

Editorial

Editorial for the Special Issue “Ecosystem Services with Remote Sensing”

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Abstract: Ecosystem services refer to the environmental conditions and utilities provided and maintained by ecosystems, which are the basis for the survival and development of human society. The studies on ecosystem services in quantitative assessments, driving mechanisms, and correlation with human well-being, based on remote sensing, have increased in recent years. Various applications of remote sensing in ecosystem services are reported in six papers published in this Special Issue. The major research topics covered by this Special Issue include the multi-method analysis (e.g., linear regression, geographical detector, and geographically weighted regression methodology) of the normalized difference vegetation index (NDVI) to reflect ecosystem structure, the dynamic changing process of ecosystem services, and the determinants, which include a new image-analysis method based on a time series of a biophysical variable and the application of fractional vegetation cover (FVC) to analyze the spatiotemporal relationship between ecosystem structure and function and the comprehensive study on ecosystem function and service based on multi-source remote sensing data. The application of remote sensing data to ecosystem services research has the advantage of monitoring ecological structure and functions at multi-scales. Furthermore, the quantitative calculation of ecosystem services, based on remote sensing, can provide a scientific basis for enhancing land use optimization and sustainable development.

Keywords: ecosystem services; remote sensing; driving factors and mechanism; service provision and demand; land use optimization

1. Introduction

Ecosystem services have become a hotspot of interdisciplinary research because of their integrated characterization of natural system structure and function, and the comprehensive reflection of natural and social system feedback mechanisms [1–4]. Among their main topics, ecological processes are the foundation, impact mechanism and trade-offs/synergy are the core, and coupling and improving human well-being is the goal. With the continuous deepening of ecosystem services research, a cascade framework of “structure–process–service–welfare” has gradually taken shape. The four core issues of the system characteristics—future trends, ecological service effects, ecological conservation, and well-being improvement—proposed in the Millennium Ecosystem Assessment, clearly reflect the logic of multi-level cascading [5]. Future Earth has launched the core research project of ecoSERVICES to reveal the related mechanisms of biodiversity, ecological services, and human well-being [6]. The ecosystem service integration framework proposed by Fu et al. [7] marks the evolution of research on ecosystem services to pay more attention to the impact on human well-being. The conceptual framework developed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) emphasizes the development of vertical series and mutual feedback research from the three dimensions of natural background, ecological utility, and quality of life [8]. It can be seen that, with ecosystem services as nodes, upstream links with ecological processes, downstream links with

regional well-being, research on cascading has effects on interconnection, and mutual feedback issues have undoubtedly become the current frontier topic with new growth points in many disciplines, such as geography, ecology, and economics [9,10].

Currently, the main themes of ecosystem services include quantitative assessment, driving mechanism, and correlation with human wellbeing [11–14]. It can be seen that all of these themes, to different extents, rely on the application of remote sensing with the significant advantages of monitoring ecological structure and functions at multi-scales. Furthermore, the quantitative calculation of ecosystem services, based on remote sensing, can provide a scientific basis for enhancing land use optimization and sustainable development. The quantitative calculation of ecosystem services is an important in the measurements of spatial and temporal changes in ecosystem services [15,16]. Therefore, the accurate assessment of ecosystem services helps to determine the important areas of ecological protection and provides scientific suggestions for the protection of the ecological environment.

This Special Sssue compiles contributions on research related to the abovementioned various aspects of remote sensing in ecosystem services. The major topics covered by the six papers in this Special Issue include: ecosystem structure and the dynamic changing process; the spatiotemporal relationship between ecosystem structure and function; comprehensive study on ecosystem function and service. A short summary of the varied contributions to this special issue is presented in the next section.

