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Editorial

Feature Papers in Landscape Ecology: An Editorial Overview

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1. Introduction

Landscapes can be seen as important socio-ecological systems. They are both the place and the scale at which humans interact with the environment [1]. They can be described as spatially heterogeneous geographic areas characterized by diverse interacting patches or ecosystems. They range from relatively natural terrestrial and aquatic systems to human-dominated environments such as agricultural and urban settings. This broad definition emphasizes that when we study landscapes, we are investigating areas that can sit somewhere on a gradient of mostly natural to intensively modified by human activity.

As society has grappled with the increasing need to acknowledge and mitigate the damage caused by the intensive use of landscapes to satisfy the ecosystem service requirements of a growing global population, the important meta science of landscape ecology has evolved. Its focus is on studying and improving the relationships between ecological and environmental processes and particular ecosystems at a variety of landscape scales and organizational levels relevant to research, policy, and management. Landscape ecology specifically seeks to integrate knowledge of human activities influencing patterns and processes and provide information that is helpful for land use planning and sustainable landscape management. As such, landscape ecology is interdisciplinary and sits at the interface of the biophysical and socioeconomic sciences. In its short time as a discipline, it has predominantly focused on the relationships between patterns, processes, and changes, but has expanded in recent years to incorporate important considerations around design and value to mitigate the risks and challenges associated with unsustainable landscape change and climate change.

In this Special Issue, 'Feature papers in landscape ecology' (SI), we aimed to bring together articles that highlighted the wide-ranging complex environmental problems and challenges that landscape ecology can be utilized to address and to showcase the many types of research and analyses conducted in the field. The 14 articles that have been published show a diversity of applications for landscape ecology theory and practice. The manuscripts also consider some of the wider challenges facing landscape ecology itself as it progresses and evolves through the 21st century.

In recent years, there has been some discussion of key research themes in landscape ecology [2,3]. With advancements in spatial and temporal analysis capabilities at multiple spatial and temporal scales, landscape ecology has developed the capability to examine

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patterns, processes, and changes with increasing definition and accuracy. The research presented in this SI demonstrates that spatial pattern analysis remains a key focus of landscape ecology today, as previously outlined by Wu [3] when he discussed key concepts and research topics. The importance of understanding landscape heterogeneity and the impact of homogenizing previously heterogeneous landscapes are discussed in multiple papers in this SI in the context of urban development and natural resource management. Similarly, some papers quantify and aim to understand the implications of land use and land cover change and examine the consequences of increasing fragmentation and loss of connectivity for biodiversity and other landscape processes. To conduct these studies, remote sensing and GIS are essential tools, and this is reflected in the number of papers in this SI utilizing this particular technology and data source.

Other key themes for landscape ecological research that emerge in this SI are landscape design, landscape–climate change interactions, and landscape sustainability, which are also consistent with Wu's emerging 'hot' topics [3]. An additional theme highlighted in this SI is that of people in landscapes, e.g., understanding the impact people have on landscape changes when interacting with more natural processes is explored in the form of socio-geomorphic units, as is the importance of people–landscape connections and the sense of place which recognizes the long-standing relationships that people have formed with landscapes and how understanding this better can assist in more effective landscape management.

2. Contributions of the Special Issue Papers

The articles presented in this SI come from researchers from across the globe, emphasizing the global reach of modern landscape ecology. The papers provided demonstrate work conducted in China, Lithuania, Brazil, Argentina, the Galapagos Islands, Italy, the USA, and Australasia. Together, these articles can provide a snapshot of landscape ecological research being carried out internationally to bring about beneficial ecological and environmental outcomes in a world facing the challenges of feeding and housing a growing population amongst the threats and uncertainty of climate change and environmental degradation responsible for the extensive loss of biodiversity.

As the global footprint of human activity increases, the pressures associated with urbanization and development mean that there is a pressing need to optimize landscape patterns to reduce environmental and ecological degradation and maintain important landscape functions and ecosystem services. Habitat fragmentation and loss of connectivity in landscapes pose particular challenges to important landscape processes and maintaining biodiversity. Understanding this change and introducing remedial action to reduce its impact is vital for sustainable landscape management and the preservation of ecological integrity. Mapping, monitoring, and measuring landscape patterns with the optimization of landscape patterns in mind is a focus of several papers in this SI. Many of the authors in this SI apply state-of-the-art spatial analysis tools and high-resolution remotely sensed imagery alongside landscape ecology theory to quantify changes to patterns and processes and to make recommendations for optimal spatial configuration for landscapes to ensure the best social and ecological outcomes.

