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Research paper

Do Biotope Area Factor values reflect ecological effectiveness of urban landscapes? A case study on university campuses in central Taiwan

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HIGHLIGHTS

- Biotope Area Factor (BAF) used to estimate ecological effectiveness is evaluated.
- BAF values of university homogenous units were compared with biodiversity data.
- BAF values were incongruent with in situ diversity of flora and fauna.
- Future system should consider factors affecting biodiversity and operation scale.

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ABSTRACT

In recent years, applying ecological concepts into landscape designs to enhance biodiversity within urban areas has become an important strategy worldwide. A commonly adopted strategy for the development of systems is to estimate the ecological effectiveness of relative landscape mosaics. Biotope Area Factor (BAF) is a general methodology that is used, however it only considers the land use surface types of the landscape mosaic unit using aerial photos and expert questionnaire method. It is not clear whether the ecological effectiveness of areas estimated by BAF system is congruent with the actual ecological characteristics and diversity of inhabiting organisms. The practicality of the BAF systems are evaluated in this study by comparing the BAF values of homogenous units amongst eight urban university campuses in central Taiwan with vegetation density/structure and arthropod/plant diversity collected in situ. We used linear models to evaluate the relationship between BAF values and in situ arthropod/plant diversities and vegetation structures. The results showed that BAF values of various homogenous units were partially correlated with vegetation structure, but were incongruent with in situ diversity of plants and arthropod. Our findings indicated that the current urban area ecological effectiveness quantifying BAF system may not be appropriate. For future studies, we suggest that the operation scale should be adjusted and factors influencing biodiversity should be considered in the weighting system to realistically and precisely designate the ecological effectiveness of landscape mosaic units.

1. Introduction

The recent increase in human population has caused rapid depletion of natural resources and natural habitats, and therefore integrated collaborative approaches aiming to achieve environmental protection and sustainability are inevitable and urgent. Applying ecological concepts and green environment managements to develop and maintain a sustainable landscape are ways of achieving a sustainable development. As the area of artificial environments continuously expands, how to make good use of green and blue infrastructure networks (such as forests, parks, water bodies, school campuses, etc.) as essential elements to enhance various levels of diversity has become an issue worldwide (Kareiva, Watts, McDonald, & Boucher, 2007). Researchers believe that landscape design will play an important role in the protection of ecological and biological diversity (Barnett, 2008; Handel, Saito, & Takeuchi, 2013; Hobbs, 1997; Müller, Werner, & Kelcey, 2013). Recently, applying ecological concepts in landscape designs to achieve environmental protection and biodiversity enhancement has become a common strategy (GBO3, 2010; Millennium

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Ecosystem Assessment, 2003; Strategic Plan, 2010). Although the area of natural habitats continues to decrease globally, we can still achieve environment protection and biodiversity enhancement to a certain degree if appropriate management policies created from well-designed ecological experiments are adopted during the planning and design of green space in urban environments (Barnett, 2008; Handel et al., 2013; Müller et al., 2013; Niemelä & Kotze, 2009; Scholes et al., 2012; Seto et al., 2012).

A commonly used strategy to enhance ecological and biological diversity in artificial or urban areas is the development of systems to measure the ecological effectiveness of various types of landscape spaces (Butchar et al., 2010; CBI, 2012; Kohsaka, 2010; Mori & Christodoulou, 2012). Biotope Area Factor (BAF) or Green Factor (GF) are procedures applied in specific European countries and the United States as a guideline to sustainably manage landscapes of urban areas (Farrugia, Hudson, & McCulloch, 2013; Finlay, 2010; Kruuse, 2011). These indices represent the ratio of the ecologically effective area (i.e., area covered by green vegetation and/or permeable to rainwater) to the total landscape area under consideration (Farrugia et al., 2013; Finlay, 2010; Kruuse, 2011). The ecologically effective areas is defined as an area exhibiting a positive effect on the ecosystem or an effect on the development of the biotope of a site (Becker, 1990; Hirst, Morley, & Ban, 2008). The higher the plant coverage, the more the permeability to rainwater and suitable for the organisms, the higher the ecological effectiveness of an area. The types of surface areas are weighted differently according to the following attributes: permeability to water, rain water storing ability, relationship to soil functioning, pureness of the environment and stipulations of suitable habitats for plants and animals (Kenworthy, 2006; Kruuse, 2011). Developers must consider the previously stated attributes and maintain a specific level of overall ecological effectiveness in their landscape design in order to obtain construction permits from local authorities (Finlay, 2010; Hirst et al., 2008; Kruuse, 2011). Currently, indexing systems are achieved by professional experts that rank the relative ecological effectiveness of various homogenous land elements by utilizing aerial photos and satellite images of the landscape space under consideration to generate a weighting system. Systems such as BAF or GF have been applied in landscape designs in various temperate cities for more than 30 years (Gómez-Baggethun & Gren, 2013). However, it is not clear whether the current expert questionnaire method of determining the weighting values of various homogenous land types can actually reflect the ecological condition, composition and abundance of organisms inhabiting these areas. For that reason, there is an urgent need to evaluate the validity of existing weighting systems to determine if they can reflect the ecological effectiveness of various landscape types.

