CHINA'S ECOSYSTEM SERVICES PLANNING: WILL SHANGHAI LEAD THE WAY?

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With 7 figures, 1 table and 1 appendix
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Summary: Ecosystem Services (ES) are a fundamental component of well-being and sustainable urban development with tremendous potential to enhance urban planning. Recently, several studies have evaluated the environmental performance of urban plans using the ES approach. To strengthen this science-policy integration, it is still necessary to perform ES assessments within the urban planning practice as well as to collect empirical evidence on the impacts of envisioned planning measures on the supply of ES in urban environments across the world. In this research, we analyzed the state-of-the-art of China's new environmental governance, which aims to change China's land use policy and particularly the role of Green Infrastructure (GI) regarding urban planning and ES. We focused on the Shanghai Baoshan district Master Plan as a case study, and analyzed it under the lenses of the supply of ES using the matrix approach. We ascertained the supply of ES as delineated in the ecological network plan for 2035, and developed an evaluation framework based on CICES v5.1 and two expert workshops. Our approach used an integrated preliminary ES-assessment, and evaluated the consequences for the supply of ES in Baoshan district, which is adaptable to varying urban geographies. The results of our assessment show that, if realized as planned, the district will increase the overall supply of ES, especially regulating and cultural services, that play an important role within GI on the urban level. In general, the land use plans should include fine-grained information within building blocks to allow for even better assessing of the spatial structure of the supply of ES

Zusammenfassung: Weltweit entwickelt sich das Konzept der Ökosystemleistungen (ÖSL) zu einer vielversprechenden Grundlage einer Stadtplanung, die am Wohlbefinden des Menschen orientiert und einer nachhaltigen Entwicklung verpflichtet ist. Kürzlich vorgelegte Studien analysieren Planvorstellungen aus europäischen und nordamerikanischen Städten im Hinblick darauf, inwiefern sie Kerngedanken des ÖSL-Konzepts berücksichtigen. Vergleichbare Studien mit Chinabezug und unter Einschluss einer Vielzahl an ÖSL sind bisher nicht bekannt. In unserem Beitrag fassen wir einleitend die neueren Entwicklungen der *environmental governance* in der VR China zusammen; die Zentralebene gibt vor, Chinas Landnutzungs-Politiken auf allen Ebenen des hierarchischen Planungssystems zu ökologisieren. Ist das ÖSL-Konzept auf der untersten, der städtischen Ebene bei der Planung der Grünen Infrastruktur erkennbar? Welche Veränderungen bei der Bereitstellung von Ökosystemleistungen sind zu erwarten? Am Beispiel des Masterplans für den Stadtbezirk Shanghai-Baoshan stellen wir die für das Jahr 2035 ableitbare Versorgung mit Ökosystemleistungen dem Ausgangszustand im Jahr 2017 gegenüber. Die Bewertungen von 15 Ökosystemleistungen nach der Matrix-Methode wurden in einem Experten-Workshop erarbeitet. Die Teilnehmerinnen und Teilnehmer wiesen einzelnen Landnutzungs- und Landbedeckungsklassen spezifische Werte für die Erfüllung von Ökosystemleistungen zu. Der Vergleich der beiden Zeitpunkte 2017 und 2035 legt nahe, dass die Versorgung mit Ökosystemleistungen gestärkt wird, sofern man Flächenanteile und -qualitäten zugrundelegt. Andererseits zeigt die Hot-Cold-Spot-Analyse Beharrungstendenzen räumlicher Muster. Dieses Ergebnis mag mit der im Planungszustand noch geringen inner-räumlichen Differenzierung auf Baublockebene zusammenhängen. Nicht nur in China erschwert diese Problematik die Möglichkeiten, die stadtökologischen Wirkungen städtischer Planungen fundiert zu beurteilen.

Keywords: ecosystem services, environmental governance, green infrastructure, urban planning, land use, China

1 Introduction: the emerging field of ecosystem services in urban planning

Ecosystem Services (ES) assessment has rapidly emerged as a promising framework for sustainable and resilient urban planning and development (TEEB 2010; Breuste et al. 2013; Haase et al. 2014; Grunewald et al. 2018; Artmann et al. 2019; von Haaren et al 2019; Geneletti et al. 2020). The ES framework provides a solid ground for the incorporation of the civil society through participatory planning processes (Fürst et al. 2014). Nevertheless, the current state-of-the-art shows that integration of scientific knowl-

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edge into policy frameworks in China is still lacking (Wong et al. 2014). In many countries, legal frameworks require adjustments to facilitate the implementation of ES into decision making (Stepniewska et al. 2017), existing institutional fragmentation and path dependencies hinder the implementation of the ES concept into planning practice (Cortinovis and Geneletti 2018). Albert et al. 2017 identified a knowledge gap concerning ES- and Green Infrastructure (GI) concepts and planning practice. Several case studies addressing the science-policy interface also pointed to difficulties concerning public awareness of nature-based solutions, for instance, in Poznan, Poland (Zwierzchowska et al. 2019), and in participatory governance arrangements of GI-planning in New York, USA (Miller and Montalto 2019). Scrutinizing 22 urban plans of Italian cities, Cortinovis and Geneletti (2018) revealed selective considerations of ES by local governments while most of the other ES remain neglected. ES can greatly foster land use planning and management while accounting for synergies and trade-offs within land use change (Inostroza et al. 2017). However, integrated assessments of ES ready to be used by planners remain a challenge (Zepp and Inostroza 2021).

Following China's Ecosystem Assessment (2000-2010), researchers used quantitative models such as InVEST to assess land use and land cover change (LULCC) in China, on national and regional scales (Xie et al. 2008; Zhan 2015; Xu et al. 2018; Wang et al. 2019) or for the delineation of large scale 'key ecological function zones'[1] (Ouyang et al. 2019). Recently, there is a growing body of literature in China focusing ES at the urban level. Wong et al. (2014) developed a '10-step approach' to link the ES framework with urban ecological management in the case of Beijing. Wang et al. (2018) applied a scenario-based approach in Wuhan to evaluate trade-offs for nine ES based on five land use classes, while Li et al. (2019) chose an index-based method to assess the environmental carrying capacity of an urban district in Changzhou. Looking at the relationship between ES and subjective well-being, Huang et al. (2020) applied a multilevel linear model in rapidly urbanizing watersheds located in northern Hebei. Bai et al. (2018, 2) indicated a lack of "standardized methods, which is impacting the consistency, credibility, and usability of ES assessments", while Guo et al. (2018) stress the neglected aspect of multidimensionality of ES, especially the importance of cultural ES on the urban scale. There are relevant matches and mismatches between the supply of and demand for ES in general (Spyra et al. 2019a) and cultural ES in particular that deserve detailed attention in the policy design (Meng et al. 2020; cf. La Rosa et al. 2016).

This paper pursues two successive objectives. First, it informs the reader on the role that the ES concept plays in China's new environmental governance and future urban planning agenda. To study and safeguard proper top-down policy implementation in local planning administrations, the central government chose Shanghai as a pilot city for implementing the new environmental institutional reforms. Shanghai issued a new Master Plan (2017-2035), in which the city's municipal government aims to "*become a paradigm of sustainable development for high-density megacities*[2]" (SUPLRAB 2018, 28). Thus, related principles and guidelines at the national level have recently been introduced into the master planning of the municipality and passed on to the district level. To this end, we chose the new 'Comprehensive Plan and General Land-Use Plan of Baoshan District 2017-2035' (BDPG 2019) to evaluate its potential effect on ES provision compared to the baseline, i.e., the ES provision when the Shanghai Master Plan was issued. Baoshan is Shanghai's most industrialized district and was one of the first urban districts to enact a district Master Plan. In terms of transferability of results, Baoshan can serve as a blueprint for old industrialized districts in other Chinese cities. We applied an LULC-based matrix expert assessment (Burkhard et al. 2012; Montoya-Tangarife et al. 2017; Mukul et al. 2017). Our conclusion points to possible avenues to strengthen ES in future planning in Shanghai to foster ecologically sound urban development. We draw parallels between our findings with experiences from other cities and regions in the world. The results point to the key issues of implementing ES, which are relevant regardless of the political system, planning level, and planning culture. Focusing on China's new environmental governance, this paper closes a gap in the international scientific literature on the implementation of ES at the municipality level.

[1] Single quotation marks indicate technical terms and official names of plans and other documents

[2] Italics indicate translations of expressions from official documents in Chinese

2 Background: China's new type of environmental governance

China's environmental governance has constantly been reshaped during the last four decades (Mol and Carter 2006; Enserink and Koppenjan 2007; Ren and Shou 2013; Wang 2018). Following the third plenary session of the 18th Central Committee in 2013, the concepts of a "systematic assessment of ecological space and natural resources", "red lines for ecological protection" and "building a beautiful China" featuring a "harmonious development between Man and Nature" (CCCPC 2013) grounded a new type of environmental governance in China. These thoughts were further promoted in an '*overall plan of ecological civilization system reform*' promulgated by the Central Committee of the Communist Party of China (CCCPC 2015), which framed the ES concept in an official document of national significance. The establishment of the Ministry of Natural Resources (MNR) and the Ministry of Ecological Environment (MEE) in March 2018 represents a major step empowering the MNR to be the sole '*owner*' and '*manager*' of China's natural resources (CCCPC 2018a), while the MEE is in charge of '*environmental protection*' and '*supervision*' (CCCPC 2018b). Between October and November 2018, the centrally administered municipalities of Beijing, Chongqing, Shanghai, and Tianjin all established a 'planning and natural resources bureau' and set up dispatched agencies in districts below. Further streamlined to the provincial level, most of China's cities above a prefectural-level such as Chengdu, Nanjing, Shenzhen, Guangzhou or Xiamen quickly followed between January and March 2019 (Chengdu, Nanjing, Shenzhen MBPNR 2019, Guangzhou Municipal Government 2019, Xiamen Net 2019).

