Chapter 16
Using Vegetation Greenness as a Criterion in Multi-criteria Analysis of Recreational Land Suitability in Protected Area: A Case Study of Krau Wildlife Reserve, Peninsular Malaysia

Saiful Arif Abdullah and Nur Hairunnisa Rafaai

Abstract Vegetation greenness usually used to interpret condition of ecological processes which are vital for sustaining biodiversity and integrity of natural ecosystems. Hence, vegetation greenness seems feasible as a criterion in multi-criteria analysis of recreational land suitability for sustainable land use planning in protected area. But, how feasible it is? Based on land suitability, analyzed using a multi-criteria analysis, two scenarios of recreational land suitability were developed using Krau Wildlife Reserve in Peninsular Malaysia as a case study. Scenario 1, does not use vegetation greenness as one of the criteria, and Scenario 2, uses vegetation greenness as one of the criteria. In this study, the proportion of recreational land suitability classes, "less suitable," "moderate suitable," and "most suitable," was measured under both scenarios. Then, the feasibility of vegetation greenness was evaluated by comparing the proportion of each suitability class in Scenario 2 with Scenario 1. Results revealed that in Scenario 1, the proportion of "most suitable" was the highest. In Scenario 2, the proportion of "most suitable" reduced but "moderate suitable" increased when compared with Scenario 1. This shows that vegetation greenness can limit the proportion of land used for recreation. Thus, vegetation greenness is feasible to be considered as a criterion for identifying recreational land suitability for sustainable land use planning in protected area.

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1 Introduction

Planning and managing land use sustainably in protected area is currently a challenge for governments, land managers, and conservationists (Geneletti and van Duren 2008; Adhikari et al. 2015; Bailey et al. 2016). They face a difficult situation in developing land for conservation and socioeconomic purposes based on the sustainable development principles (van Lier 1998). Generally, forests represent the major component in protected area which provides a suitable place for recreation such as picnic, hiking, camping, and bird watching. In this regard, related infrastructures such as information center, chalet, camping site, and observation tower are built to support the recreational activities. Nevertheless, when the recreational land uses are not properly planned and managed, it is economically disadvantageous and, ecologically, may cause disturbance to the natural resources of the forest and the sustainability of the protected area as a conservation site (Pickering and Hill 2007; Pickering et al. 2010; Steven et al. 2011).

Identifying land suitability is one of the approaches for ensuring the balance between recreational land uses and the conservation of natural resources in protected area. Generally, land suitability emphasizes the need to conserve natural resources and to minimize conflicts in land use management (Cendrero et al. 1993). In addition, land suitability represents a mechanism for identifying strategies and achieving the management objectives of protected area (Thomas and Middleton 2003). Therefore, land suitability for specific purposes, such as recreation, is required to minimize the conflict between land use and management in protected area (Haas et al. 1987; Cendrero et al. 1993). If not, the forest in protected area could experience high level of fragmentation and deforestation (Gaveau et al. 2007, 2009), which could ultimately prevent achieving the objectives of the establishment of the system (Sabatini et al. 2007).

Generally, identifying land suitability for specific purposes involves several criteria in which land attributes are mainly used. For example, Hsiaofei et al. (2006) identified land suitability for ecological service zones of a forest ecosystem in Hui-Sun, Taiwan, based on land attributes such as elevation, slope, forest condition, road network, and rivers. Liu and Li (2008) employed not only land attributes but also human disturbance factors, such as the distance from farmland, tourist sites, and construction sites, in identifying land suitability for protected area zoning in China. Land attributes such as geology, vegetation cover, and land use also used by Geneletti and van Duren (2008) in identifying land suitability for a protected area zoning in Italy. Even though ecological processes have been recognized important for sustaining, protecting, and conserving natural resources (Dunning et al. 1992; Bennet et al. 2009), they have not previously been considered as criterion for identifying land suitability for sustainable land use planning in protected area.