One area of particular focus is the application of landscape ecology to explore the implications of the loss of more natural environments to urban development. This is a major problem in developing countries, and in particular in nations with high urban growth like China. The environmental and ecological implications of this are discussed in several papers in this SI with a strong emphasis on using landscape ecological theory to reduce ecological risk and vulnerability. For example, Wang et al. (List of Contributions) examine changes to landscape structure due to land use change caused by urbanization and try to quantify and reduce the landscape ecological risks associated with this by optimizing landscape patterns. They apply a landscape ecological risk assessment method (ERI) and a minimum cumulative resistance model (MCR) based on landscape ecological theory to try to reduce the risks associated with increasing fragmentation and decreasing

ecological connectivity in the landscape. The landscape ecological risk assessment provides an assessment of environmental vulnerability and optimizing landscape structure in the study area of Jinan, Shandong Province, China through recommendations of returning farmland to forestry and constructing ecological corridors that provide an opportunity to strengthen the regions ecological resources.

Also in China, in Hangzhou City, Hu et al. (List of Contributions) additionally investigate the optimization of landscape patterns with a view to addressing ecological challenges. They apply a landscape index analysis to Landsat-8 remotely sensed data to explore the spatiotemporal evolution of landscape patterns in urban areas at the district scale and apply multiple regression analysis to explore the drivers of change utilizing Fragstats 4.2. The indices investigated in their study included indices at both the patch and landscape level. At the patch scale, these included percent of land, largest patch index, patch density, edge density, and landscape shape index. At the landscape level, they included aggregation index, contagion index, landscape division index, and Shannon diversity index. They found that urban and industrial growth associated with an increasing population were the main drivers of changes to landscape patterns and made suggestions as to how to best optimize landscape patterns to promote ecological restoration.

Furthering the discussion of the ecological challenges of urbanization in China, Jiang et al. (List of Contributions) examine the importance of landscape design for ensuring effective operation of important landscape processes. Urban development can be responsible for disruptive surface and subsurface flows through an increase in impervious surfaces. They suggest that creating a 'sponge city' utilizing aquatic plants within the landscape design process can reduce the water flow speed within urban environments and help to increase the penetration of runoff, thus preventing damage due to water-based erosion. Aquatic plants used in this way can also help to absorb nutrients, reducing runoff with high nutrient content, and emulate conditions more consistent with undeveloped environments. The authors therefore explore the optimum design required to assist environmental management of urban environments and the sustainable development of cities that focus on environmental protection.

Continuing with the theme that landscape design is critical in the future sustainable development of urban environments, Zhu et al. (List of Contributions) explore the use of future development scenario selection to manage regional eco-environmental risk. They use a Patch-Generating Land Use Simulation (PLUS) model for the simulation of land use data between 2030 and 2050 under two scenarios: one of natural development and another of ecological protection in the Chengdu–Chongqing Economic zone, Southwest China. In their study, they analyze trends in landscape ecological risk and make recommendations about regional landscape optimization and risk reduction with the ecological protection scenario being determined conducive to reducing risk.

Further discussion of landscape ecological risk is explored by Zhang et al. (List of Contributions), who explore the importance of minimizing risk and promoting ecosystem services for the sustainable development of watersheds. Looking at the study area of the Min River Basin, Fujian Province, China, they also utilized a PLUS model as a predictive tool to predict land use distribution in 2030. Alongside this, they undertook a landscape ecological risk assessment, applying the InVEST tool as well as Carnegie–Ames–Stanford (CASA) models and a coupling coordination model to evaluate risks and ecosystem services under five shared socioeconomic pathways. The research presented assists with decision making to reduce landscape ecological risk and improve ecosystem functions within the watershed, further demonstrating the important role for landscape pattern optimization for sustainable development.

