stadt Frankfurt am Main 2011) and worth every cent of it, because this place not only won several prizes for its landscape design and program, but also successfully run and used by people for more than a decade now without losing its charm. From a certain perspective, the Old Airfield is a miniature Greenbelt itself, or even goes beyond Greenbelt, that it finds a way to combine and to balance between nature preservation and recreational demands, so as to provide leisure space, social space and ecological space in one site.

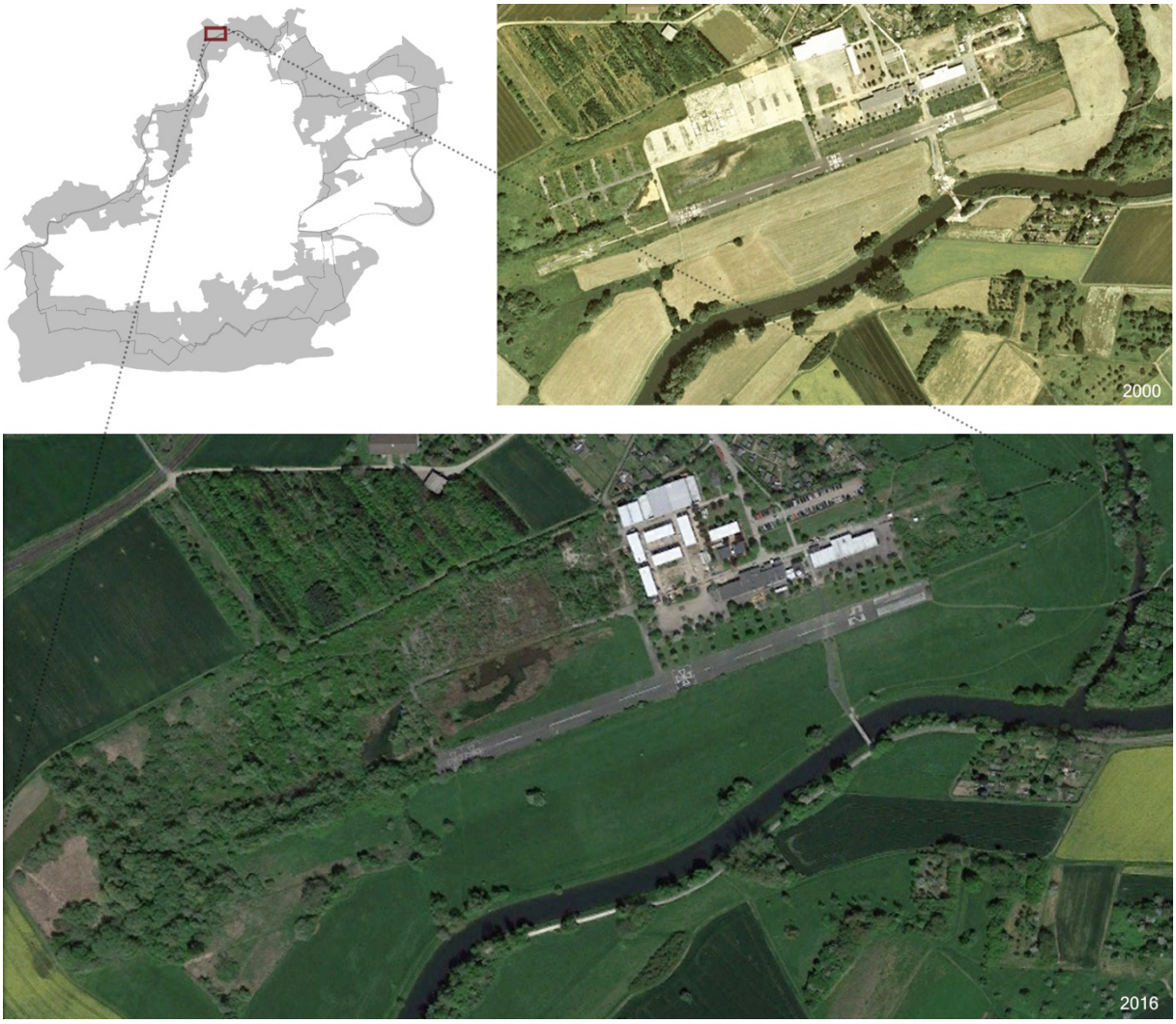


Fig 6.2. 1 The location of the Old Airfield in Greenbelt and the images of the site in 2000 before the reconstruction (upper right) and current status in 2016 (below), satellite images from Google Earth and edit by author.

6.2.1.1 History of the Old Airfield

The grasslands along the Nidda river were traditionally used as pasture land or mowing meadows for hay. These areas were regularly flooded by the winding and overflowing Nidda river and were thus often in a damp status. After the War, the US army built an airfield in the meadow, which is now the project location. It was first only for airplanes, later also for helicopters, which sent forth loud noises. Since 1980s, the surrounding residential areas developed and an increasing number of complaints were made by nearby residents against the particular large noise of helicopters, especially at night.

Situation changed in 1989 after the falling of the Berlin Wall and the nation reunion, that this air base was no longer a necessity. In the 1991 Greenbelt Plan, this area was already defined as a part of the belt to be reused for green purpose. After the US army left the site one year later, the reuse of the space began with the planting of tree groups in the open space of the airfield by the Greenbelt GmbH in 1993. Meanwhile, a re-naturalization project of Nidda started from Berkersheim along the river. The river meander area in which the airfield lies, about two kilometers west of Berkersheim, was also

canalized between Eschersheim and Harheim in 1962. In this way, later this area was also recovered to be closer to its natural hydrological pattern. Later in 1994, the buildings of the airfield were rent by Workshop of Frankfurt but no further actions were taken for the whole area.

In 1997, the Greenbelt Project Group replace the former GmbH and in 2001, the entire airfield finally became the property of the Frankfurt city. Since then, the reuse process was able to be accelerated. Under the suggestion of the Lower Nature Conservation Agency (Unteren Naturschutzbehörde), the planning of the area was taken by the Greenbelt Project Group and the landscape architect company GTL. This work started first with the consultation of natural conservation experts, as well as multiple discussions with the local councilors of Kalbach and Bonames. The latter part as a form of public participation helped a lot in capturing the demands of local residents.

The reconstruction and redevelopment work started in January 2003 and lasted for about a year. In the meantime, some small activities took place in the area functioned as warm-up and publicities for the project, like the planting of tree groves by volunteers and donators, the newly built bridge across the Nidda river. The Old Airfield was also designated as a Greenbelt learning station in the educational program for children named "Discover, research and learn", followed by the furnishing and rename of a "Green Classroom" and the entering of the Nature School of Hessen (Die Naturschule Hessen). Moreover, thanks to the effort of the nature conservation, the drainage into Nidda river was reduced and the backwater could keep a block of field in wet situation; besides, a pond was excavated to store the still water for the spawning of invertebrates (Projektgruppe 2013).

The reconstruction project won the first prize of the German Federal Landscape Architects in 2005 but the work did not stop there. Later in the same year, the parking lot and the entrance area were redesigned; in the following year, the watchtower was newly painted with red and white checkers, a bright pattern suits perfectly with the green environment (Fig 6.2.2-left). On May 1st 2006, the Greenbelt mascot was created by artist Robert Gernhardt and the first mosaic sculpture was put on the entrance bridge which was later named after the artist (Fig 6.2.2-middle). Furthermore, a former contaminated and fenced site was cleaned and added into the old airfield in 2007.

More tangible and intangible efforts on the Old Airfield were added year by year. Since 2008, a new sub-project called "Pilots of the landscape" began to provide professional interpretations on the landscape of the area to the children (Fig 6.2.2-right); in 2009, an old river branch at the eastern edge of the area was tied back to the Nidda river; later an art device of a stork's nest on top of a tall mast was set up to remain the significance of nature preservation. As the achievements of this project being widely realized, more honors came. This project was also awarded by the German Environmental Aid in 2009 and by the Green Good Design in 2012. Today the whole place still functions in harmony and being actively used by diverse group of people and creates new possibilities.

Fig 6.2. 2 Typical elements of the Old Airfield. Left: The Klaus-Hoppe-Tower; Middle: The Greenbelt Mascot; Right: The Flag and people works in the project Pilots of Landscapes. Left and Middle photos taken by author and right from Umweltamt brochure.

6.2.1.2 Financial and institutional support

From a military location to an important green center of nature conservation, education and recreation, the Old Airfield project spent in total 2.4 million euros from 2002 to 2013, which came from multiple sources. 58% (1,385,000 euros) of the amount came from the nature conservation compensation fund of the State Hessen; about 17% (420,000 euros) came from the city Frankfurt am Main; a little less than 10% (233,500 euros) from the Regional Park RheinMain Taunushang GmbH and 9% (225,000 euros) from European Union; and the rest 110,000 euros were financed by the Planning Association of Metropolitan Area Frankfurt RheinMain (Projektgruppe 2013). Besides, the Regional Park GmbH also supports the project "Pilots of the landscape".

The reconstruction work in 2003 for the general reshaping of the area used about 1.3 million and others are used in smaller sub-projects after 2004. Even these smaller parts of the project are financed by multiple groups. For example, entrance bridge cross Nidda costed 590,000 euros which came from the city, the planning association, the regional park and EU funding together. So was the same for the establishment of the Green Classroom and the reconstruction of parking lot.

The project "Pilots of the Landscapes" is a unique one among others, that it is a long term project runs since 2008. On the weekend in the period from March to October, landscape pilots would be found on site of the Old Airfield. They provide information about the nature in the area as well as alert for potential conflicts. They also answer questions from visitors and offer guided tours. This project costs 25,000 euros per year and funds by the Regional Park RheinMain Taunushang GmbH(Stadt Frankfurt am Main 2011). The Nature School of Hessen and the Department of Biology of University Frankfurt am Main are the project partners who provide experts for the place.

Besides the impressive budget, the Old Airfield contributes more on the multiple groups of people. The Project Group, with Klaus Hoppe as the leader and soul character, guided the planning and reconstruction of the project. Under that diverse demands from stakeholders, it was their great creativity and patience made the project came to reality. The GTL Landscape Architects contribute the brilliant

planning concept of designing with wild vegetation. The natural preservation associations, include the Lower Nature Conservation Agency, the Nature Protection Union of Germany and the Senckenberg Research Institute, not only contributed on funding and experts, but also keep monitoring and study the place after years. Moreover, farmers, beekeepers, workers of drainage, people in the coffee shop and small museum of the Old Airfield, their efforts have made the place lasting. In a word, the Old Airfield has presented a rare and valuable corporation of people and institutions from a variety of backgrounds, and has reached, from many aspects, mutual wins between nature and people.

6.2.2 The undertaken functions

When directly extract urban level function analysis of the Old Airfield, the general result (Fig 6.2.3-left) is not particularly outstanding like that in the urban forest. Two reasons can probably be used to explain this phenomenon which is different from the actual experiences. First is the non-negligible scale difference. The entire mapping on Urban level targets on the over 8000 ha Greenbelt and the basic grid of the raster information keeps to a 1:10,000 scale to capture the whole map. However, the center reconstructed part of Old Airfield is approximately 8 ha, within the entire functional area of less than 30 ha, which is too small to be mapped in detail. In this way, the amplified mapping result itself seems to be rough and oversimplified.

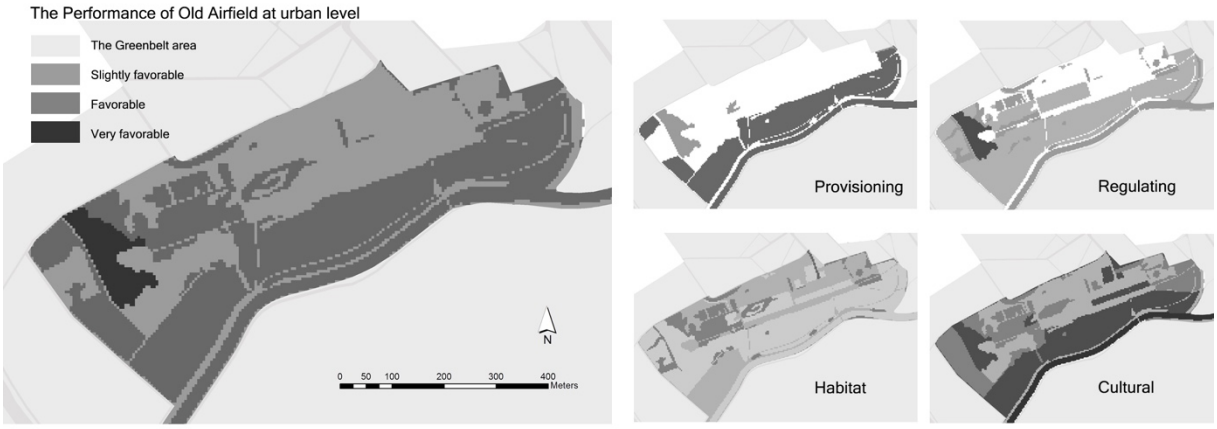


Fig 6.2. 3 The general performance of Old Airfield at urban level(left) and the performance in each type (right), by author.

The second reason lies in the base of the mapping process at urban scale, which is the land use/ land cover data, as well as policies matters on urban level. The main land use in the area is grassland and sealed constructed surface, with small patches of woodland and wetland. These grasslands counted for pasture production but generally have only medium capacity in regulating services (Fig 6.2.3-right). Similarly, the performance of small groves and tiny wetland is not significant for habitat functions considering from urban scale, and the higher potential in cultural services have limited compensation capacity although the site is very favorable for education and recreational purposes. In a word, the Old

Airfield presents with medium capacity of multifunctionality for the entire Greenbelt. This result also provides vital clue on the scale limitation of pure land-use based ES evaluation method.

Combining the detailed information of the project and field investigation, the specific usage of the area (Fig 6.2.4) has been far more abundant than only from biotope type classification. Within the small walkable site, the majority of functions especially the possibilities from cultural aspects, have maximized and densified. The former sealed surfaces like roads and building sites were transformed into multiple possibilities, like the old offices are now the restaurant and educational green classrooms; the old watchtower turned to a small exhibition and sight seeing location; the old garage were reused as fire museum and aeronaut workshop; and the old runway are now the recreational open space for children to take sports like skateboarding, roller skating and kite flying.

