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Classification of Recreation Opportunity Spectrum Using Night Lights for Evidence of Humans and POI Data for Social Setting

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Abstract: The recreation opportunity spectrum (ROS) has been widely recognized as an effective tool for the inventory and planning of outdoor recreational resources. However, its applications have been primarily focused on forest-dominated settings with few studies being conducted on all land types at a regional scale. The creation of a ROS is based on physical, social, and managerial settings, with the physical setting being measured by three criteria: remoteness, size, and evidence of humans. One challenge to extending the ROS to all land types on a large scale is the difficulty of quantifying the evidence of humans and social settings. Thus, this study, for the first time, developed an innovative approach that used night lights as a proxy for evidence of humans and points of interest (POI) for social settings to generate an automatic ROS for Hunan Province using Geographic Information System (GIS) spatial analysis. The whole province was classified as primitive (2.51%), semi-primitive non-motorized (21.33%), semi-primitive motorized (38.60%), semi-developed natural (30.99%), developed natural (5.61%), and highly developed (0.96%), which was further divided into three subclasses: large-natural (0.63%), small natural (0.27%), and facilities (0.06%). In order to implement the management and utilization of natural recreational resources in Hunan Province at the county (city, district) level, the province's 122 counties (cities, districts) were categorized into five levels based on the ROS factor dominance calculated at the county and provincial levels. These five levels include key natural recreational counties (cities, districts), general natural recreational counties (cities, districts), rural counties (cities, districts), general metropolitan counties (cities, districts), and key metropolitan counties (cities, districts), with the corresponding numbers being 8, 21, 50, 24, and 19, respectively.

Keywords: ROS; night lights; POI; factor dominance; natural recreation resource

Citation: Zeng, W.; Zhong, Y.; Li, D.; Deng, J. Classification of Recreation Opportunity Spectrum Using Night Lights for Evidence of Humans and POI Data for Social Setting. *Sustainability* **2021**, *13*, 7782. https://doi.org/10.3390/su13147782

Academic Editors: Christos Polykretis and Marc A. Rosen

Received: 23 May 2021
Accepted: 9 July 2021
Published: 12 July 2021

1. Introduction

The recreation opportunity spectrum (ROS) is a spectrum or continuum defined based on the combination of three elements: activities, settings, and experience opportunities [1]. That is, people seek to participate in preferred activities in preferred settings (physical, social, and managerial) to achieve a preferred experience. The physical setting has three components (remoteness, size, and evidence of humans) and is defined by the absence/presence of human sights and sounds, size, and amount of environmental modification caused by human activity. The social setting, measured as user density, reflects the frequency and types of association between individuals and groups, indicating opportunities for solitude, or interaction with selected persons or large groups [1]. The managerial setting reflects the number and types of behavior restrictions on people by management institutions or private land owners, and can be combined with a physical layer and a social layer to generate a ROS map.

ROS was initially proposed in the late 1970s by the United States Department of Agriculture (USDA) Forest Service as a framework for the inventory and planning of outdoor recreational resources in national forests. Since then, it has been developed as an effective tool for recreational resource planning and management and has been widely used, not only in the USA, but also in many other countries, including Australia, Canada, New Zealand, and China. ROS can be used to identify, classify, map, plan, and manage outdoor recreational settings for both existing and preferred conditions, and can effectively address the paradox between protection and use [2]. Although the ROS has been recognized as the best available tool for recreational planning and management, its applications have been largely limited to single forest areas or other non-forest dominated settings, and few studies have extended the scope to all land types at the province/state level. Studies on recreational ecology and visitor impact in China have accumulated a modest body of literature. However, the diversity and maturity of the research, though improved, is still low compared to North America, Europe, and Australia, and the distribution of research activities is highly uneven [3,4]. The demand for outdoor recreation and tourism in China has been increasing due to the rise of the middle classes. Paralleled with this increasing demand is escalating urbanization and rapid economic growth, which requires appropriate planning and the use of natural resources at a regional scale to achieve long-term sustainability. Therefore, it is deemed necessary to develop a ROS on a large scale that goes beyond a single land use/land cover, such as forests. It should be noted that the classification of a ROS can help resource managers to control the recreational impact on the environment more effectively.