2. Overview of Contributions

2.1. Ecosystem Structure and Its Dynamic Change Process

Liang et al. [17] adopted the remote sensed index (Normalized Difference Vegetation Index, NDVI) as an effective index for describing the dynamics of urban vegetation. More than 3000 cities in China were used to study the effect of urbanization and local climate variability on urban vegetation across different geographical and urbanization conditions. The national scale estimation shows that China's urban vegetation depicts a trend of degradation from 2000 to 2015, especially in developed areas, such as the Yangtze River Delta. Panel regression estimation shows how the increase in precipitation, light, temperature, and humidity all improved urban vegetation. Nighttime light intensity, population density, and the morphological sprawl of the city had serious negative effects on the urban vegetation. The study showed that the heterogeneity of the impact of climatic and urbanization factors on urban vegetation was driven by background climate and urbanization condition.

Based on the latest updated NDVI data downloaded from the Global Inventory Monitoring and Modeling System (GIMMS), Guo et al. [18] investigated the spatial pattern of interannual variability in the growing season NDVI for different biomes and its relationships with climate variables in Inner Mongolia during the period 1982–2015 by jointly using linear regression, geographical detector, and geographically weighted regression methodologies. NDVI interannual variability was significantly related to that of the corresponding temperature and precipitation for each biome, characterized by an obvious spatial heterogeneity and time-lag effect, marked in the later period of the growing season. The study highlighted the relationships between vegetation variability and climate variability, which could be used to support the adaptive management of vegetation resources in the context of climate change.

2.2. The Spatio–Temporal Relationship between Ecosystem Structure and Function

Hou and Gao [19] quantified the correlation between land use fragmentation and vegetation activity, based on the theories of structure–function correlation in Geography, and landscape pattern–ecological function correlation in Landscape Ecology. Effective mesh size ($meff$) was calculated to represent landscape fragmentation for land use, and the NDVI was used to reflect vegetation activity. The study considers the multi-scaled and spatially heterogeneous effects of lithology, geomorphology, and human

factors on landscape structure and its correlation with vegetation activity. This research provides scientific guidance for landscape management in karst regions.

Ghoussein et al. [20] developed a new image analysis method to extract water hyacinth areas on the river. The method is based on a time series of a biophysical variable obtained from Sentinel-2 images. After defining a reference period between two growing cycles, the fractional vegetation cover (FVC) was used to estimate the water hyacinth surface area in the river. This method makes it possible to monitor water hyacinth development and estimate the total area it colonizes in the river corridor. It can also help ecologists and other stakeholders to map invasive plants in rivers and improve their control.

2.3. Comprehensive Research on Ecosystem Functions and Services

Remote sensing data offer a privileged view on ecosystems and a unique possibility to evaluate the status and the reliability of the services they provide. Zampieri et al. [21] introduced two indicators for estimating the resilience of terrestrial ecosystems from local to global levels. NDVI time series were used to estimate annual vegetation primary production resilience. Moreover, annual precipitation time series were used to estimate annual green water resource resilience. Resilience estimation was achieved through the annual production resilience indicator, originally developed in agricultural science, which was formally derived from the original ecological definition of resilience, the largest stress that the system could absorb without losing its function. Coherent relationships between annual green water resource resilience and vegetation primary production resilience were found over a wide range of world biomes, suggesting that green water resource resilience contributes to determining vegetation primary production resilience.

Gao et al. [22] indicated that soil conservation and water retention were important metrics for designating key ecological functional areas and ecological red line (ERL) areas. This paper presented a case study of Beijing's ERL areas. In order to objectively reflect the ecological characteristics of ERL areas in Beijing, which was mainly dominated by mountainous areas, the application of remote sensing data at a high resolution was important for the improvement of model calculation and spatial heterogeneity. Combining the multi-source remote sensing data and environmental factors, a quantitative attribution analysis was performed on soil erosion and water yield in Beijing's ERL areas. The results indicated that the high-risk areas of soil erosion and water yield varied significantly among different ERL areas. In efforts to enhance ERL protection, focus should be placed on the spatial heterogeneity of soil erosion and water yield in different ERL areas.

3. Conclusions

The six papers published in this Special Issue highlight a variety of topics related to the remote sensing of ecosystem services. This Special Issue provides valuable insights into understanding the performances of different ecosystem models and monitoring ecological structure. In addition, green water resources and vegetation resilience indicators have been proposed. The remote sensing application of high resolution makes the calculation of ecosystem services more accurate and provides important suggestions for land management.

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