Creating sustainable future landscapes to preserve ecological integrity is a theme for many of the papers in this SI. Crucial to this will be the ability to monitor and evaluate the quality of the environment under scenarios of change. Focusing on evaluating environmental quality, Zhang et al. (List of Contributions), working in Guangzhou, China used a principal component method to generate an index of environmental quality. The Optimal

Parameter Geographic Detector (OPGD) model and the R package Relaimpo were used to quantitatively analyze the contributions of the Normalized Difference Vegetation Index (NDVI), wetness (WET), normalized differential build-up and bare soil index (NDBSI), and land surface temperature (LST) to the remote sensing ecological index (RSEI). This provides useful insights to assist with landscape optimization and ensure environmental quality as development persists.

Climate change is one of the greatest environmental challenges facing the world in the 21st century. Landscape ecology can play an important role in informing global land change science and policy [4], and can assist with mitigation and adaptation strategies to address land use under climate change. Additionally, land surface albedo plays an important role in the Earth's radiation balance by influencing the amount of shortwave radiation reflected off the Earth's surface. Alterations to shortwave radiative forcing impacts its ability to regulate climate warming effects. Sciusco et al. (List of Contributions) consider how changes to land use in the form of deforestation, urban and agricultural development, and intensification can impact on land surface albedo. In their study, using an upper Midwest USA watershed to characterize the landscape albedo-induced impact of global warming seasonally and monthly, Sciusco et al. (List of Contributions) show that landscape composition affects net landscape global warming impact in different ecoregions over a 19-year period. Their study was undertaken using the National Land Cover Database consisting of nine land cover types (barren, cropland, forest, grassland, pasture, shrubland urban, water, and wetland) captured at 30 m resolution, and the MODIS albedo product at 500 m resolution captured daily between 2001 and 2019 with Google Earth Engine was used to analyze and process the datasets and statistical analysis conducted in ArcMap and R.

Also with a focus on climate change, Skersiene et al. (List of Contributions) investigated the change in accumulation of soil organic carbon within red fescue (*Festuca rubra* L.) swards, comparing them with an arable field. The findings of this field-based study, which took place in the central part of the Middle Lithuanian Lowland, revealed that conversion from arable land to permanent red fescue pasture cover improved the soil organic carbon. These results suggest that there is a need to determine which plants could contribute to greater soil-based carbon sequestration in different regions.

Under scenarios of climate change and land clearance for more intensive urban and agricultural development, there is increasing scope for a loss of biodiversity associated with changes to landscape patterns and configurations. The composition of landscapes can also change with opportunities for invasive species to become more dominant over native species. Landscape ecology therefore has an important role in understanding the distribution and spread of invasive plant species to inform vital land management action to reduce their detrimental impact on native species. The use of satellite imagery for sustainable landscape management was explored by Carrion-Klier et al. (List of Contributions), who examined the importance of very-high-resolution imagery to map invasive plant species on the Galapagos Islands. In their article, they address the threat to biodiversity of invasive species through accurate mapping of invasive plant species. To assist with the management of invasive plant species, an evaluation of the effects of spatial resolution on the mapping accuracy of invasive species on the Galapagos Islands using multispectral satellite imagery was conducted. The results showed that overall accuracy when using very-high-resolution imagery was significantly higher than that of medium-resolution data, and that although medium-resolution data were suitable for mapping the distribution of some species that form monospecific stands, other species with smaller growth forms and that contrast less with their surrounding environment were better distinguished in higher-resolution imagery. The importance of accurate mapping is significant in terms of the cost of invasive species management and being able to prioritize management action, and the results of this study form an important baseline dataset for ongoing monitoring of the spread of invasive plant species on the Galapagos Islands.

Also concerned with the application of landscape ecological theory to reduce biodiversity loss, Benitez et al. (List of Contributions) examined how landscape and stand

characteristics influence bird assemblage in the managed *Nothofagus antarctica* forests of Tierra del Fuego, Argentina. Landscape variables such as patch shape and size were explored using Fragstats in conjunction with stand information which rated the structure of the forest and the availability of food, combined with bird count data across 48 sites, and then analyzed using detrended and canonical correspondence analysis. The results showed that landscape configuration variables like shape and stand variables like canopy cover had more impact on bird assemblage than landscape composition, but bird functional groups had different responses to different spatial scale variables. This highlights the importance of investigation at multiple spatial scales to understand the requirements of different species and that multi-strategy management procedures could have a wider impact on a range of bird species.