The demand for a large ROS that involves all land types at the state level was also echoed in the USA. For example, in 2003, the USDA Forest Service prepared a ROS mapping protocol for the New England region, which consists of six states in the northeastern USA, wherein an eight-class spectrum was suggested for the region: primitive, semi-primitive non-motorized, semi-primitive motorized, semi-developed natural, developed natural, and highly developed, which is further divided into three subclasses: large-natural, small natural, and facilities [1]. This adoption of the eight-class ROS in the New England region is reflective of the land use patterns and landscape characteristics of the region, and is more applicable than the typical five-class ROS (primitive, semi-primitive non-motorized, semi-primitive motorized, roaded natural, rural, and urban) initially proposed for forest-dominated settings. This modified classification of the ROS provided a template for other states to follow and was used for this study, as described later in this paper.

Traditionally, a ROS was created manually, and then digitized in a Geographic Information System (GIS) environment [5]. The GIS-based land use planning method originated from transparent overlays and computer cartography [6], making it possible to generate a ROS cost effectively on a large scale. The application scope has been expanded from land use suitability analysis to specific resource assessment, such as landslide risk potential and green space planning [7–10]. The GIS has been widely used to compile the ROS supporting leisure policies [11]. One study created an objective and repeatable GIS model to map the ROS in New Zealand, which can develop program modeling to guide management decisions over time [12]. Another study, with Sweden as an example, attempted to propose an alternative method to assess the accessibility value of recreational activities by integrating the intensity of land development into the use of a GIS, thereby defining the spatial scope of recreational activities in landscapes [13].

Of the three settings (physical, social, and managerial), information on physical setting (particularly remoteness and size) is readily available, while information on social setting and managerial setting is difficult to obtain and usually incomplete for an area at the regional scale. This may explain why some studies only used the physical setting to create a ROS without considering the other two settings [14]. In terms of evidence of humans in the physical setting, land ownership (public vs. private) was used in some studies [14,15], which may not be applicable in the context of China where almost all land is publicly owned.

Some scholars have criticized the use of population and housing construction to represent evidence of humans. First, due to the limitation of administrative units, they cannot obtain detailed population or housing data that can show the internal differences of administrative divisions [16]. Second, it is impossible to carry out spatial analysis combined with grid unit data such as natural ecological environment data [17]. Recently, the USDA Forest Service proposed the use of route density or level of development as options to represent evidence of humans [18], which provided an opportunity to use night lights as a proxy for evidence of humans as night lights have been successfully used to monitor/detect human use levels [19,20].

Night light brightness is the satellite data obtained by remote sensing technology, which, to some extent, avoids the subjectivity of artificial statistics of human evidence. At present, night light data are widely used in geography and economics research, mainly concentrated in land use, urbanization, economic growth, and population economic spatialization [21,22]. Therefore, this paper aims to express evidence of humans in ROS physical setting criteria using night-time light data to determine the impact of human landscape change, in order to provide a reference for the scientific and objective construction of a ROS.

Today, with increasing population mobility and the exponential growth of information data, geographical big data provide new opportunities for complex geographical research. It can realize the simulation and deduction of geographical system [23], explore the development law and trend of geographical space, excavate valuable spatial information at a deeper level and scale, and improve the service value of geographical information [24]. Points of interest (POI) refers to point data on landmark buildings and geographical entities that are closely related to people's lives, such as schools, hospitals, shopping malls, parks, and government agencies [25]. POI data describe the spatial location and attribute information of these geographical entities. POI data have a large number of data samples with rich information, which, to a certain extent, can reflect various activities in a certain region. Each POI generally contains four aspects of information: name, category, latitude and longitude, and address. Compared with traditional land survey data, remote sensing data and socio-economic statistics, POI data are easier to obtain and process with greater precision and recognition. Therefore, POI data can compensate for a lack of population, price, night light, and other conventional data [26]. There are four main aspects of the application of POI in geospatial studies, namely urban functional zoning, urban center (boundary) identification, format clustering analysis, and interest point recommendation. In this paper, geographical information POI data are used to represent ROS social setting criteria to reflect the frequency and type of associations between individuals and groups.