At the landscape scale, vegetation greenness usually used to interpret the condition of ecological processes (Burgan and Hartford 1993; Zhang et al. 1997; Ikeda et al. 1999). Intervention such as uncontrolled clearance of trees for land use development affecting the vegetation greenness which eventually disturb the ecosystem function and structure, which are vital for protecting the biological diversity and ecological integrity of ecosystem (Debinsky and Holt 2000; Weibull et al. 2003). This is contrary to land attributes that do not convey any information about ecological processes (Louisa and Antonio 2002). Thus, sustaining the vegetation greenness means sustaining natural and aesthetic values of a particular land. And, greenness can attract or encourage people for recreational activity (Thompson and Aspinall 2011; Almanza et al. 2012) which also has a positive association with health and quality of life (de Vries et al. 2003; Sugiyama et al. 2008; Pereira et al. 2012). In this context, vegetation greenness seems feasible as a criterion in multi-criteria analysis of recreational land suitability for sustainable land use planning in protected area. But, how feasible it is? To address this question, the suitability land for recreation in a protected area of Peninsular Malaysia was first analyzed. Second, the distribution and proportion of suitable land for recreation where the vegetation greenness is not used as a criterion were compared with analysis where the vegetation greenness is taken into account. The objective is to determine the feasibility of vegetation greenness in identifying land suitability with a case study of protected area in Peninsular Malaysia.

2 Case Study Site: Krau Wildlife Reserve

Krau Wildlife Reserve (latitude between 3° 35′N and 3° 52′N; longitude between 102° 5′E and 102° 17′E) is located in the state of Pahang on the west coast of Peninsular Malaysia (Fig. 1). The total area of this reserve is approximately 60,338 ha, and the altitude ranges from 45 to 2108 m above sea level (Yusof and Sorensen 2000). The largest part of this reserve is lowland, which extends from the central to the southern part of the reserve and is mainly covered by lowland dipterocarp forest. At the western part, the topography is rough terrain with steep slopes. The mountainous area with the highest peak is located in the northwestern part, while isolated small hills can be found in the southern part of the reserve.

The climate of this reserve is hot and humid. The mean daily minimum and maximum temperatures are approximately 23 and 33 °C, respectively, and the mean annual rainfall is approximately 2000 mm. This reserve harbors diverse species of flora and fauna as well as diverse ecosystem types. Five floristic altitudinal forest zones have been identified in the reserve: lowland dipterocarp, hill dipterocarp, upper dipterocarp, montane oak-laurel, and montane ericaceous forests (DWNP/DANCED 2001). This reserve falls under the Wildlife Reserve IV (Managed Nature Reserve) and Forest Reserve VIII (Multiple-use Management Area) categories of the International Union for Conservation of Nature (IUCN).

At present, there is no area being identified for recreation in the reserve, but the Department of Wildlife and National Parks Peninsular Malaysia has designated recreational area that potential and/or suitable to be set up in the Krau Wildlife Reserve (DWNP/DANCED 1999). The department defines recreational area as

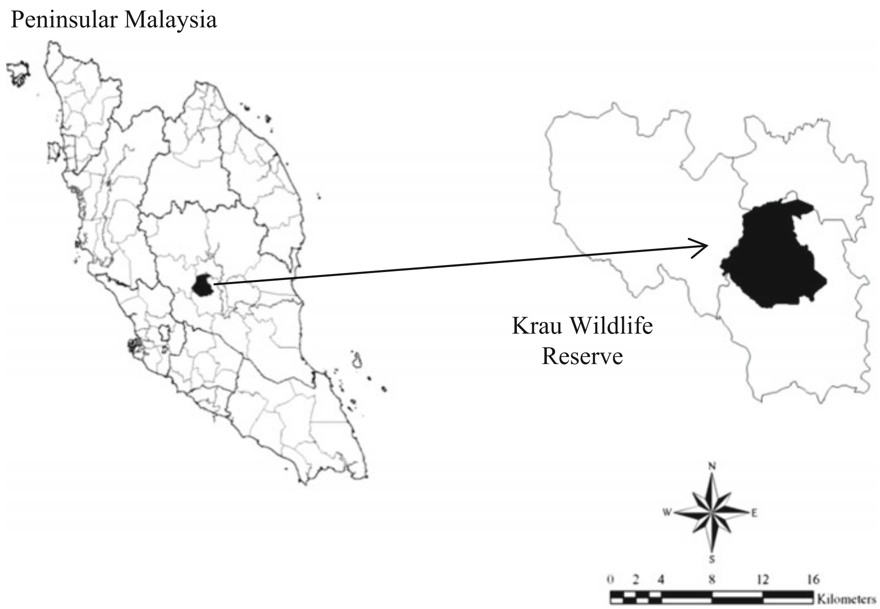

Fig. 1 Location of Krau Wildlife Reserve in the State of Pahang, Peninsular Malaysia

"area with recreational, tourism and educational value, where sustainable eco-tourism, recreation, conservation education and public awareness activities can be conducted" (DWNP/DANCED 1999).