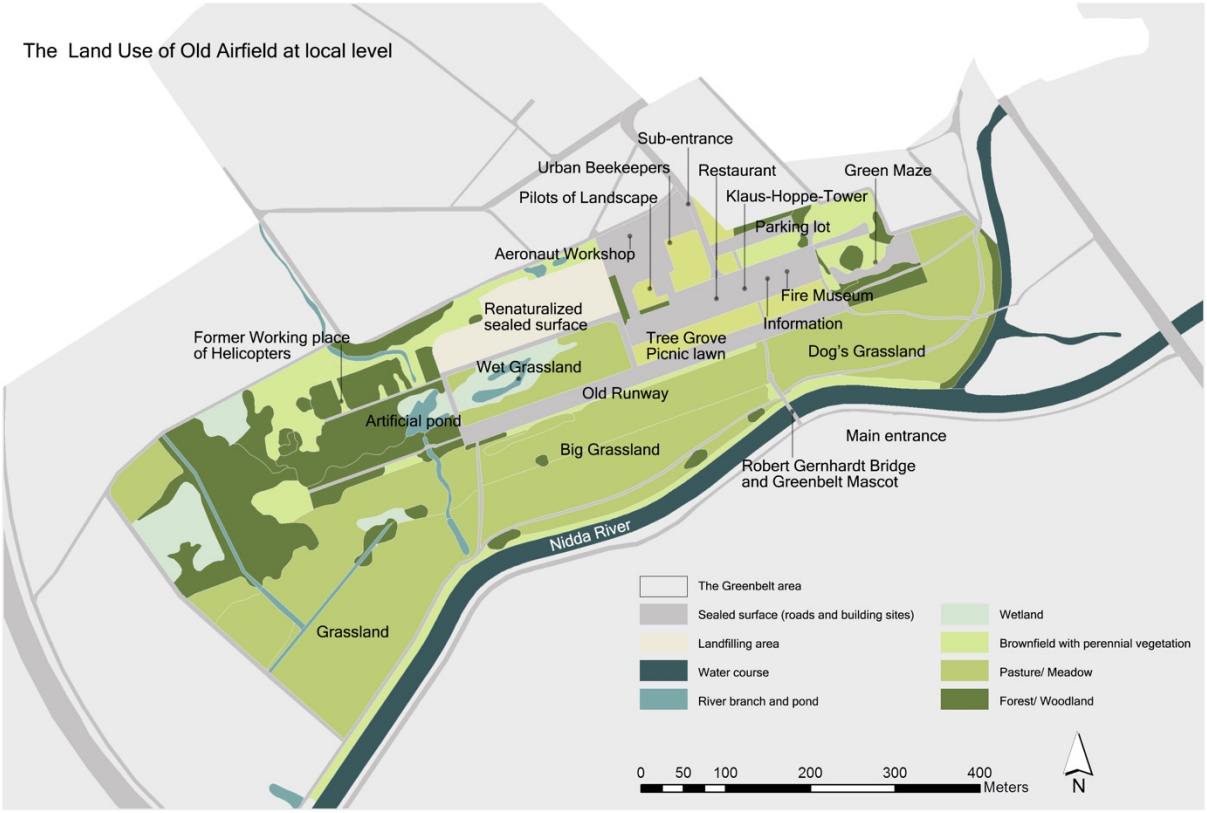


Fig 6.2. 4 The land cover and use of the Old Airfield on local level, by author.

The transformation of landscape is also an incredible achievement. They all got "updated" comparing to the old forms. The old lawn which separated the runway from other working places, was reformed to a wet grassland closer to a natural status. This form could function better in dealing with water regulation and water purification, as well as providing diverse habitats for local species. The parking apron on north of the wet grassland was a reconstruction difficulty for it was totally sealed with concrete and asphalt. Instead of removing these construction waste to another stock dump site, they were only break into pieces and left on its original sites. After years of natural regeneration, this block was

covered by shrubs and small trees that grow toughly from the soil beneath. It could be hardly recognized as concrete waste site from above.

So are the same for the other two blocks at the east end, which used to be working places for helicopters, that they are already heavily covered by dense wood and the former trail is hard to get into. The artificial pond excavated inside this area connect river branches of the Nidda and provide stable, undisturbed habitat for amphibian species. No land is simply used for one purpose, like the grassland at the entrance not only produce pastures, but also functions as a foreground view of the buildings, or the specific place for dogs. These changes made the sites under same biotope type function differently, thus is hard to deliver their value base only on land use and ignore their histories and tangible values.

6.1.3 Forming of functions and interactions

As a project which won several prize, the beauty in design has been repeatedly written. The original plan for the reconstruction of the center part in the Old Airfield has a quite minimalism concept and site plan (Fig 6.2.5). The idea was quite simple, that is to remove or break part of the sealed surface for greening and left others for recreation and connection. The specific measurements diverse due to the location and needs. For example, the 500-meter long runway are completely preserved as it was on the east half near the main room for activities, while the west half was narrowed to a small strip with the removed pieces of concrete piled on both road sides. However, this narrow part and the concrete is almost completely buried under vegetation and is barely walkable today (Fig 6.2.6-a). The tree grove in front of the tower used to be a sealed little square. Here the concrete was thoroughly moved and turned into a picnic lawn with 55 regularly planted trees which provide shade and fresh air. Almost each individual tree belongs to a different species and has a donor. The smashed concrete was put into iron cages which set near the grove and sometimes function as sitting benches (Fig 6.2.6-b).

Greater changes happen in the west and north part of the place. The concrete floor of former parking apron was excavated but break into larger pieces. These pieces were piled up to imitate the picture “The Ice Sea” by Caspar David Friedrich, thus the place was named “The plaice fields” to indicate the similarity. Furthermore, researchers form the Senckenberg Research Institute have been monitoring and documenting the development of this large natural experimentation since 2003 (GTL 2004). Now the big “floating ices” have lost their sharp edges but cover by moss and merge into dense plants (Fig 6.2.6-c). The former helicopter parking area had better conditions and was strengthened in the habitat functions. The concrete slabs were piled up neatly, and the permeable lawn turned to woodlands (Fig 6.2.6-d). The artificial pond in the middle of one river branch highly increase the diversity of small animal species and formed a natural text book of habitat diversity for children. In a word, all these construction wastes were integrated into the planning as critical design resources. The gradual demolition of concrete and asphalt as well as the process of the overtaken of natural regeneration present as a dynamic picture of how landscape could transform through time.

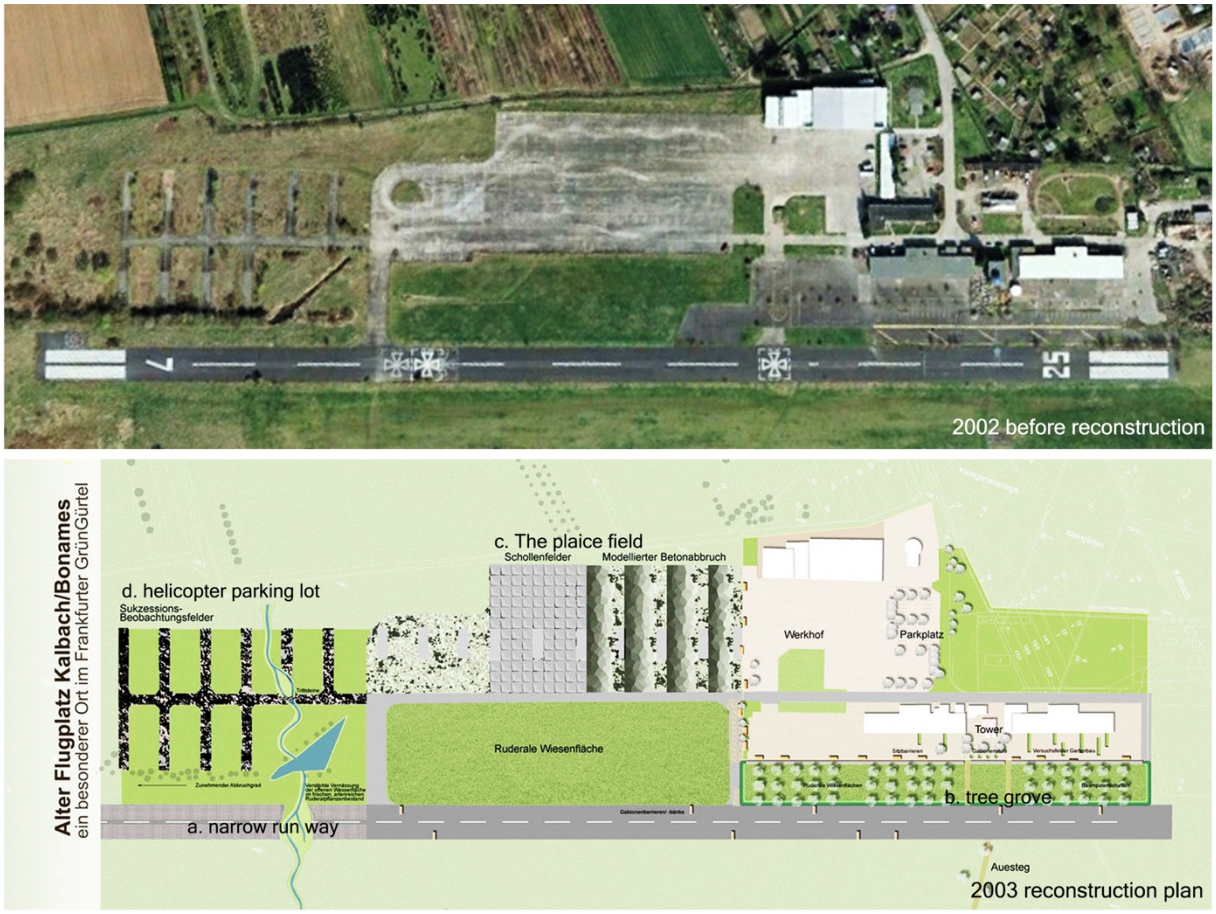


Fig 6.2. 5 The Old Airfield satellite image in 2002 before reconstruction (upper, from Google Earth historical map) and the site plan in 2003 for the reconstruction (lower, from GTL), edit by author.

Fig 6.2. 6 The dynamic landscapes of Old Airfield, photos of 2003 from Greenbelt Project Group and photos of 2016 taken by author.

Furthermore, from the perspective of how functions interact with each other, new inspiration can be found. Using a simplified diagram to illustrate the complex functions undertaken by this small site (Fig 6.2.7), it is quite clear that how different categories of functions locate and combine with each other to a maximum extent. The general arrangement of the center area follows the gradient from the human dominated east end to the nature dominated west end of the main runway. The east part seems to be a quite normal recreational center, with museums, restaurant, parking lot and green spaces, while the west is more wild and deep in the control of nature.

However, no part takes single functions but all highly combines with other types of services especially the cultural services. For instance, the tree grove on the east end is an active place contributing in air purification, carbon sequestration and water regulation, as well as being used as recreational activities like picnic and sunbath, or for aesthetic appreciation by users in restaurant. The wet grassland and the re-naturalized former parking apron in the middle part have provided unique habitats for local species, for scientific monitor and studies, as well as for the education on children. The former helicopter parking place in the west end of the runway functions similarly but lay higher emphasis on habitat nurturing. Even the large grassland on the south of runway is a productive land besides being a green open space. All these highly functional parts are linked together by the round runway, thus gain closer relationships with each other and gradually create synergies with each other.

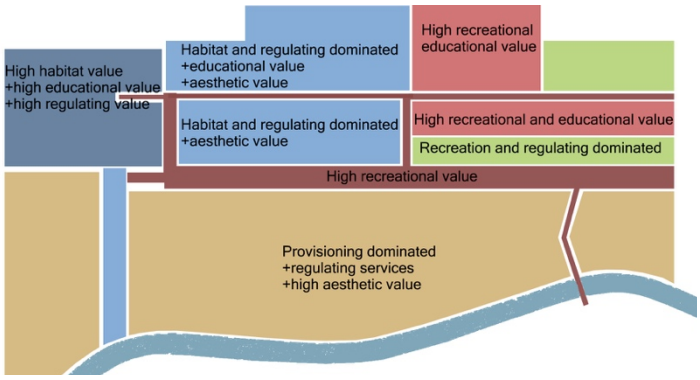


Fig 6.2. 7 Diagram of the functions and relationships in Old Airfield, by author.

It seems to be an unspectacular way to plan the function structure by the first glance but it is actually a textbook example. Cultural services, in order to gain people's interests, need a relatively high density; nevertheless, habitat functions demand relatively less human intervention. It would easily form potential conflict with each other like that in the urban forest, or they are separated in location without any possibility of combination. The runway here functions both segregation and connection to make these two types of functions synergy together to generate positive effects, thus the place becomes the so called multifunctional open space by all means.

Another interesting finding from the case is that the cultural services are different with each other, which has not been discussed by former studies. The common cultural services can be categorized into two groups, the negative and positive ones. Negative services, include the C1 aesthetic appreciation and C5 cultural heritage value, are site-dependent which means their value mainly hinge on the quality of the objective space, could be certain types of landscapes or with specific historical memories. The positive ones refer to C2 recreation, mental and physical health and C4 scientific and educational value, which depend more on the planning. Under appropriate arrangement, the positive cultural services have

higher suitability on variety places and can play a higher role in activating the place. The cultural services of Old Airfield are typical examples of how the positive services synergy across categories and enhance the general vitality of the whole project.

6.1.4 Multifunctionality for planning

The case of the Old Airfield proved that multifunctionality as an analytical framework can also be applied on the small scale site. This extent the scale possibility much further comparing with former cases (Raudsepp-Hearne, Peterson et al. 2010, Koschke, Fuerst et al. 2012, Yang, Ge et al. 2015). Through the analysis on functions and interactions, it is clear that the success of this project depends mainly on the planning concept especially the function structure other than the pure beauty in design. Three measurements can be summarized in searching for higher quality of multifunctionality. The first is the necessary distinguish between functions with diverse core demands, like the cultural services and the habitat functions. The second is the combination of functions especially with different cultural services in appropriate approaches. In the Old Airfield, educational and scientific purposes are deeply combined with other functions and create great success for both sides. The third measurement is the promoting of synergy effects among the whole area. The Old Airfield uses the runway to connect all smaller elements and functions together. The target groups, children and families, become the living parts of the project to experience the potential possibilities of all spaces. Similar ways like the round route for the Greenbelt is planned for same purpose.

The Old Airfield is no doubt a multifunctional local green open space, that it contains multiple functions and promotes positive and active synergies among functions, furthermore, it reaches a dynamic balance of the social-natural system. Moreover, observing from this case, the emphasis of multifunctionality shifts from the spatial distribution and richness of single functions to the combination and interaction of functions from a temporal and spatial scale, which further enrich the concept.

6.3 The Hiking Route of Springs

6.3.1 Introduction of the route

In addition to the 62-kilometer Greenbelt round route for pedestrians, more than a dozens of other small and local hiking trails are planned for citizens, with the length from 0.3 to 18 kilometers, and half of the trails lie in the urban forest. Each of these hiking routes follows a specific topic, which is normally historical background or cultural landscape related, and doesn't limited in the range of Greenbelt itself, but rather stretches into city districts or links to destinations outside Frankfurt. Each route has its own signage marked along the trail, besides, all routes are presented in the Greenbelt Leisure Map and detailed described in independent free brochures.

