Zusammenfassende Darstellung des Vorhabens

There is an increasing worldwide reception of the ecosystem services (ES)-framework in urban planning. Germany actively fosters Green Infrastructure(GI) utilizing ES terminology on all levels of spatial planning. In China, the central government now streamlines an ecosystem-based approach of environmental governance accompanied by major institutional reforms. Surprisingly, in both countries, there is a substantial lack of an up-to-date conceptualization of ES. Research in the policy-science interface is needed focusing on explicit policy goals, inclusion of relevant stakeholders, representative and thorough data coverage, and iterative development of ES toolboxes. IMECOGIP will substantially alleviate this deficit. As a major result of the definition phase, we stated the different degrees of integration of the ES concept into urban planning and– especially- into GI planning in the two regional, socio-cultural and political contexts of China(Shanghai) and Germany(Ruhr area). In the latter, we detected a discrepancy between the planning levels, where ES-thinking has not yet inspired planning routines connected to land use and GI planning (zoning plans, landscape plans, Environmental Impact Assessment, compensation mechanisms, etc.). In a joint Sino-German action, the IMECOGIP research group determined 8 most significant and 14 significant ES for Shanghai and the Ruhr area and graded the ES supply of specific land use/land cover classes(LULC) in a qualitative manner. Furthermore, the group was able to compile a huge body of high quality data with a high spatial resolution(< 1 m) that enable quantitative ES assessments in Shanghai and the Ruhr area.

During the R&D-Phase IMECOGIP will develop a user-friendly, scientifically sound and spatially explicit open source toolbox to assess and evaluate ES (demand and supply), synergies and trade-offs in the context of GI for different urban development scenarios; The toolbox will allow for comparative evaluations of ES-conformity of different planning scenarios. We will develop and test methods how GI planning can be improved by applying ES principles in real word cases studies and using Big Data. The principal purpose is to strengthen urban resilience.

To that end, we can rely on a consortium of distinguished researchers in three Chinese research institutions with far-reaching relationships to provincial and local planning. The IMECOGIP network is backed-up by nine cooperation agreements (MOUs). In Germany, together with municipalities and the Ministry of Environment, we defined case and pilot studies and research areas in the Ruhr area. Further, three renowned German consulting companies, two of which are very active in urban and landscape planning all over China, support IMECOGIP in its implementation efforts with potential for significant economic prospects.

Cities represent a catalyst point of interaction between men and nature. Over time however, unsustainable urban development has caused ecosystems to deteriorate. Nowadays, cities all over the world not only have to ensure access to basic services (water, food, housing, energy, security, recreation ...), to mitigate current environmental challenges (waste management, water, air, soil, and noise pollution), but also have to cope with future gee-hazards, extreme events, and climate change impacts while facing pressure from a steadily growing population in a globalized economy. Thus, the United Nations 'New Urban Agenda' calls for a paradigm shift in urban development in which 'urban planning' represents the 'catalyst' for sustainable development (UN-Habitat 2016: 125). Despite the political mainstreaming of sustainable urban development, there are still substantial research gaps, especially concerning the 'potential ecosystem services provided by cities and the interaction between vegetation and urban metabolism' (WBGU 2016: 426).

Within its Biodiversity Strategy to 2020, the European Union has outlined a policy agenda for 'green infrastructure' as well as 'nature-based solutions & re-naturing cities' (European Commission 2013; 2015) and since launched several research projects related to urban ES such as ESMERALDA and MAES (European Commission 2016; 2018). Findings from the MAES urban pilot show that there is an increasing reception of the ES-framework in urban planning (European Commission 2016). However, more research is needed to link the existing expertise of a growing research community with the administrative-structural thinking of local planning cultures in order to deepen knowledge on the complex interaction between urban ecosystems and human wellbeing (European Commission 2016: 90). Germany actively fosters the GI concept on all levels of spatial planning (e.g. *'Bundeskonzept Grune Infrastruktur',* Bundesamt fur Naturschutz 2017; *'Weif3buch Stadtgriln',* Bundesministerium fur Umwelt, Naturschutz, Bau und Reaktorsicherheit 2017). North Rhine-Westphalia, for instance, set up a funding instrument based on the ERDF (European Regional Development Fund), (Landesregierung NRW 2016). Up to 15 March 2020, 11 projects, worth 88 million€, have been subsidized.

In China, the growing awareness about the deterioration of urban ecosystems and the impacts of environmental pollution on human wellbeing (Pei 2002; Dong et al. 2007; Li et al. 2013) induced an institutional change of China's environmental governance. The Central Government now streamlines an ecosystem-based approach of environmental governance, featuring integrated and resilient urban development nationwide (CCCPC 2013; 2015; 2019) under supervision of the newly established Ministry of Natural Resources and the Ministry of Ecological Environment (CCCPC 2018a; b). Since July 2019, all provinces,

municipalities, prefectures and counties in China are urged to gather spatial data on resource endowments within their jurisdiction, assess the environmental carrying capacity according to a unified scheme, and submit it to the Ministry of Natural Resources by the end of 2020 (CCCPC 2019; MNR 2019a-d).

In recent years, the ES-based GI-development emerged as a promising framework for sustainable and resilient urban planning and development (TEEB 201O; Breuste et al. 2013; Haase et al. 2014; Grunewald et al. 2018; von Haaren et al. 2019; Geneletti et al. 2020). Nevertheless, the current state of the art shows that frictions, and research gaps still exist in terms of the use of methods to determine supply of and demand, and the spatial integration of trade-offs and synergies. Further, the fuzzy use of ES working definitions and the linkage of academic knowledge with corresponding political frameworks and existing institutional path dependencies in urban planning administrations still pose challenges.