Since the MNR has taken the institutional lead and responsibility by issuing corresponding policies, ecosystem services represent a key concept in China's integrated spatial governance approach. When Chinese researchers introduced the term ecosystem services into China, some terminological inaccuracy occurred in translations from English to Chinese. Therefore, some official documents use ecosystem service functions and ecological functions. In most cases, the context clarifies that ES are meant. In these cases, we standardized the expressions and used the term ES. It is crucial to observe how China's environmental governance evolves as the Central Government now streamlines an ecosystem-based approach from the central to the local level targeting at integrated and resilient urban development nationwide (CCCPC 2018a-b).

3 The Shanghai Policy Environment and Master Plan 2017-2035

The Shanghai Urban Master Plan 2017-2035 attempts to strengthen ecological functions[3] [生态功能] of green infrastructure and to enforce a zero-growth strategy in terms of land consumption (SUPLRAB 2018). This has to be seen in the context of Shanghai's tremendous urban expansion and enormous conversion of agricultural land into urban fabric over the last decades (Sha et al. 2014, 9-18; Shi et al. 2019; NASA Earth Observatory 2019), which is connected to rapid economic development and population growth. Opposed to that, the government intends to limit the permanent population size to 25 million people by 2020 (SUPLRAB 2018, 27). For the first time in Shanghai's history, built-up infrastructure will be demolished on a large scale to make way for an interconnected ecological network, while most parts of Shanghai's existing green areas shall be preserved, following the municipal government's '*ecological red line*' approach. In areas delineated by a red line, construction is prohibited to protect important ecosystem services. Bai et al. (2018) discussed meaningful delineation of ecological red line areas based on assessments of carbon sequestration, water conservation, nitrogen retention, and soil retention for four future development scenarios. The Master Plan had been enacted before in 2017 but it remains unclear to what extent the considerations of Bai et al. (2018) have influenced the plan. The policy of '*linking the increase of urban construction land by decreasing rural construction land* [增减挂钩]' represents a major incentive for local governments to develop green infrastructure. While Shanghai's cropland conservation red line restricts further urban-rural conversion, the transformation of polluting, hazardous, or energy intensive industrial areas into green infrastructure now becomes an economically viable option: Once reclaimed, it allows for additional construction land.

The centerpiece of Shanghai's GI development is the '*Ecological Network Plan for Shanghai Municipality*' (Fig. 1b). It consists of nine '*ecological corridors over 1000 m wide*', ten '*ecological conservation zones*' as guaranteed strategic ecological space as well as '*16 ecological space belts over 100 m wide*' within the central city area and a new urban-rural park system. Corridors span across jurisdictional borders of Shanghai's 16 administrative divisions such as the Jiabao Ecological Corridor. By 2035,

[3] We added the original Chinese term to allow readers who are well-versed in Chinese to understand the nuances that must be considered when Chinese terms are translated.

Shanghai intends to realize a forest coverage of 26%, double the ratio of municipality-wide park space per capita of 13 m² (7.6 m² in the central area). In 1982, the public green space in urban Shanghai accounted for 0.45 m² per capita (Shanghai Urban Planning Institute 2007, 253). It increased to 3.62 m² per capita in 1999 (He 2015, 172).

In addition to the corridors and belts, the plan distinguishes four classes of ecological spaces. Classes 1 and 2 represent ecological red line areas. Although the Master Plan does not explicitly mention ES here, it includes strategic goals and measures to enhance the city's overall resilience by improving and protecting the marine, atmospheric, water, and soil environment. For instance, the construction of "*marine natural reserves*" shall "*remediate land-based pollutants entering the sea*", further constructions on the "*sponge city*" shall "*enhance flood control and drainage*" while "*air ducts*" shall "*mitigate the urban heat island effect*" (SUPLRAB 2018, 67-69). In addition, SMPG (2018a) stresses the importance of urban GI infrastructure outside of the ecological red line areas to meet the "*demand for ecosystem services* [生态服务需求] *of the general public*" [市民的基本生态服务需求]. Class 3 mainly consists of permanent basic farmland, forests, wetlands, rivers, and lakeside green areas as well as wildlife habitats. Assignment to class 3 implies protection and enhancement of ecological functions. However, construction activities are not explicitly prohibited here. Class 4 ecological space focuses on ecological and recreational functions of green infrastructure.

The Shanghai Master Plan represents a mandatory planning framework, which the district government of Baoshan must implement accordingly. Thus, the next chapter takes a close look at how upper-level policies are legislatively deployed and spatially delineated at the subordinate planning level.

4 Study area and methods

4.1 Study area

Shanghai's Baoshan district is situated in northern Shanghai (Fig. 1b). It is one of sixteen districts in Shanghai, covering an area of 425 km² and is home for roughly two million people. Being a part of the Yangtze delta, flat terrain and high groundwater table prevail. The Huangpu River forms the southeastern border of the district, which is well-known for its steel industries along the Yangtze (Changjiang) River in the north and the southeast. Small-scale industrial plots locate alongside and south of the Shanghai outer ring road as well as in central Baoshan, whereas the large industrial plots of state-owned enterprises, notably the Baosteel Group, are in the eastern and northeastern parts. Peri-urban land use with scattered village structures dominate in the northwestern parts of Baoshan. However, urban tissue occupies two-thirds of the district. Baoshan is in the process of urban transformation. The retreat of heavy industries offers chances for a comprehensive spatial reorganization of land uses.

The '*Comprehensive Plan and General Land-Use Plan of Baoshan District* 2017-2035' was issued in March 2019. It zones ecological spaces as well as permanent cropland areas and delineates urban development boundaries. The prospective ecological space in the Baoshan district covers the classes 2-4 of ecological space (Fig. 1c). Class 4 ecological space covers an area of 29.5 km² located within the urban development boundary. In Class 3 ecological space, the plan prohibits any construction activities that affect ecological functions here but allows for some controlled space for municipal and transport infrastructure. The plan spares out former industrial land between the Luobei Road and Lianhe River ecological corridor, which explains the scattered layout of class 3 ecological space. With a total area of 86.8 km², class 3 ecological space (53.7 km²) represents the largest share of green infrastructure (BDPG 2019, 32). The Chenhang and Baosteel Reservoir (3.53 km²) as well as a small wildlife habitat bordering it (0.07 km²), located at the northeastern tip of Baoshan, represent the only ecological red line areas (SMPG 2018b, 11-12). These class 2 ecological spaces supply drinking water and aim at biodiversity conservation (SMPG 2018a). The eight interconnected elements of green infrastructure depicted in Fig. 1c cover approximately one-quarter of Baoshan's land surface (BDPG 2019, 56).

A centerpiece of this strategy is to "*increase the ecological service function*" of forests by establishing a "*well-functioning urban forest ecological network"* that covers 20% of the Baoshan district. It shall consist of a water protection forest belt alongside the Yangtze River, two forest belts alongside the outer and suburban ring roads, a forest network consisting of roadside and riverside greening, farmland as well as forests in urban parks (BDPG 2019, 60). Additionally, the Master Plan establishes that the '*ecosystem services and biodiversity'* of tidal mudflats and wetlands in Baoshan shall be improved. The overall water quality shall be ameliorated by enforcing pollution prevention efforts (upgrading or closure of polluting enterprises, industrial solid waste treatment of 98%, environmental monitoring) and the restoration of polluted waterways and contaminated soils on industrial land (BDPG 2019, 62).

