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Strengthening energy systems to enhance urban resilience
Climate resilient energy supply infrastructure and green spaces – Examples from three cities

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Abstract:

In this article, three selected cities – New York, Singapore and Berlin – will be presented with a focus on the ecosystem services their green spaces provide for disaster risk reduction and energy security. A database for the modeling of hazards and risks of extreme weather events on renewable energy infrastructures will be shared. The water-energy-food security nexus concept has been used to frame the research. The paper will also discuss the trade-offs and competition of critical urban infrastructure (in e.g. the energy and the emergency services sector) for disaster reduction and city inhabitants' well-being.

Keywords:

Ecosystem Services, Energy Supply Infrastructures, Extreme Weather Events, Green Infrastructures, Urban Resilience

1. Introducing the different concepts around climate resilience, energy supply and green space

A variety of concepts and ideas around resilience court for the favour of cities. Among them are Climate Action Plans, the City Biodiversity Index, the Biotope Area Factor, Ecosystem Services Reviews and Disaster Risk Reduction. Still, there are several common key elements in these approaches. One of the main points is climate resilience against extreme weather events, another major topic is the safe supply of energy and energy efficiency. Moreover, especially the concept of Critical Infrastructures with eight identified sectors – namely energy supply, water and food supply, urban development, disaster risk management, cultural goods, air pollution as well as waste and sanitation - show an amount of parallels/similarities to the concept of Ecosystem Services with said sectors as main services to be provided by nature.

A rather underrated issue is the function of green spaces in urban agglomerations especially for the quality of life of the cities' inhabitants where the ecosystem service of recreation is highlighted. Furthermore, this research and practical implementation deals with fundamental outcomes of the Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction as well as the balance between sustainability and resilience.

In the debate on ecosystem services and critical infrastructures, one main topic needs to be integrated in the planning and construction phases. This is the conflicting use and the competition on construction areas where either/or decisions dictate the further planning steps. Also, the German Energy Transition leads to further requirements for wind turbine construction areas where the interests of conservation areas and nature reserves need to be reconsidered.

The conflicting use of urban space for the purpose of ecosystem services and energy supply are subject to further research in this paper and the corresponding project. Here, three exemplary cities will be discussed, New York and Singapore in the context of green and critical infrastructures in combination with recreation as an ecosystem service, Berlin in terms of the impact of extreme weather events on energy supply.

2. Case studies from New York, Singapore and Berlin

In November 2014, the City of New York released its updated hazard mitigation plan called "NYC's risk landscape" (City of New York, 2014). Therein, the most eminent risks of coastal storms, erosion, flooding, windstorms, extreme heat, winter weather as well as water shortage, earthquakes and influenza are highlighted. Moreover, in 2013 the plaNYC was ratified, taking into account the resilience of

infrastructures and the built environment (City of New York, 2013). A very comprehensive list of initiatives and measures addresses the main points to make NYC resilient and highlights the importance of critical infrastructure adaptation such as for energy or green infrastructures. Nevertheless, extreme weather events and their implementation into concepts such as an Urban-ESR and the risk factors are not explicitly framed. Therefore, a database for the modelling of hazards and risks of extreme weather events on renewable energies helps to define the options of green spaces to reduce heavy impacts. Additionally, competitions between renewable energies, other critical infrastructures and greenery are analysed and rated.

Singapore started developing its vision of becoming a "City in a Garden" already in the 1960's with the Green City Plan. Due to this programme, the green areas in the city could be increased from 35.7 % to 46.5 % in the time period 1986 - 1997. Consequently in 2008, the Ministry for National Development Singapore proposed an "index to measure biodiversity in cities" – the first reference to the "Singapore Index on Cities' Biodiversity" later on known as City Biodiversity Index (CBI) (Ministry of National Development Singapore, 2013, Rodricks, 2010). Exemplary indicators of the CBI are the percentage of natural areas in the city, the cooling effect of vegetation as climate regulation and awareness of greenery in education and recreation. Until 2012, 50 cities were in the state of applying the CBI. Between 2012 and 2015, EIFER developed an Urban Ecosystem Services Review (Urban-ESR) with an application on Singapore in order to describe the most relevant ecosystem services, their distribution in the city and their influence on people's wellbeing. Among the priorities were aesthetic quality of green spaces, recreational functions of nature in the urban environment as well as food production (see Sieber, Fremgen & Pons, 2015; Sieber & Pons, 2015; Sieber & Fremgen, 2014).