Surprisingly, there is a substantial lack of an up-to-date conceptualization of ES, as the use of concept is loosely based on the 'Millennium Ecosystem Assessment'-report (MA 2005; Wang et al. 2019 Zhang & Ramfrez 2019) or an amalgam of ES-concepts based on MA 2005 and TEEB 2010 (Jacobs et al. 2015, Malinga et al. 2015; Turkelboom et al. 2018). Contrary to that, the proposed framework of Common International Classification of ES (Haines-Young & Potschin 2013; 2018) offers a much more sophisticated and peer reviewed classification system, that avoids double counting of ES. Nevertheless, only recently there is an increased reception of the CICES framework in Europe (Zepp & Mizgajski 2016; Tammi et al. 2017; Sutherland et al. 2018; Zepp 2018; Elliot et al. 2019) and China (Yang et al. 2015; Cheng et al. 2019; Liu et al. 2020).

Often, studies focus on either a phenomenological, indicator-based assessment of ES (Tammi et al. 2017; Capotorti et al. 2019) or they apply a rather qualitative, proxy-based matrix approach (Burkhard et al. 2012; Jacobs et al. 2015; Zepp et al. 2016; Zhang & Ramfrez 2019) to map and assess ecosystem services. Testing both proxy-based (easy to use and fast) and phenomenological approaches (more nuanced results, but time consuming) to assess ES of peri-urban GI in Paris, Roussel et al. (2017) also detect substantial spatial mismatches between CORINE land cover data and ground truth evidence that needs further consideration on the (sub)urban scale. Other studies (Tomscha & Gergel 2016; Cord et al. 2017; Cortinovis & Geneletti 2018; Sutherland et al. 2018; Turkelboom et al. 2018) stress the importance of multidisciplinary and integrated in-situ assessments on ES trade-offs including the biophysical constraints of landscapes, stakeholder relationships, opportunity costs for land-use change and the time lag of ES trade-offs. Research

addressing the science-policy interface revealed the need for more practice-oriented approaches, which pay attention to local geographies (Sutherland et al. 2018), governance cultures (Kabisch 2015; Turkelboom et al. 2018). Here, researchers discovered knowledge gaps concerning the ES and GI concept in the case of Hanover, Germany (Albert & von Haaren 2017) and Ontario, Canada (Lam & Conway 2018) while other studies revealed varying public awareness of nature-based solutions in Poznan, Poland (Zwierzchowska et al. 2019) and GI-planning in New York, USA (Miller & Montalto 2019). In addition to that, findings from three urban areas in Brazil show that the benefit people gain from urban greenspace is 'context dependent' and 'conditioned by a range of social and material factors' such as 'fear of crime' as well as 'poor access' (Juntti et al. 2019).

In China, early adaptions of the ES-concept focused on a national or regional scale to assess land-use and land-cover change (LULCC) in terms of productivity (Xie et al. 2008; Zhan 2015; Xu et al. 2018). Only recently, there is a growing body of literature focusing on the urban level: Wang et al. (2018) use a scenario-based approach in Wuhan to evaluate trade-offs for nine ES based for five different kinds of land-use, while Li et al. (2019) choose an index-based method to assess the environmental carrying capacity of an urban district in Changzhou. In addition to that, Bai et al. (2018) developed a transdisciplinary framework using five criteria in order to identify ecological redline areas for the Shanghai Urban Master Plan. Specific studies on perceptions on ES provided by urban GI however are just emerging in China (Shi et al. 2020; Tian et al. 2020).

All in all, Cortinovis & Geneletti (2019: 1) stress that 'urban planning is the most relevant process affecting urban regulating ecosystem services' but 'a clear understanding of the effects of planning decisions on both the supply and demand of urban regulating ecosystem services is still lacking'. They thus call for a more detailed spatial analysis of GI in urban areas that is also able depict the actual flow of ES within the urban area and corresponding 'real-world case studies' to develop feasible solutions for urban planning (Cortinovis & Geneletti 2019: 9).

Stand der Wissenschaft und Technik sowie eigener Vorarbeiten, durchgefuhrte Arbeiten wahrend der Definitionsphase und erreichte Ergebnisse

A recent review by Gret-Regamey et al. (2017) scrutinizing 68 tools for integrating ES into decision-making revealed a lack of integrated ES-assessment tools focusing on urban ecosystems, especially concerning cultural ES. In addition to that, the authors stress the importance of accompanying research in the policy-science interface focusing on explicit

policy goals, timing of policy windows, inclusion of relevant stakeholders, representative data coverage and iterative development stages during the development of ES-toolboxes (Gret-Regamey et al. 2017: 313).

Concerning the integrated assessment of ES, existing frameworks eligible for regional assessment such as InVEST (sources), QUICKScan (Verweij et al. 2016) which rely on predefined datasets such as Urban Atlas or CORINE land-cover-data in the EU, or SAORES (Hu et al. 2015) in China so far remain unfeasible at the urban scale and below. According to (Roussel et al. 2017: 512), the lack absence of GI-patches below the 'minimum mapping unit of 1 ha' lead to 'noise' in the ES-assessment of fragmented areas in cities. They thus state the necessity, that "with the increasing attention for resilient and healthy cities, it is important to realise that readily available land cover and ES mapping methods may not adequately capture the spatial and thematic (vegetation) detail relevant in peri-urban regions" (Roussel et al. 2017: 513). Focusing on the spatial scale, Cortinovis & Geneletti (2019: 7) state that "most urban regulating ES produce effects [...] in the immediate surrounding of urban green infrastructure components" e.g. on the 'street/block' and 'district-level'.