ROS classes can be further used to describe naturalness or recreation resource status at a country level [3]. There are other methods that have been used to identify recreational counties. For example, a study identified 285 non-metropolitan counties based on empirical measurement of recreational activities, including level of employment, level of income in tourism-related industries, and the presence of seasonal housing [27]. These three indicators were used in 2002 to construct a weighted average based on the standardized Z-scores (0.3 employment + 0.3 income + 0.4 seasonal homes). Counties scoring greater than 0.67 on this recreation dependency measure were considered recreational counties [28]. In another study, the impact of non-urban recreational counties on employment, education, health, and crime was further discussed. These are based on socio-economic and social welfare perspectives of recreational use to distinguish recreational counties in non-urban counties [29].

'Outdoor recreation' occurs in the natural environment while 'natural recreation' is the synonym of 'outdoor recreation', but it is more vivid than 'outdoor recreation' and can reflect the importance of natural landscape [30]. In order to effectively integrate and manage natural recreational resources, this paper organically combined ROS with China's social and economic conditions from the perspective of natural recreational resources by creating ROS for Hunan Province based on data on roads, night lights and POI. Combined with factor dominance, the ROS classification visualization results are extended to the management of natural recreational resources in 122 counties (cities and districts) in the province. The 122 counties (cities and districts) of Hunan Province were divided into five grades: key natural recreational resources counties (cities and districts), general natural recreational resources counties (cities and districts), rural counties (cities and districts), general metropolitan counties (cities and districts) and key metropolitan counties (cities and districts). The classification of ROS and the division of natural recreational resources can also combine and analyze different data in the future to provide reference and suggestions for relevant departments to develop natural recreation activities, new land acquisition proposals or major facilities development.

2. Materials and Methods

2.1. Study Area

Hunan Province as shown in Figure 1 is located in central China in the middle reaches of the Yangtze River, and the provincial capital is Changsha. Fourteen cities (states) and 122 counties (cities and districts) are under the jurisdiction of the province. Hunan is located in 108°47′–114°15′ east longitude and 24°38′–30°08′ north latitude, with a total area of 2,118,000 square kilometers, accounting for 2.2% of the national land area, ranking 10th in all provinces (autonomous regions and municipalities directly under the central government) and the first in the central region. The cultivated land area of Hunan Province is 4144.88 million hectares, accounting for 3.1% of the total cultivated land area. Forest land covers an area of 122,103 million hectares, accounting for about 4.8% of the total national forest land area. The grassland area is 47.48 million hectares, accounting for 0.22% of the total national grassland area. Hunan Province is home to abundant natural recreational resources. In 2019, 180 nature reserves with an area of 1.509 million hectares were approved in Hunan Province, among which are 23 national nature reserves, 30 provincial nature reserves, and 14 national geological parks. The annual afforestation area was 33.3 million hectares. The forest land area was 12.996 million hectares at the end of the year. The standing timber volume was 595 million cubic meters, and the forest coverage rate was 59.90%.