In the 1970's, Berlin enacted several laws with reference to nature and environmental protection, among others the Berlin Nature-Conservation Law and the State Forest Law. Consequently, Berlin established the conservation of historic gardens, the Environmental Atlas of Berlin, the expanded habitat and species protection and the courtyard-greening programme in West Berlin (Senatsverwaltung für Stadtentwicklung und Umwelt, 2013). The courtyard-greening programme, established between 1983 and 1997 was dedicated to courtyard, rooftop and façade greening with the main goal of improving the quality of life. Furthermore, Berlin started the creation of its Land Use Plan and the associated Landscape Programme in 1984 with a revision in 1994 (Kopetzki, 2010). Both of these programmes shape the frame for the Biotope Area Factor (BAF). The BAF aims at setting a benchmark in terms of improving ecosystem functions and developing biotopes and biodiversity in inner city areas. Moreover, the targets or functions of the BAF are tackling several ecosystem services such as an improvement of the microclimate and air quality, retaining habitats and improving the residential environment in terms of quality of life (Landschaft Planen & Bauen, 1990; Kopetzki, 2010). Here again, an Urban-ESR was conducted.

3. Modelling qualitative and quantitative indicators using GIS-based approaches

To deal with these key elements is the purpose of this paper. With applied Geographical Information System (GIS)-based tools, EIFER tackles climate resilience in cities since many years (see chapter 2 for references, Sieber, 2013a; Sieber, 2013b). Next to the modelling of the hazards of and adaptation to extreme weather events of energy and city infrastructures and the implementation of renewable energy systems, the necessity of green space in urban centres is displayed as a set of analysis. First of all, literature research as well as online questionnaires led to an identification of the main ecosystem services to be tackled in the coming discussions (Tab. 1).

Table 1: Comparison of New York City (NYC), Berlin (BER) and Singapore (SGP) in terms of size, population and urban ecosystem services to be tackled.

Ecosystem Services	NYC	Berlin	Singapore	Comparison for further studies
Size [km²]	789,4 (1212.4)	891.7	710.2	
Population [Mio]	8.5	3.5	5.5	
Provisioning	Food	Food	Food	Food
			Fresh Water	
Regulating	Air quality regulation (carbon storage/pollution)	Air quality regulation	Air quality regulation	Air quality regulation
	Local temperature regulation	Local climate regulation (UHI)		
	Runoff mitigation		Waste water treatment	
Habitat	Habitats	Habitats	Habitats	Habitats
Cultural and amenity		Aesthetic quality/Tourism	Aesthetic quality	
	Recreation	Recreation	Recreation	Recreation

In a first step, the infrastructures important for this study are integrated into a georeferenced database in order to display them in their location in the city. The maps below of NYC on the left and SGP on the right show the distribution of green infrastructures in green, of neutral infrastructures with an effect on the resilience like white/cool roofs or green building status in orange and critical infrastructures such as fuelling stations, PV installations and waste disposal sites in red colour.

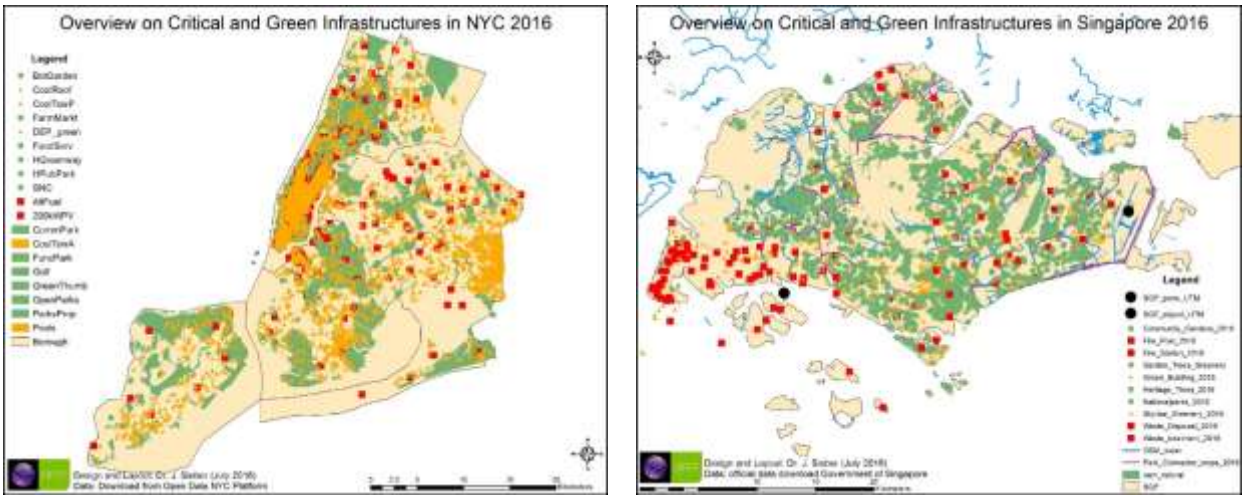

Figure 1: City examples of critical and green infrastructures in NYC and SGP

In a second step, these infrastructures are combined with the ecosystem service of recreation. In this context, the modelling application InVEST®[1] is used. Therein, the "Recreation Model" calculates a ratio of "users per day on average" based on infrastructures and land use information as input and a connection to the *flickr* database for geotagged photography information. This ratio is shown in the maps below, where darker areas display more visited places – an indicator for recreation as defined by the model.