Thus, a major obstacle identified in current urban GI-assessment and research is the lack of access to high-resolution LULC-data as well as the high transaction costs stemming from the acquisition and processing of data. We therefore aim at an innovative approach that offers a systematic approach to extract land-use cover data from high-resolution earth observation data, process it with ground-truth validation and merge it with additional LULC-date in a GIS- database environment.

As a major result of the definition phase, we stated the different degrees of integration of the ES concept into urban planning and especially into GI planning in the two regional, socio-cultural and political contexts of China (Shanghai) and Germany (Ruhr area). In the latter, we detected a discrepancy between the planning levels, where ES-thinking has not yet impregnated planning routines connected to land use planning, especially binding land use plans, Environmental Impact Assessment, compensation mechanisms for encroachments into nature and landscape. Considering that addressing ES was compulsory in the Provincial Subsidiary Program 'Green Infrastructure', yet the 'Integrated Action Plans' do not reflect ES. This is for one part due to the inherited terminology in legal institutions and for the other part due to different academic professional education of the experts and politicians. Often, ES categories are translated in a rather unreflect manner into 'landscape functions' use in traditional German landscape planning. For landscape planning outside the urban core areas, Albert et al. (2012) concluded similarly. Based on our document

studies and interviews during the definitions phase, we now have clear understanding of some entry-points to translate the multi-differentiated ES concept into existing administrative contexts.

As for China, we were positively surprised about the openness of officials of the regional and local level to adapt ES thinking. Definitely, the institutional reform of the environmental political supported this mind-set. One expression of this is the nomination of IMECOGIP project coordinator as member of the Advisory Board of the "Technology Innovation Center for Landscape Eco-Restoration in Greater Metropolitan Areas" on 22 June 2019.

In a first effort, the research group determined the 8 most significant plus 14 significant ES (Tab. 1) for detailed methodological improvement and incorporation in the toolbox during the Research and Development phase. Then, during a workshop held in October 2019 the cooperation partners (RUB und ILS), the Chinese project partners as well as invited experts from the provincial, regional and local level were asked to give a preliminary assessment of ES provided by LULC units. The 27 LULC types for the Ruhr area and 20 map-units for Shanghai represent ecologically significant urban structural subtypes. The result is a matrix expressing the graded significance of the selected ES as a function of land use.

Tab. 1: Selected ES, based on CICES (2018). Chinese and German experts have rated their significance for Shanghai and the Ruhr area (20 and 27 land/land cover map units, resp.) qualitatively. The order follows the workflow during the R&D phase.

Legend:

Provisioning
Regulation & Maintenance ecosystem services
Cultural ecosystem services

	Mediation of waste or toxic substances
	Visual screeninq
	Hydroloqical cycle and water flow requlation
	Temperature requlation
	Biotic environments promotinq health throuqh outdoor activities
	Biotic environments promotinq health throuqh passive interactions
	Biotic environments enablinq education and traininq
	Biotic environments enablinq aesthetic experiences
	Cultivated plants for nutritional purpose
	Surface water for drinkinq
	Requlation of chemical conditions of freshwaters by livinq processes
	Elements of livinq systems used for entertainment or representation
	Surface water used as material
	Maintaininq nursery populations and habitats
	Characteristics enablinq scientific investiqation/ecoloqical knowledqe
	Characteristics that are resonant in terms of culture or heritaqe
	Mediation by other chemical or physical means
	Noise attenuation
	Abiotic characteristics enablinq spiritual, symbolic interactions
	Pollination
	Elements of livinq systems that have symbolic meaninq

(a)

(a) shows the northern Shanghai, Baoshan district and his thirteen sub-districts (Shanghai Municipal Statistics Bureau). In addition, existing Green Infrastructure is shown (own LULC Classification) and planned Green Infrastructure according to the land-use plan for the year 2035. In relation to that, existing residential area is mapped in light red (Baoshan District People's Government 2019: 44). The detailed map sections of the northern area by the Gucun Park (b) is highlighted with a pink rectangle.

(b) present the number of green verges on streets in the foreground. The NOVI from Pleiades image (24.08.2017) with a 50-centimetre resolution of this area is shown in the background (CNES (2017), Distribution AIRBUS DS-ESA TPM). In addition, population per square kilometre in each committee is shown. In the section depicted, more than 171,000 residents per square kilometre are registered (Baoshan Yearbook 2018, Shanghai Municipal People's Government). The detailed map sections of (c) is highlighted with a red rectangle.

(c) shows in transparent the same true colour Pleiades image in the foreground. In the background, there is a hillshade of the digital surface model (DSM) and the same DSM with different heights. This DSM was processed from stereo Pleiades satellite images. It is intended to merge census with DSM data to further project the population of residential buildings.

(d) presents the population density in capita/ha from the census 2011 of Gelsenkirchen (Datenlizenz Deutschland - Version 2.0). The detailed map sections of (e) and (f) are highlighted with a purple rectangle. In this detailed map, the population density is approx. 5200 p./km^2.