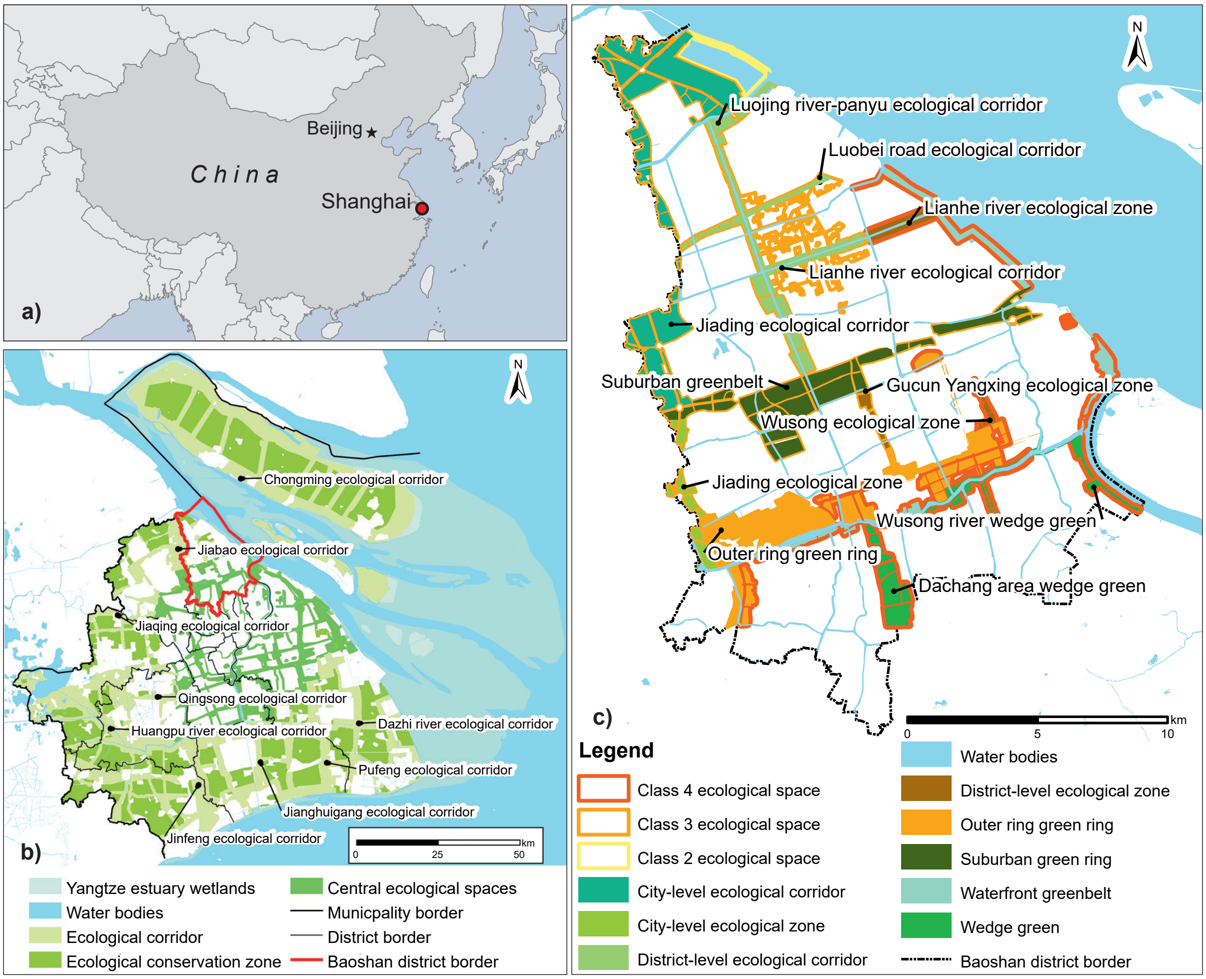

Fig. 1: a) Location of Shanghai; b) Ecological Network Plan from the Shanghai Master Plan 2017-2035 (redrawn from SUPLRAB 2018, 66); c) Ecological Space and Network Plan for Baoshan District. Redrawn based on BDPG (2019, 33 and 57).

Baoshan intends to cut the share of industrial land by half, from 34.4% to 17.2% (BDPG 2019, 43). At the same time, the proportion of residential land shall increase from 21.4% to 25.3%, green space from 9.2% to 16.8%, and public facilities from 6.2% to 9.2% (BDPG 2019, 43).

4.2 Methods

4.2.1 Present and future land use and land cover

Our assessment of ES provision is based on present and prospective LULC patches, for which a matching classification for both points in time was elaborated. We mapped the LULC of Baoshan district in the year 2017 using a three-step approach combining visual interpretation, spatial overlay analysis and object based-classification (Antrop and Eetvelde 2000; Cadenasso et al. 2007; Shao and Wu 2008; Zhou et al. 2014). We overlaid Planet and Pleiades multispectral satellite images with a spatial resolution of 3 m and 0.5 m respectively, from August and September 2017. To cross-check and verify urban street networks, waterways, and public facilities, we used Open Street Map (© OpenStreetMap-contributors). We further classified urban residential areas according to building density by conducting spectral data analysis (NDVI, Zhou et al. 2014; Kaspersen et al. 2015; Zhou et al. 2016). We set parameter values for residential urban >80 % sealed (NDVI = 0.0-0.249), residential urban 80-30 % sealed (NDVI = 0.25-0.379), residential urban <30 % sealed (NDVI = 0.38-0.7) to delineate LULC patches accordingly. Additionally, we visually interpreted archived satellite images (Google Earth) to detect permanent greenhouse areas. We distinguished 18 LULC-classes (Table 1, Column 1), including areas that could not be classified adequately.

The '*Comprehensive Plan and General Land-Use Plan of Baoshan District* 2017-2035' establishes only 16 LULC classes, (Column 2 in Tab. 1). The Plan does not allow for subdivisions of residential areas. To resolve the mismatch between class designations of Column 1 and 2, we aggregated the 2017 categories ('unclear', 'under construction') and 2035 categories ('*strategic empty space*', '*land reserved for development*' and '*construction area for other land use*') to 'land reserved for development or under construction' (Column 3). Industrial R&D area was subsumed in the category 'industrial area and warehouses' and greenhouses in 'agricultural land'. Ultimately, we performed a spatial overlay for 2017 and 2035 LULC patches to calculate the LULCC in GIS (©ArcGIS 10.5.1).

4.2.1 Assessment of (prospective) ecosystem services

We applied the Common International Classification of Ecosystem Services v5.1 (CICES) in our assessment (Haines-Young and Potschin 2018). The CICES framework represents a sophisticated and peer-reviewed classification system used in recent European (Zepp et al. 2016; Tammi et al. 2017; Sutherland et al. 2018; Zepp 2018; Elliot et al. 2019) and Chinese (Yang et al. 2015; Cheng et al. 2019; Liu et al. 2020) ES studies. During an initial workshop held in October 2019, out of 90 ES listed in CICES v5.1, the principal investigators and Chinese partners, supported by their respective team, preselected the most relevant ES for large

Tab. 1: Land use land cover (LULC) classifications used in Master Plans and harmonized for ES assessments. (1) Baoshan LULC 2017 is the classification we used in our own analysis of the present state. It is more detailed than (2) Baoshan LULC (General Land-Use Plan). To be able to assess and compare ES for both years, we prepared the (3) Workshop LULC assessment.

<table>
<tr><th>(1) Baoshan LULC 2017</th><th>(2) Baoshan LULC 2035</th><th>(3) Workshop LULC assessment</th></tr>
<tr><td>residential urban >80 % sealed</td><td rowspan="3">residential area</td><td>residential urban >80 % sealed</td></tr>
<tr><td>residential urban 80-30 % sealed</td><td>residential urban 80-30 % sealed</td></tr>
<tr><td>residential urban <30 % sealed</td><td>residential urban <30 % sealed</td></tr>
<tr><td>residential rural</td><td></td><td>residential rural</td></tr>
<tr><td>green area</td><td>green area</td><td>urban green areas (parks)</td></tr>
<tr><td>basic farmland</td><td>basic farmland protection area</td><td>agricultural land</td></tr>
<tr><td>greenhouses</td><td></td><td>greenhouses</td></tr>
<tr><td>agroforestry area</td><td>agroforestry area</td><td>agroforestry</td></tr>
<tr><td></td><td></td><td>forest</td></tr>
<tr><td>water bodies</td><td>water bodies</td><td>water bodies</td></tr>
<tr><td>water bodies (river)</td><td>water bodies (river)</td><td>water bodies (river)</td></tr>
<tr><td>commercial area</td><td>commercial area</td><td>commercial area</td></tr>
<tr><td>industrial area and warehouses</td><td>industrial area and warehouses</td><td>industrial area and warehouses</td></tr>
<tr><td></td><td>industrial R&D area</td><td></td></tr>
<tr><td>sports & recreational area</td><td>sports and recreational area</td><td>sports and recreational area</td></tr>
<tr><td>educational, cultural and welfare area</td><td>educational, cultural and welfare area</td><td>educational, cultural and welfare area</td></tr>
<tr><td>municipal infrastructure</td><td>municipal infrastructure</td><td>municipal infrastructure</td></tr>
<tr><td>transportation facilities</td><td>transportation facilities</td><td>transportation facilities</td></tr>
<tr><td>unclear</td><td>strategic empty space</td><td rowspan="3">land reserved for development or under construction</td></tr>
<tr><td>under construction</td><td>land reserved for development</td></tr>
<tr><td></td><td>construction area for other land use</td></tr>
</table>

metropolitan areas. Thereafter, we invited experts from regional planning, municipalities, and universities to an assessment workshop. Seventeen scientists and professionals from practice assessed the ES significance of each LULC class listed in Table 3, Column 3. All experts who finally contributed to the assessment held academic degrees in urban or environmental planning (n = 5), landscape architecture (n = 3), environmental science (n = 7), economics (n = 1), and social science (n = 1), and were already familiar with the concept of ES. In the workshop, we explained in detail the different LULC classes, both orally and using supporting photos, to prepare the individual work phase. The organizers asked the participants to rate the potential ES provision of each LULC in numbers from zero (no contribution) to five (maximum contribution), as done by Montoya-Tangarife et al. (2017) and Mukul et al. (2017). The assessment took place on-site during the afternoon of the same day. We calculated means, and to express the degree of consensus between the participants, we looked at the variability of ratings. The procedure is adapted to the matrix approach, originally suggested by Burkhard et al. (2012). Additionally, Jacobs et al. (2015) performed a knowledge-based survey among experts. Roche and Campagne (2019, 1) concluded that "using expert knowledge through the matrix approach yields results very close to those from quantitative proxies or biophysical models for the evaluation of ES at the regional level, particularly when there is a need to evaluate many ES or in a data scarce region." Data are fuzzy in the case of LULC in general land use plans. With the matrix approach, we covered all major LULC classes (n = 18) presently found in the Baoshan District, approximating China's system of current land use classification (Chen and Zhou 2007; Guo et al. 2018). We included different degrees of imperviousness for urban residential areas to better explore ES by type of urban-dwelling structure. For the expected LULC 2035, we estimated the building density for new residential areas based on recently built neighborhoods.