[1] InVEST: *Integrated Valuation of Ecosystem Services and Trade-Offs,* The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund

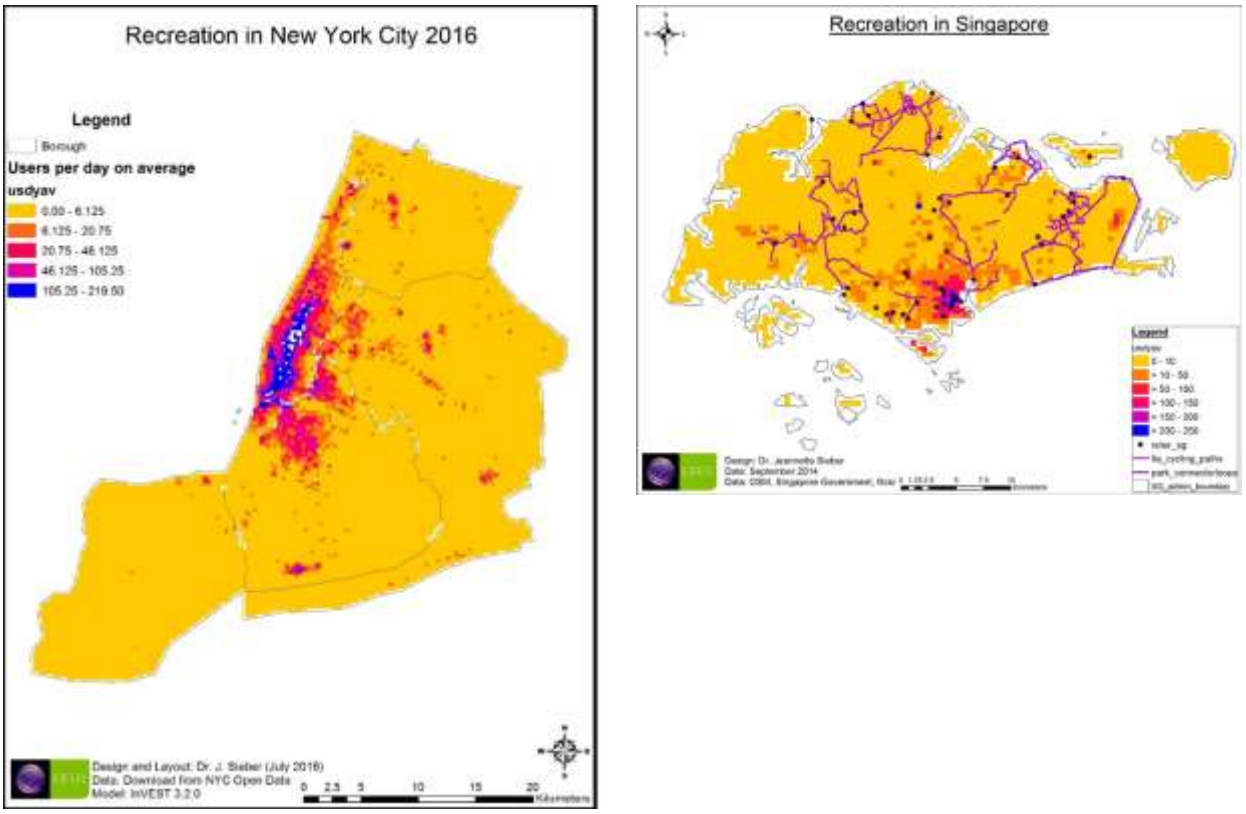

Figure 2: City examples cultural ecosystem services – recreation in NYC and SGP

A separate assessment of extreme weather events and their influence on Renewable Energies like PV installations, wind turbines and run-of-river plants was conducted earlier. Therein, a zip-code based analysis of hail, lightning and tornadoes in Germany showed the distribution as displayed in the following maps. Tornadoes are marked in red, lightning in yellow and hail in green colours. Striped administrative districts show more than one of these extreme events with an influence on electricity generating infrastructures. Highlighted by a bold frame and in the maps heading are urban municipalities in Germany.