(e) shows the NOVI of the northern part of the "Nordsternpark" in Gelsenkirchen processed from the digital Ortho Photo (2018) with a 10 cm-resolution (Datenlizenz Deutschland - Zero - Version 2.0). Different street trees species are labelled and coloured according to the crown diameters in the tree-cadastre published by the city administration of Gelsenkirchen (Datenlizenz Deutschland - Version 2.0).

(f) shows in transparent the same digital Ortho Photo in the foreground. In the background, there is hillshade of the DSM and the same DSM with different heights. This DSM were processed from LiDAR Data (Datenlizenz Deutschland - Zero - Version 2.0).

Fig. 1: Examples of spatial explicitness of base data from Baoshan and the Ruhr area

Parallel to that, data compilation reached a quality level that assures a sound assessment of ES for both Shanghai and the Ruhr area. First proxy-based matrix assessment have been applied for both areas. On the ESP Conference in Hanover (October 2019), we presented preliminary ES evaluations of the current situation of Baoshan and the expected future based on the Master plan 2035. Figure 1 exemplifies the quality level and spatial resolution of data we were able to compile during the definition phase by earth observation, digitizing maps and linking them with statistics. They form the database for developing the GIS-based toolbox during the research and development phase.

Zielsetzung, Losungsansatz, Indikatoren zur Beschreibung des Projekterfolgs

Objectives: The general objective of this research project (R&D and implementation phase) is to translate the ES framework into real spatial planning of GI (Fig. 2). This translation is based on

- an analysis of the green governance related to ES in GI planning in Chinese in comparison to German cities as a result of the definition phase
- the identified deficits of the claim for implementation from both the continued literature research and insights gained during the definition phase, which can be summarized as follows:
  - lack of profound understanding of ES concept in large parts of the planning administration
  - lack of understanding of the effects of planning decisions on ES supply and demand as well as ES-Trade-Offs stemming from LULCC focusing on single ES
  - lack of spatially explicit analyses based on high-resolution LULC-data to include spatially small sections of the urban landscape(< 1 ha)
  - lack of iterative and practice oriented development of ES-toolboxes at the policy-science interface.

Outcomes: The research project claims four major outcomes:

i) to strengthen the capacities of actors (stakeholders, planning institutions) to embed ES-philosophy and assessments in formal and informal instruments, and institutions as parts of GI planning in city environments;

ii) an innovative, spatially explicit, and ready to use method to assess GI development in spatial planning, which is based in current cutting edge research on urban ecosystem services;

iii) a spatially explicit GIS-based toolbox to evaluate trade-offs for different urban development scenarios;
iv) the toolbox will allow for comparative evaluations of ES-conformity of different planning scenarios.

In the Research and Development Phase, we will develop and test methods how integrated GI planning can be fostered by applying ES principles in real word cases studies. We will provide templates for the systematic consideration of ES in various practical planning instruments. The framework conditions according to differing planning cultures as well as national, regional, and local conditions will be taken into account. In cooperation with our partners from planning institutions, regional and local administrations and consulting agencies and based on open data as well as on acquired data, we will shape the toolbox and adapt it to the needs of the intended users.

The toolbox will address both the regional scale and down to the sub-district scale. For the first time, we will develop a certification standard for ES-conform urban planning, a very much needed complement to existing standards for buildings (LEED, DGNB, BREEAM) and infrastructure (CEEQUAL), or for communities (BREEAM).

At the end of the Research and Development Phase, we will have contributed to technical innovations (A) and capacity building (B). The toolbox we will be ready for use as an GIS-based open source product to function on various computer platforms and databases. It will be ready for use in companies and institutions, for economic activities as well as for responsibilities of public administration and in science. It will be transferable and the open source code allows for adaptions by users.

Approach: We will achieve that by means of:

- *Documentation:* We will record the development of the toolbox and the practical guide how to deploy the system in a manual and videos.
- *Communication and Demonstration of best practice examples in pilot areas:* Key persons on the regional and local level as well as staff from consultancy agencies will have be acquainted with the advantages, challenges and technical resources to implement ES in daily planning routines.
- *Data:* Preparation of spatial data sets and methods for data integration;
- *Partners and implementation:* Intensifying viable collaboration between universities, research institutes, planning authorities, and companies at the regional and city level in both countries, supported by various formats of science to policy-dialogues.

Indicators of success:

- Atlas (Map collection) on ES supply and demand for all pilot areas (China, Ruhr)
- Open source toolbox (releases a- o)
- Practical guide, manual and videos how to deploy the toolbox
- Publication of four scientific papers
- Outline of a certification standard for ES-conform urban and GI planning

Bezug des Vorhabens zu den forderpolitischen Zielen der Bekanntmachung

The project will strengthen the competence of German and Chinese partners to find culturally adapted and suitable solution to integrate ES in GI planning on the local and regional scale. GI is widely acknowledged as a means for strengthening sustainable urban development and resilient infrastructures. Enduring implementation is realized by: i) delivering user-friendly software tools in an open access environment. ii) strengthening of ES and NbS-thinking in current sustainable urban planning in the Ruhr area. Close cooperation with partners from state, regional and local authorities and companies in the Ruhr area and in German companies engaged in urban and environmental planning in China ensures both applicability and application. We explicitly refer to current and future hot-topics of regional and local planning (GI-Strategy of the State of NRW (ERDF), Regional Plan, IGA 2027, forthcoming activities of the Ruhr Conference). iii) Effects on the curriculum of both universities (Double Degree Master Study Programme 'Transformation of Urban Landscapes'; capacity building).