Prior to estimating the effect of land use changes on ES provision, we performed a minimum-maximum standardization according to Mouchet et al. (2017). For each mean rating of ES, we subtracted the minimum mean rating of ES occurring in any LULC and then divided by the difference between the maximum and the minimum values, i.e., the range of mean ES ratings in any LULC (Equation 1):

$$ESs = \frac{ES - MIN(ES)}{MAX(ES) - MIN(ES)} \quad (1)$$

with ESs standardized ES

ES mean rating of ES

$MIN(ES), MAX(ES)$ minimum and maximum of mean ratings of ESs occurring in any LULC

For each combination of LULC and ES, the result is a dimensionless and comparable indicator, ranging from zero to one (Mouchet et al. 2017). The standardization attributes equal importance to all ES and are area-specific.

For each ES, we calculated an area-weighted ES significance ESs_w (Equation 2) for both 2017 and 2035. The change in area weighted significance is ES_C according to Equation (3). To express the relative change of area weighted ES significance, we calculated a handy ESs_C-*Index* (Equation 4). We subtract the value of 100 to accentuate differences between the 2017 and 2035 results. An increase in ES significance results in a positive index, while negative values indicate a deterioration of the situation.

$$ESs_w = \sum_{LULC=1}^{n} \left(ESs_{LULC} \times \frac{A_{LULC}}{A_t} \right) \quad (2)$$

$$ESs_C = ESs_{w;\,2035} - ESs_{w;\,2017} \quad (3)$$

$$ESs_C\ Index = \left(ESs_C \times 100 \right) - 100 \quad (4)$$

with ESs_w area weighted ES significance

n number of LULC

ESs_{LULC} ES significance of LULC class

A_{LULC} area covered by LULC class

A_t total area (Baoshan district)

ESs_C change of area weighted significance

ESs_C-*Index* index expressing relative ES_C

To ascertain changes in the spatial structure of ES provision from 2017 to 2035, we performed a hot-cold spot analysis on ARGIS ©, using the Getis-Ord Gi* statistic and a cluster analysis using the Anselin Local Moran's I statistic (Anselin 1995). Therefore, we grouped the ES into the three groups provisioning, regulating and cultural ES.

5 Results

5.1 Land Use Land Cover Change (LULCC)

The maps of Figure 2 formed the base to assess the supply of ES in 2017 and 2035, the anticipated state. The largest LULCC (change between Columns 1 and 2 of Table 1) is attributed to the transformation of industrial land. According to the plan, a total of 198 industrial plots are in need of consolidation and rehabilitation (BDPG 2019, 56). Our calculations show (Fig. 3) that the share of industrial land in the Baoshan District would decrease from 30.7% in 2017 to approximately 11.7% in 2035, of which 3.2% would be transformed into "*industrial R&D areas*". Although the amount of residential area showed a marginal increase from 20.6% to 21.1%, our analysis showed that this change would also imply an increase from 18.6% to 21.1% in urban residential area, presumably multistoried buildings, at the expense of rural residential land (villages). GI would represent the largest net gain (from 15.5% to 28.2%) with green areas, including urban parks and agroforestry, more than doubling their share, from 4.8% to 10.6% and 4.4% to 11%, respectively. LULC for transportation and freight facilities is also foreseen to increase by approximately one-third, primarily due to the widening of narrow, rural streets to multilane streets for cars and motorbikes. Cultivated agricultural land is planned to shrink from 7.7% to 5.1%.

We further depicted the intended sites of prospective, newly added GI (Fig. 4a) and calculated the amount by type of former land use in 2017 (Fig. 4b). In total, almost 66 km², around 16% of Baoshan's district total area, would be newly added GI. Industrial areas and warehouses would make up the largest share, 50.5% of former land use.

Though LULCC would include the conversion of rural residential area (10%) and agricultural land (7.5%) to create the ecological corridors (Fig. 2), the intended LULCC implies a substantial conversion of formerly sealed land to GI accounting for more than 52 km². We evaluate the implications for the supply of ES in the following section.

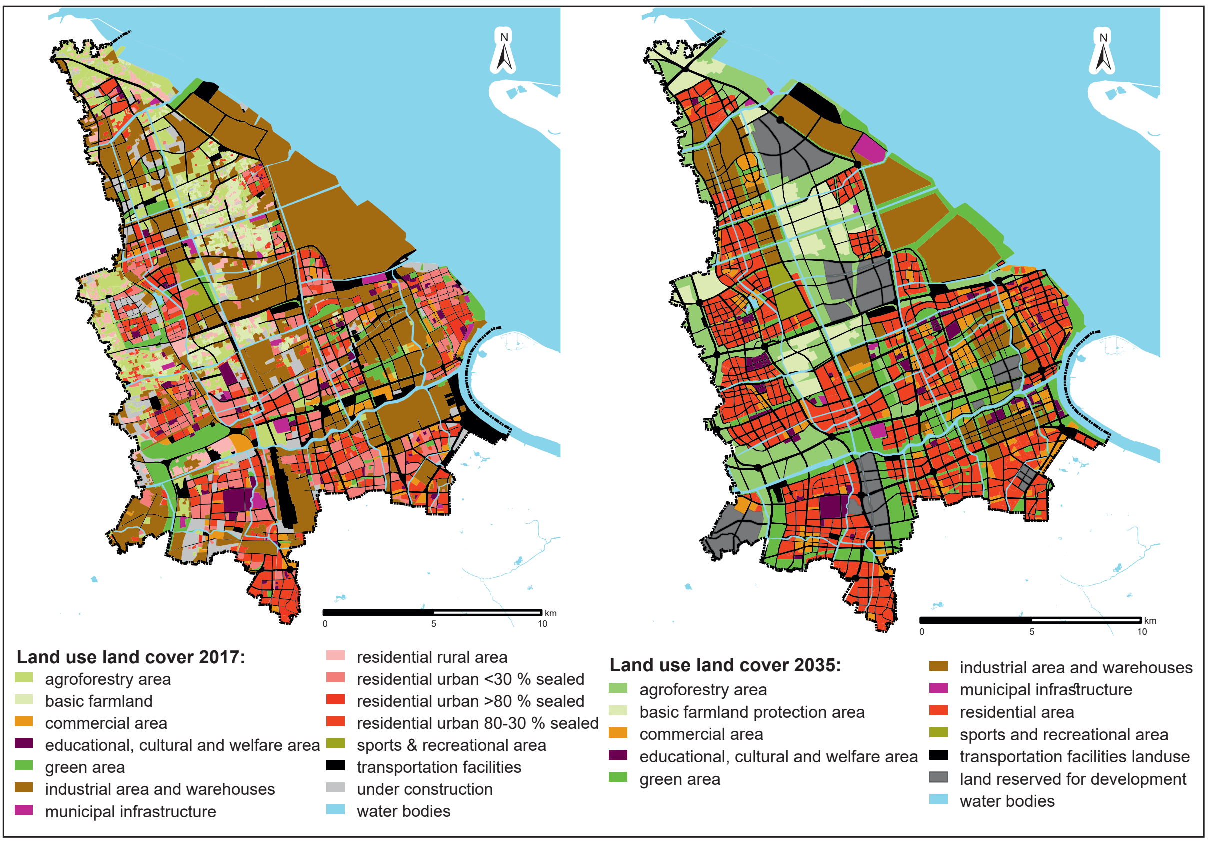

Fig. 2: Land use land cover in 2017 (based on satellite interpretation and existing maps) and for 2035 according to the 'Comprehensive Plan and General Land-Use Plan of Baoshan District 2017-2035' (BDPG 2019).