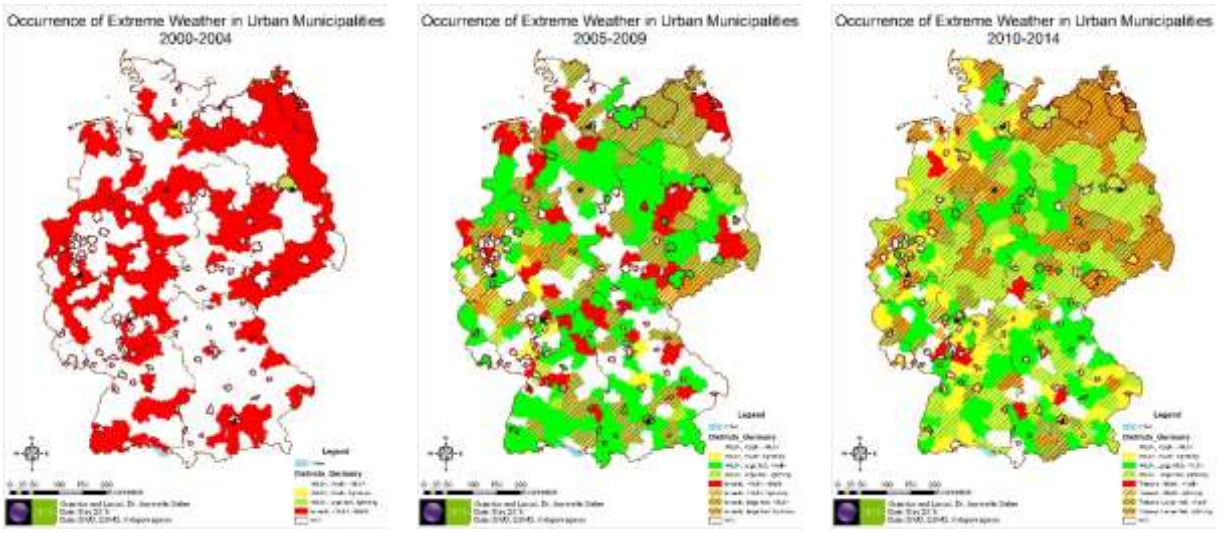

Figure 3: Distribution of extreme weather events (tornadoes, lightning and hail) on a district level with influence on Renewable Energies in the time slices 2000-2004, 2005-2009 and 2010-2014

It becomes clear that besides an increase in the number of installations of Renewable Energies in Germany, also the risk of these systems to be subject to extreme weather increases. Also, the number of combined events or cascading events is increasing – as the districts with striped colouring show explicitly. Berlin, as being the capital city with a former insular status, has seen all types of events as analysed here and with its special status needs to be under consideration of further assessments as described in this paper.

4. Setting the context of the food-water-energy nexus

The introduction, review and assessments have shown that food and fresh water supply belong to the ecosystem services as well as to the critical infrastructures. The direct comparison of the three exemplary cities NYC, BER and SGP identified especially food as a main topic to be analysed further. In the context of a resilient urban development, urban gardening and public parks as well as rooftop greenery play an important role to fulfil the needs of the cities' inhabitants in terms of food supply and integrate very well into the discussion.

Urban gardening and green rooftops can also be regarded in the frame of the mixed use and conflicting use debate. Using resilient urban planning strategies, co-benefits regarding energy demand increase, food supply, green development, cooler outdoor and indoor air temperatures as well as well-being and quality of life can be addressed.

Already during the Dresden Nexus Conference in 2015 this nexus and debate on food-water-energy supply has been discussed profoundly. Moreover, the nexus is part of the Sustainable Development Goals and represents the complexity of resilience and sustainability.

5. Conclusions

The paper highlighted the planning and implementation of green areas and their functions in terms of ecosystem services (natural benefits to people), disaster risk reduction of extreme weather and secure energy supply. Therein, a competition of critical infrastructures (e.g. water tanks for fire extinction, renewable energies) and green spaces for wellbeing and quality of life was discussed. Mapping approaches and databases complete the assessment.

Overall, big cities such as Berlin, Singapore and New York City deal with similar conflicts regarding green and critical infrastructures and their resilient implementation in urban planning. Additionally, the development in Renewable Energies causes new planning requirements by contrasting the development of ecosystem services and critical infrastructures. Programs such as the Singapore City Biodiversity Index, the Berlin Biotope Area Factor and the New York MillionTree Campaign are just examples of the long-term awareness of cities in terms of sustainable and resilient ecosystem service care. Two different approaches were therefore tested here. One deals with the critical infrastructures in contrast to green infrastructures and the benefits that arise from ecosystem services while the other tackles the influence of extreme weather events on critical electricity supply infrastructures. While the latter was used on the country-scale of Germany and the more general implications, the option for recreation was calculated on the city-scale with a local approach.

Nevertheless, nature-based solutions, ecosystem services and green/blue infrastructures are often thought of as non-tangible solutions especially when it comes to cultural factors like recreation. Another aspect that open up in the debate on the integration of such services is the proportion of ecosystem services and ecosystem disservices that are regarded as non-beneficial for inhabitants.

A stepwise GIS-based assessment of the described aspects can overcome the difficulties in urban planning. It is a considerable instrument to compare different scenarios in different stages of urban planning and development.

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