Sound and coordinated GI planning which accounts for urban development trends can have a tremendous impact on the wellbeing of urban populations. It may contribute, directly and indirectly, to decrease the levels of air pollution, lower the emission of greenhouse gases, increase the carbon sequestration of emitting areas, reduce stress and noise and thus illness related problems of urbanites, and increase the infiltration capacity, among many others.

Beschreibung der geplanten Forschungsarbeiten. d. Arbeitsprogramms, Darstellung von Methoden und Meilensteinplanung

Interplay of work packages: In accordance with the overall goal, the work packages (WPs) are geared towards the overarching 'Implementation Research' WP of the project (Fig. 3). This WP investigates the perception and use of the methodologically oriented achievements that have been put into practice. The 'Transfer' WP acts on an intermediate level between the WPs 'Development of the Toolbox' and 'Implementation Research'. It communicates the project achievement to a broader audience of experts and scientists. As the

toolbox grows by feeding in new ES assessment routines and enhanced functionalities, the project team is putting four releases of the toolbox into practice. The team members who develop the methods and the technology will receive feedback from practitioners and experts who use and evaluate the toolbox. This meets the demands expressed in literature to iteratively develop and introduce ES thinking into planning practice and policies. Consequently, two of the five WPs ('Development of the Toolbox' and the 'Assessment and Evaluation of individual ES') terminate before the end of the project's Research and Development Phase. The Milestones are closely related to Transfer and Implementation. This stresses the project's claim to exert effects in the real planning world. Four Milestones stand for the release of toolbox versions (200, 600, 800 and 1500). The implementation research milestones 100, 300, 400 etc. usually follow the previous new releases.

The time chart assigns more than 160 major work steps (WS) and milestones to the work packages. It also assigns the responsibilities for individual or joint tasks of team. As a peculiarity of the work program, each of the team members have tasks in several work packages. This should prevent 'silo-thinking' and foster a common understanding.

Doing Implementation research in the Ruhr area and in China will bring about comparisons of best practice and probably stimulate each other, always having the context-specificity in mind. A major challenge will be to parallel implementation potentials and application in the Ruhr area and in China. The workflow envisages the development of the toolbox to the needs of both regions at the same time rather than doing it successively.

Fig. 3: Work packages and corresponding milestones (cf. time chart).

WP 'Assessment and Evaluation of Individual ES': Successively, the team will conceptualize and program groups of ES that, during the definition phase, were pre-selected by

experts from Shanghai and the Ruhr and later on further ES will be included for toolbox gamma and delta. Some proven ES concepts from the literature can be adapted to the needs of the toolbox, for others, we will develop new algorithms. As the project progresses, the team members will take into account the literature discussions on ES assessment. Especially for the translation of biotic features, much needs to be done to decide to which extent generalizations of biotic structures in the two research areas are acceptable and meaningful. Wherever it is possible, assessments will use biophysical values to quantify ES demands and supply. The team will discuss options for expressing the ES significance in monetary values. Economic valuation can be a vehicle for better communication of ES to the public and decision makers, as outlined in TEEB, but monetary valuation is not the prime interest of the project.

Technically, the project team decided to use the open source GIS software QGIS for the development of models. As we make the most of high resolution data (0,1 and 0,5 m-resolution), thus dealing with Big Data, we have to rely on extended computer capacity for data processing and storage (Big Data). Spatially explicit data will be retrieved from a variety of resources as outlined in the project report from the definition phase and then rasterized, homogenized to result in a common database (Fig. 4) that is independent from platforms and software packages. It will be necessary to build models for the estimation of parameters and input variables needed in the various assessment routines.

WP 'Development of the Toolbox': The toolbox will integrate the individual ES assessments and provide a common user interface. Especially, balancing demands and supplies, detecting synergistic and antagonistic bundles of ES are the functions of the toolbox that previously need to be conceptualized, then computed and programmed. We will test strengths and weaknesses of various methods to transform and standardize single ES ratings and their performance in combinations. Exchanging ideas with the practitioners will foster the development of a user-friendly front-end. All in all, four releases of the toolbox have to be realized. Towards the end of the Research and Development Phase', the toolbox will enable to optionally evaluate planning scenarios and rate them according to their ES-conformity.

WP 'Transfer': All team members will be involved in the 'Transfer' WP to demonstrate the project achievements in a series of conference contributions and scientific papers. Keeping in touch with the research frontier is important for the sustained quality.

WP 'Implementation Research': Communicating the toolbox to policy makers, administration staff, and practitioners and receive their direct responses as well as their suggestions how to further develop the tools is the main concern of this WP. There will be several feedback events with partners in China and in the Ruhr area. We will sound the options where to apply the toolbox in the various formal and informal planning instruments. This will be done with key persons from the provincial and the local level in both research areas by means of consultations and workshops. In the Chinese cultural context, we involve professional provider experienced in facilitating science-to-policy-dialogues and networks. A significant contribution is expected from discussions with our partners, the medium-sized consulting companies, both active in China and in Germany. These partners also play a decisive role in creating a standard to rate the ES-conformity of urban spatial planning.