3 Land Suitability for Recreational: Criterion Selection

Identifying land suitability is a process for determining a unit of land for a specific use (Geneletti and van Duren 2008). In the process, land unit assessment is the most appropriate because it is the basis for rational land use planning and management (FAO 1993; Rossiter 1996). In this study, the analysis was conducted in two stages. First, the selected criteria include the elevations, slopes, land uses, and riparian areas of the study area. Land attributes of elevation and slope as well as land uses are considered to be the basic criteria for identifying land suitability (Geneletti and van Duren 2008). The riparian area is important because its health and condition depend on the surrounding land uses (Naiman et al. 1993). Furthermore, the riparian area becomes the main focus in conservation and natural landscape management (Naiman et al. 1993). This first stage is designated as Scenario 1.

Second, the same criteria (i.e., the land attributes) were used, but vegetation greenness was included. This second stage is designated as Scenario 2. In this analysis, the normalized difference vegetation index (NDVI) was used because apart commonly used to measure vegetation greenness (e.g., Hermann et al. 2005; Xu et al. 2011), it also exhibits a strong relationship with the leaf area index (LAI) (Ramsey and Jensen 1996; Green et al. 1997; Kovacs et al. 2004) which LAI is closely related to various ecological processes, such as the net primary production (Gholz 1982; Meyers and Paw 1987), the energy exchange between plants and the atmosphere (Gholz et al. 1991), the rate of photosynthesis (Pierce and Running 1988; Gamon et al. 1995), and various plant physiological processes (Glenn et al. 2008). These revealed a strong relationship of vegetation greenness with ecological processes. Therefore, it can be considered as a reliable indicator to represent the vegetation greenness in a particular area (Svoray et al. 2003).

4 Data Sources and Multi-criteria Analysis

This study used a land use map of the study area from the year 2007 developed by Rafaai (2011). This map was based on a SPOT 5 image (2.5 m resolution) analyzed using ERDAS Imagine 9.2 and ArcGIS 9.3. The overall accuracy of the map is 86.4%, and the value of the kappa statistic is 0.83 (Rafaai 2011). The other data sources used were a digital elevation model (DEM) (scale 1:50,000), to generate elevation and slope maps, and maps of the rivers and the border of the Krau Wildlife Reserve were obtained from the Department of Wildlife and National Parks Peninsular Malaysia. The vegetation greenness map which was based on NDVI was analyzed using the spectral enhancement menu of ERDAS Imagine 9.2. The NDVI values are between −1 (no vegetation) and +1 (highest vegetation greenness) (Tucker and Sellers 1986; Lillesand et al. 2004). The layer of each criterion used to develop suitability map for recreation in the protected area is shown in Fig. 2.

A multi-criteria analysis is developed to characterize a particular land unit to achieve certain specific objectives (Zeleny 1982). Many studies have applied multi-criteria analyses and described their usefulness for achieving sustainable planning and management of protected area (Villa et al. 2001; Bojórquez-Tapia et al. 2004; Hjortsø et al. 2006). This type of multi-criteria analysis includes three main steps: ranking, scoring, and pair-wise comparison to determine the weight for each criterion (Saaty 1997).

Each criterion used in this study was divided into either three, four, or five sub-criteria. As the recreational area in Krau Wildlife Reserve has its own definition, the level of suitability of all sub-criteria needs to be ranked. In this process, the first step is to establish a standard measurement system to rank the criteria/sub-criteria. Here, the suitability value was ranked in three classes: 1 = “less suitable”; 2 = “moderate suitable”; and 3 = “most suitable.” The highest priority sub-criteria of each criterion were given the highest suitability ranking for recreation of 3, whereas 1 indicates the lowest priority. The rankings were based on the perceived significance of natural resource conservation and suitability for recreation, which were determined based on the expert knowledge and the existing

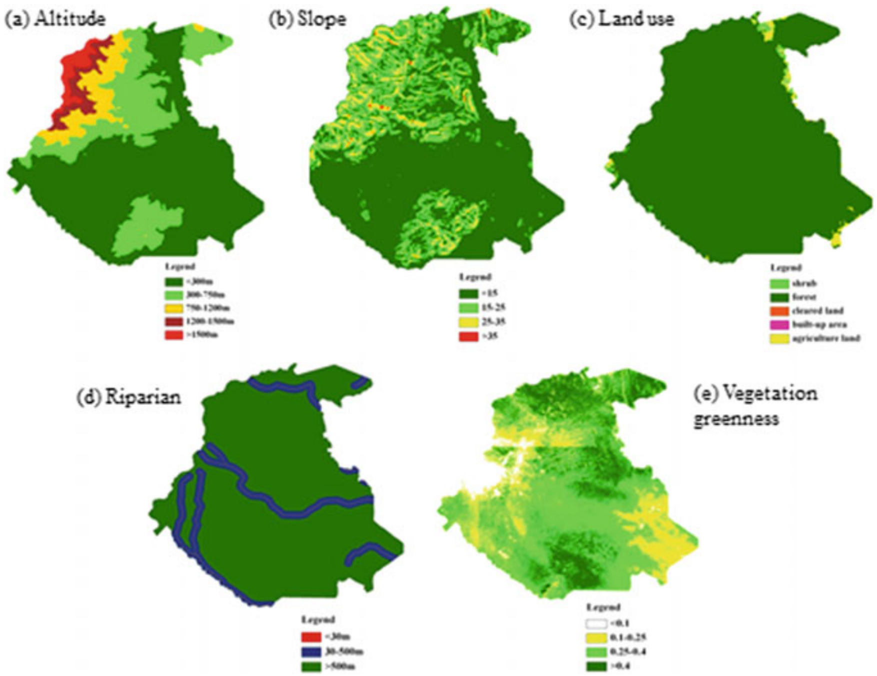

Fig. 2 Criteria used in Scenario 1 (**a**–**d**) and Scenario 2 (**a**–**e**)

literature. The ranking of the sub-criteria of each criterion for Scenario 1 is shown in Table 1. This ranking was also used in the second analysis (Scenario 2), with additional ranking of NDVI (vegetation greenness) sub-criterion (Table 1).

The process for determining the weight of each criterion is subjective. In a multi-criteria analysis, the process that widely used for achieving this goal is the analytical hierarchical process (AHP) developed by Saaty (1977). In the AHP, a weight value is obtained through pair-wise comparison analysis, and the relative importance is fixed based on the comparison of two criteria using the importance weight scoring scales (Saaty 1980). The weight values of each criterion for Scenario 1 and Scenario 2 are shown in Table 2. To determine whether the pair-wise comparison is consistent, an eigenvector method (Saaty 2000) was applied. Thus, the consistency ratio (CR) was used to assess the consistency of the pair-wise comparison. The steps for calculating the CR follow Saaty (1980). The pair-wise comparison is assumed to be consistent if the CR is less than 10% or 0.1, whereas if CR $\geq$ 0.1, the score given in the pair-wise comparison must be re-evaluated. The CR values for Scenario 1 and Scenario 2 are shown in Table 3.

Geographic information system and multi-criteria analysis are used to generate land suitability map for recreation via weight linear combination (Eastman et al. 1995). In weight linear combination (WLC), the weight of each criterion is combined to generate a land suitability map. The WLC model applied here is

Table 1 Ranking value for each sub-criterion of recreational zone used in the multi-criteria analysis

Criteria	Ranking
1. Elevation (m) (Whitmore 1986)	
0–300	3
300–750	3
750–1200	2
1200–1500	1
>1500	1
2. Slope (^{0}) (JPBD and LESTARI 2007)	
<15	3
15–25	3
25–35	1
>35	1
3. Land use (Rafaai 2011)	
Forest	3
Agriculture	2
Built-up area	1
Shrub	1
Cleared land	1
4. Distance from river (m) (Fisher and Fischenich 2000)	
<30	3
30–500	2
>500	1
5. [a]NDVI (vegetation greenness) (Byzedi and Saghafian 2009)	
<0.1	1
0.1–0.25	2
0.25–0.4	3
>0.4	1

Note: The first four criteria were used in Scenario 1 and Scenario 2 whereas [a]NDVI (vegetation greenness) was included only in Scenario 2

Table 2 Weight of each criterion under Scenario 1 and Scenario 2

Criterion	Scenario 1	Scenario 2
Elevation	0.401	0.343
Slope	0.282	0.258
Land use	0.092	0.071
Riparian	0.225	0.212
NDVI (vegetation greenness)	–	0.115

$S = \sum W_i X_i$, where S = suitability index; W_i = the weight of criteria i; and X_i = the score of criteria i. The higher the value of S, the higher the suitability of a particular land uses. In this study, this process was carried out using the model

Table 3 Consistency ratio (CR) for Scenario 1 and Scenario 2

	Consistency ratio (CR)
Scenario 1	0.069
Scenario 2	0.090

builder technique and weighted overlay method in ArcGIS ver 9.3 (ESRI 2000). GIS data were applied to the raster model because data analysis and operation are faster in raster format, especially for overlay analysis (Dangermond 1990).

5 Land Suitability Distribution and Proportion

The Scenarios 1 and 2 include three land suitability classes—"most suitable," "moderate suitable," and "less suitable"—for recreation as shown in Fig. 3. In the Scenario 1, the highest proportion of "most suitable" (81%) was observed (Fig. 4). The proportion of "moderate suitable" (17%) was approximately 60% lower than the "most suitable," whereas the lowest proportion was "less suitable" (2%).

In the Scenario 2, the proportions of "most suitable" (51%) and "moderate suitable" (47%) were not much different, whereas the proportion of "less suitable" was less than 10%. Compared with the Scenario 1, the proportion of the "moderate suitable" increased (Fig. 4) by about 64%. However, the proportion of the "most

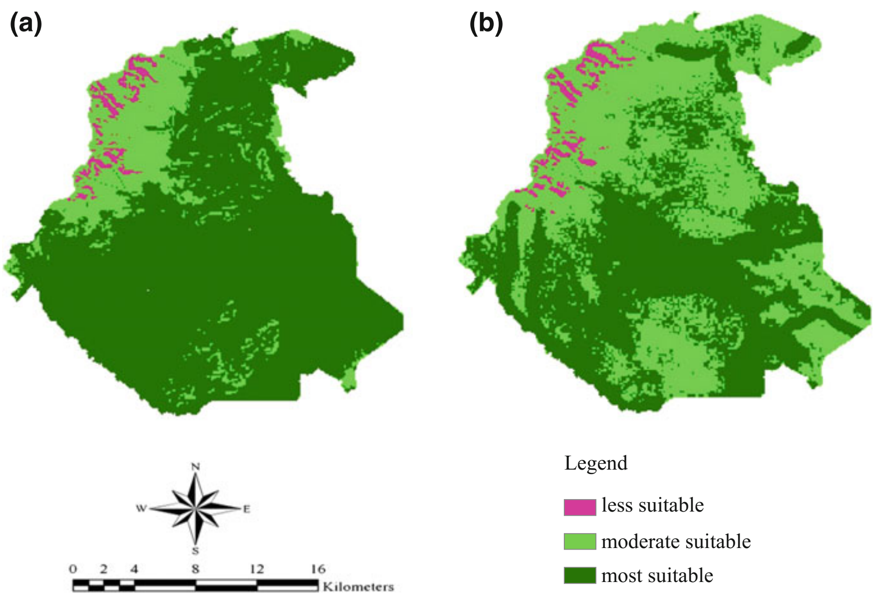

Fig. 3 Land suitability map for recreation **a** Scenario 1 and **b** Scenario 2 in the study area

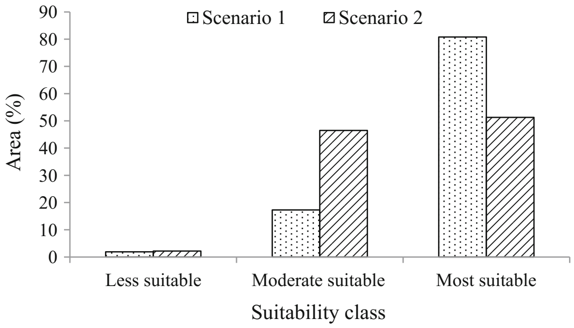

Fig. 4 Proportion of each land suitability class for recreation of Scenario 1 and Scenario 2 in the study area

suitable" decreased by about 37%. The proportion of "less suitable" remained the lowest and was not considerably different from that in Scenario 1 (Fig. 4).