The Hiking Route of Springs (Quellenwanderweg) is a 6 km trail between Seckenbach and Bergen-Enkheim in the north-east of Greenbelt (Fig 6.3.1). The location of this route is one of the most fragmented area in Greenbelt that constantly being cut by built areas. However, these areas also provide with people who works in this huge agricultural district. The trail starts and ends in the residential area and only half of the route lies inside the boundary of Greenbelt, where the height is about 200 meters above sea level thus has a great view over the center city. This small hill area Lohrberg and Berger Hang is special in the geographic structure for it contains spring layers, which contribute to the springs, wells and water mills with a history behind them. The Hiking Route of Spring is thus planned to connect this cultural valuable sites together.

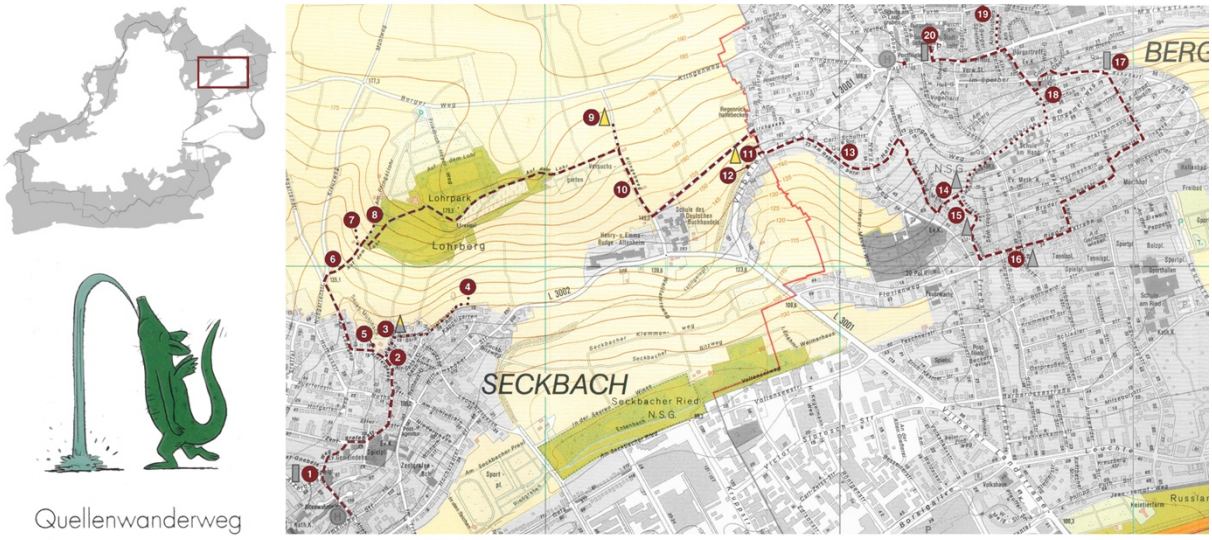


Fig 6.3. 1 The Hiking Route of Spring. Upper left: The location in Greenbelt; Lower left: The logo of the route; Right: The site plan of the route, grey area is out of the Greenbelt. Base map from Umweltamt brochure and re-draw by author.

The route contains 20 stations and the first five stations lie inside the built area of Seckbach. The starting point Station 1 named The Old Born and located in an unnoticed corner a green space near a playground of the quite residential area. The German word Born, which is normally translated as spring, describes a spring fossil which everyone could cover their requirements. The station 2 “Draisborngraben” presents part of an underground spring course which could be located following the sound of spring in quiet time. This spring runs continuously to “the Seckbacher Mühlbach”, the station 5, a stream drove the Seckbach water mill until the end of the 19th century. The medieval-looking house was built behind the millstones and now became a testimony of the water mills. This stream is created by the confluence of several springs and has a length of approximately 1 km including the pipeline. The stream was once buried under concrete and only until recently got relocated to its old bed in the natural conservation project. After a short open flow course, the Seckbacher Mühlbach disappears into the underground pipe. Since 1990, the stream ends in the nature reserve Seckbacher Ried and feeds this 7 ha wetland all year long. On the crossroad of station 2, a sideway off the main route leads to station 3 and 4, which is

respectively a former pumping station and an old spring site which had large amount of water but now only left with an area of wetland.

Since the station 6, the route enters the range of Greenbelt and begins to climb up steadily. The station 6 is the outflow of the Pfingstlohr down from the Lohrberg, and presents as a trickle flows by the street side. The Pfingstgetrieschen Spring, the station 7 that lies little off the main route, lies on the slope of the Lohrberg in a former leisure gardens/ small gardens, which was recently purchased by the City Frankfurt from the funds of Nature Conservation Law. In this way, the spring source area which was intensively used before could now be better protected. Both springs, the Pfingstlohr and Pfingstgetrieschen, run down to feed the Seckbacher Mühlbach.

The former main collection water tank of the Seckbacher waterworks dated in 1897 is the 8th station located in the Pfingstlohr street. The concrete main tank has a capacity of 300 cubic meters and collected water of the strong springs include the Draisborn, Wüst and Pfingstlohr as drinking water source for the west of Seckbach. Since 1903, this pipeline network was connected into the Frankfurt system and the tank was able to supply both west and east part when necessary. The Klingenborn and Klingelbach, station 9 and 10, are both springs origin from the higer layer of Lohrberg. They run down the hill and was collected for drinking purpose until 1953, and later become the source water of the Seckbacher Ried wetland. The rest two sites inside the Greenbelt related to Judenborn, a spring with large amount and leaks out of the ground.

The rest 8 sites all locate in the Enkheim district at the east foot of the Lohrberg. These springs related stations are almost identical with that in Seckbach, but the route is about twice long. All together 5 springs and one well can be found within the area which were once critical as drinking water supply but now lose their provisioning functions. Some of them are now buried underground and hard to relocate. Besides, similar as in Seckbach, a historical mill and its driven stream, the Enkheimer Mühlbach of station 14, locates also near the Lohrberg hill and once served for the area.

The Hiking Route of Springs aims at the recollection of the water sources sites that largely interweaved with local histories. Along the route, 11 springs, 2 wells, 3 streams, 2 water facilities and 2 traditional water mills are connected to tell the stories lasts since hundreds of years. The abundant water sources used to promote prosperous towns, now their remains still provide with cultural, recreational and educational value.

6.3.2 The undertaken functions

The route belongs to the Lohrberg area in the north-east part, where the capacity of general Ecosystem Services presents as medium level of the whole Greenbelt. The route itself is too small to be analyzed, however, the performance of its surrounding area could be used as reference (Fig 6.3.2). As a traditional agricultural district, the area presents as generally medium productivity in food provisioning. The center of the Lohrberg area, where the route goes across from west to east, has relatively lower

capacity due to the extensive pasture tradition and ornamental lawn in the Lohrpark. The regulating services basically show limited capacity due to the agriculture dominated ecosystem, with the exception of the nature reserve Seckbacher Ried wetland. Many springs of the district finally converge here into this reed wetland, which thus keeps in a moist status and provides valuable habitats for species. The center of the Lohrberg area shows strong competitiveness in cultural services, which may contribute to the Lohrpark and the nearby Apple House.

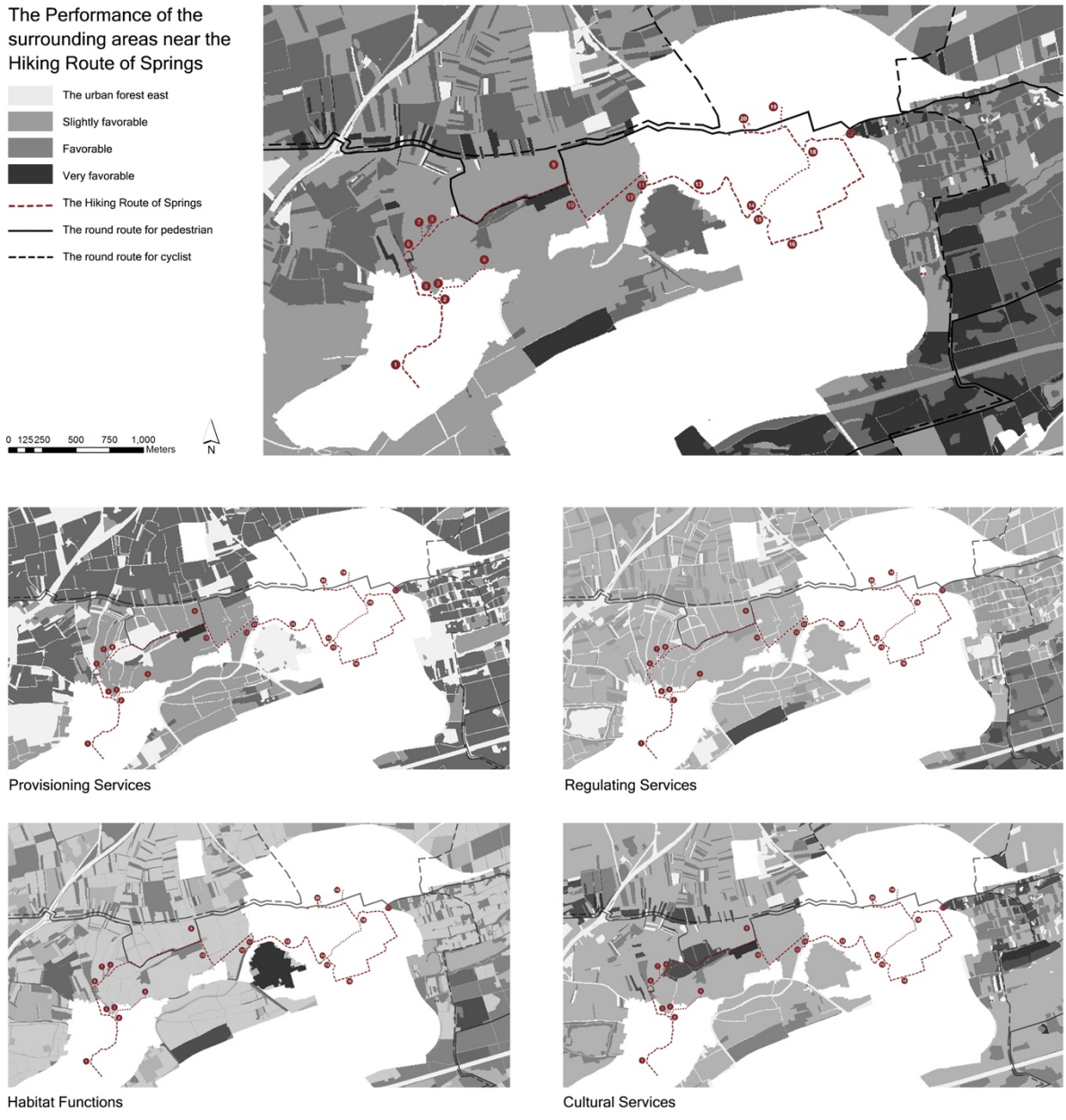


Fig 6.3. 2 The performance of the surrounding area of the Hiking Route of Springs, by author.

Based on the result from urban level, the Hiking Route of Springs seems to have chosen a less favorable place and dives deeply into the built area instead. Without the awareness of its historical background, this route seems less attractive. By contrast, the Greenbelt round routes for pedestrians and cyclists, show as continuous and dash lines in black color, have made better selection of the landscapes on both sides. The pedestrian round route goes along the places with higher general performance in east,

directly goes through Enkheim, and only overlapped with the Spring Hiking Route in the Lohrpark, which is the most favorable place in its circumference.

The local level functions of the route center in the cultural aspect, especially the historical heritage value. However, the expression forms of the heritage information are relatively deficient. Besides the 6-page German brochure which gives a detailed introduction of the site location and background histories, the only clues are the information board along the route (Fig 6.3.3-upper). Some of the boards are hidden deeply unnoticed, while others maybe humdrum for children or normal passers-by to be interested into the story line. This status leads to the fact that, despite the lavish heritage or educational value and the ample provision from planners' perspective, the acceptance and attractiveness of this value from users' side is considerably low.

From the recreational usage of this route, the flaw is also obvious, that the monotony in sight and complexity in route are sometimes unfriendly to hikers (Fig 6.3.3-lower). Between many of the 20 stations are only walking without objects, except a few places have specific sight of landscape of unique local residential buildings. 65% of the trails are inside built areas, where the roads are narrow and mix-used with limited space for pedestrians; while some part of the route include crossing main road. Furthermore, the guide system for the route is poor and people who are not familiar with the district can easily got lost.

6.3.3 The supply and demand of multifunctionality

It is interesting that the place with best experience in the springs hiking route is the part inside the Greenbelt and irrelevance with the spring topic (Fig 6.3.4). This area provides with unique landscapes of the city and of the natural environment, as well as necessary supporting facilities like benches, shade, restaurant, coffee shop and farm store, which cannot be found in other parts of the route. This part of Greenbelt is a relatively hot spot even in urban level with one essential advantage that much more possibilities can be chosen here than purely walking along the route. The multifunctionality of this area bases on its natural resources and enhances by appropriate cultural services, which makes the acceptance of functions stay at a higher level, on the contrary, the value of the spring route is partly decreased due to the lack of positive interaction with other functions.

The supply-demand perspective of the Ecosystem Services is a relatively recent topic start to rise attention (De Groot, Alkemade et al. 2010, Burkhard, Kroll et al. 2012). This topic has been especially critical since more urban planning perspectives are merging into the field. The demand perspective has been hard to locate or map in regional scale due to the lack of valid data. However, qualitative approach at local scale, which rely on methodologies like field research and interviews, is currently a effective way to capture the social aspects and compensate the quantitative mapping (Vollmer, Prescott et al. 2015). From this perspective, the case of spring hiking route proves the importance of the acceptance of Ecosystem Services in its actual performance and emphasis the critical role of the quality of cultural services in local scale.

Fig 6.3. 3 The information board (upper) and The signs and roads(lower) of the Hiking Route of Springs, photos by author.

Fig 6.3. 4 Some sights of the Hiking Route of Springs inside Greenbelt and irrelevant with the topic, photos by author.

6.4 Summary

Follow the urban level results of multifunctionality analyzed in chapter 5, this chapter focuses on the multifunctionality of local scale sites for two main questions: first, how is the urban level multifunctionality delivered to local level, and how are these two level connected; second, how can the interactions among functions influence the efficiency of multifunctionality at local level. Using three different sites inside the greenbelt, a qualitative analysis is made and lead to many useful findings.

The east part of urban forest is chosen because it represents the hottest area in the total performance of multifunctionality at urban scale. This area has shown high capacity in all four of the Ecosystem Services categories especially in regulating functions. By adding additional local information, the actual cultural capacity of the area is further enhanced. However, combining the results from both, it is clear that the provision capacity of all the diverse functions in the area has approaching to a maximum limit, that it may get overload if more functions are added recklessly in the future. In another word, multifunctionality has its own limitation depends on specific local use and management, and the hottest spot in urban scale may indicate potential danger from a sustainable point of view.