Human resource allocation

Urban Geography (RUB, PhD MF[1]): The project manager (PM) is assigned to the PI Zepp. His major tasks, besides the overall project coordination, cover the conceptual development of the toolbox, the transfer of major research findings and concepts and both data acquisition for the ES-evaluation & assessment as well as the implementation research in China.

Project coordination: The PM will be responsible for the inter-locking of (international) partners, manage the workflow and exchange of information and be in charge of the reporting (WS 1000, 1400, 1504-1506, 1520-1521) and accounting. Moreover, he coordinates the

[1] Abbreviations are initials and correspond with task allocations in the time chart (Tab. 2) and in Tab. 3(budget).

project staff and assistants at the Ruhr University Bochum (WS 1501), facilitates the scientific cooperation with the ILS, and organizes the stays abroad and the annual workshops (WS 0, 100, 500, 700, 1200, 1300).

Data gathering and ES-assessment: The PM is in charge of acquiring the necessary data for the assessment of cultural ES in China via desk and field research that - together with the implementation research - takes place twice a year (WS 211, 229, 614, 626, 826, 843). In cooperation with the School of Sociology, Shanghai University, the results of the empirical research serve as a perception analysis of green infrastructure. The research facilitates socio-structural evaluation schemes of cultural ecosystem services, which will be iteratively incorporated into the successive toolbox versions. Interviews with experts shed further light on China's evolving new environmental governance and its implications for Shanghai's GI planning. Each field trip is framed by preparatory (WS 208, 224, 609, 622, 817, 839) and subsequent (WS 217, 231, 617, 628, 830, 1515) work packages.

Implementation research: In his role as 'Liaison Officer', the PM accompanies the planning culture and implementation of GI projects in Shanghai and is institutionally docked in the 'Research Lab of Eco-Urban Design, Ministry of Education' on the Tongji Campus. During the research stays in China (WS 210, 228, 613, 625, 825, 842) and starting with the master planning in the Gucun sub-district, the further development of the toolbox takes place in close consultation with project partners of the faculties for spatial planning and landscape architecture, planning bureaus and representatives of the respective local government at sub-district and community level.

Toolbox development & *Transfer:* Together with the project team members, the PM conceptually guides the index development as well as supply & demand analysis of ES (WS 203, 605, 811, 1510), the trade-off analysis (WS 219, 615, 827, 1519) and oversees the programming of corresponding scripts (WS 226, 624, 841, 1523) during the toolbox' successional development. The PM takes the lead in preparing joint research articles (WS 232, 630, 844) and, together with the research team, presents major research findings on relevant conferences (WS 215, 622, 823, 1518).

Geomatics (RUB, scientist LG): *Assessing and evaluating individual ES:The* staff member geospatially analyses each ES by means of GIS and earth observation methods. To this end, he will process all available geodata with up-to-date and innovative methods informed by accompanying literature studies. After analysis, calculated geodata will be revised and corrected by ground truth validation during field trips in the Ruhr area (WS 225, 620, 834, 1521), in China (WS 222, 807, 837) and with experts. In addition, the geodata specialist will repeatedly perform change detection based on LULC classifications in the year 2023

including data from 2017 and 2020 (WS 835). The detected and evaluated ES will be transferred in a LULC shapefile (WS 205, 606, 812, 1516). After discussion with other team members, the staff member will group bundles of ES and analyse the interplay with other ES, to detect synergies and trade-offs (WS 219, 615, 827, 1519). His literature studies and expert-based knowledge will enable best results to support these core issues of the toolbox. The result of this step will be represent the ES supply and demand in neighbourhoods and districts. All results will be transparent and accessible. Thus, users can understand underlying assessments and evaluations and we prevent a black box. Each ES will be made comparable by developing a non-dimensional index (WS 203, 605, 811, 1510). After balancing and weighing ES, the user will be able to compare results from different LULC planning scenarios (WS 226, 624, 841, 1523). The results will be scripted to process these important steps of evaluating.

Toolbox development: The main task of the staff member is the development of the toolbox. To automate calculations, four toolbox versions (alpha, beta, gamma, and delta) will be developed and modular upgraded. In each version, new ES will be added, former results will be calibrated, the user interface will be improved by user experience (WS 607), the geodatabase will be updated, and operating instructions of the toolbox will be documented in manuals and later complemented by 'How-To-Videos-Tutorials'. - The alpha version (WS 200) will be a QGIS add-on based on Model Builder. The final product of this version will be a raster map. - The script of the beta version (WS 600) will be a python script and a user-friendly graphic user interface will be realized. Results will include three scenarios: the status quo, the target-state and the optimum state in graphical manners, e.g. spider webs diagrams, giving hints to planners how to improve the ES-conformity of the planning area. - The gamma version (WS 800) includes all ES selected in the project. Additionally, this version is able to calculate ES demand and supply at two scales. At the local scale, based on LULC of VHR Satellite Images in China and VHR airborne images in Germany, and at the regional scale, the calculation is based on LULC of Sentinel-2 and Landsat. - The delta version (WS 1500) is ready for the subsequent implementation phase and is able to calculate further ES of unspecified areas.

Furthermore, a certification will be developed for ES-conformity urban spatial planning (WS 1350).

Biogeography (RUB, scientist MB): The main task of the staff member will be the assessment of ES as an ongoing process during the R&D phase. He will focus on the biotic aspects of the work package. Among his tasks are the corresponding screening and evaluation of data and knowledge from published and grey literature. After analysis, calculated

geodata derived from satellite images will be revised and corrected by ground truth validation during field trips in the Ruhr area (WS 225, 620, 832, 1521), in China (WS 222, 807, 837). Results of the supply and demand analysis and the toolbox development will be discussed with experts.