Construction of green infrastructure networks in urban areas can create an ecologically functional environment to help reduce the impacts generated from urban developments and activities (McPhearson, Maddox, Gunther, & Bragdon, 2013). In addition, the green spaces in urban areas are important locations for city residents to conduct recreational activities (Schaffler & Swilling, 2013). In many East Asian countries, a substantial percentage of green space in urban areas is located in school campuses. Among the various types of school campuses, universities are considered the largest (Colding, 2007; Kulkarni et al., 2001). Therefore, university campuses represent substantial green space and ecological habitats, which are potentially significant elements for enhancing the ecological effectiveness of the urban areas in East Asia (Varghese, 2006). In this study, we focus on university campuses located in urban areas to evaluate whether the original BAF system of designating ecological effectiveness of expert questionnaire method can realistically reflect the ecological condition and biodiversity of these areas. We chose eight universities in central Taiwan and for each campus we identified typical landscape types according to the land-use intensity. We classified homogenous units within each landscape type and determined their ecological effectiveness by the expert questionnaire method. In addition, systematic ecological data collection and biodiversity surveys were conducted in these units and such information was used to assess the suitability and validity of the BAF indexing system.

2. Materials and methods

2.1. The study area

In this study, the university campuses surveyed were all located in Taichung City, Taiwan. These universities have been established from 13 to nearly 100 years and their campus area ranges from 9 to 145 ha. Despite the small area of some campuses, the student populations of these universities were all greater than 10,000 (Table 1).

2.2. Classification of land use surface types and homogenous units

Digital satellite aerial photos of the university campuses studied were purchased from The Aerial Survey Office, Bureau of Forestry, Taiwan to perform subsequent processing and analyses. According to the land use type identified from the photos and results of in situ surveys, we were able to determine seven homogenous units from the eight university campuses studied. From these seven homogenous units a total of eight land use surface types were classified. We established the ecological effectiveness weighting values of these eight land use surface types using the expert questionnaire method (Becker, 1990). Photos ($n = 35$) of these land use surface types taken from eight campuses were sent to landscape architecture, architecture, ecology, water conservation, urban planning, environmental engineering, forestry and horticulture professionals ($n = 20$). For each surface type, the ecological effectiveness weighting value was derived from the mean of scores (ranging from 0 to 10) given by 20 experts of the aforementioned academic fields. The area of each homogenous unit and the area of each surface type in each humongous unit for all the campuses were determined by ArcGIS program (ESRI, 2011). This information was used to calculate the relative area for every surface type. The ecological effectiveness weighting value and relative area of land use surface types were used to estimate the Biotope Area Factor for each homogenous unit (Becker, 1990). The BAF values and relative area of homogenous units were used to estimate the overall BAF values of each university campus.

2.3. Ecological data collection and biodiversity survey

Ecological data collection and biodiversity survey were conducted between April and June, 2013. Initially, we used the satellite aerial photos and ArcGIS program to determine the area of green space in each campus homogenous unit. In the green space one sampling plot (area 10 m × 10 m) was designated per hectare and the distance between any two plots was at least 60–70 m. Within the eight university campuses a total of 180 10 m × 10 m sampling plots were established. Each of the sampling plots were divided into four 5 m × 5 m subplots. In the center of each subplot we investigated the coverage of herb plants in a 1 m × 1 m area. For each species of herb plant the percentage covered in the 1 m^2 was determined by eye. In each 100 m^2 sampling plot, each woody plant species with a diameter greater than 1 cm was identified and its DBH was measured. To measure the understory vegetation structural complexity (UVD) we used a red cloth (1 m × 1 m) as the background and estimated the density of vegetation in front of it. The red cloth was held by one person whom stood at each of the four cardinal edges of the sampling plot, while one person stood in the center of the plot and took pictures with a digital camera