The performance of Old Airfield project in local level exceeds its general capacity in urban level. Through massive intended positive interactions with other services, the cultural services elaborately planned in the area upgrades the multifunctionality. In contrary, the isolated cultural services in the Hiking Route of Springs have much less acceptance and attractiveness, especially in the built area where not much Ecosystem Services are provided. These two case proves the vital role of synergies among functions in local level, that these positive interactions are critical for the efficiency of multifunctionality delivers from supply perspective to usage perspective.

The three cases provide multiple detailed aspects of multifunctionality in local urban green space. Through this three cases with a size from approximately 10 ha to 1500 ha, the apply of the approach is much more extended to a small scale with few attentions until now. It is proved that the smaller the scale is, the more critical role play by the appropriate arrangement of cultural services. However, the cultural services won't sustain along, but rely on the positive and creative interactions with other ones to increase the efficiency in the delivering of multifunctionality from urban to local level.

Chapter VII Conclusion and Discussion

This dissertation argues that the extensively used but less discussed term multifunctionality is a comprehensive status, best suited for the interpretation of urban green space in a systematical way. It can be used as a general framework for the analyzing of cases of different scales. Further on, a specific analytical framework of multifunctionality is built for the overall interpretation of the development of Greenbelt Frankfurt, including related planning efforts and implementation status on both urban and local scales. The result proves the feasibility of the framework and helps to give detailed suggestions for the future development of the Greenbelt.

7.1 Overview of Findings

This dissertation focuses on the interpretation and application of multifunctionality in the context of urban green space. The first part studies theoretical background of the relevant literature and centers around the question of "what is the multifunctionality of the urban green space". In the course of the review of the term and organization of the current theoretical base, the content, property and significance of the term are clarified, defining it as a status for a comprehensive description of the urban green space that could be best used as an analytical framework. The second part explores the case study by applying this framework to analyze the of Greenbelt Frankfurt in terms of planning efforts and implementation at urban and local levels. As a final result, a relatively multi-dimensional picture of the place is drawn, and it can contribute greatly to the understanding of the current situation as well as to paving avenues for future development.

7.1.1 The concept of multifunctionality for urban green space

Multifunctionality has been repeatedly emphasized in the open space planning as well as in the number of related disciplines or concepts, including Green Infrastructure, Urban Agriculture, Ecosystem Service, Landscape Planning, etc. However, cases when the word was over-used in diverse situations greatly prevail over those, when it was thoroughly comprehended with respect to its multi-level underpinning. Through studying the literature, a review and an outline of the concept of multifunctionality in urban green open space is presented to clarify the definition as well as to argue its significance.

- **Functions of the urban green space constitute the fundamental content of multifunctionality and the majority of these functions have been applied for a long period of time throughout the urban history.**

  Function initially was introduced as an urban planning term to describe the anthropological classification of the built environment. Further on, it experienced continuous subdivision and

extension, until the functions of the green space became an independent group. Having disciplines like urban ecology as a reference and a source, functions of green space gradually became a neutral term representing both social and natural systems. The components of this group seem to be growing over time, but in fact the functions of green space are only perceived and explained from a human perspective rather than being discovered out of nothing. Thus a few new functions have emerged in the recent years but the new perspectives or understandings are missing.

- **The general co-existence of multiple functions in green space is a certainty, however, their quantity, quality, types and distribution represent the actual subject to discussion.**
  An ecosystem without human interferences naturally possesses multiple functions that are balanced and, as a rule, work highly efficiently. Urban green space, as a semi-natural system, possesses functions of both types, which excludes the possibility of it being purely mono-functional. Nevertheless, it is also the combination of the two that makes the system fragile and thus a constant monitoring and maintenance is required in order to keep it well-functioning. The quality, quantity, types and distribution of green space functions are critical characteristics that influence the balance and efficiency of general performance of the multiple functions.

- **The Ecosystem Services concept has a great advantage of understanding the essential nature of the massive functions in urban green space. More attention needs to be paid to the application of the concept in the green open space planning context.**
  The Ecosystem Services concept originated in 1980s in close relation with economics and has gained a greater influence for the evaluation of urban ecosystems in the new millennium. One of the significant advances of the concept lies in its classification of the functions, or the services provided by ecosystems. These could be categorized into four types: provisioning, regulating and cultural services as well as habitat functions. Each type has its different generation mechanism and all together they summarize functions from relatively all standpoints. Such a platform itself is a valuable perspective for the planning of urban green space, in which to balance and arrange multiple functions is the core task.

- **The existence of positive interactions among multiple functions is an optimal status, while the presence of the negative interactions would decrease the general performance of multifunctionality.**
  The interactions between functions are divided into synergy and trade-off, which refers to the positive and negative effects respectively. Currently existing quantitative researches on the the two interactions are not sufficient and mostly limited to the regional scale. They also sometimes experience difficulties distinguishing between synergy and simple co-existence. In fact, the positive synergy effect is critical for the multifunctionality in urban green space, for it indicates

a status of balance between functions in a system with human interference. The analysis and promotion of such status would help improve the quality of the urban green system.

- **The emphasis of multifunctionality on urban green space has scale difference and continuity at the urban and local levels.**

  So far most of the related empirical studies have centered around the distribution of multiple functions at the regional level, and only a small fraction has focused on a specific city or urban area with a smaller range of target functions. Despite the insufficient number of studied cases, it can be clearly noticed that the regional scale analysis pays more attentions to the distribution of functions, while the urban scale tends to describe the general effects and potential relations. In another word, the rationale behind multifunctionality at the larger scale is the more functions, the better, and at the smaller scale the more useful, the better. From a planning perspective, these two have their own approaches and reflect different aspects of multifunctionality that can be further discussed on the condition they are analyzed in combination.

Therefore, a preliminary definition can be based on these findings, which imply that multifunctionality of urban green space is a status, that describes the type, quality, distribution and potential interactions between multiple functions and switches focus between different scales. In addition, positive interactions create synergy effects and promote the better performance of multifunctionality, while the negative ones cause the opposite results. Thus, as a status, multifunctionality belongs to all urban green spaces, whereas the level and the quality differ. Furthermore, since urban green spaces is rooted in the geographic condition and local tradition, multifunctionality is also a context-dependent term without an absolute and universal standard. When it is used as an aim in planning, it refers to the higher level of performance in comparison to its status quo, rather than a specific goal. In this way, multifunctionality is better used as an analytical framework for systematical interpretation of a specific case in order to get more thoroughly comprehension of the urban green place in term of its failure and success, legacy and potential, as well as future choices.

7.1.2 The efforts and reality of multifunctionality in the Greenbelt Frankfurt

By adopting the classification of Ecosystem Services in the reports of the Millennium Ecosystem Assessment (MA 2005) and The Economics of Ecosystems and Biodiversity (TEEB 2010, TEEB 2011), a methodology of using multifunctionality as an analytical framework has been designed. It combines together semi-quantitative and qualitative approaches together on urban level, and further extends the qualitative analysis to the local level, in order to ensure an in-depth examination. The included functions for analyzing are selected based on the local context to eliminate the irrelevant ones.

The case study has covered two scales using the Greenbelt of Frankfurt am Main, Germany. At the urban level, the entire Greenbelt with more than 8000 ha area has been used to analyze the multifunctionality with regard to its implementation and planning practices. For the mapping of the current status(around 2011) of multifunctionality in the Greenbelt, a land use based approach (Burkhard, Kroll et al. 2012, Kopperoinen, Itkonen et al. 2014) has been adopted and revised with respect to local policy and related information. In addition, the land use changes from 1991 to 2011 have been preliminarily discussed through the comparison of Greenbelt Leisure Maps. Encoding of the planning efforts of multifunctionality in the Greenbelt has relied on qualitative analysis methods to categorize the explicit and inexplicit planning efforts that targeted at each function. The results of this analysis have shown a multi-layered picture of how the Greenbelt is understood, planned and used at the urban level.

- **The multifunctionality of Greenbelt represents a highly uneven spatial distribution that is centered around the southeastern part, and this tendency has probably increased over the last two decades. The fundamental changes within the whole area are almost negligible.**

  The vast urban forest in the south has large natural advantages as to regulating services and habitat functions that contribute to its overall high performance. However, the huge differences between the forest and the Nidda area indicate possible ignorance of the latter as well as its great undeveloped potential. Especially, more attention should be paid to increasing spatial and functional continuity of the Nidda area. An even performance of the agriculture area in the north-east is not a good sign, but it suggests the lack of highlights in the area and its stiffness as part of the urban green space. Furthermore, the small and fragmented land use changes over the last 20 years could mean that a limited tangible progress has been made since the founding of the Greenbelt.

- **The original 1991 guidelines for the Greenbelt present as a relatively balanced vision but the collective results of multiple specific projects show a notable emphasis on intangible aspects such as cultural services.**

  It may be a typical situation that the master plan is all-inclusive while the actual implementation is opportunistic. As old as the Greenbelt Plan of 1991, it covers all aspects of multifunctionality, but this balanced attention was lost in the course of practices followed. The major part of official resources, related to cultural services, cannot easily lead to high efficient results, if not closely bonded with other concrete changes.

- **The efforts in addressing multifunctionality in the Greenbelt and the implementation suggest a mismatch between demand and supply.**

  The focus of small projects has been in an “add-on” mode, which implies the better natural condition is, the more additional intangible meaning is to be added to the area. This has led to the further polarization of the situations.

At the local level, three sites of the Greenbelt are chosen for a closer observation and analysis of both functions and interactions. The first is the east part of urban forest (about 1200 ha), which is the area with the highest level of multifunctionality, base on the mapping result at the urban level. The second one is the Reconstruction Project of the Old Airfield (about 10 ha), which is a place favored by citizens but outstanding in terms of urban level performance. The third case is a local hiking route (about 6km long), which has a spring theme and lies in the north-east of the Greenbelt. These three cases of different shapes and sizes represent the diversity of forming elements of the Greenbelt. Their observation and analysis contribute to the better understanding of multifunctionality.

- **A hot spot from the standpoint of multifunctionality may also be the spot of potential danger or limited capacity.**

  The east urban forest illustrates the maximum level of the provisioning of multifunctionality, at least in terms of quantity of functions and interactions. Besides full-capacity supply of regulating services and habitat functions, this area also actively provide cultural services and is used by a great number of citizens. After adding timber production, this area can be considered fully use from spatially and time wise. The current fragile balance is supported by an elaborate management system but any changes to the current situations need to be carefully considered.

- **Synergy effects, especially between cultural services and other types of services, play a vital role in the performance of multifunctionality that is delivered on a local scale, but these positive interactions will not happen without a concrete base for multifunctionality.**

  The Old Airfield presents more advances on the local scale due to the great number of intended positive interactions among functions, which increase the efficiency of the delivery of multifunctionality. On the opposite, the Hiking Route of Springs is much less attractive, because the simple supply of cultural services is a less efficient way to deliver multifunctionality.

In general, multifunctionality of the Greenbelt Frankfurt is spatially uneven with high capacity in the south and medium to low in other place. Considering the nearly overload situation in the south, further efforts need to be focused on the enhancement of general capacity of the Nidda area and highlight quality of specific spots in the north-east to balance the weight and increase overall multifunctionality of the Greenbelt as a whole. Promoting of positive effects between cultural services and other types of services is an optimal solution for locations with limited degree of multifunctionality, the Old Airfield being a good example.

The case study of multifunctionality of the Greenbelt, as how it was intended and how it turned to be in reality, both on urban and local scales, has testified the feasibility and continuity of multifunctionality as an analytical framework, that results from different perspectives and scales, which can be joined together for the comprehensive interpretation of urban green space. Through this

framework, a dynamic and multi-layered image of the studied area is illustrated with clearer advantages and flaws, as well as possible revising directions for the future.

7.2 Discussion

7.2.1 The future development of Greenbelt Frankfurt

Base on the analysis results, the main problems of the multifunctionality in Greenbelt area lie in the unequal distribution of spatial functions on the urban scale and in the quality of interactions on the local scale. In the meantime, the majority efforts were focused on publicity and other non-material undertakings, evenly spread over the whole area. It matches with the results of a large scale questionnaire in 2010, stated that 68% of the interviewee are aware of the Greenbelt Frankfurt but the satisfaction rate with the urban green space is much lower than that in Munich, where the average open space area is two times smaller than in Frankfurt. Moreover, the satisfaction degree with the on green space in Frankfurt rises with the age, while the people within the age group between 18-24 years area the least satisfied. Half of these young people demand for more possibilities and facilities for sport and other activities in free time (Projektbüro 2010).

The Greenbelt does have highly multifunctional places, but the number is disproportionate to its overall area. This situation is partly due to the shortages in the independent budget, which has been applied since 1997. Due to the insufficient funding, works in the Greenbelt were switched to a "small steps" mode since the Greenbelt Project Group. Big goals in guideline were divided into smaller ones that can be done one by one without huge financial investments. Only occasionally, as in the Project the Old Airfield, external support can be provided, but in most other cases an opportunistic approach is practiced. Thus, the big and substantial changes have less chances to be pushed through, while the non-material ones are overemphasized.

An investigation by an independent working group has been made recently (Projektbüro 2014) and the report has pointed out problems in the use of Greenbelt from a urban design point of view. These included the large proportion of closed entrances from the city into the Greenbelt area, the lack of necessary facilities for free time recreation, as well as the fragmented open spaces cut by transport. Thus, the new Spoke and Ray Plan along with and the development guideline all target on the connection and activation of the whole area.

This case study in the dissertation partly proved the above result, concluding that the Greenbelt is currently less functional as an active area of the urban open space, but more positive on natural aspects within the fragmented patches. In other words, there are not enough material changes coming from the perspective of a human-friendly open public space. Based on this study, Greenbelt should not be developed in this even and small scale actions, which have also been proved inefficient in the past development. Instead, the limited budget and attention need to be focused on one area in the first line. For example, the Nidda area need to built several other "best practices" like the Old Airfield in order to

create a new “hot area” of multifunctionality. In this way, the heavy burden resting on urban forest could be partly alleviated without the urge for potential trade-offs between social and natural needs.

The “small steps” development approach saved the Greenbelt 20 years ago from being abandoned and also helped to consolidate the abstract cognition to the citizens that this large ring of open space around the city center is a treasure and an integral part of the Frankfurt city image. However, there is a possibility that the development direction has reached a bottleneck, while new approaches, such as “concentrated steps”, are upcoming solutions to best meet the increasing demand for multifunctionality by the citizens.

7.2.1 Inspiration and experience

Nowadays, new concepts emerge with fancy names and bright promising results on a daily bases. However, the majority of them stand for old topics, with the only difference in perspectives or demand they address. For instance, urban climate change adaptation and mitigation exemplify the titles of new planning strategies but their basic principles have not changed much over the last three decades. Chasing new concepts and making massive new plans will not help solve existing problems, but getting closer to the understanding of the past may provide a valuable lesson for the future. Nevertheless, some concepts, especially the Urban Green Infrastructure, do provide fresh and fundamental changes to the ways the urban green space could be reconsidered in terms of organizing and interpreting urban components, but substantially more efforts are required in order to push forward the concept and avoid becoming another buzz word.