The implementation of biophysical vegetation parameters, especially of tree species, will be a major goal to understand and evaluate the ES of biotic structures and of biodiversity (WS 209, 213). Further research has to be done to evaluate to which extent generalizations of biotic structures are acceptable and meaningful (WS 601, 806). Therefore, data collection during field trips in China and Germany is essential throughout the R&D phase to constantly improve the database. The scientist will quantitatively investigate the significance of the within-biotope-biodiversity as this must to be taken into account in the trade-off analyses. This will be a major contribution to the development of the toolbox (WS 202, 603, 836, 841). The evaluated ES will be made available in a LULC shapefile (WS 205, 615, 841, 1516).

The work package contributes to the development of the toolbox by evaluating the trade-offs among the pre-selected ES (WS 219, 615, 827, 1519). Therefore, the staff member will develop non-dimensional indexes (WS 605, 811, 1510). Afterwards, balancing and weighing ES among each other is among his tasks to enable comparisons between different planning scenarios. The work package will also contribute to the development of scripts to process these important steps of evaluating ES (WS 226, 624, 841, 1523).

Kooperationen und Arbeitsteilung

The teams from RUB and ILS are based in neighbouring cities, which enables regular meetings including ad-hoc gathering each month. Project management is executed by RUB. The scientific steering lies in the responsibility of the PI, the proposers, who know each other through cooperation in the Competence Field Metropolitan 'Transformation' of the University Alliance Ruhr (UAR) founded in the Ruhr area in 2017. Continuous exchange of ideas and findings between RUB and ILS are guaranteed and triggered by milestones and implementation activities. The WP 'Implementation research' is divided among RUB and ILS: ILS takes over the majority of the activities in analyzing the planning situation in the Ruhr area, whereas RUB is responsible for the implementation research in the Chinese context. Both institutions contribute to the development of the ES assessment methods. Assessing cultural ES needs fine-tuning in response to demographic and socio-demographic groups. For the Ruhr area, this part is taken over by ILS by means of questionnaire surveys. Our Chinese partners will contribute aspects of cultural contexts related to ES demand and supply perception and GI planning culture.

Fig. 5: Project structure, national and international partners

We signed Memoranda of Understanding with national and international partners (see appendix) that promise fruitful reciprocal stimuli. Each memorandum assign a specific function to the partner to ensure contributions according to the strengths of the entities:

The Joint International Research Laboratory of Eco-Urban Design (Ministry of Education), Shanghai is involved in developing the conceptual design of the toolbox. Scientists come from the College of Urban Planning and Landscape Architecture with whom we have established close collaboration. We have several years of mutual experience in running the Double Degree Master Study Programme Transformation of Urban Landscapes, sponsored by DAAD. Furthermore, we recently signed an Agreement and applied for a Joint Research Project on Brownfield Biotopes to DFG and NSFC. The Lab also helps to organize meetings with experts from business, academia, and government representatives on township- and sub-district-level in order to facilitate the applicability of the toolbox according to the local planning culture. Test runs and subsequent feedback talks will successively lead to technical and methodological refinements of the toolbox.

The Department of Sociology of Shanghai University is involved in developing the conceptual design of the toolbox. More than half of the key ES selected are cultural ES such as the recreational, aesthetic, and educational value resulting from different types of GI. By providing feedback talks with experts from business, academia, and government representatives for GI development and urban park management, the project will deepen its knowledge about the socio-structural perception of GI. These findings will help to improve the methodological framework (weighing of indicators) and facilitate the applicability of the

toolbox according to local (planning) culture. Test runs and subsequent feedback talks will successively lead to technical and methodological refinements of the toolbox.

The Chinese Academy of Sciences, Research Center for Eco-Environmental Sciences, is involved in developing the conceptual design of the toolbox. The Research Center's expertise on evolution principles, control techniques and planning method of China's urban ecosystem will contribute to refine the methodological design of a toolbox prototype version, paying special attention to the trade-offs of the eight ES (provisioning, regulating as well as cultural) selected so far. Test runs and subsequent feedback talks will successively lead to technical and methodological refinements of the toolbox. The scientific progress will be presented on renowned conferences and jointly published in relevant academic journals. Moreover, the Research Center for Eco-Environmental Sciences supports the project by further streamlining the toolbox in the Chinese policy-science interface.

Bochum city administration, Department of Construction, Environment, Mobility will contribute experiences from local GI planning. Bochum is on its way as a forerunner city within the state of North-Rhine-Westphalia-led 'Ruhr Conference'. The 'Innovation District Bochum East' will provide extended planning challenges to test the IMECOGIP toolbox It will enable comparative evaluation the effects of planning scenarios on ES demand and supply. The city of Bochum will provide us with the necessary data and insider information.

Gelsenkirchen city, Department of Nature Conservation is ready to assist in developing and testing the IMECOGIP toolbox to the needs of various explicitly mentioned city districts and their GI and ES challenges. They selected parks, heap landscapes, and local green belts areas and their surrounding urban tissue ('Revierpark Nienhausen', der 'Biomassepark Hugo', 'Halde Rheinelbe', der 'B0rgerpark Hassel' sowie der 'Buer'sche Gr0ng0rtel') for the IMECOGIP project. They make up intermediate level of the International Garden Exhibition to take place in the Ruhr area in 2027 (IGA 2027). Development and tests of single ES modules to assess ES demand and supplies are the main activities in our cooperation with Gelsenkirchen.