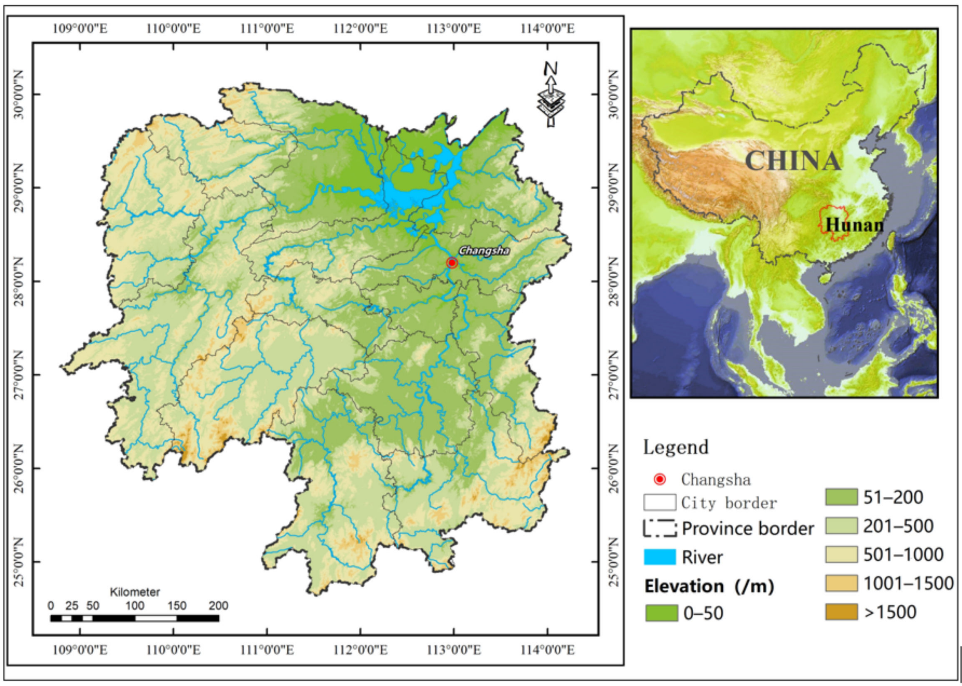

Figure 1. Map of Hunan Province.

2.2. Data Sources

2.2.1. Road Data

Through a comparative study, this paper uses the road distribution data obtained by the National Basic Geographic Information Center, which is more refined and in line with the actual distribution of roads. According to the JTG B01-2003 standard, roads are divided into railways (including high-speed railways, ordinary railways and subways), expressways, national roads, provincial roads, county roads, urban trunk roads and urban secondary trunk roads, and other roads.

2.2.2. Night Light Data

In this paper, the night light data of NPP-VIIRS in Hunan Province in 2019 were obtained from the National Geophysical Data Center (NGDC) of the USA under the National Oceanic and Atmospheric Administration (NOAA), which represents evidence of humans in the study area, and determines the impact of human activities on natural landscape through light density.

2.2.3. POI Data

POI data are the basic data based on a location-based service (LBS). Through the API interface provided by the Gordes Amap Open Platform, python was used to obtain the latitude, longitude, and the name of public service resources such as schools, stations, hospitals, governments, and public inspection and law institutions. The results were 18,956, 27,134, 5702, 49,630, and 1526, respectively.

2.3. Methods

2.3.1. ROS Regionalization Criteria

Referring to the *Extending the Recreation Opportunity Spectrum to Nonfederal Lands in the Northeast: An Implementation Guide*, this study obtained the mountain, water, and forest coverage data of six states in New England in 2019, and obtained the mountain, water, and forest coverage data of Hunan Province in 2019 from the Hunan Provincial Bureau of Statistics, as shown in Table 1.

Table 1. Mountain, water, and forest coverage of New England and Hunan in 2019.

	Area (km^2)	Mountain Ratio	Water Ratio	Forest Coverage
Hunan Province	211,800	51.20%	6.37%	59.90%
New England	186,447	47.92%	12.92%	69.57%

According to the *ROS Users Guide* issued by the USDA Forest Service in 1982, the physical setting is determined based on the types of recreational opportunities, and states that *relatively flat terrain with low tree cover, or large bodies of water, may require great distances to achieve screening for remoteness, while deep canyons or heavily wooded terrain may provide equivalent screening with less distance.* Therefore, the remoteness and size of the physical setting area are related to the topography, water area, and forest coverage of the study area. Table 1 is obtained from the official websites of the USDA Forest Service and United States Geological Survey and the Hunan Provincial Bureau of Statistics. It can be seen from the table that the topography and other natural environmental conditions of Hunan Province are comparable to those of New England. Therefore, the remoteness and size of the physical setting area of the ROS in Hunan Province are in accordance with the relevant criteria of the *Extending the Recreation Opportunity Spectrum to Nonfederal Lands in the Northeast: An Implementation Guide* in New England. The definition and description of managerial setting in 1982 and the 2003 ROS application guidelines of the USA are more suitable for the management and control after the determination of the ROS, which cannot guide the quantitative research of the ROS in Hunan Province. Because the management of natural protected areas in China is still in the process of adjustment and optimization, an accurate vector boundary of natural protected areas is unable to be obtained. Thus, this research does not use the managerial setting criteria, and only uses the physical setting criteria and social setting criteria to zone the natural recreational resources in Hunan Province.