Moreover, in the era of globalization and informatization, good examples of urban open space development from other cities or other countries have become easily accessible, which can potentially be disadvantageous. The simple transfer of the form is useless since no two cities have the absolutely identical context. Even through the pure copy may work for a period, it always unavoidably led to diverse results. The Greenbelt Frankfurt took its lesson of incremental development approach from the Ruhr Districts, but the fascination vanished in the process, since the institutional structures and many other conditions were totally different. The development of urban open space, from this perspective, is an internal issue with core solutions lying within.

7.3 Looking Ahead

In this study the term multifunctionality in the context of urban green space is preliminarily reviewed and interpreted based on the empirical case, to clarify and illustrate its significance. However, limitations are unavoidable and more work need to be condected in the future. To begin with, the methodology applied in the dissertation can be further improved. The land use-based evaluation approach has the advantage of close connection to planning and the relatively simple process in comparison to the monetary approach, however, its strong dependency on land use data and potential

ignorance of differences among the same types refer to the distinct flaws. This dissertation revised the problem using more precise local data and additional information, but the resolution of different scales needs to be further improved, especially for cultural services. Another limitation is the reliability of information and data. Limited to research period and manpower, the number of expert interviews and the range of field research was reduced to a minimum number, which might have resulted in subjective judgment. Given suitable chance, the incredibility of data should be further enhanced.

As mentioned in the beginning, the final aim behind this research is not narrowed to one term, instead it highlights the representative character of this term for the study of Urban Green Infrastructure. Thus, the study on the multifunctionality of urban green open space has aimed to contribute to the clarification of the GI concept, in order to allow for substantial changes within this framework in the future. Therefore, the short-term assignment for the future relies on two major parts, which are learning the experience of other cities as a comparison to the current case study, and a more in-depth study of interactions among the functions. The long-term targets lie in the exploration and experimentation as to how the concept could be better applied in planning and decision making. The final goal, as for a planner and a designer, is to build a better urban green space and the first step has already been made.

Figure List

Appendix

Appendix 4.1 List of Expert Interview

Interviewee: Ms. Lydia Specht

Institution and task: Umweltamt, Frankfurt am Main; Current member of Greenbelt Project Group; Landscape planning and design, publicity and management.

Date and time: 04.06.2014, 09:00 – 11:30

Main content: 1. The concept forming of the new "Spokes and Rays" plan for Greenbelt;
2. The current progress and short term arrangements of the new plan;
3. The general development back stories and people in the Greenbelt project;
4. Current financial and institutional problems in the development.
5. The experiences in the everyday working of the Greenbelt project.

Interviewee: Ms. Jutta Wippermann

Institution and task: Regionalpark RheinMain GmbH; Landscape architect, authorized representative.

Date and time: 11.04.2014, 14:00 - 15:30

Main content: 1. The background of Till Behrens and his Greenbelt plan;
2. The history and main problems during Greenbelt GmbH time;
3. The involvement and investment of Regionalpark RheinMain GmbH in the projects of Greenbelt Frankfurt.

Interviewee: Ms. Lydia Specht

Institution and task: Umweltamt, Frankfurt am Main; Current member of Greenbelt Project Group; Landscape planning and design, publicity and management.

Date and time: 11.11.2015, 14:00 – 16:30

Main content: 1. The planning process of the small projects in the Greenbelt project;
2. The institutional structure and funding sources of the project;
3. Relationships between Umweltamt and the Greenbelt project group;
4. The targeted (ecosystem) functions in the Greenbelt project;
5. Internal reports and current difficulties in the implementation of small projects;
6. Current efforts and demands on the recreational and aesthetic functions;
7. Relevance of each cultural services for the Greenbelt;
8. Main challenges for the future development of Greenbelt.

Interviewee: Mr. Klaus Wichert

Institution and task: Regionalpark RheinMain GmbH; Former leader and member of the Greenbelt Project Group.

Date and time: 11.18.2015, 10:00 – 11:30

Main content: 1. The early planning concept of the Greenbelt Frankfurt and the later development as well as compromise;

2. Key persons and back stories during the early development stages;
3. The organisation and management of the Greenbelt Project Group;
4. The planning process of the Old Airfield Project;
5. The current main problems for Greenbelt Frankfurt.

Interviewee: Mr. Johannes Hölzel

Institution and task: Stadtforst Frankfurt am Main, leader of production.

Date and time: 06.12.2016, 07:30 – 09:30

Main content: 1. The brief development history of urban forest;

2. The relationship between Stadtforst and the Greenbelt Project Group;
3. Current productivity and ecological status in urban forest;
4. The main undertaken functions of the urban forest;
5. The conflicts between ecological protection, timber production and recreational use;
6. Members and responsibilities of the urban forest group;
7. Critical problems in the development and management, as well as short-term plans.

Interviewee: Mr. Dirk Bönsel

Institution and task: Forschungsinstitut Senckenberg, Abteilung Botanik und Molekulare Evolutionsforshung; leader of the Biotope Mapping Working Group.

Date and time: 31.01.2017, 14:00 – 15:30

Main content: 1. The history of biotope mapping in Greenbelt Frankfurt;

2. Methods and working stuff in the mapping process;
3. Relevant level of each ecosystem service in Greenbelt Frankfurt;
4. The comparison between biotope classification and CORINE system;
5. The specific standard concerning the classifying of biotope types;
6. The capacity of specific biotope types for certain ecosystem services.

Appendix 5.3.1 The comparison and tranferability between CORINE land cover and Biotope Map classificaion

CORINE Land cover			Biotope Map classification			
No.	Nomenclature	Definitions	Counterp further classification		Nomenclature (original)	Explanation
C111	Continuous urban fabric	Most of the land is covered by . Buildings, roads and artificially surfaced area cover almost all the ground. Non-linear areas of vegetation and bare soil are exceptional.	B11		Städtisch geprägte, gemischte Bauflächen	
				B112; B113, B1131; B1132; B114; B1141; B1142; B1151; B1152; B1161; B1162	Moderne Innenstadt; Altstadt; Blockbebauung; Blockrandbebauung; Zeilenbebauung; Hochhäuser und Großformbebauung	continunous built areas.
				B1143; B1153; B1163	Versiegelungsgrad (VG) < 50%	with more permeable surface
C112	Discontinuous urban fabric	Most of the land is covered by structures. Buildings, roads and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces.	B12-14		Gemischte Bauflächen der mehr ländlich geprägten Siedlungsstrukturen; Sonstige Einzelgebäude; Bunker	
				B1171-1173, B1191; B131; B133; B141	(Öffentliche) Gebäude; Sonstige Einzelgebäude; Bunker	discontinunous buildings for residential and other purpose, with normal permeable rate
				B118; B1192; B1193; B1194	Alte Villen mit parkartigen Gärten; (Öffentliche) Gebäude mit hoher Grünflächenanteil	have higher greening level
				B1212; B122; B123; B124	Landwirtschaftliche Produktionsanlagen/Groß betriebe; Schuppen, Scheune, Stall, Silo	storages and area for agricultural production
C121	Industrial or commercial units	Artificially surfaced areas (with concrete, asphalt, tamacadam, or stabilised, e.g. beaten earth) devoid of vegetation, occupy most of the area in question, which also contains buildings and/or vegetated areas.	B2		Industrielle und gewerbliche Bauflächen/Ver- und Entsorgungsanlagen	B2231, B2232 and B2233 have higher rate green open space
				B21, B211, B2111-2114, B2121-2124, B221, B2221-2224, B2234, B23, B231, B233, B235, B237	Industrieflächen und stark versiegelte Ver- und Entsorgungsanlagen	typical industrial loactian
				B2231, B2232 and B2233	Mäßig versiegelte Gewerbeflächen mit hohem Freiflächenanteil, VG 30 - 70%	commercial areas with higher rate of greeening

	CORINE Land cover		Biotope Map classification			
No.	Nomenclature	Definitions	Counterp further classification		Nomenclature (original)	Explanation
C122	Road and rail networks and associated land	Motorways, railways, including associated installations (stations, platforms, embankments). Minimum width to include: I 00 m.	B3		Verkehrsflächen	considering the type, traffic, surface permeability, walking possibility, landscape
				B3211-3215, B3221-3225	Autobahnen, autobahnähnliche Schnellstraßen und mehrspurige Stadtstraßen; Land- und Durchgangsstraßen	dominated by impermeable transit heavy traffic which lead to pollution and noise
				B3132-3134, B3141-3144, B3151, B3231-3235	Bahnanlagen (Versiegelt); Neben- und Seitenstraßen	dominated by impermeable urban traffic and railways, medium pollution and increase accessibility
				B3241-3244, B3251-3255	Dörfliche Wege, Gassen und Spielstraßen; Versiegelte Fahr-, Fuß- und Feldwege	dominated by impermeable local traffic
				B3111-3114, B3152	Bahnanlagen (unversiegelt)	railways and trams with permeable surface
				B3261-3263, B3271-3275	Unversiegelte Fahr-, Fuß- und Feldwege; Fuß gängerzone, Fußgängerbereiche > 5 m Breite	non-motor vehicle area with permeable surface
				B3216, B3226, B3236, B3256,	mit überwiegend beidseitigem Baumbestand (Allee)	roads with trees on both sides and protected by local law
				B3281-3284, B35, B33, B34	Parkplätze, -häuser, Garagenanlagen und Lagerplätze; Versiegelte Freiflächen unbestimmter Nutzung	impermeable affiliated areas
C123	Port areas	Infrastructure of port areas, including quays, dockyards and marinas.		not found in Greenbelt		
C124	Airports	Airport installations: runways, buildings and associated land.		not found in Greenbelt		The old airfield has restored as recreational area.
C131	Mineral extraction sites	Areas with open-pit extraction of industrial minerals (sandpits, quarries) or other minerals (opencast mines). Includes flooded gravel pits, except for river-bed extraction.		not found in Greenbelt		
C133	Construction sites	Spaces under construction development, soil or bedrock excavations, earthworks.		not found in Greenbelt		
C141	Green urban areas	Areas with vegetation within urban fabric. Includes parks and cemeteries with vegetation.	B41, B43-45		(Öffentliche) Grün- und Parkanlagen; Friedhöfe; Gärten; Botanische und zoologische Gärten	

CORINE Land cover			Biotope Map classification			
No.	Nomenclature	Definitions	Counterp	further classification	Nomenclature (original)	Explanation
				B4111, B4112, B4115, B4121, B4122, B4125	überwiegend mit Altbaumbestand, Baumbestand mittlerer Altersstruktur, mit Baumbestand, Altersstruktur der Bäume durchmischt	parks dominated by old aged, middle aged and mixed trees provide more abundant ecosystems for biodiversity
				B4113, B41143, B4123, B4124	mehr oder weniger ohne Baumbestand; überwiegend Jungpflanzung oder Strauchpflanzungen	parks dominated by young trees or no trees have smaller ecosystem services comparatively
				B4131	Schloß- bzw. Burgpark	traditional buildings enhance aesthetic value
				B431-436	Friedhöfe	peaceful places with high greening rate
				B441-445	Kleingartenanlage; Freizeitgärten; Siedlergärten; Aufgelassene Gärten; Kleintierzuchtanlage	hobby gardens provide with orimental resources and local food
				B45	Botanische und zoologische Gärten	high rate greening and educational value
C142	Sport and leisure facilities	Camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc. Includes formal parks not surrounded by urban zones.	B41, B42		Sport- und Erholungsanlagen	
				B4141, B4142, B4145, B4152, B4161, B4162, B4165, B4171, B4172, B4175	gering versiegelte Sport- und Erholungsanlagen VG 10-40% überwiegend mit Altbaumbestand, Baumbestand mittlerer Altersstruktur, mit Baumbestand, Altersstruktur der Bäume durchmischt	areas for outdoor recreational and sport activities, with better natural environment
				B4163, B4164, B4173, B4174, B4181, B4182, B4191, B4192	gering versiegelte Sport- und Erholungsanlagen VG 10-40% mehr oder weniger ohne Baumbestand; überwiegend Jungpflanzung oder Strauchpflanzungen	areas for outdoor recreational and sport activities, with permeable surface
				B42, B421-429	Stärker/stark versiegelte Sport- und Erholungsanlagen mit Gebäudeflächenanteilen (inkl. Sporthallen), VG > 40%	sport field and playground with impermeable surface and limited artificial green spaces
			B7		Flächen der Landwirtschaft	

CORINE Land cover			Biotope Map classification			
No.	Nomenclature	Definitions	Counterp	further classification	Nomenclature (original)	Explanation
C211	Non-irrigated arable land	Cereals, legumes, fodder crops, root crops and fallow land. Includes flower and tree (nurseries) cultivation and vegetables, whether open field, under plastic or glass (includes market gardening). Includes aromatic, medicinal and culinary plants. Excludes permanent pastures.		B7131, B7132, B7212, B7214, B7513, B7523, B7533	Ackerbrache; Landwirtschaftliche Sondernutzungen; Grünlandflächen brachliegend	mainly the permeable fellow land
				B722,B7221, B7222	Erwerbsgartenbau; Gärtnereien; Baumschulen	orimental resources
				B731-733	Stark versiegelte Nutzflächen der Landwirtschaft	impermeable surfaces
C212	Permanently irrigated land	Crops irrigated permanently and periodically, using a permanent infrastructure (irrigation channels, drainage network). Most of these crops could not be cultivated without an artificial water supply. Does not include sporadically irrigated land.		B7111	intensiv genutzte Äcker	
C213	Rice fields	Land developed for rice cultivation. Flat surfaces with irrigation channels. Surfaces regularly flooded.		not found in Greenbelt		
C221	Vineyards	Areas planted with vines.		B7213	Weinberge	only three such parcel still exist, also high traditional value
C222	Fruit trees and berry plantations	Parcels planted with fruit trees or shrubs: single or mixed fruit species, fruit trees associated with permanently grassed surfaces. Includes chestnut and walnut groves		B7211	Mittel- und Niederstamm-Obstkulturen	
C223	Olive groves	Areas planted with olive trees, including mixed occurrence of olive trees and vines on the same parcel.		not found in Greenbelt		
C231	Pastures	Dense, predominantly graminoid grass cover, of floral composition, not under a rotation system. Mainly used for grazing, but the fodder may be harvested mechanically. Includes areas with hedges (bocage).	B75	B7521, B7531, B754, B7551	extensiv genutzte, meist artenreiche Grünlandflächen; Stark degradiertes Intensivgrünland	
				B7522, B7532, B7552	intensiv genutzte, eher artenarme Grünlandflächen	