Ministry for Environment, Agriculture, Conservation and Consumer NRW (MULNV) is the most important body to urge municipalities on implementing GI in their administrative units. We are in contact with the department leaders responsible for the Provincial Subsidiary Program 'Green Infrastructure' (ERDF subsidies) and for the forthcoming programme 'Offensive Grune Infrastruktur' and 'Klimaresiliente Metropole Ruhr' being parts of the Province's 'Ruhr Conference' initiative that was launched in 2019. As a voluntary action, we already provided the Ministry with ES maps during the preparation of the 'Ruhr Conference' in 2019, based on our expertise in the very field of IMECOGIP. We see discussions with

the higher levels of policy making as decisive to reach the project's overall objective, which is implementation of ES-thinking in GI-planning.

The Ruhr Regional Association (RVR) is responsible for the regional planning for the Ruhr region. Currently, it prepares the regional plan that determines the extent of regional green belts and others. The RVR has also received the lead management for the 'Offensive Grune Infrastruktur 2030'. Due to the corona epidemic, it was not possible to finalize the MOU between RVR and IMECOGIP. However, in an e-mail, the department director expressed his interest to join the IMECOGIP at a later stage. The use of the Toolbox to monitor and support GI analysis and planning on the regional level is IMECOGIP's offer towards RVR.

Bosch und Partner GmbH will be cooperating with the IMECOGIP project team in exploring extended fields of application for the toolbox. Preliminary fields of application are zoning plans and regional plans, impact regulation under nature protection law (compensation regulation) as well as the optimized consideration of protected goods according to Environmental Impact Assessment. Bosch und Partner GmbH are prepared to test prototype versions taking real world examples from their consulting activities.

OBERMEYER Engineering Consulting (Beijing) Co., Ltd. already gave valuable hints as to the development of the toolbox towards a certification standard for ES-conform urban planning with potential for implementation in China. OBERMEYER Engineering Consulting is active on the Chinese market providing landscape design, smart city design and integrated planning solutions including ecologic and sustainable principles. The company is willing to continue their support by regular consultations with the project team.

Coming from Germany, 'energydesign (Shanghai) Co. Ltd.' was founded in 2008 as a Shanghai-based engineering and consulting firm for low-energy, high functionality and optimal cost solutions for the built environment, district, industrial process. It is a 100% subcompany of 'EGSplan international GmbH' in Stuttgart that has realized innovative projects in China. The company is experienced in various certifications, among them a certification for urban districts. As Obermeyer Engineering and Consulting, 'energydesign' is willing to support the project team to develop a certification standard for ES-conform urban planning with potential for implementation in China.

The nomination of the IMECOGIP project coordinator as member of the Advisory Board of the 'Technology Innovation Center for Landscape Eco-Restoration in Greater Metropolitan Areas' has the potential to influence policy-making in the province of Shanghai. As in 2018 and 2019, we expect that there is the chance for repeated consultation of the newly installed 'Shanghai Land Consolidation and Rehabilitation Center'. A step forward in dissemination of IMECOGIP.

Erwartetes Ergebnis, Anwendungspotential und angestrebte Ergebnisverwertung,

Economic prospects: The project will lay the ground for consulting companies from Germany that are actively involved in planning projects in China and other South-East Asian countries to demonstrate the strength of German environmental planning expertise and skills. What's more, a certification of ES-conform planning would open new opportunities for new contracts. As outlined before, the institutional reforms of Chinese environmental planning promise a wider acceptance of the methods and tools to be developed in the projects. Innovative planning tools and setting standards are the economic prospects of success.

Scientific prospects: Scientists worldwide are striving for improved concepts of introducing ES-thinking in GI planning. Our state-of-the-art analysis clearly shows that the objectives of the project perfectly fit to the observed deficits in GI-Planning and ES-Implementation Research. With team members (PI and employees) from different disciplines (landscape ecology, planning, sociology, geomatics) we follow integrate scientific progress in various research fields. By developing and testing the toolbox in Germany and China, we can evaluate its limitations and adaptations. We claim that it is transferable to any humid mid-latitude climatic region. A definite advantage and peculiarity of the project is the strategic dual approach comparing fairly opposite planning cultures in its strengths and weaknesses to implement the ES concept.

Scientific and Economic Connectivity: The Pis are part of the international community, which is demonstrated by organizing and participating in congresses (Ecosystem Service Partnership, Society of Urban Ecology) as well as being active in editing of leading journals of their disciplines. The science to policy-dialogue and the science-meets-practice-activities are integral parts of the project documented through the MOUs with public administrations and leading consulting agencies

We do not expect conflicts between RUB and ILS. The allocation of tasks was agreed upon unanimously. In case of conflicts that cannot be solved internally, we will ask the supervisory authorities for mediation (Rectorate of the RUB, State of North Rhine-Westphalia).

Tab. 4: Zeit- und Finanzierungsplan fur die Implementierungsphase

During a following implementation phase, the project team seeks to implement an up-to-date certification standard for ES-conform urban and GI planning. This phase is based on the experiences achieved during the R&D phase in collaboration with the economic partners in the fields of urban and landscape planning. Due to the economic prospect for internationally active companies, we expect their considerable interest and co-financing.