International Journal of Social Ecology and Sustainable Development
Volume 11 • Issue 3 • July-September 2020

Integrating Entropy Problem and GIS for Studying Landscape Ecology

The Simulation Case of Boundary Determination to Conserve Forest Landscape Ecology in Sa Pa District, Lao Cai Province, Vietnam

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ABSTRACT

Information entropy has been widely applied to assess and analyze landscape ecology. Results from previous studies were the indicators only, not able to describe the spatial distribution of the landscape. In this article, the application results of information entropy in the assessment of ecological landscapes in Sa Pa district, one of the highest mountainous area in Vietnam, based on GIS (Geographical Information System) were simulated. GIS technology was used to store information of layers on landscape structure, indicator analysis, and a map-layer assessment. Results of information entropy were simulated by the map evaluation. Results from this work showed the landscape diversity in Sa Pa zone. The Shannon-Weaver diversity index was over 1.5. The connectivity level of natural forests increased 234.21ha; simulation results by GIS were identified two suitable groups of landscapes to protect and develop forest ecology.

KEYWORDS

Ecology, Entropy, Forest, GIS, Landscape, Sa Pa

1. INTRODUCTION

Recently, many researches on applying the quantitative problem in quantitative landscape study have been reported. For examples, the application of Information Entropy in landscape study and environmental assessment, utilization of Entropy to demonstrate the status and landscape variability in the model of Shannon and Weaver (Adams et al., 1979, Boer et al., 1990), characterizing watershed-delineated landscapes in Pennsylvania by using conditional entropy profiles (Glen et al., 2001); application of Entropy algorithm and regression analysis in assessing the landscape of North America (Turner, 2005); maximum entropy and ecology: a theory of abundance, distribution and energetic (Harte, 2011); the Information Entropy was applied in desertification process warning and assessment (Shen et al., 2013); order and disorder in ecological time-series: Introducing normalized spectral entropy (Zaccarelli et al., 2015); application of Entropy in confirming the function of landscape heterogeneity and forest biodiversity in agricultural landscape (Fahrig, 2016); applying Etropy to evaluate land conservation alternatives in Binh Thuan province, Vietnam (Nguyen et al., 2016). These studies were successfully applied entropy algorithm to determine the indices in the evaluation and analysis of landscape ecology. The above-mentioned studies discussed about many aspects of the

DOI: 10.4018/IJSESD.2020070102

landscape ecology study such as structure analysis, components analysis, and motivation of landscape development. However, those studies have not simulated the spatial distribution of landscape yet. Moreover, the quantitative problem of the relationship between landscape structure and ecological processes is very important for the management of natural resources and environmental protection. Particularly the conservation and development of forests require not only attention to biological resources and biodiversity, but also to conservative structures as well as the value of the physics, biology and culture of the landscape, and also describing the conservative spatial structure of forest landscape.

Sa Pa is the highest mountainous area in Vietnam with natural diversity. Sa Pa topography was separated from height of 400m to 3143m that makes natural unique and diversity. This is the only area in Vietnam where exists full 30 kinds of soil, especially Humic Ferralsols, Haplic Alisols and Histric Alisols. Climate of Sa Pa is separated by height with annually average temperature of 10 to 28°C, rain fall of 1500-2800 mm/year. Plant system of Sa Pa was changed very much by human activities. Primary forest was significantly decreased but the secondary one had been increasing in recently. At 1500m height, mixed forests and coniferous forests are very popular. The Information Entropy was applied to study the landscape ecology of Sa Pa district because it has ecological conditions, varied landscape, with the Hoang Lien National Park - one of the largest ecological sanctuary in Asean. Landscape ecology of Sa Pa district is distinguished by three functional areas: conservation, protection and production. The conservation function is defined in the core zone of the national park, within the strict protection boundaries. The protective function is located in the watershed area and buffer zone of Hoang Lien National Park. Production function is defined at areas of forest-agriculture development models for exploiting the economic benefits of forestry.

Geographical Information System (GIS) has now widely been applying in many research fields, especially in the field of landscape ecology. In this work, the results of Information Entropy were simulated in landscape assessment based on GIS. The objectives of the study were to assess the ecological efficiency, and to determine the boundaries of conservation and expanded forest landscapes. The GIS was used to establish landscape index maps, overlay unit map layers to form forest landscape assessment map based on the data analysis of the Information Entropy. The assessment map of forest landscape conservation will be the scientific basis for proposing plans of exploitation and sustainable use of forest resources. This model was successfully applied in Sa Pa district, Lao Cai province, Vietnam. It is the first time the Entropy Algorithm simulation using GIS technology has been applied to landscape ecology study in Vietnam. This work is helpful for the district administration. This study overcame the limitations in determining the boundaries of forest landscape conservation areas, strict conservation areas, conservation and restoration areas. The boundary of buffer zone was also determined on map.

2. MATERIALS AND METHODS

The concept of entropy ("*entrepein*" means "chaos" in Greek), related to the second law of thermodynamics, is the measurement of uniform and non-reversible state in the system. It is likely to use entropy to represent the states and landscape diversity by the Shannon-Weaver model (Adams et al., 1979):

$$H(V) \to SDI = -\sum_{i=1}^{n} p_i \log_2 p_i \text{ and } SEI = \frac{-\sum_{i=1}^{m}\left(p_i \ln p_i\right)}{\ln m} \quad (1)$$

where: H(V) is the entropy caused by development activities V; SDI is Shannon-Weaver diversity index; SEI is Shannon-Weaver smooth index; p_i is the probability of occurrence of the i^{th} landscape.

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