Referring to the remoteness and size of the area criteria in the physical setting of *Extending the Recreation Opportunity Spectrum to Nonfederal Lands in the Northeast: An Implementation Guide* released by the USDA Forest Service in 2003, the night light data and POI data were used as evidence of human criteria in the physical setting and the user density criteria in the social setting, respectively. The GIS was used to process the image map of Hunan Province, and the geographical information database was constructed. The buffer analysis, overlay analysis, density analysis, and reclassification were carried out to draw the ROS of Hunan Province, and the results are displayed intuitively in the form of maps. ROS comprehensive criteria of regionalization are as Table 2.

Table 2. ROS(Recreation Opportunity Spectrum) comprehensive criteria of regionalization.

ROS Class		Comprehensive Criteria
Primitive		Areas larger than 12.14 km^2 outside 3.22 km of all roads
Semi-primitive non-motorized		All roads in 0.81–3.22 km area are greater than 4.05 km^2; Areas out of 3.22 km of all roadslarger than 4.05 km^2 and less than or equal to 12.14 km^2
Semi-primitive motorized		Areas of 3.22 km of all roads less than or equal to 4.05 km^2; Areas within 0.81–3.22 km of all roads less than or equal to 4.05 km^2; Areas larger than 4.05 km^2 of original and semi-original motor vehicle-free area removed from all roads except 0.81 km
Developed natural		Areas of level 2/3 after overlaying night lighting and POI data within 0.81 km of all roads
Highly developed	Large natural	Areas of level 4 after overlaying night lighting and POI data within 0.81 km of all roads
	Small natural	Areas of level 5 after overlaying night lighting and POI data within 0.81 km of all roads
	Facilities	Areas of level 6 after overlaying night lighting and POI data within 0.81 km of all roads
Semi-developed natural		Regions other than the above areas

2.3.2. Road Data

Buffer analysis is the establishment of a certain distance (buffer radius) around a given spatial entity (set) of a banded area (buffer polygon) to determine the impact of these objects on the surrounding environment or service range. The buffer zones of 3.22 km and 0.81 km are analyzed for all roads. Outside the buffer zone of 0.81 km are the original and semi-original areas, inside the buffer zone of 0.81 km are the semi-developed natural areas, developed natural areas, and highly developed areas.

2.3.3. Night Light Data

Since Visible infrared Imaging Radiometer (VIIRS) has a very small number of problems, such as negative values, transient light sources, and background noise, the minimum threshold of 0.3×10^{-9} W$\cdot$m$^{-2}\cdot$sr^{-1} proposed by MA is used to eliminate background noise and transient light sources, and the negative value is uniformly assigned to 0 [31–33]. Taking the maximum light value of Changsha, which is the most economically developed city in Hunan Province, as the maximum threshold, the average filtering method is used to eliminate the maximum value of pixels with surrounding 8 pixels as larger than the threshold range [34,35].

The corrected 12-month light image was used to synthesize the annual night light value:

$$DN_y = \frac{\sum_{i=12} DN_i}{12}. \quad (1)$$

where DN_y represents the combined annual night light value. DN_y represents the night light value for each month of 2019. Then the natural break method is used to reclassify it into six categories.

2.3.4. POI Data

In this study, the point density analysis tool in the GIS is used to analyze the spatial distribution characteristics of the extracted public service industry POI. A point density analysis tool is used to calculate the density of point elements around each output grid pixel. The principle defines a neighborhood around each grid pixel, adds the number of points in the neighborhood, and then divides by the neighborhood area to obtain the density of POI point elements. Assuming that the density of a point element is ρ, the neighborhood area is S, and the number of points in the neighborhood is N, the calculation formula of the point density is:

$$\rho = \frac{N}{S} \quad (2)$$

Subsequently, the natural discontinuity method is used to reclassify it into six categories to obtain the social layer.