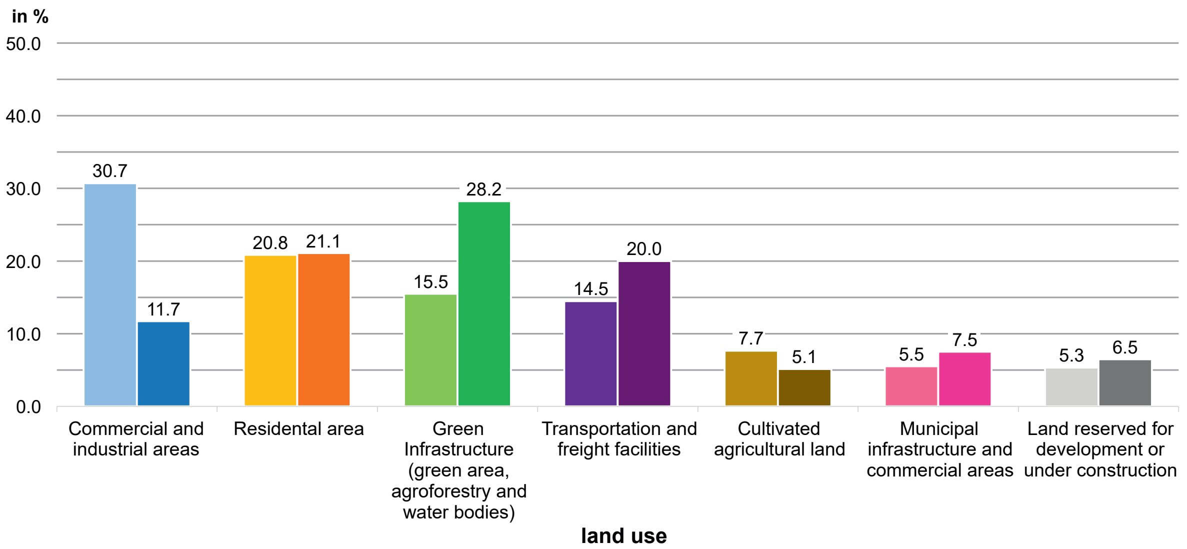

Fig. 3: Prospective land use change between 2017 and 2035 for the Baoshan District, Shanghai. Calculation based on Figure 2.

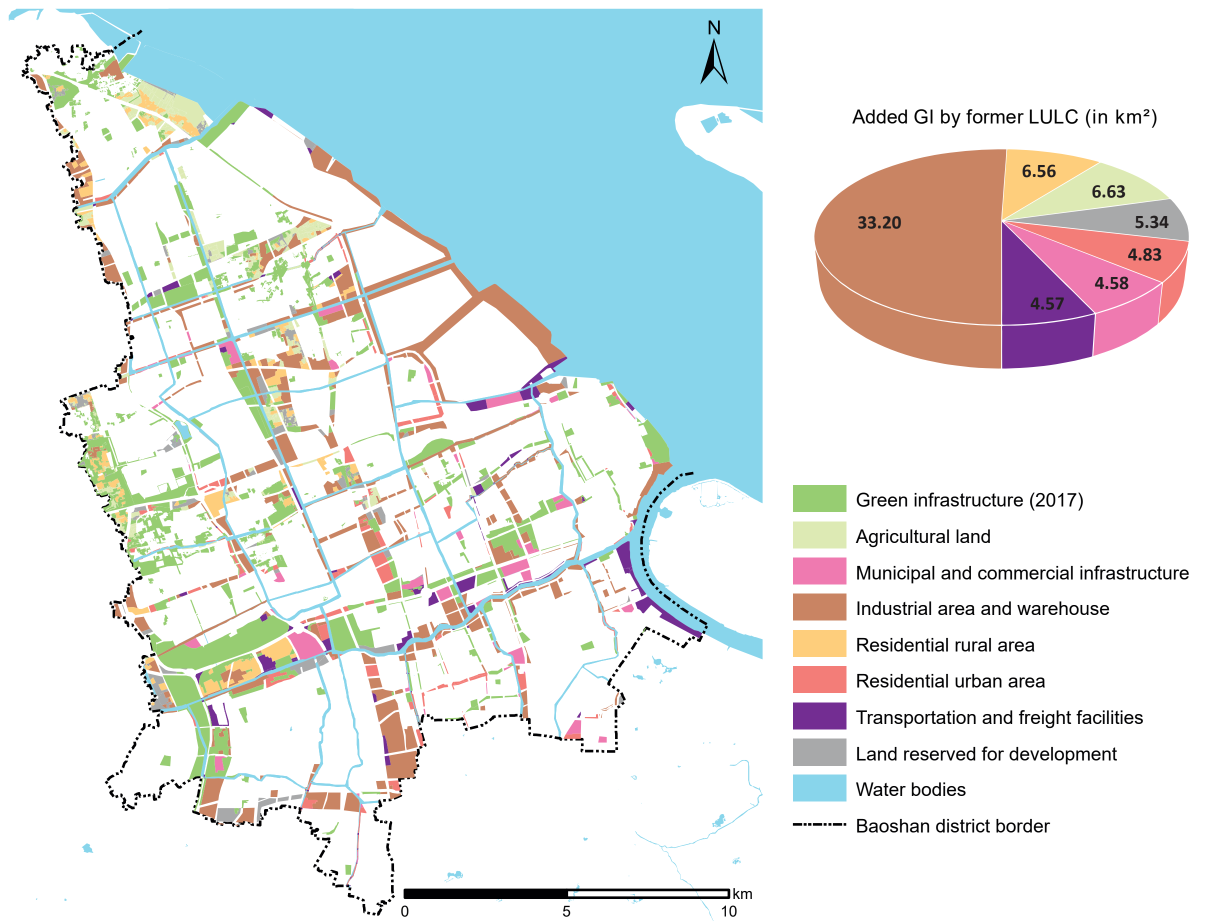

Fig. 4: a) Prospective green infrastructure (GI) in 2035. In the map, the existing GI is shown in green, the potentially added new GI is differentiated according to the original land use in 2017. b) The pie chart quantitatively illustrates the origin of potentially added GI. Map and calculations are based on Figure 2.

5.2 ES assessment matrix

Appendix 1 shows the significance of ES on a scale from zero to five, expressed as the arithmetic mean of the experts' evaluation. The LULC classes are according to Column 3 in Table 1. Urban green areas, forests, and bodies of water exhibit the highest scores. Regulating services reveal the highest significance for most of the LULC classes. In a metropolitan context, cultural ES can play a more important role than provisioning and regulating ES according to the experts' opinions. This is especially the case for "educational", "sports and recreational" LULC and for "urban green areas". With a view of provisioning ES, we noticed that almost all LULC-based maximum values stem from the section of abiotic ES (surface and groundwater used as a material), while biotic ES (aquatic and reared animals for nutritional purpose) delivered almost non-significant levels (close to one) or were even rated as irrelevant (close to zero). The lowest mean ratings were assigned to transportation (0.67), commercial areas (0.80), and industrial areas and warehouses (0.86). Forests, urban green areas, and sports and recreational areas exhibit the highest contrasts between ES. There is a strong contrast with nearly all regulating and cultural services. The same is true for urban green areas. Sports and recreational areas provide respectable cultural services, which is the cause for the contrast to provisioning and regulating ES.

Ratings between the experts varied. The variability increases with decreasing ES significance (Fig. 5a), i.e., the consensus between the experts was higher in the case of LULC, which was rated as providing a higher ES supply. As the data are not normally distributed and no confidence interval can be visualized, Figure 5a depicts the ranges of variabilities that cover 75% of the lowermost variabilities within the five classes of ES significance. This confirms that the experts unanimously rated the strong ES performance of the various LULC systems. The scattergram of the standard deviations as a function of the five significance classes (shown by Fig. 5b) reveals that good agreements occur when mean ratings exceeded 3.5. On the other hand, the dome-shaped distribution illustrates that LULC with irrelevant (insignificant) ES performance (ratings of less than one) was unanimously rated to be low by the experts. Q3 of standard deviations in the ES significance classes 0-1, > 1-2, > 2-3, > 3-4, and > 4-5 are 1.0, 1.5, 1.7, 1.5, and 1.3, respectively.

5.3 Hypothetical changes in ES provision 2017-2035 in terms of contributing areas

Assuming the prospective LULC changes are implemented, ES provisioning in the Baoshan district will increase in terms of areas. The area-weighted changes of ES supplies would be strengthened by 10% to 28% in comparison to 2017 (Fig. 6), depending on the ES considered. Again, provisioning services such

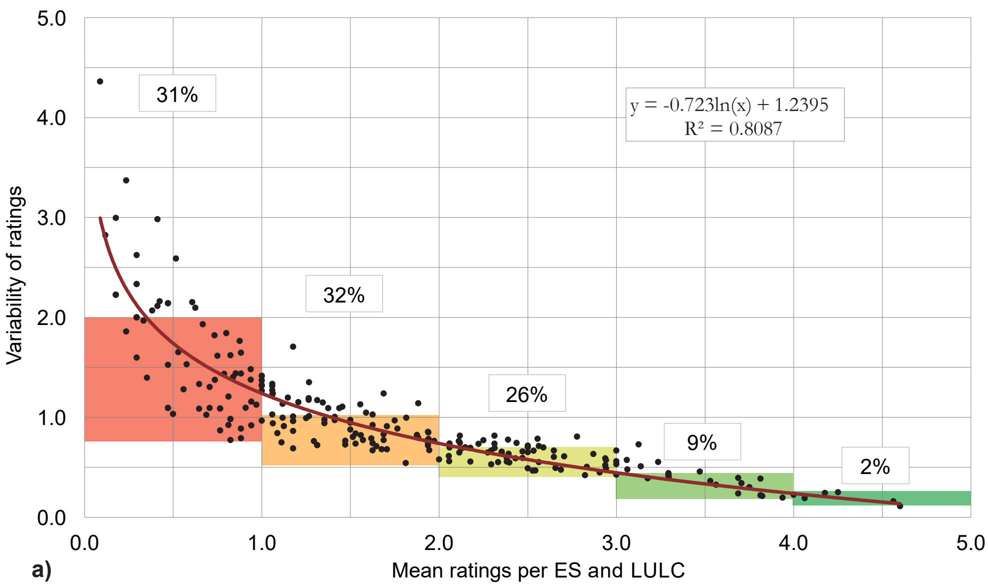

Fig. 5a: Variability of the ratings as a function of mean ratings per ES and LULC. Shaded areas visualize the intervals comprising 75% of the lowermost variabilities of each significance class. Colors are the same as in Appendix 1. Percentages refer to the proportion of all ratings within each significance class. Regression line for illustration only.

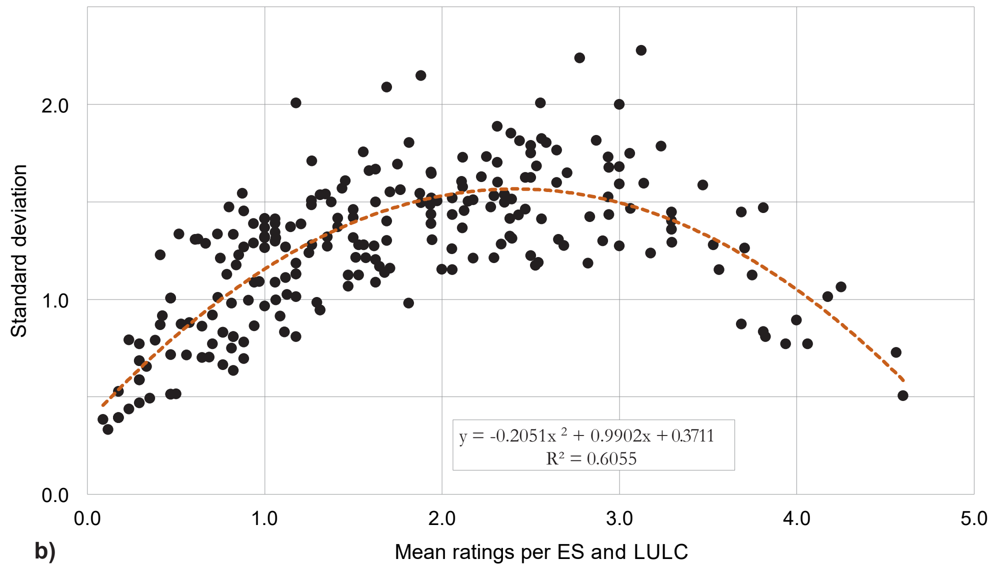

Fig. 5b: Standard deviation as a function of mean ratings per ES and LULC. Regression line for illustration only.

as animals reared by in-situ aquacultures (CICES 1.1.4.1, +3.2%) and surface water used as a material (4.2.1.2, +6.6%) represent the smallest net gain in the supply of ES due to the lack of explicitly added blue infrastructure apart from ditches and ponds in agroforestry and urban green areas. Contrary to that, regulating ES exhibit the largest increase in the supply of ES, especially pollination (CICES 2.2.2.1, +28%) and decomposing and fixing processes and their effect on soil quality (2.2.4.2, +27.3%). Besides this, the planned LULCC will considerably strengthen cultural ES (CICES 3.1.1.1 to 3.2.2.4, +18% to 23.2%).

5.4 Changes in the spatial distribution of ES. Hot and Cold Spot Analysis

The hot spot analysis shows that the spatial structure of supply of ES slightly changes (Fig. 7a), despite the relevant land use restructuring envi-

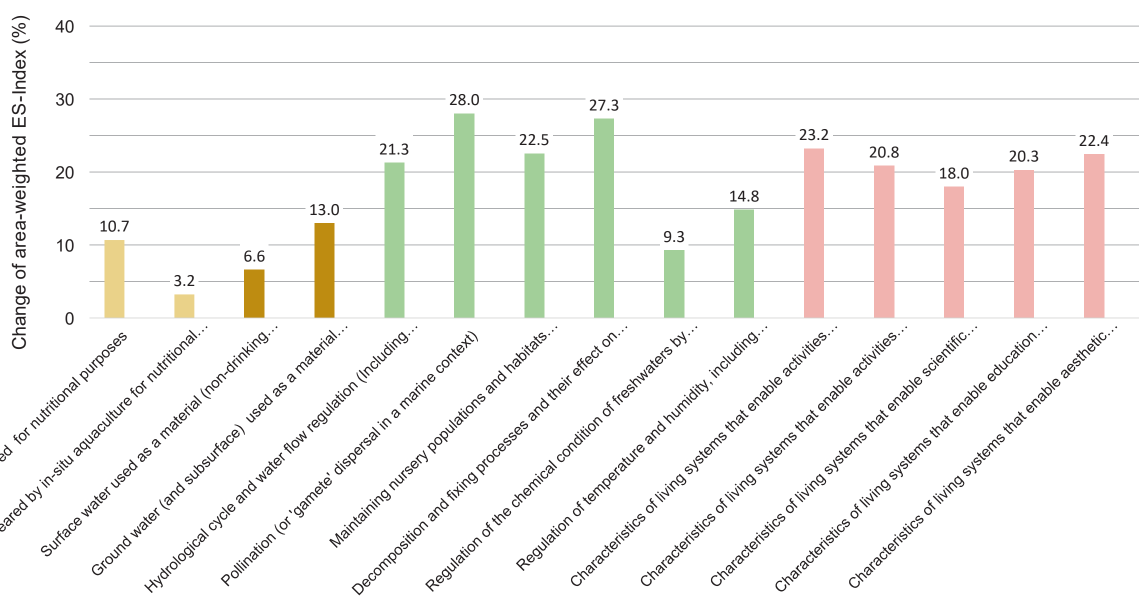

Fig. 6: Change of area-weighted ES-Indices between 2017 and 2035. The index visualizes relative changes to compare the effects on single ES. It does not depict absolute increase of decrease of ES provision.

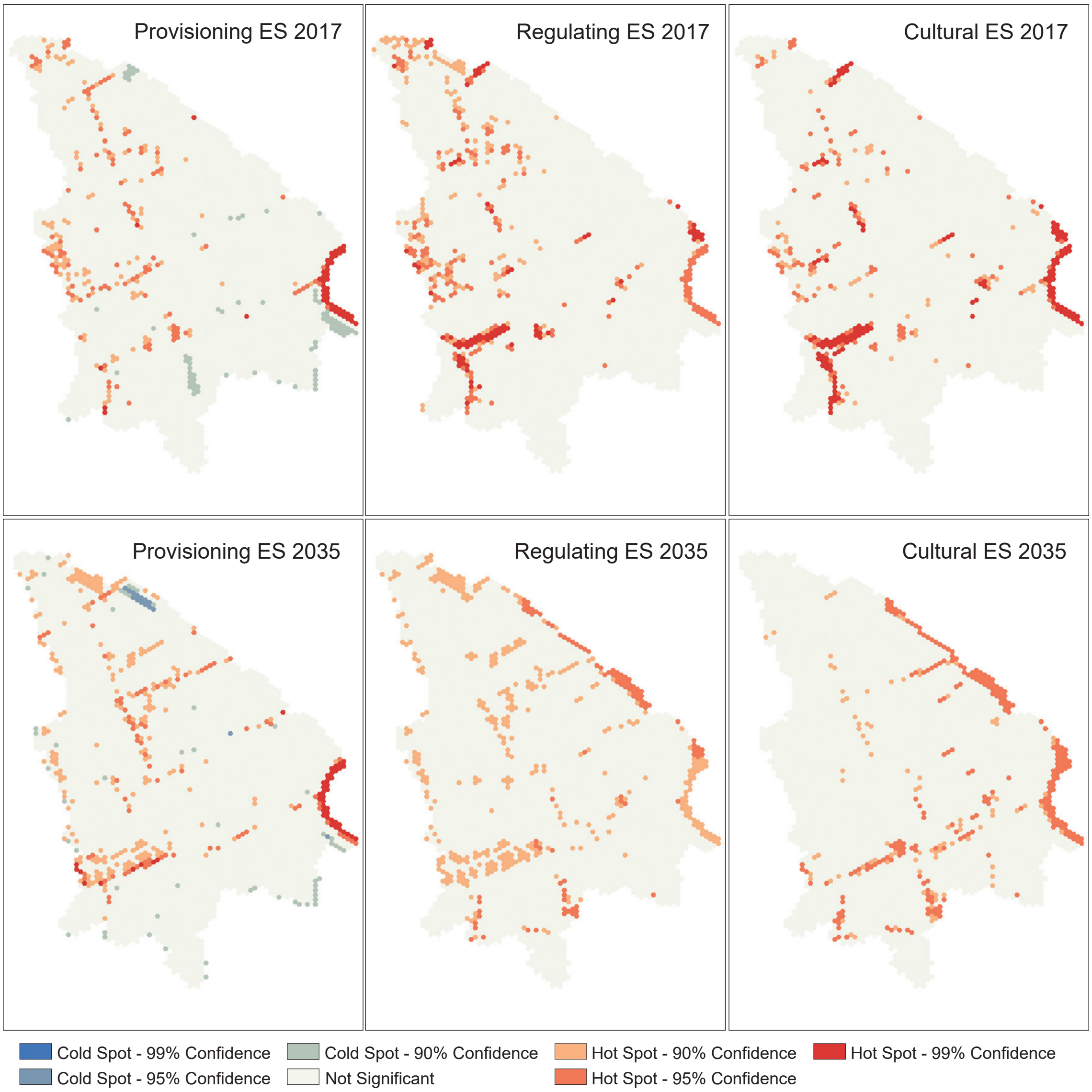

Fig. 7a: Hot (red) and cold (blues) spots of ES in Shanghai 2017 and 2035 showing the areas with high concentration (hot spots) and low (cold spots) concentration of ES provision in the respective year at 99%, 95%, 90% confidence levels.

sioned in the Master Plan. The envisioned changes occur alongside the new ecological network, which will reinforce the current strengths in the supply of ES. For methodological reasons, revitalization of the waterfront along the Yangtze river is not reflected. There might be effects comparable to what the hot spot analysis shows for the area along the Huangpu river. However, the existing lack of ES at the inner residential areas remain. One reason is that the Master Plan depicts the residential blocks as homogenous building blocks (red blocks in Fig. 3). Hence, the hot spot analysis reveals no improvement there. The effect of the Master Plan in the supply of ES is reflected in the spatial structure of clusters (Fig. 7b). We observe a discrete reduction in the spatial extension of low ES clusters, the areas providing the less amount of ES, and also in the extension of high ES clusters.