6 Discussion and Conclusion

Sustainable land use and conservation planning are related to physical land planning with the purpose of optimizing the distribution and segregation of land in a limited spatial context (van Lier 1998; Leitáo and Ahern 2002). The assessment and selection of suitable areas for specific purposes based on multi-criteria analysis are important for land use and conservation planning in protected areas (Bibby 1998). In this context, application of land suitability is suggested, aimed to achieve sustainable development (Xu et al. 2006).

Land suitability analysis emphasizes permanent aspects, one of the most important of which is the land attributes of a particular area (Leitáo and Ahern 2002). On the Scenario 1, land attributes of elevation and slope exhibit the highest weight compared to the other criteria or factors determining the suitable land distribution and proportions for recreation. The highest weight is because in land use planning, the elevation and slope are considered to be the most important criteria for determining land suitability (Veldkamp and Lambin 2001; Butler et al. 2004), with elevation being more important compared to slope (Busing et al. 1993), as it exhibits a close relationship with the biological diversity in a particular region (Begon et al. 1996).

In the context of wildlife conservation, elevation influences the richness and diversity of species (Lee et al. 2004; Ellu and Obua 2005). The richness and diversity of many species decrease with increasing elevation (Körner 2000) due to the limited food sources and decreased ecosystem productivity at higher elevations compared to lowlands and flat areas (Singh et al. 2009). Furthermore, increasing elevation results in decreasing habitat size thus providing a limited area for many species to occupy (Körner 2000; Colwell et al. 2004). In land use and conservation planning, the forest areas in lowland are easier to access compared to that at higher elevations (Chomitz and Gray 1996; Nagendra et al. 2003; Fearnside 2006).

This study revealed that the most suitable land for recreation in Krau Wildlife Reserve was mostly distributed at the lowland. Therefore, control of recreational land use is needed at the lowlands, but it is less suitable at higher elevations (Scott et al. 2001). Land development for recreation at the lowland in particular may impose a threat to conservation efforts in this protected area because it may facilitate further encroachment of human activities.

On the Scenario 2 (with vegetation greenness included), the elevation and slope are still the main criteria for determining the suitable land distribution and proportion for recreation. When the vegetation greenness was included, the vegetation area of the reserve was divided into three classes based on NDVI values: high greenness (>0.4), moderate greenness (0.25–0.4), and lower greenness (0.1–0.25). These values provide different implications regarding the suitable land distribution and proportion for recreation. The "most suitable" for recreation decreased in proportion and might have changed to "moderate suitable," as the proportion of the latter increased noticeably.

A high vegetation greenness value is an indication of a healthy ecosystem and good primary productivity, which contribute to the existence of more species, particularly herbivorous species (Bourgarel et al. 2002). Therefore, there is a positive relationship between the spatial and temporal variations of the vegetation greenness and the species richness in a particular area (Gould 2000; Oindo and Skidmore 2002; Levin et al. 2007). In this study, areas with high vegetation greenness values have been allocated less for recreation. This finding shows that using the vegetation greenness as a criterion is feasible because it reflects ecosystem functions, such as the distribution, density, and diversity of animals and plants (Reed et al. 1994; Krishnaswamy et al. 2004; Feeley et al. 2005), as well as vegetation quality, where the greenness rate shows a relationship with food quality (Griffith et al. 2002) and can be used to measure the amount of energy that enters the ecosystem (Levin et al. 2007). Hence, the vegetation greenness supports ecosystem structure and function (Hsiofei et al. 2006; Pommerening and Stoyan 2006). Therefore, its application can have a significant influence on the conservation of natural resources and ecological integrity of a particular ecosystem.

This study revealed that the inclusion of vegetation greenness in identifying recreational land suitability is important for sustainable land use and conservation planning of the protected area. Its inclusion can limit or minimize the proportion of land suitable for recreation. This may enable many forested areas to be protected for natural resource conservation and also significant to support the conservation efforts of the protected area. This case study of Krau Wildlife Reserve can be served as a model that might also be applicable to the other protected areas in Peninsular Malaysia.

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