2.3.5. Factor Dominance

Dominance is used to reflect the status and role of population in community composition structure in community ecology research. The landscape dominance index is constructed by using the principle of dominance index to measure the degree of overall landscape controlled by one or a few landscape elements. The higher the dominance of a certain type of landscape elements in the landscape, the higher the degree of landscape control by such landscape elements. On the contrary, if there is no obvious dominant landscape element, the landscape has high heterogeneity [36]. The dominance of class i landscape elements can be calculated as follows:

$$D_i = \frac{1}{4}DP_i + \frac{1}{4}DF_i + \frac{1}{2}DC_i \quad (3)$$

where DP_i denotes the relative density of landscape elements of class i, which is the number of patches of landscape elements accounting for the percentage of the total number of patches studied. DF_i represents the relative frequency of landscape elements for class i, which is the percentage of the total number of landscape elements patches in the landscape grid samples. DC_i represents the relative coverage of class i landscape elements, which is the percentage of the total area of such landscape elements in the total landscape area.

In this paper, the ratio of each county (city, district) of all kinds of ROS advantage degrees and all kinds of ROS advantage degrees in the province is used to reflect the ROS advantage degree of each county (city, district). According to the ROS advantage degree of each county (city, district), and according to the criteria in Table 3, it is divided into key metropolitan counties (city, district), general metropolitan counties (city, district), rural counties (city, district), general natural recreational resources counties (city, district), and key natural recreational resources counties (city, district).

Table 3. ROS advantage degree and county (city, district) zoning criteria.

ROS Advantage Degree	Zoning Result
Facilities	Key metropolitan counties (city, district)
Small natural or large natural	General metropolitan counties (city, district)
Developed natural or semi-developed natural	Rural counties (city, district)
Semi-primitive motorized or semi-primitive non-motorized	General natural recreational resources counties (city, district)
Primitive	Key natural recreational resources counties (city, district)

3. Results

3.1. ROS Class

Using a GIS, referring to the 2003 ROS application guidelines of the USA, and combining with the physical setting criteria and social setting criteria, the ROS of Hunan Province was constructed. The results are shown in Figure 2. The Figure 3 shows that Hunan Province is featured by ROS classes that are relatively small in size, geographically discontinuous, and physically irregular. The primitive accounts for 2.51% of the total area of the province, and is mostly distributed in forest parks or nature reserves. It is mainly concentrated in the Nanling in the south of Hunan Province, the southern section of the Luoxiao Mountains in the east, the Xuefeng Mountains and Wuling Mountains in the northwest, and the Dongting Lake and Datong Lake areas in the north. The semi-primitive non-motorized accounts for 21.33% of the whole province and mainly relies on the original regional distribution, concentrated in the western and southern parts of Hunan Province, and a small amount of distribution in the eastern Mulian Jiushan Mountains. The distribution of primitive and semi-primitive non-motorized is in line with the horseshoe-shaped topography of Hunan Province, which is surrounded by mountains in the east, south and west, hilly in the middle, a lake basin plain in the north, and fertile fields. The semi-primitive motorized and semi-developed natural accounted for the largest proportion of the whole province, which are 38.60% and 30.99%, respectively. Developed natural accounts for 5.61% of the province. Highly developed accounts for 0.96% of the province area, of which large natural accounts for 65.63% of the highly developed, small natural accounts for 27.95% of the highly developed, and facilities accounts for 6.42% of the highly developed. In addition to the Chang-Zhu-Tan region, developed natural regions mainly rely on the decentralized distribution of administrative regions with population and economic agglomeration in each city. The highly developed areas are mainly concentrated in the eastern part of Hunan Province, especially the Changzhutan block and the Dongting Lake block.