Another important concern in landscape management, especially under scenarios of climate change and global warming, is that of wildfire. With an increasing number of hotter, dryer days in some locations under climate change, the threat of wildfire is becoming an increasing hazard, not only for wildlife but also for people. Landscape management that considers the risk of wildfire to biodiversity and local communities is of vital importance. Certain landscape actions may exasperate this threat, and therefore it is important to apply landscape ecological theory to identify these. Salis et al. (List of Contributions) examine the risk of land abandonment in terms of potential for wildfire. They applied a fire-spread modelling approach to examine wildlife potential in relation to the spatial patterning of land abandonment. Their study site was in north-western Sardinia and consisted of 1200 km^2 of agropastoral land. They analyzed nine land abandonment scenarios at different percentages, and for each scenario they assessed wildfire hazard and likelihood through simulations of 17,000 wildfire seasons. The results showed that land abandonment can impact the risk of wildfire spread and behavior, heightening the dangers associated with large and fast-spreading fire events. This type of modelling demonstrates the role it can play in protecting rural communities and ecosystems and in developing mitigation strategies to reduce the threat caused.

The value of ecosystem services is also important in landscape ecology. Forest ecosystem services (FES) can play an important role in ecological sustainability and carbon neutrality, as well as improving the well-being of people through their contribution to the provision of important resources like food, fuel, and water and offering financial and economic gain. Being able to accurately quantify FES value is of national and ecological importance. Liu et al. (List of Contributions) explore methods for FES valuation and trends in China and investigate value realization approaches. They looked at the main methods of FES assessment utilized, including InVEST, ARIES, energy analysis, and the value-transfer approach whilst identifying challenges and uncertainties around realizing FES valuation. Their results show that realizing FES value requires government support and greater development of market-orientated strategies, including creating accounting and assessment mechanisms.

In studying landscapes, it is important for landscape ecology to recognize the diversity in interpretations of landscape and that landscapes can mean different things to different cultures. This is an issue investigated in this Special Issue by Pearson and Gorman (List of Contributions) who acknowledge in a review paper the importance of integrated landscape approaches that recognize the connection that people can have with landscapes, and in particular the important traditional knowledge that people can hold. Acknowledging complex cultural relationships with landscapes, Pearson and Gorman discuss the importance of understanding cultural perspectives and the cognition of landscapes in landscape ecology. They recognize the importance of stewardship in sustainable management that can result from the long-standing connections to place that indigenous people have and the role of traditional ecological knowledge in the pursuit of sustainable landscape management. They highlight how the human cognition of landscapes plays an important part in successful landscape ecology which can be translated into better research, emphasizing that if researchers themselves have a stronger sense of place that comes from a connection to a

landscape, then better environmental outcomes can result. Researchers can often lack an in-depth sense of place and connection, which might result in less successful conservation and environmental protection. This means that landscape ecology needs to better integrate ideas of participation and knowledge into its theory and application.

Furthering discussion on the importance of people in landscapes, Gonzalez-Avila et al. (List of Contributions) investigate the idea of socio-geomorphological (SGUs) units (e.g., the interaction between social activities and geomorphic processes) in relation to land use and land cover change in a headwater basin in Southern Brazil. The study evaluated spatiotemporal changes in land use and land cover change by evaluating natural processes and anthropogenic activities, utilizing the idea of socio-geomorphological units as important units for land management. The analysis identified 15 classes of SGUs which assisted with the understanding of interactions between social and natural processes that influence land use, land cover change, and the overriding landscape.

3. Conclusions

Overall, the papers presented in this Special Issue emphasize the interdisciplinary nature of landscape ecology and the importance of understanding the dynamics of patterns and processes at landscape scales relevant to land use and land cover change in a variety of land systems. They also highlight the role of ecosystem services and the part that people play in bringing about changes to the landscape and the important services that they provide. Also emphasized in this Special Issue is the significant interactions that people have with landscapes, which influence not only their appearance and sustainability but also how interconnected people are with them and thus their sense of stewardship and management.

In bringing together a broad spectrum of papers, methodologies, and approaches related to landscape ecological research, this Special Issue demonstrates the important role that landscape ecology can play in helping to tackle some of the complex problems facing the world today. It is hoped that this Special Issue will encourage more interdisciplinary research that applies landscape ecological theories and practices and that it inspires researchers to seek optimal ways to mitigate risk from unsustainable land use and encourage more sustainable landscape management in the face of climate change.

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