CORINE Land cover			Biotope Map classification			
No.	Nomenclature	Definitions	Counterp	further classification	Nomenclature (original)	Explanation
C241	Annual crops associated with permanent crops	Non-permanent crops (arable lands or pasture) associated with permanent crops on the same parcel.		B7412-7416, B7421-7426	Streuobstbestände	the combination of fruit trees with grass, herbs or crops, with high landscape and traditional value
C242	Complex cultivation	Juxtaposition of small parcels of diverse annual crops, pasture and/or permanent crops.		B7121, B7122	extensiv genutzte Äcker	
C243	Land principally occupied by agriculture, with significant areas of natural vegetation	Areas principally occupied by agriculture, interspersed with significant natural areas.		B714	Wild-Acker	
			B8		Bäume, Feldgehölze, Gebüsche, Wälder	
C244	Agro-forestry areas	Annual crops or grazing land under the wooded cover of forestry species.		not found in Greenbelt		
C311	Broad-leaved forest	Vegetation formation composed principally of trees, including shrub and bush understories, where broadleaved species predominate.		B8721-8724	Laubwälder feuchter bis nasser Standorte	in wet areas, not mainly used for forestry
				B8711-8714	Laubwälder trockener bis frischer Standorte	in dry areas, forestry use
				B8731-8733	Sonstige forstlich geprägte Laubwälder	orimental resources and forestry
				B821, B831, B851	Baumreihe, Gehölze, überwiegend Laubgehölze	group of trees, not forest
C312	Coniferous forest	Vegetation formation composed principally of trees, including shrub and bush understories, where coniferous species predominate.		B8751	Stark forstlich geprägte Nadelwälder	have forestry use
				B8752	Sandkiefernwälder	special old-aged type with high value
				B822, B832, B852	Baumreihe, Gehölze, überwiegend Nadelgehölze	group of trees, not forest

	CORINE Land cover		Biotope Map classification			
No.	Nomenclature	Definitions	Counterp	further classification	Nomenclature (original)	Explanation
C313	Mixed forest	Vegetation formation composed principally of trees, including shrub and bush understories, where broadleaved and coniferous species co~dominate.		B8741-8743	Forstlich geprägte Laub-Nadel-Mischwälder	for forestry
				B876, B8771-8774, B878, E	Schlagfluren und Pionierwald; Aufforstungen, Schonungen; Naturnah entwickelter Waldmantel; Waldlichtung	functional forest, not for forestry
				B824, B833, B834, B853-855, B861-863	Baumreihe, Gehölze, Mischbestand, oder nicht einheimischer Gehölzarten	group of trees, not forest
C321	Natural grassland	Low productivity grassland. Often situated in areas of rough uneven ground. Frequently includes rocky areas, briars, and heathland.		not found in Greenbelt		
C322	Moors and heathland	Vegetation with low and closed cover, dominated by bushes, shrubs and herbaceous plants (heath, briars, broom, gorse, laburnum, etc.).		not found in Greenbelt		
C323	Sclerophyllous vegetation	Bushy sclerophyllous vegetation. Includes maquis and garrige.		B841-843	Gebüsch, Gestrüpp, Strauchgruppe (Höhe max. 2 m)	
C324	Transitional woodland/shrub	Bushy or herbaceous vegetation with scattered trees. Can represent either woodland degradation or forest regeneration/colonisation.		B81	Landschaftsprägender Einzelbaum	
C331	Beaches, dunes, and sand plains	Beaches, dunes and expanses of sand or pebbles in coastal or continental , including beds of stream channels with torrential regime.		not found in Greenbelt		
C332	Bare rock	Scree, cliffs, rocks and outcrops.		not found in Greenbelt		
			B9		Stadtbrachen, Ruderalfluren, Bauwagenplätze, Abgrabungs- und Aufschüttungsflächen sowie Sonderstandorte	

	CORINE Land cover		Biotope Map classification			
No.	Nomenclature	Definitions	Counterp	further classification	Nomenclature (original)	Explanation
C333	Sparsely vegetated areas	Includes steppes, tundra and badlands. Scattered high-attitude vegetation	B91, B92, B93, B94		Mehr oder weniger vegetationslose Brachflächen, unversiegelte Freiflächen; Brachflächen mit überwiegend kurzlebiger Ruderalvegetation; Brachflächen mit überwiegend ausdauernder Ruderalvegetation; Strukturreiche Brachflächen mit kleinräumigem Vegetationswechsel unterschiedlicher Sukzessionsstadien	
			B76	B761-765	Magerrasen und Heiden	
C132	Dump sites	Landfill or mine dump sites, industrial or public.	B95, B97		Aufschüttungsflächen, Bauwagenplätze, Wagenburgen	B95 is too small to be calculated alone
C334	Burnt areas	Areas affected by recent fires, still mainly black.		not found in Greenbelt		
C335	Glaciers and perpetual snow	Land covered by glaciers or permanent snowfields.		not found in Greenbelt		
C 411	Inland marshes	Low-lying land usually flooded in winter, and more or less saturated by water all year round.	B6	B61-65	Röhrichte, Feuchtbrachen, Hochstaudenfluren, Seggenriede und Vegetation periodisch trockenfallender Standorte	68.7% of B6 is B61, the dominace of reed type plants on humit to flooded sites; 23% is B62, the pertepual wetland with high grass/reed.
C412	Peatbogs	Peatland consisting mainly of decomposed moss and vegetable matter. May or may not be exploited.		not found in Greenbelt		
C421	Salt marshes	Vegetated low-lying areas, above the high-tide line, susceptible to flooding by sea water. Often in the process of filling in, gradually being colonised by halophilic plants.		not found in Greenbelt		
C422	Salines	Salt-pans, active or in process of . Sections of salt marsh exploited for the production of salt by evaporation. They are clearly distinguishable from the rest of the marsh by their segmentation and embankment systems.		not found in Greenbelt		

CORINE Land cover			Biotope Map classification			
No.	Nomenclature	Definitions	Counterp	further classification	Nomenclature (original)	Explanation
C423	Intertidal flats	Generally unvegetated expanses of mud, sand or rock lying between high and low water-marks. On contour on maps.		not found in Greenbelt		
			B5		Binnengewässer	
C511	Water courses	Natural or artificial water-courses serving as water drainage channels. Includes canals. Minimum width to include: 100 m.	B53, B54		Bäche, Flüsse und Ströme	
				B5311-5314	Bäche mit eher strukturarmer Gewässermorphologie (naturferne Bäche)	
				B5321-5326	Bäche mit eher strukturreicher Gewässermorphologie (naturnahe Bäche)	abundant natural structure
				B541-545	Flüsse und Ströme	re-naturalization project
C512	Water bodies	Natural or artificial stretches of water.	B51, B52, B55-58		Quellbereiche; Gräben; Altarme und Altwässer; Tümpel und temporäre Gewässer; Teiche, Weiher; Bagger- und Abgrabungsgewässer	
				B521-526, B551-556, B56, B58	Gräben und grabenartige Bäche; Altarme und Altwässer (inkl. Qualmgewässer und Totwässer); Tümpel und temporäre Gewässer; Bagger- und Abgrabungsgewässer	dead water, old arms of the Nidda river and temporary water body
				B5111-5113, B5711-5726	Ungefaßte Quellen; Teiche, Weiher	natural springs with higher landscape value
C521	Coastal lagoons	Unvegetated stretches of salt or brackish waters separated from the sea by a tongue of land or other similar topography. These water bodies can be connected with the sea at limited points, either permanently or for parts of the year only.		not found in Greenbelt		
C522	Estuaries	The mouth of a river within which the tide ebbs and flows.		not found in Greenbelt		
C523	Sea and ocean	Zone seaward of the lowest tide limit.		not found in Greenbelt		
			B0		Nicht erfasste Fläche	

Appendix 5.4.1 The Projects series of Greenbelt Frankfurt

Project (Series)	Year	Area or sites/ ha	Fund /Euro	Finacial sources	Involved land use/cover type	Partner	Main Sub-projects
Greenbelt Marks	since1998	#270	113,450	städtische Mittel; Ausgleichsmaßnahmen; donations from citizens and enterprises	Road sides, Water sides, Grassland	Citizens, Enterprises, Local groups	placement of 250 wooden or stone benches with GreenBelt Sign; planting 20 tree grops or grove with GreenBelt description
Special Landscapes-The orchard meadow	since 1995	app.200	12,500	(for the road)städtische Mittel	Orcard, Meadow, Grassland,	Bund für Naturschutz und Umwelt, Ortsverband Frankfurt-West und Sielmanns Natur-Ranger	"Appe Appeal"project; the Orchard Meadow Road with brochure
Round Routes	since 1992	app. 70km long	840,000	städtische Mittel;GreenBelt GmbH;	Forest, Water sides, Parks, Residential areas	Allgemeiner Deutscher Fahrrad-Club; Naturpark Bergstraße-Odenwald e. V.	Round Route for Bycicles, Walkers and themes like the Spring
Old Airfield Reconstruction	2003-2006	7.7	2,113,500	städtische Mittel; Naturschutzrechtliche Ausgleichsabgabe; Europäische Union; Planungsverband Frankfurt; Regional - park RheinMain Taunushang GmbH; EU interreg IV SAULProgramm;	Meadow, Grove, Park, Roads and Platz	Büro GTL; Straßenbauamt; Hochbauamt, Werk-statt Frankfurt; Museum für Komische Kunst	Reconstruction; Bridge over Nidda river; Green Classrooms; Sculpture
Parks and cemeteries renovation	1996-2009	app. 15	697,600	Regionalpark RheinMainSüdwest GmbH; Municiple source;GreenBelt GmbH;	Parks, Playground, Parking lots,	Local children and associations; Werkstatt Frankfurt;	Nordparks Bonames;Forest Play Park Louisa; Forest Play Park Goetheturm; Old Jewish Cemetery
Green connection-Haven park	2007-2013	4	8,000,000	städtische Mittel (Bürgerbefragung: EU-Mittle)	Parks, Playground, Glassland, Roads		
Arts and Device	2001-2011	#12	133,700	städtische Mittel; Regionalpark RheinMainSüdwest GmbH; Regionalpark RheinMain Dachgesellschaft GmbH	Parks, Forest	Museum of Comic Arts	The GreenBelt Mascot; Chlodwig-Poth-Anlage; Eule im Norwegerpullover; Struwwelpeter; Monsterkinder; Mosterpecht; Pinkelbaum; Eichhoernchenkoenig; Elfmeterpunkt; Dicke Raupe; ICH-Denkmal

Project (Series)	Year	Area or sites/ ha	Fund /Euro	Finacial sources	Involved land use/cover type	Partner	Main Sub-projects
Education Program	since 2003	-	105,000	Department of Green ares, of environment, of city schools; donations	Orcard, Meadow, Grassland,Forest, River, Parks, Museum		The Programs for families and schools; The learning stations; The learning roads
Nature reservation	since 1993		10,676,450	städtische Mittel; Regionalpark RheinMainSüdwest GmbH; Naturschutzrechtliche Ausgleichsabgabe; Umweltfonds Fraport	Rivers and banks, Grassland; sand dune; Trees; Reed	Bund für Um-welt- und Naturschutz; Frankfurt West; Stadtentwässerung Frankfurt; BUND Ortsverband Frankfurt-Ost	re-naturalization of rivers and banks; construction of special roads in natural reservation area; construction of avenue
Public activites	since 1997	-	125000/year	städtische Mittel	-	The GreenBelt GmbH; The GreenBelt Group	Brochures; Books; the City Map for free time; Walking in the GreenBelt

Appendix 5.4.2 The Coding Protocol of Case Greenbelt Frankfurt

Types	Nr.	Service/Function	Clear target	Indirect target/ byproduct	Examples in Greenbelt constitution
Provisioning services	P1a	Food/crop	Agriculture; food production;food security; farm	-	The GreenBelt comprises areas used for agriculture; A dialogue between the city and agriculture; Modern farms; supplies Frankfurt with fresh local farm produce
	P1b	Food/wild	Berries, mushrooms, fishing (recreation context), hunting	context	
	P2	Raw materials/ Timber & Fuel	Forestry; Timber; Wood	forest economics	The city forest is a multifunctional area with functions such as environmental protection, recreation and economics
	P3	Fresh water	drinking water, fresh water resources; underground water; water supply	context	groundwater systems; natural water management; provides the groundwater supply
	P6	Ornamental resources	Horticulture	Park; Garden	horticulture; garden; park
Regulating Services	R1	Air quality regulation	air cleaning, air pollution , air quality; fresh cold air	Green areas	provide fresh cold air
	R2	Local climate regulation	Evapotranspiration;local climate regulation; albedo; shade; city climate	Green areas	city climate
	R3	Carbon sequestration and storage	Greenhouse gas sink;global climate regulation;albedo	Green areas	
	R4	Moderation of extreme events/ Flood	Water flows (extreme events context),bush fire, shade (context), flooding (flood plains, flood mitigation, flood control)	river buffer zone	water reservoir
	R5	Water regulation	natural water management; groundwater systems	rain water; decrease sealed off areas	area sealed off from the rain water is minimized;
	R6	Water purification and waste treatment	natural water quality improvement; Water cleaning, sewage treatment, water quality, water pollution (general), “natural sewage plant”	river buffer zone	natural water management;The quality of rivers, streams and groundwater will be improved significantly

Types	Nr.	Service/Function	Clear target	Indirect target/ byproduct	Examples in Greenbelt constitution
	R7	Erosion prevention and maintenance of soil fertility	Landslides;erosion regulation; river bank protection; soil preservation and protection	context	The naturally grown structure of the soil will be preserved and protected from pollution
	R8	Pollination	Pollination	ecological linkage, linked green areas , barrier, corridors, linkage, allotment gardening	radial and circular green links
	R9	Biological control	Disease regulation	Green areas (context)	
	R10	Noise regulation	Noice regulation	Green areas (context)	
Habitat functions	H1	Habitat for species	spaces for animals; protect rare and endangered types; diversity of habitat and biologic	ecosystem diversity/ protection	The room for plants and animals
	H2	maintenance of genetic diversity	biodiversity; genetic diversity; biologic diversity	biologic diversity; endangered species ; ecosystem diversity	to protect rare and endangered types;diversity of habitat and biologic
Cultural Services	C1a	Aesthetic values	Scenic views, beautiful nature; landscape	landscape protection	the awareness of environment ;the symbol of city ; the preservation and education of local identity, from the peculiarities of landscape to the cognition of a citywide natural space.
	C1b	Inspiration	inspiration for art, folklore, national symbols, architecture, and advertising;	ecosystem diversity;	
	C2a	Recreation/ ecotourism	closeness to/access to nature/recreation,strolling area, walking area, active outdoor life,golf course, nature silence, park, fishing	infrastructure; connectivity; accessibility; ecosystem diversity; landscape protection; open space systems	multi-usable spaces for citizens;leisure, recreation, exercises;

Types	Nr.	Service/Function	Clear target	Indirect target/ byproduct	Examples in Greenbelt constitution
Services	C2b	Health	Health related (outdoor recreation and appreciation context including green areas and beaches)	infrastructure; connectivity; accessibility; open space systems	Open-air activities, sports and games contribute to public health
	C4a	Scientific research	specific info	ecosystem diversity	
	C4b	Educational value	activities/lessons of learning about nature; specific info	Botanical garden, informational plaque, experiencing nature; ecosystem diversity	gardens; activities
	C5a	Cultural heritage	historial spaces	cultural landscape	protect cultural landscape;to regenerate and preserve historic parks
	C5b	Cultural diversity	lifestyle	ecosystem diversity	diversity of lifestyles

Bibliography

Ahern, J., S. Cilliers and J. Niemelä (2014). "The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation." Landscape and Urban Planning **125**: 254-259.