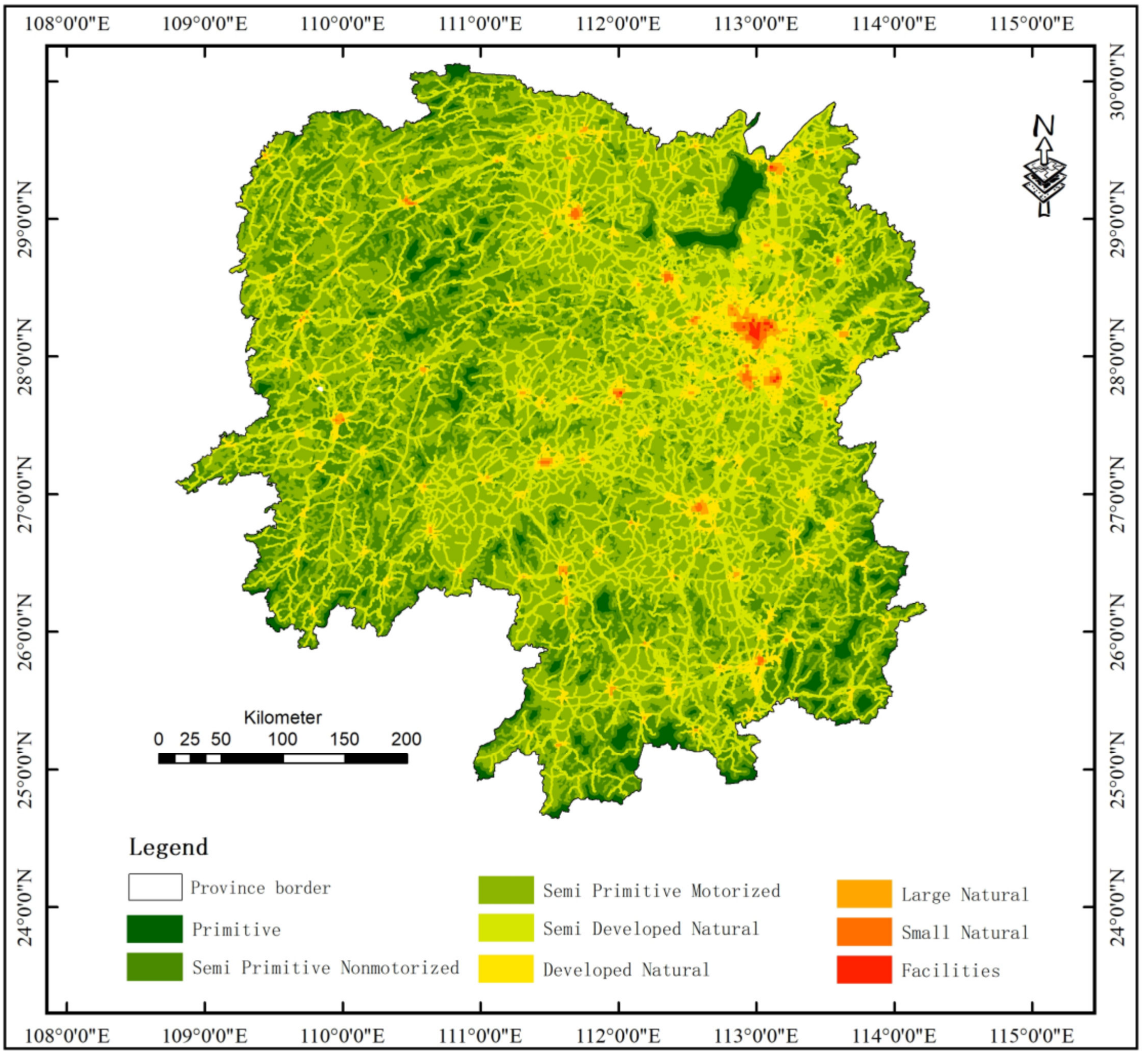

Figure 2. ROS classes in Hunan.

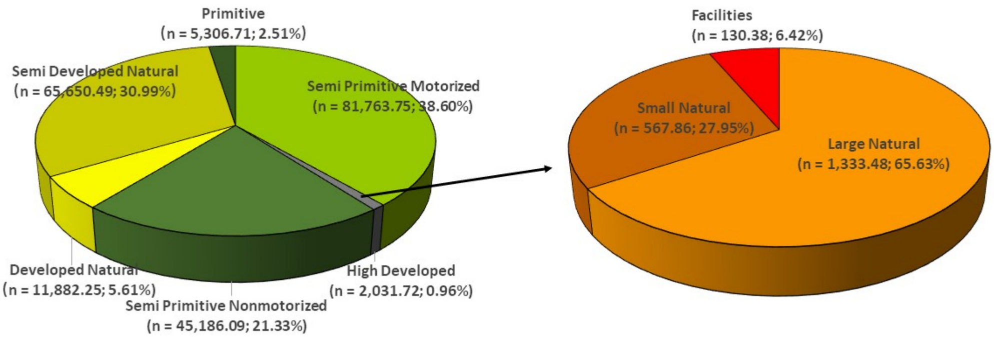

Figure 3. Percentages of ROS classes.

3.2. County Zoning of Natural Recreational Resources

The natural and developed levels of a region are relative, so the corresponding ROS classification result is also relative. This research was based on the provincial road, night-time light, and POI data to construct the ROS. The factor dominance at all levels in the province reflects the dominance of each factor in the province. Therefore, the factor dominance at all levels in each county (city, district) should be compared with the factor dominance at all levels in the province. The ratio is used to represent the natural recreational resources of each county (city, district), and the ROS advantage types of each county (city, district) are obtained. Through the ratio of factor superiority of each county (city, district) to that of the whole province, the ROS superiority types of 122 counties (city, district) in Hunan Province were determined and divided. The results are shown in the Table 4 and Figure 4. There are 19 key natural recreational resource counties (cities and districts), 24 general natural recreational resource counties (cities and districts), 50 rural counties (cities and districts), 21 general metropolitan counties (cities and districts), and 8 key metropolitan counties (cities and districts).

Table 4. Results of 122 counties zoning.

Zoning	Counties (Cities and Districts)
Key natural recreational resource counties (cities and districts) (19)	Chaling County, Dao County, Guidong County, Jianghua Yao Autonomous County, Jiangyong County, Lanshan County, Linwu County, Lingling District, Ningyuan County, Rucheng County, Shimen County, Tongtong Dong Autonomous County, Xiangyin County, Yanling County, Yichang County, Yuanjiang City, Yuanling County, Yueyang County, Zixing City
General natural recreational resource counties (cities and districts) (24)	Anhua County, Baojing County, Chenxi County, Chengbu Miao Autonomous County, Cili County, Dong'an County, Guzhang County, Hengyang County, Hongjiang City, Huitong County, Jingzhou Miao and Dong Autonomous County, Longshan County, Qidong County, Qiyang County, Sangzhi County, Shuangpai County, Suining County, Xinhuang Dong Autonomous County, Xinning County, Xintian County, Xupu County, Yongshun County, Zhijiang Dong Autonomous County, Zhongfang County
Rural counties (cities and districts) (50)	Anren County, Anxiang County, Changning County, Dingcheng District, Dongkou County, Fenghuang County, Guiyang County, Hanshou County, Hengdong County, Hengnan County, Hengshan County, Huayuan County, Huarong County, Jishou City, Jiahe County, Jinshi City, Junshan District, Leiyang City, Lengshuijiang City, Li County, Liling City, Lianyuan City, Linli County, Linxiang City, Liuyang City, Longhui County, Luxi County, Mayang Miao Autonomous County, Miluo City, Nan county, Nanyue District, Ningxiang City, Pingjiang County, Shaoshan City, Shaodong County, Shaoyang County, Shuangfeng County, Suxian District, Taojiang County, Taoyuan County, Wugang City, Wulingyuan District, Xiangtan County, Xiangxiang City, Xinhua County, Xinshao County, Yongxing County, You County, Yunxi District, Zhuzhou County
General metropolitan counties (cities and districts) (21)	Beihu District, Beita District, Daxiang District, Heshan District, Hecheng District, cold water beach area, