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EDITORIAL

Promoting sustainable landscape pattern for landscape sustainability

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Background

As a consequence of the global scientific interest in sustainable development, sustainable landscape patterns have been proposed following the research paradigm "spatial pattern—ecosystem processes/functions—ecosystem services—human well-being" and become a frontier research topic in the intersection of landscape ecology and landscape sustainability science (Cumming et al. 2017; Wu 2013). Sustainable landscape patterns describe a typology of landscape that provides the ecological benefits required to meet the economic, social and ecological demands of both present and future generations (Wu 2013). This novel concept is supported by the scientific community studying landscape ecology and sustainability science, and forms a tangible target for ecosystem-based management approaches (Musacchio 2013; Peng et al. 2018b). There are several typical sustainable landscape patterns which could be distinguished depending on the various environmental protection targets and regional development needs. For example, 'urban growth boundary' (UGB) ensures the protection of sustainable ecosystems in the context of rapid urbanization characterized by intensified habitat fragmentation (Huang et al. 2019). Whereas, 'ecological network' (EN), a concept rooted in landscape connectivity, provides an operational approach for conserving biodiversity (Hofman et al. 2018), and 'green infrastructure' (GI) shows a vision of a cost-effective, nature-based solution for ecosystem maintenance as well as social development (Matthews et al. 2015). Finally, 'ecological security pattern' (ESP) provides an integrated focus on individual or coupled landscape elements which can protect and enhance regional ecosystem structures, functions and services (Peng et al. 2019).

Sustainable landscape patterns emphasize the coupling of spatial patterns, social-ecological processes and ecosystem services across multiple disciplines, including landscape ecology, urban planning and

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landscape design. Hence, identifying and preserving sustainable landscape patterns will not only provide basic regional protection for critical ecosystem services and a healthy living environment, but can also be seen as an effective measure to control in a sustainable way the threats imposed by anthropogenic activities (Peng et al. 2018a). Consequently, planning, designing and constructing sustainable landscape patterns to effectively preserve regional ecological stability and security is an important way to maintain regional sustainable development. This special issue is a collection of innovative contributions focusing on sustainable landscape patterns, including but not limited to landscape sustainability science, UGB, EN, GI and ESP.

Overview of the special issue

In reviewing the contributions to the special issues, there are three themes that emerge as current issues in the field of sustainable landscape patterns:

(i) Methods related to observing and forecasting of pattern typologies. Here the interest is in gaining a better understanding of the patterns themselves, and their resilience as well as stability over time.
(ii) Assessment of the societal value of these landscapes in terms of natural capital and ecosystem services.
(iii) The development of planning and design approaches with respect to sustainable landscape patterns, and how to optimize these patterns for conserving natural ecosystems and enhancing ecosystem services provision.

Observation and simulation of landscape patterns

There are five papers within the topic of 'observation and simulation of landscape patterns', which provide support for data analysis as well as mapping the past and future distribution of elements of sustainable landscape patterns.

Urban landscapes are highly dynamic with changes frequently occurring at short time intervals, which has been an obstacle in observing and understanding urban landscape change in time series. This is particularly a challenge where rapid urbanization occurs (Nor et al., 2017). Yu et al. (2021a) addressed this challenge by integrating object-based image analysis with time-series change detection techniques on all available Landsat images for Shenzhen City, China from 1986 to 2017. The new approach could accurately and efficiently detect urban landscape changes for facilitating sustainable landscape planning.

Identifying high-resolution urban landscape patterns with distinct spatial configuration and their thermal properties is not well explored in recent studies. Zawadzka. et al. (2021) made a key contribution in this context based on a two-tiered unsupervised k-means clustering approach to subdividing major land cover classes according to the relationship between land surface temperature and urban form patterns at fine spatial resolution in three medium sized towns within the UK. The new approach to mapping land cover typologies could promote the practice of mitigating urban heat island effect.

To support sustainability, it is of great importance to algorithmically optimize land-use planning from a spatial point of view. In that respect, Gao et al. (2021b) assessed the two NSGA-II algorithms for sustainable land-use optimization based on the improved initialization, crossover, mutation and additional resultant solutions. Furthermore, they developed an evaluation framework of four hierarchal levels to compare the usability of two improved NSGA-II algorithms through six indicators characterizing effectiveness, efficiency, and satisfaction.

As the effects of environmental, social and economic variables on urban growth of intermountain basins are less emphasized, Wang et al. (2021a) applied generalized linear regression and random forest models to quantify the importance of basin configuration, topography, climate, administrative structure and roads. In this study it was shown that understanding the effect of physical and socio-economic factors on urban landscape patterns played an important role in achieving urban sustainability in mountain areas.

As oases in China are experiencing large-scale land use change, the future effects of the land use policies on oasis landscape sustainability should be investigated urgently. Consequently, Gong and Liu (2021) simulated 56 land use change scenarios for these particular environments considering six land-use policies in order to explore their effects on three key

ecosystem services and the water stress index. The results showed that these policies would lead to an increase in water consumption despite the improvement of ecosystem services and as such would not comprehensively improve the landscape sustainability on the long term.

Evaluation of landscape services

There are six papers covering the subject of 'evaluation of landscape services', which provide methodological supports for evaluating the functional attributes in sustainable landscape pattern management as well as for spatial planning.

Quantifying the dynamics of integrated landscape and seascape carbon flows under the natural and anthropogenic changes is critical for promoting coastal sustainability. As such, Fan et al. (2021a) developed a spatial carbon flow network model of land-sea integration to analyze the associated temporal carbon dynamics within a typical coastal city (Xiamen in China) during the period 2000–2015. The results showed that total coastal carbon flows were four times greater than that on land, and the coastline was characterized by a remarkable carbon deficit. The findings could provide support to coastal restoration programs aiming for an optimization of the coastal land-sea-scape.

GI is an effective approach to enhancing the sustainability of the urban social-ecological fabric through providing multiple ecosystem services. Within this context, Wang et al. (2021b) used biophysical models and social questionnaires to assess GI multifunctionality and developed an adaptive model to improve GI multifunctionality for local planning practice. This study also offered new insights into how we could bridge the gap between landscape sustainability science and urban planning.

As an in-depth understanding of the relationships between ecosystem services demand and supply is still lacking, Yao et al. (2021) calculated the associated deficit ratio and supply–demand ratio in order to determine whether annual or seasonal mismatches between ecosystem services demand and supply existed, and further analyzed the extent to which ecosystem services supply met demand. This study clearly underlined that the quantification of ecosystem services demand–supply relationship across different temporal scales would be useful to decision-makers in developing targeted strategies for sustainable urban development.

The Qinghai-Tibet Plateau is an important geographical region with unique but fragile ecosystems in which key landscape services should be assessed quantitatively for regional sustainability. Hence, Hou et al. (2021) explored the relationships of multiple landscape services within this particular region in order to identify the associated key influencing factors considering specific landscape gradients. Subsequently, according to the trade-offs and synergies of landscape services, sustainable management guidelines were further proposed in a climate change and national policy context.

Studies on the effect of landscape configuration on ecosystem service trade-offs and synergies in urban areas are limited. To address this shortcoming, Karimi et al. (2021) applied a Bayesian Belief Network to predict ecosystem service trade-offs and synergies in urban areas. This allowed them to analyze whether landscape configuration affected the provision of ecosystem services and could drive their interactions, which can contribute to urban planning and ecosystem management.

It is crucial for sustainable landscape management to quantify ecosystem service values according to the government policies of developing land and protected areas. Jin et al. (2021) simulated the land use change under different scenarios based on forecasted land expropriation prices implemented by the government of Hubei Province in China. In addition, sustainable landscape management strategies of controlling ecosystem service loss risks were proposed based on the measurement of ecosystem service values under future land use change scenarios.

Construction of sustainable landscape patterns

There are nine papers within the topic of 'construction of sustainable landscape patterns', which introduce various new indicators and methods, and provide spatial planning indications for optimizing sustainable landscape patterns.

As ecological corridors that allow migratory birds to access urban green landscapes are essential for conserving biodiversity in urbanized areas, Liu et al. (2021) used three-dimensional landscape data and

historical eBird records in order to identify the flight corridors for migratory birds across Shenzhen City in China. The identified flight corridors in and around the city could be used to link natural reserves with urban parks, and hence, provide key insights for enlarging bird habitats and conserving biodiversity across the city.

In recent years, regional ENs play an important role in biodiversity conservation. An et al. (2021) constructed ENs for the conservation of Asian elephants affected by human disturbance, with a special focus on the importance of steppingstones. The results showed that the source areas could be effectively determined through the integration of morphological spatial pattern analysis and the patch importance index. It was concluded that introducing the conservation of small steppingstones would have a strong impact on improving landscape connectivity.

Connectivity modeling is the basis for assessing the effectiveness of ENs in nature conservation and land use planning, as well as for human recreation. As such, Beaujean et al. (2021) combined the least-cost model and circuit model to (i) identify urban priority corridors, (ii) assess the connectivity and (iii) identify critical connections for both human recreation and natterjack toad movement. The combined model was proved to be useful in supporting ENs to protect biodiversity, ecological processes and ecosystem services, as well as guide urban planning for the maintenance and improvement of existing green corridors.

Climate connectivity is an interesting concept to understand the future spatial configuration of ENs and assess associated impacts on species under projected climate change settings. Within this context, Su et al. (2021) used human footprint and current as well as future temperature to analyze and compare the distribution of ecological sources, corridor patency and climate connectivity across the Yangtze River Delta urban agglomeration. In this particular study a range of scenario with or without corridors as well as different levels of climate warming were considered. The results highlighted that linkage migration through enhancing climate connectivity could guarantee species to tolerate higher level of warming.

There is a lack of ESP research on geologically fragile regions such as karst areas often characterized by important ecological shelters which are endangered by significant land use conflicts. Gao et al. (2021a) addressed this knowledge gap by analyzing ecosystem services and ecological sensitivity within the context of the rocky desertification process in karst regions. More precisely, they modelled the expansion probability of construction land and cultivated land in order to create a resistance surface in ESP, which is a key methodological improvement to ecologically assess this particular type of ecosystems.

As ESP should not only protect regional ecological processes but also meet human needs for ecosystem services (Zhang et al. 2017), Jiang et al. (2021) introduced the index of comprehensive supply–demand ratio of ecosystem services in order to identify ecological sources using an improved resistance surface based on nighttime light data. The results showed that this novel ecosystem service supply–demand methodological framework provided new perspectives for ESP construction.

There is a lack of attention paid to the scale effects in ESP construction. In order to address this shortcoming, Dong et al. (2021) assessed the ecosystem service importance and integrated the ecological sources from both local and interregional scales, and subsequently, identified the associated ecological corridors, followed by comparing the differences of ESPs under different study extents using several landscape metrics. The results showed that compared with ESP in the local perspective, the corridor connectivity could be enhanced, and local ecosystem conservation needs would be met simultaneously through integrating the local and interregional perspectives.

Most of the urban green infrastructure studies are case-based and explore the effects of the existent landscape pattern on urban heat island mitigation rather than modeling an optimized spatial pattern. Hence, Yu et al. (2021b) classified three urban green infrastructure types, i.e. "ecological, efficient, and elementary", combined with two physical landscape properties, i.e. "size and cooling distance", and proposed an idealized urban thermal security pattern model conformed to a theoretical hierarchical hexagonal structure. The latter could be successfully applied in a climate adaption planning context.

When setting the goal of landscape sustainability in landscape management, a key theoretical question should be which landscape patterns are the most sustainable. However, only few studies focused on comparing optimization scenarios in this particular

context. Through predicting three landscape services under the RCP 2.6, RCP 4.5 and RCP 8.5 scenarios with the year of 2020 and 2030, Fan et al. (2021b) constructed and compared corresponding simulated ESPs for the Qinghai-Tibet Plateau. This study showed the potential of using ESP scenarios to quantitatively assess the sustainability of landscape patterns.

Conclusion

In conclusion, sustainable landscape pattern that emphasizes the coupling of spatial patterns, social-ecological processes and ecosystem services, is a conceptual intersection of landscape ecology and landscape sustainability science. Furthermore, sustainable landscape patterns are constructed through taking regional social-ecological elements into account, which offer the opportunity to address practical needs of achieving multiple sustainable development goals in current spatial planning. Aiming at promoting landscape sustainability, the original research papers in this special issue mainly focused on (i) the observation and simulation of landscape patterns, (ii) the evaluation of landscape services, and (iii) the construction of sustainable landscape patterns. In this special issue, the current research frontier of sustainable landscape patterns was clearly highlighted. Moreover, it is shown that the concept of sustainable landscape patterns has a tremendous potential to become a key topic within sustainability science because of the specific focus on long-term social-ecological sustainability under the increasing trend of anthropogenic disturbance across a range of spatial and temporal scales.

However, as sustainable landscape patterns are still a novel field of research, further contributions are required in order to build a more complete framework linking theory with practice. Within this context, there are great challenges such as the acquisition of novel and pertinent datasets as well as the development of scientifically based methods for the robust evaluation and simulation of sustainable landscape patterns. Hence, the identification, design and development of more functional sustainable landscape patterns will be key for supporting future landscape planning. New theories and improved methods, such as ecosystem service flows (Schirpke et al. 2019), biodiversity offsets (Shumway et al. 2018), meta-coupling framework (Liu 2017) and nature-based solutions (Xie and Bulkeley 2020), will increasingly promote the development of various sustainable landscape pattern related research fields.

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

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