Albert, C., J. Hauck, N. Buhr and C. von Haaren (2014). "What ecosystem services information do users want? Investigating interests and requirements among landscape and regional planners in Germany." Landscape ecology **29**(8): 1301-1313.

Albrechts, L., P. Healey and K. R. Kunzmann (2003). "Strategic spatial planning and regional governance in Europe." Journal of the American Planning Association **69**(2): 113-129.

Amati, M. and L. Taylor (2010). "From Green Belts to Green Infrastructure." Planning Practice and Research **25**(2): 143-155.

Andersson, E., T. McPhearson, P. Kremer, E. Gomez-Baggethun, D. Haase, M. Tuvendal and D. Wurster (2015). "Scale and context dependence of ecosystem service providing units." Ecosystem Services **12**: 157-164.

Baró, F., L. Chaparro, E. Gómez-Baggethun, J. Langemeyer, D. J. Nowak and J. Terradas (2014). "Contribution of ecosystem services to air quality and climate change mitigation policies: the case of urban forests in Barcelona, Spain." Ambio **43**(4): 466-479.

Bastian, O., D. Haase and K. Grunewald (2012). "Ecosystem properties, potentials and services–the EPPS conceptual framework and an urban application example." Ecological Indicators **21**: 7-16.

Bastin, G. N., J. A. Ludwig, R. W. Eager, V. H. Chewings and A. C. Liedloff (2002). "Indicators of landscape function: comparing patchiness metrics using remotely-sensed data from rangelands." Ecological Indicators **1**(4): 247-260.

Batchelor, P. (1969). "The origin of the garden city concept of urban form." The Journal of the Society of Architectural Historians: 184-200.

Behrens, T. (1988). Grüngürtel: Frankfurt am Main. Die Stadt wider bewohnbar machen.

Benedict, M. A. and E. T. McMahon (2012). Green infrastructure: linking landscapes and communities, Island Press.

Bettencourt, L. M. and J. Kaur (2011). "Evolution and structure of sustainability science." Proceedings of the National Academy of Sciences **108**(49): 19540-19545.

BGR (2007). Pot. Erosionsgefährdung der Ackerböden durch Wasser (PEGWasser1000)

Bolund, P. and S. Hunhammar (1999). "Ecosystem services in urban areas." Ecological Economics **29**(2): 293-301.

Bomans, K., T. Steenberghen, V. Dewaelheyns, H. Leinfelder and H. Gulinck (2010). "Underrated transformations in the open space—The case of an urbanized and multifunctional area." Landscape and Urban Planning **94**(3–4): 196-205.

Bönsel, D. W., Sabine; Malten, Andreas (2007). Biotoptypenschlüssel der Stadtbiotopkartierung Frankfurt am Main, Senckenberg Forschungsinstitut 59.

Bowler, D. E., L. Buyung-Ali, T. M. Knight and A. S. Pullin (2010). "Urban greening to cool towns and cities: A systematic review of the empirical evidence." Landscape and Urban Planning **97**(3): 147-155.

Boyd, J. and S. Banzhaf (2007). "What are ecosystem services? The need for standardized environmental accounting units." Ecological Economics **63**(2–3): 616-626.

Brandt, J., B. Tress and G. Tress (2000). Multifunctional Landscapes: Interdisciplinary Approaches to Landscape Research and Management: Conference material for the conference on" multifunctional landscapes", Centre for Landscape Research, Roskilde October 18-21, 2000, Centre for Landscale Research.

Brown, G., V. Helene Hausner and E. Lægreid (2015). "Physical landscape associations with mapped ecosystem values with implications for spatial value transfer: An empirical study from Norway." Ecosystem Services **15**: 19-34.

Burkhard, B., M. Kandziora, Y. Hou and F. Müller (2014). "Ecosystem service potentials, flows and demands-concepts for spatial localisation, indication and quantification." Landsc Online **34**: 1-32.

Burkhard, B., F. Kroll, S. Nedkov and F. Müller (2012). "Mapping ecosystem service supply, demand and budgets." Ecological Indicators **21**: 17-29.

Burton, R. J. F. and G. A. Wilson (2006). "Injecting social psychology theory into conceptualisations of agricultural agency: Towards a post-productivist farmer self-identity?" Journal of Rural Studies **22**(1): 95-115.

Campbell, S. (1996). "Green cities, growing cities, just cities?: Urban planning and the contradictions of sustainable development." Journal of the American Planning Association **62**(3): 296-312.

Caspersen, O. H. and A. S. Olafsson (2010). "Recreational mapping and planning for enlargement of the green structure in greater Copenhagen." Urban Forestry & Urban Greening **9**(2): 101-112.

Coleman, N. (2014). Lefebvre for Architects, Routledge.

Commission, E. (2013). Green Infrastructure (GI) — Enhancing Europe's Natural Capital. T. C. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. Brussels.

Corbusier, L. (1987). The city of to-morrow and its planning, Courier Corporation.

Corner, J. (1999). Recovering Landscape: Essays in Contemporary Landscape Theory, Princeton Architectural Press.

Costanza, R., R. d'Arge, R. De Groot, S. Faber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'neill and J. Paruelo (1997). "The value of the world's ecosystem services and natural capital."

Crossman, N. D. and B. A. Bryan (2009). "Identifying cost-effective hotspots for restoring natural capital and enhancing landscape multifunctionality." Ecological Economics **68**(3): 654-668.

Czechowski, D., T. Hauck and G. Hausladen (2014). Revising Green Infrastructure: Concepts Between Nature and Design, CRC Press.

Dan, M. B. (2007). Von der [den] Partizipationsmodellen der 70er Jahre zu Kommunikationsformen Ende des XX. ten Jahrhunderts in Architektur und Städtebau, Cuvillier Verlag.

de Groot, R. (2006). "Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes." Landscape and Urban Planning **75**(3–4): 175-186.

de Groot, R. S. (1992). Functions of nature: evaluation of nature in environmental planning, management and decision making, Wolters-Noordhoff BV.

De Groot, R. S., R. Alkemade, L. Braat, L. Hein and L. Willemen (2010). "Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making." Ecological Complexity **7**(3): 260-272.

de Groot, R. S., M. A. Wilson and R. M. J. Boumans (2002). "A typology for the classification, description and valuation of ecosystem functions, goods and services." Ecological Economics **41**(3): 393-408.

Debinski, D. M. and R. D. Holt (2000). "A survey and overview of habitat fragmentation experiments." Conservation biology **14**(2): 342-355.

Dennis, M. and P. James (2016). "Site-specific factors in the production of local urban ecosystem services: A case study of community-managed green space." Ecosystem Services **17**: 208-216.

Ebenezer, H. (1902). "Garden cities of tomorrow." London: S. Sonnenschein & Co., Ltd.

Environment, D. (2012). The Multifunctionality of Green Infrastructure. In-depth Reports. S. f. E. Policy.

Ernstson, H. (2013). "The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes." Landscape and Urban Planning **109**(1): 7-17.

Faehnle, M., P. Bäcklund, L. Tyrväinen, J. Niemelä and V. Yli-Pelkonen (2014). "How can residents' experiences inform planning of urban green infrastructure? Case Finland." Landscape and Urban Planning **130**: 171-183.

Fishman, R. (1982). Urban Utopias in the Twentieth Century: Ebenezer Howard, Frank Lloyd Wright, and Le Corbusier, MIT Press.

FrankfurtRheinMain, R. A. (2013). The Regional Authority FrankfrutRheinMain: Structures, tasks and services. Frankfurt am Main.

Freestone, R. (2002). "Greenbelts in city and regional planning." From Garden City to Green City: The Legacy of Ebenezer Howard: 67-98.

Galler, C., C. von Haaren and C. Albert (2015). "Optimizing environmental measures for landscape multifunctionality: Effectiveness, efficiency and recommendations for agri-environmental programs." Journal of environmental management **151**: 243-257.

Gómez-Baggethun, E. and D. N. Barton (2013). "Classifying and valuing ecosystem services for urban planning." Ecological Economics **86**: 235-245.

Gómez-Baggethun, E., R. De Groot, P. L. Lomas and C. Montes (2010). "The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes." Ecological Economics **69**(6): 1209-1218.

Grüngürtel-Projektbüro (1991). Ergebnisbericht Grüngürtel Planung. 1990/91., Frankfurt am Main, GrünGürtel,.

GTL. (2004). "Alter Flugplatz Kalbach / Bonames Konversion des ehemaligen " Retrieved April 1st, 2017, from http://landschaftsarchitektur-heute.de/newapp-projekte/details/1098.

Gulickx, M. M. C., P. H. Verburg, J. J. Stoorvogel, K. Kok and A. Veldkamp (2013). "Mapping landscape services: a case study in a multifunctional rural landscape in The Netherlands." Ecological Indicators **24**: 273-283.

Haase, D., N. Larondelle, E. Andersson, M. Artmann, S. Borgström, J. Breuste, E. Gomez-Baggethun, Å. Gren, Z. Hamstead and R. Hansen (2014). "A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation." Ambio **43**(4): 413-433.

Haines-Young, R. and M. Potschin (2010). "The links between biodiversity, ecosystem services and human well-being." Ecosystem Ecology: a new synthesis: 110-139.

Haines-Young, R., C. Watkins, C. Wale and A. Murdock (2006). "Modelling natural capital: The case of landscape restoration on the South Downs, England." Landscape and Urban Planning **75**(3–4): 244-264.

Hall, P. and M. Tewdwr-Jones (2010). Urban and regional planning, Routledge.

Hansen, R., N. Frantzeskaki, T. McPhearson, E. Rall, N. Kabisch, A. Kaczorowska, J.-H. Kain, M. Artmann and S. Pauleit (2015). "The uptake of the ecosystem services concept in planning discourses of European and American cities." Ecosystem Services **12**: 228-246.

Hansen, R. and S. Pauleit (2014). "From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas." Ambio **43**(4): 516-529.

Hausner, V. H., G. Brown and E. Lægreid (2015). "Effects of land tenure and protected areas on ecosystem services and land use preferences in Norway." Land Use Policy **49**: 446-461.

Hediger, W. (2004). On the economics of multifunctionality and sustainability of agricultural systems. Conference Paper for the 90th EAAE Seminar: Multifunctional Agriculture, Policies and Markets in October.

Hein, L., K. van Koppen, R. S. de Groot and E. C. van Ierland (2006). "Spatial scales, stakeholders and the valuation of ecosystem services." Ecological Economics **57**(2): 209-228.

Howard, E. and F. J. Osborn (1965). Garden cities of to-morrow, Mit Press.

Huang, J., M. Tichit, M. Poulot, S. Darly, S. Li, C. Petit and C. Aubry (2015). "Comparative review of multifunctionality and ecosystem services in sustainable agriculture." Journal of Environmental Management **149**: 138-147.

Ives, C. D. and D. Kendal (2013). "Values and attitudes of the urban public towards peri-urban agricultural land." Land Use Policy **34**: 80-90.

James, P., K. Tzoulas, M. D. Adams, A. Barber, J. Box, J. Breuste, T. Elmqvist, M. Frith, C. Gordon, K. L. Greening, J. Handley, S. Haworth, A. E. Kazmierczak, M. Johnston, K. Korpela, M. Moretti, J. Niemelä, S. Pauleit, M. H. Roe, J. P. Sadler and C. Ward Thompson (2009). "Towards an integrated understanding of green space in the European built environment." Urban Forestry & Urban Greening **8**(2): 65-75.

Jones-Walters, L. (2008). "Biodiversity in multifunctional landscapes." Journal for Nature Conservation **16**(2): 117-119.

Kabisch, N. (2015). "Ecosystem service implementation and governance challenges in urban green space planning—The case of Berlin, Germany." Land Use Policy **42**: 557-567.

Kabisch, N. and D. Haase (2014). "Green justice or just green? Provision of urban green spaces in Berlin, Germany." Landscape and Urban Planning **122**: 129-139.

Kates, R. W. (2011). "What kind of a science is sustainability science?" Proceedings of the National Academy of Sciences **108**(49): 19449-19450.

Koenigs, T. (1991). Vision offener Grünräume: GrünGürtel Frankfurt, Campus-Verlag.

Konijnendijk, C. C. (2010). "The role of forestry in the development and reform of green belts." Planning, practice & research **25**(2): 241-254.

Konijnendijk, C. C., S. Sadio, T. B. Randrup and J. Schipperijn (2004). "Urban and peri-urban forestry in a development context - Strategy and implementation." Journal of Arboriculture **30**(5): 269-275.

Kontogianni, A., G. W. Luck and M. Skourtos (2010). "Valuing ecosystem services on the basis of service-providing units: A potential approach to address the 'endpoint problem'and improve stated preference methods." Ecological Economics **69**(7): 1479-1487.

Kopperoinen, L., P. Itkonen and J. Niemelä (2014). "Using expert knowledge in combining green infrastructure and ecosystem services in land use planning: an insight into a new place-based methodology." Landscape Ecology **29**(8): 1361-1375.

Koschke, L., C. Fuerst, S. Frank and F. Makeschin (2012). "A multi-criteria approach for an integrated land-cover-based assessment of ecosystem services provision to support landscape planning." Ecological Indicators **21**: 54-66.

Lafortezza, R., C. Davies, G. Sanesi and C. C. Konijnendijk (2013). "Green Infrastructure as a tool to support spatial planning in European urban regions." Iforest-Biogeosciences and Forestry **6**: 102-108.

Laurance, W. F., J. Sayer and K. G. Cassman (2014). "Agricultural expansion and its impacts on tropical nature." Trends in ecology & evolution **29**(2): 107-116.

Law, E. A., E. Meijaard, B. A. Bryan, T. Mallawaarachchi, L. P. Koh and K. A. Wilson (2015). "Better land-use allocation outperforms land sparing and land sharing approaches to conservation in Central Kalimantan, Indonesia." Biological Conservation **186**: 276-286.

Leitão, A. B., J. Miller, J. Ahern and K. McGarigal (2012). Measuring landscapes: A planner's handbook, Island press.

Li, F., R. S. Wang, J. Paulussen and X. S. Liu (2005). "Comprehensive concept planning of urban greening based on ecological principles: a case study in Beijing, China." Landscape and Urban Planning **72**(4): 325-336.