6 Discussion

Bai et al. (2018, 2) claimed that “China is the first major economy to formulate a national policy, mandating governments to establish ES assessments in land-use planning”. However, reforms from na-

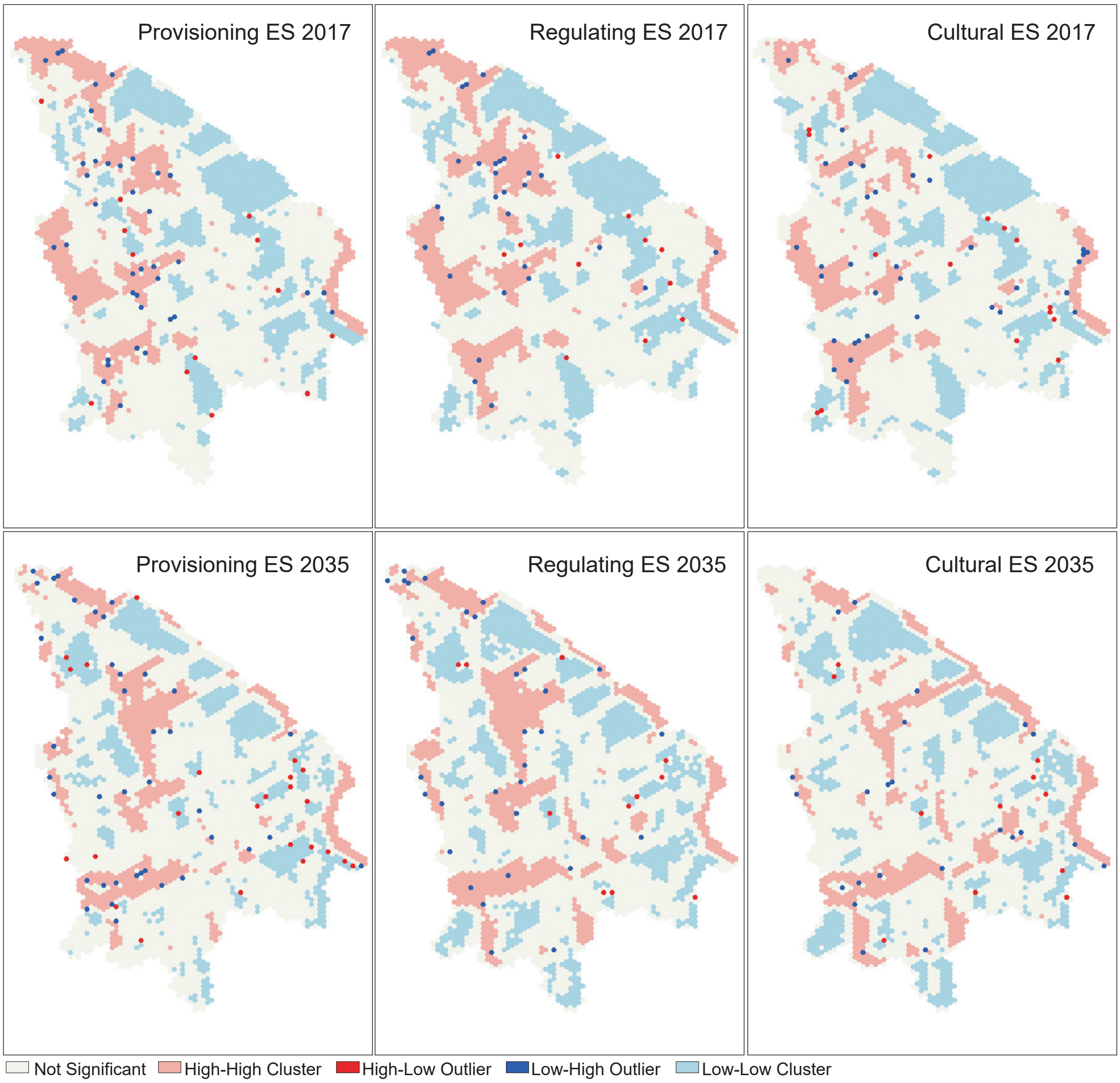

Fig. 7b: Persistence of clusters of high and low ES provision in Shanghai 2017 and 2035. Statistically significant clusters of high ES provision are represented in red and blue where HH (high–high) are high values surrounded by high values; HL (high–low): high values surrounded by low values; LH (low–high): low values surrounded by high values; LL (low–low): low values surrounded by low values.

tional authorities have yet to be implemented at the provincial and local levels. We showed that principles and guidelines addressing eco-terms (e.g., ecological environment, ecological function, ecosystem functions, ecosystem services) entered Master Planning in Shanghai. We verified that, following the multilevel planning system, the ES terminology, including the ecological zoning and ecological red line areas, was transferred to the district level. Our contribution explores to what extent the implementation of the ES concept has already permeated to the urban level, using the Baoshan District in Shanghai as an example.

6.1 Concepts and language

Our analysis was based on official documents written in English and on other documents that we translated from Chinese. We are aware of biases due to translation. However, the intensity with which terms from ecology are used in official documents is noteworthy. What could be observed in Western countries as an obstacle to implementing the ES concept, the translation of ES jargon into layman terms (Verutes et al. 2017) is even more critical in regard to transferring terms into the Chinese language for scientific, planning, and everyday usage.

Spyra et al. (2019b) saw the challenges of developing a cohesive understanding among actors. In countries where the ES concept was newly introduced, the common understanding of ES was first developed in policy regulations, which are in its infancy in China. Chinese scholars have published a broad and manifold body of scientific literature in the English language, including urban ES. In addition to what Albert et al. (2020) call the knowledge-to-action gap, we pointed to the extra challenges of literal translations. When Spyra et al. (2019b) attested to the potential of the ES concept to become the new Esperanto in planning processes, the hurdle to effectively implement this concept in countries with different cultural and linguistic backgrounds should not be overlooked.

6.2 Assessment matrix data base

We used the matrix approach (Burkhard et al. 2012; Roche and Campagne 2019) to outline which effect the '*Comprehensive Plan and General Land-Use Plan of Baoshan District*' might have on future ES provision. The LULC of Shanghai's Baoshan District as of 2017 served as our benchmark to assess prospective changes set forth by the Plan 2017-2035. In contrast to the works of many Chinese scholars who analyzed carrying capacity (Li et al. 2019), delineated tentative ecological red line areas (Bai et al. 2018; Gao et al. 2020), or restricted their analysis to a limited selection of ES, we scanned the full CICES list to select and assess 15 ES. We distinguished up to 18 LULC classes for ES regionalization (shown by Columns 1 and 2 in Table 1) and matrix assessment (Column 3 in Table 1), depending on the classification of available maps and plans, whereas other studies on China ran evaluation models for only a few LULC classes (e.g., Wang et al. 2018).

There are some limitations to our analysis to consider. Being limited to the 16 LULC covered by the land use plan of Baoshan for the year 2035 (Column 2 in Table 1), our mapping assumptions do not allow for more sophisticated ES assessments. Depicted in large-scale polygons, these LULC types do not hold the level of detailed information necessary for biophysically-based ES assessments. A database for ecologically sound assessments, however, should include crucial parameters that affect ecosystem functions, such as biotope structure, soil properties, groundwater flow regimes, urban form characteristics including building heights, technomass, and local climate variables. In the future, more nuanced subdistrict plans and detailed construction plans will shed light on the internal structure of homogeneous LULC classes. These limitations relate to the general shortcomings addressed by Albert et al. (2020). Whereas the regional scale is found to be predestined for ES assessment, lack of data on the local scale is problematic, especially in urban areas (cf. Longato et al. 2021). We interpreted building densities for future residential areas from neighborhoods that were recently constructed. In reality, progress in ecologically friendly design and subsequent construction might attenuate the suboptimal assessment.

6.3 Prospective LULCC and change in ES supply

The prospective loss of agricultural land can be expected. However, the loss of industrial areas is due to both the transformation of partly derelict industrial land and the relocation of small-scale and light industries from central Shanghai began in the late 1990s (Shanghai Urban Planning Institute 2007, 55 and 95; He 2015, 117-119). The first planning drafts assessed in 2019 indicated an increase in GI on plots of state-owned enterprises that had not been explicitly delineated in Shanghai's Master Plan thus far. Overall, there will be a significant increase in GI if the plan is implemented accordingly.

Shanghai's endeavor for net-zero land consumption elaborated in ecological network plans leads to high expectations. The results of our case study of Baoshan showed that, if realized as planned, the district would increase its areas supplying ES. Future waterfront revitalization along the Yangtze River, which is not considered in this study, will affect additional gains in ES supply. The realization of elements of prospective GI will certainly influence the degree to which ES will increase. Optimization of the spatial structure of large residential blocks according to ES demands should also be considered in detail.

6.4 What makes putting ES into practice so difficult

Our analysis confirms similar experiences from other cities and regions (Kopperoinen et al. 2014; Montoya-Tangarife et al. 2017; Mukul et al. 2017; Zepp and Inostroza 2021): Detailed urban planning must explicitly include analysis of ES synergies and trade-offs, along with careful consideration of their spatial distribution to maximize the positive impacts on peoples' well-being, alongside analysis of ES demand (cf. Burkhard et al. 2012, Meng et al. 2020, Shen et al. 2019), for which reliable demographic statistics are indispensable.

Case studies show that proposed changes to land use contained in planning instruments normally diminish the supply of ES, especially the provisioning and regulating ES (Aldana-Domínguez et al. 2019, Shen et al. 2019). The fact that, general urban planning practices do not explicitly include analysis and measurement of ES, as was the case in our example from Baoshan, limits the capacity of plans to assess the future provision of ES.

The existing literature on putting ES into practice is dominated by conceptual papers from outside of China (e.g., Asadolahi et al. 2017, Inkoom et al. 2017, Stepniewska et al. 2017, Tammi et al. 2017, Aldana-Domínguez et al. 2019, Albert et al. 2021), case studies (e.g., Spyra et al. 2019b, Grunewald et al. 2021), and review papers (e.g., Albert et a. 2020, Hersperger et al. 2021, Longato et 2021). We observed a certain homogeneity as to planning instruments in Western contexts, such as the strategic environmental assessment (SEA) implemented in the US and in the European Union (cf. Geneletti 2015), to which the integration of ES was postulated long ago (Geneletti 2011, Mascarenhas et al. 2014) but was not formally implemented in EU directives and national legislations. Rozas-Vásquez et al. (2019) discussed the potential of integrating ES in spatial planning in general and especially in SEAs. They concluded that there is still a lack of scientifically sound and policy-contextual guidelines. ES were included in the national guidelines for sustainable spatial planning (Rozas-Vásquez et al. 2018) in Chile. The EU (EU-commission 2013) also included ES on the political agenda and supported numerous research projects. ES is promoted in action plans at the federal level in Germany but has not yet entered spatial planning legislation.

7 Conclusion

We now return to the initial question of how far the concept of ES has already been embedded within the institutional reforms of environmental governance in China. Longato et al. (2021) pointed to the fact that supportive frameworks foster the implementation of the concept of ES in planning. China's environmental governance reforms thus might offer a window of opportunity. However, the introduction of ES thinking and its transformative effect on established planning procedures is still in its infancy in China and in most other countries. The forthcoming regulatory frameworks may serve as vehicles for institutional optimizations. The role and significance of GI and environmental governance in Shanghai have rapidly changed during the last few decades. In the past, master plans to establish GI emerged without ecological integration in terms of a strategically developed GI (Dong 2006, 207). Therefore, the inclusion of ES in official planning documents marks a milestone for China. Pilot cities such as Shanghai can lead the way by providing initial blueprints and benchmarks for China's future urban development at the metropolitan level. Whereas China is well known for constructing new towns and designing cities following the eco-city concept (de Jong et al. 2016), Baoshan District may serve as a benchmark for the transformation of old-industrialized districts in other Chinese cities.

Our example shows that, in the future, careful consideration should be spent on the fine-grained supply of ES within areas depicted as homogenous LULC in land use plans in China and in other parts of the world. To this end, intelligent policy designs are needed. Detailed planning could largely contribute to a performance-based assessment of ES that will help balance ES demand and supply. Stronger consideration of integrated ES approaches could lead to ecologically healthier urban environments.

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Appendix 1: Graded significance of ES (derived from CICES 5.1) by LULC class for Shanghai. Calculations based on results of an expert workshop held in 10/2019. Contrast (bottom row) is the range between highest and lowest ratings.

Class	Residential / Urban / >80 sealed	Residential / Urban / 30-80 sealed	Residential / Urban / < 30 sealed	Residential / Rural	Urban Green Areas (parks)	Agricultural Land	Greenhouses
Animals reared for nutritional purposes	0.2	0.2	0.6	1.5	1.1	1.8	1.6
Animals reared by in-situ aquaculture for nutritional purposes	0.2	0.3	0.4	0.9	0.9	0.6	0.4
Surface water used as a material (non-drinking purposes)	1.9	2.7	2.7	2.9	2.9	2.4	2.3
Ground water (and subsurface) used as a material (non-drinking purposes)	1.6	2.1	2.5	2.6	2.9	2.9	2.6
Hydrological cycle and water flow regulation (Including flood control)	1.4	1.6	2.1	2.3	3.8	3.1	2.5
Pollination (or ‚gamete' dispersal in a marine context)	1.3	1.7	2.1	2.5	3.8	3.3	2.8
Maintaining nursery populations and habitats (Including gene pool protection)	0.8	1.1	1.6	2.0	3.6	2.7	2.6
Decomposition and fixing processes and their effect on soil quality	0.8	0.9	1.5	2.1	3.9	3.1	3.1
Regulation of the chemical condition of freshwaters by living processes	1.0	1.1	1.3	1.6	2.5	2.3	1.9
Regulation of temperature and humidity, including ventilation and transpiration	2.1	2.2	2.5	2.5	3.8	2.9	2.6
Characteristics of living systems that enable activities promoting health (active)	1.6	1.7	2.1	2.4	4.6	2.3	2.3
Characteristics of living systems that enable activities promoting health (observational)	1.5	1.6	2.4	2.8	4.3	2.4	2.4
Characteristics of living systems that enable scientific investigation	1.0	1.1	1.3	1.1	4.0	2.4	2.5
Characteristics of living systems that enable education and training	1.0	1.1	1.3	1.2	4.1	2.3	2.4
Characteristics of living systems that enable aesthetic experiences	1.3	1.4	1.9	2.1	4.6	2.4	2.1
Maximum Provisioning Service	1.9	2.7	2.7	2.9	2.9	2.9	2.6
Maximum Regulating Service	2.1	2.2	2.5	2.5	3.9	3.3	3.1
Maximum Cultural Service	1.6	1.7	2.4	2.8	4.6	2.4	2.5
Contrast	1.9	2.5	2.3	2.0	3.7	2.7	2.7

Agroforestry	Forest	Water Bodies (river)	Water Bodies	Commercial Area	Industrial Area and Warehouses	Sport and Recreational Area	Educational, Cultural	Transportation Facilities	Municipal Infrastructure	Land reserved for Development/ Under Construction
1.9	1.3	2.1	1.1	0.3	0.3	0.2	0.5	0.2	0.3	0.1
1.1	0.8	3.8	3	0.5	0.5	0.2	0.4	0.1	0.3	0.3
3.0	3.2	3.3	3.1	1.7	1.6	1.3	2.0	0.8	1.9	2.6
3.0	4.7	2.5	1.9	1.2	1.1	1.5	1.5	0.7	1.4	2.2
3.8	4.5	3.8	2.8	0.8	0.8	1.0	1.3	0.8	1.1	1.4
4.2	4.5	2.3	1.7	0.6	0.7	1.1	1.2	0.7	0.9	1.5
3.7	4.3	3.4	2.1	0.5	0.5	0.8	1.1	0.4	0.7	1.2
3.5	4.8	1.9	1.2	0.3	0.4	0.9	0.8	0.3	0.5	0.9
2.5	4.0	4.5	3.2	0.6	0.9	0.7	0.8	0.5	1.3	1.0
3.5	3.5	3.8	3.0	1.4	1.8	1.9	1.7	1.5	1.6	2.3
3.7	4.3	4.0	2.4	1.2	1.1	3.3	2.3	0.9	1.3	1.9
3.3	4.0	4.1	2.5	0.8	0.8	2.4	1.8	1.0	1.6	1.7
3.2	4.8	4.1	2.1	0.5	0.9	1.2	1.8	0.7	1.0	1.0
3.3	4.7	4.1	2.2	0.6	0.8	1.9	2.6	0.6	1.4	1.0
3.7	4.8	4.6	2.9	0.9	0.9	1.5	1.9	0.8	1.3	1.5
3.0	4.7	3.8	3.1	1.7	1.6	1.5	2.0	0.8	1.9	2.6
4.2	4.8	4.5	3.2	1.4	1.8	1.9	1.7	1.5	1.6	2.3
3.7	4.8	4.6	2.9	1.2	1.1	3.3	2.6	1.0	1.6	1.9
3.1	4.0	2.7	2.1	1.4	1.5	3.1	2.2	1.4	1.6	2.5