Lovell, S. T., S. r. DeSantis, C. A. Nathan, M. B. Olson, V. Ernesto Méndez, H. C. Kominami, D. L. Erickson, K. S. Morris and W. B. Morris (2010). "Integrating agroecology and landscape multifunctionality in Vermont: An evolving framework to evaluate the design of agroecosystems." Agricultural Systems **103**(5): 327-341.

Lovell, S. T. and J. R. Taylor (2013). "Supplying urban ecosystem services through multifunctional green infrastructure in the United States." Landscape ecology **28**(8): 1447-1463.

Lyytimäki, J. and M. Sipilä (2009). "Hopping on one leg – The challenge of ecosystem disservices for urban green management." Urban Forestry & Urban Greening **8**(4): 309-315.

MA, M. E. A. (2005). Ecosystems and Human Well-being: Synthesis. Washington, DC.

Maes, J., A. Barbosa, C. Baranzelli, G. Zulian, F. B. e Silva, I. Vandecasteele, R. Hiederer, C. Liquete, M. L. Paracchini and S. Mubareka (2014). "More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe." Landscape Ecology: 1-18.

Marsden, T. and R. Sonnino (2008). "Rural development and the regional state: Denying multifunctional agriculture in the UK." Journal of Rural Studies **24**(4): 422-431.

Martínez-Harms, M. J. and P. Balvanera (2012). "Methods for mapping ecosystem service supply: a review." International Journal of Biodiversity Science, Ecosystem Services & Management **8**(1-2): 17-25.

Maruani, T. and I. Amit-Cohen (2007). "Open space planning models: A review of approaches and methods." Landscape and Urban Planning **81**(1-2): 1-13.

McHarg, I. L. and L. Mumford (1969). Design with nature, American Museum of Natural History New York.

Naveh, Z. (2001). "Ten major premises for a holistic conception of multifunctional landscapes." Landscape and Urban Planning **57**(3–4): 269-284.

Niemelä, J. (2014). "Ecology of urban green spaces: The way forward in answering major research questions." Landscape and Urban Planning **125**: 298-303.

Nilon, C. H., A. R. Berkowitz and K. S. Hollweg (1999). "Editorial: Understanding urban ecosystems: A new frontier for science and education." Urban ecosystems **3**(1): 3-4.

O'Farrell, P. J. and P. M. L. Anderson (2010). "Sustainable multifunctional landscapes: a review to implementation." Current Opinion in Environmental Sustainability **2**(1–2): 59-65.

Otte, A., D. Simmering and V. Wolters (2007). "Biodiversity at the landscape level: recent concepts and perspectives for multifunctional land use." Landscape Ecology **22**(5): 639-642.

Paetzold, A., P. H. Warren and L. L. Maltby (2010). "A framework for assessing ecological quality based on ecosystem services." Ecological Complexity **7**(3): 273-281.

Palacios-Agundez, I., M. Onaindia, P. Barraqueta and I. Madariaga (2015). "Provisioning ecosystem services supply and demand: The role of landscape management to reinforce supply and promote synergies with other ecosystem services." Land Use Policy **47**: 145-155.

Palermo, P. C. and D. Ponzini (2010). Spatial planning and urban development: Critical perspectives, Springer Science & Business Media.

Parsons, K. C. and D. Schuyler (2004). "From Garden City to Green City. The Legacy of Ebenezer Howard."

Patrick, G. (1915). Cities in evolution, Londres, William & Norgate LTD.

Paul, A. (2000). "Freiraumsysteme in großen Städten." Stadt+ Grün(1): 22-30.

Paustian, K., J. Six, E. Elliott and H. Hunt (2000). "Management options for reducing CO2 emissions from agricultural soils." Biogeochemistry **48**(1): 147-163.

Peng, J., X. Chen, Y. Liu, H. Lü and X. Hu (2016). "Spatial identification of multifunctional landscapes and associated influencing factors in the Beijing-Tianjin-Hebei region, China." Applied Geography **74**: 170-181.

Peng, J., H. Lv and Y. Liu (2015). "International research progress and perspectives on multifunctional landscape." Advances in Earth Science **30**(4): 465-476.

Potschin, M. and R. Haines-Young (2013). "Landscapes, sustainability and the place-based analysis of ecosystem services." Landscape Ecology **28**(6): 1053-1065.

Projektbüro, F. v. B. (2010). Momentaufnahme GrünGürtel Frankfurt. Frankfurt am Main**:** 412.

Projektbüro, F. v. B. (2014). Gutachten, Kanten und Übergänge: Grüngürtel Frankfurt am Main**:** 57.

Projektgruppe, G. n. r. (2013). Landebahn zur Wildnis, der Alte Flugplatz im Frankfurter Grüngürtel. U. Stadt Frankfurt am Main, Projektgruppe GrünGürtel. Frankfurt am Main, Hassmuller**:** 48.

Queiroz, C., M. Meacham, K. Richter, A. V. Norström, E. Andersson, J. Norberg and G. Peterson (2015). "Mapping bundles of ecosystem services reveals distinct types of multifunctionality within a Swedish landscape." Ambio **44**(1): 89-101.

Raudsepp-Hearne, C., G. D. Peterson and E. Bennett (2010). "Ecosystem service bundles for analyzing tradeoffs in diverse landscapes." Proceedings of the National Academy of Sciences **107**(11): 5242-5247.

Renting, H., W. A. H. Rossing, J. C. J. Groot, J. D. Van der Ploeg, C. Laurent, D. Perraud, D. J. Stobbelaar and M. K. Van Ittersum (2009). "Exploring multifunctional agriculture. A review of conceptual approaches and prospects for an integrative transitional framework." Journal of Environmental Management **90, Supplement 2**: S112-S123.

Roces-Díaz, J. V., R. A. Díaz-Varela, P. Álvarez-Álvarez, C. Recondo and E. R. Díaz-Varela (2015). "A multiscale analysis of ecosystem services supply in the NW Iberian Peninsula from a functional perspective." Ecological Indicators **50**: 24-34.

Rodríguez-Loinaz, G., J. G. Alday and M. Onaindia (2015). "Multiple ecosystem services landscape index: A tool for multifunctional landscapes conservation." Journal of Environmental Management **147**: 152-163.

Rossing, W. A. H., P. Zander, E. Josien, J. C. J. Groot, B. C. Meyer and A. Knierim (2007). "Integrative modelling approaches for analysis of impact of multifunctional agriculture: A review for France, Germany and The Netherlands." Agriculture, Ecosystems & Environment **120**(1): 41-57.

Rowley, A. (1996). "Mixed-use development: ambiguous concept, simplistic analysis and wishful thinking?" Planning Practice and Research **11**(1): 85-98.

Rydberg, D. and J. Falck (1998). "Designing the urban forest of tomorrow: pre-commercial thinning adapted for use in urban areas in Sweden." Arboricultural Journal **22**(2): 147-171.

Savard, J.-P. L., P. Clergeau and G. Mennechez (2000). "Biodiversity concepts and urban ecosystems." Landscape and urban planning **48**(3): 131-142.

Schenker, H. M. (1995). "Parks and politics during the second empire in paris." Landscape Journal **14**(2): 201-219.

Selman, P. (2009). "Planning for landscape multifunctionality." Sustainability: Science, Practice, & Policy **5**(2): 45-52.

Seppelt, R., C. F. Dormann, F. V. Eppink, S. Lautenbach and S. Schmidt (2011). "A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead." Journal of Applied Ecology **48**(3): 630-636.

Shi, W. (2013). Landscape management for urban green space multifunctionality: a comparative study in Sheffield (UK) and Yuci (China), University of Sheffield.

Spirn, A. W. (1996). "Constructing Nature: The Legacy of Fredericlz Law Olmsted."

Stadt Frankfurt am Main, D. f. U., Gesundheit und Personal (2003). Die Grüngürtel Verfassung. G. u. P. Dezernat für Umwelt.

Stadt Frankfurt am Main, D. f. U., Gesundheit und Personal (2011). 20 Jahre GrünGürtel Frankfurt : Menschen, Daten, Projekte ; 1991 - 2011. Frankfurt am Main.

Stadt Frankfurt am Main, U. (2011). Kreuz und Quer im Frankfurter GrünGürtel. Hanau, CoCon-Verlag.

Statistik, F. a. M. (2016). Statistisches Portrait Frankfurt am Main 2015.

Tank, N. W. G. I. T. (2008). North West Green Infrastructure Guide, Version 1.1.

Taylor, J., C. Paine and J. FitzGibbon (1995). "From greenbelt to greenways: four Canadian case studies." Landscape and urban planning **33**(1): 47-64.

Taylor, N. (1998). Urban planning theory since 1945, Sage.

Taylor, N. (1999). "Anglo-American town planning theory since 1945: three significant developments but no paradigm shifts." Planning Perspectives **14**(4): 327-345.

TEEB (2010). The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB, UNEP, Ginebra (Suiza).

TEEB, T. (2011). "Manual for Cities: Ecosystem Services in Urban Management." The Economics of Ecosystems and Biodiversity (TEEB).

Thompson, C. W. (2002). "Urban open space in the 21st century." Landscape and Urban Planning **60**(2): 59-72.

Todorova, S. and J. Ikova (2014). "Multifunctional Agriculture: Social and Ecological Impacts on the Organic Farms in Bulgaria." Procedia Economics and Finance **9**: 310-320.

Tress, B., G. Tress, H. Décamps and A.-M. d'Hauteserre (2001). "Bridging human and natural sciences in landscape research." Landscape and Urban Planning **57**(3–4): 137-141.

Turner, K. G., M. V. Odgaard, P. K. Bøcher, T. Dalgaard and J.-C. Svenning (2014). "Bundling ecosystem services in Denmark: Trade-offs and synergies in a cultural landscape." Landscape and Urban Planning **125**: 89-104.

Turner, T. (1992). "Open space planning in London: from standards per 1000 to green strategy." Town Planning Review **63**(4): 365.

Tyrväinen, L., K. Mäkinen and J. Schipperijn (2007). "Tools for mapping social values of urban woodlands and other green areas." Landscape and urban planning **79**(1): 5-19.

Tzoulas, K., K. Korpela, S. Venn, V. Yli-Pelkonen, A. Kaźmierczak, J. Niemela and P. James (2007). "Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review." Landscape and urban planning **81**(3): 167-178.

Umweltamt, S. F. a. M. (2016). "Geschichte." Retrieved February 18th, 2017, from http://www.frankfurt.de/sixcms/detail.php?id=4131&_ffmpar[_id_inhalt]=51052&_ffmpar[_id_eltern]=3066.

Van Huylenbroeck, G., V. Vandermeulen, E. Mettepenningen and A. Verspecht (2007). "Multifunctionality of agriculture: a review of definitions, evidence and instruments." Living Reviews in Landscape Research **1**(3): 1-43.

Van Oudenhoven, A. P., K. Petz, R. Alkemade, L. Hein and R. S. de Groot (2012). "Framework for systematic indicator selection to assess effects of land management on ecosystem services." Ecological Indicators **21**: 110-122.

Vollmer, D., M. F. Prescott, R. Padawangi, C. Girot and A. Grêt-Regamey (2015). "Understanding the value of urban riparian corridors: Considerations in planning for cultural services along an Indonesian river." Landscape and Urban Planning **138**: 144-154.

von Döhren, P. and D. Haase (2015). "Ecosystem disservices research: A review of the state of the art with a focus on cities." Ecological Indicators **52**: 490-497.

Waldheim, C. (2012). The landscape urbanism reader, Chronicle Books.

Wallace, K. J. (2007). "Classification of ecosystem services: Problems and solutions." Biological Conservation **139**(3–4): 235-246.

Weber, T., A. Sloan and J. Wolf (2006). "Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation." Landscape and Urban Planning **77**(1–2): 94-110.

Wichert, K. (2012). Greenbelt- Frankfurt.

Wilkinson, C., T. Saarne, G. D. Peterson and J. Colding (2013). "Strategic spatial planning and the ecosystem services concept–an historical exploration." Ecology and Society **18**(1): 37.

Willemen, L., L. Hein, M. E. F. van Mensvoort and P. H. Verburg (2010). "Space for people, plants, and livestock? Quantifying interactions among multiple landscape functions in a Dutch rural region." Ecological Indicators **10**(1): 62-73.

Willemen, L., A. Veldkamp, P. H. Verburg, L. Hein and R. Leemans (2012). "A multi-scale modelling approach for analysing landscape service dynamics." Journal of Environmental Management **100**: 86-95.

Willemen, L., P. H. Verburg, L. Hein and M. E. F. van Mensvoort (2008). "Spatial characterization of landscape functions." Landscape and Urban Planning **88**(1): 34-43.

Wilson, G. A. (2007). Multifunctional agriculture: a transition theory perspective, CABI.

Wilson, G. A. (2008). "From 'weak' to 'strong' multifunctionality: Conceptualising farm-level multifunctional transitional pathways." Journal of Rural Studies **24**(3): 367-383.

Wilson, G. A. (2009). "The spatiality of multifunctional agriculture: A human geography perspective." Geoforum **40**(2): 269-280.

Wolch, J. R., J. Byrne and J. P. Newell (2014). "Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'." Landscape and Urban Planning **125**: 234-244.

Wolff, S., C. Schulp and P. Verburg (2015). "Mapping ecosystem services demand: a review of current research and future perspectives." Ecological Indicators **55**: 159-171.

Wright, H. (2011). "Understanding green infrastructure: the development of a contested concept in England." Local Environment **16**(10): 1003-1019.

Wu, J. (2013). "Landscape sustainability science: ecosystem services and human well-being in changing landscapes." Landscape Ecology **28**(6): 999-1023.

Xue, H., S. Li and J. Chang (2015). "Combining ecosystem service relationships and DPSIR framework to manage multiple ecosystem services." Environmental monitoring and assessment **187**(3): 1-15.

Yang, G., Y. Ge, H. Xue, W. Yang, Y. Shi, C. Peng, Y. Du, X. Fan, Y. Ren and J. Chang (2015). "Using ecosystem service bundles to detect trade-offs and synergies across urban–rural complexes." Landscape and Urban Planning **136**: 110-121.

Yang, Z., J. Cai and R. Sliuzas (2010). "Agro-tourism enterprises as a form of multi-functional urban agriculture for peri-urban development in China." Habitat International **34**(4): 374-385.

Young, R. F. (2011). "Planting the living city: Best practices in planning green infrastructure—Results from major us cities." Journal of the American Planning Association **77**(4): 368-381.

Zaręba, A. (2014). "Multifunctional and Multiscale Aspects of Green Infrastructure in Contemporary Research." PROBLEMY EKOROZWOJU–PROBLEMS OF SUSTAINABLE DEVELOPMENT **9**(121): 149-156.

Zasada, I. (2011). "Multifunctional peri-urban agriculture—A review of societal demands and the provision of goods and services by farming." Land Use Policy **28**(4): 639-648.

Zhang, J. and J. Lv (2003). "From Large Scale Urban Design to Everyday Living Space." Urban Planning **27**(9): 40-45.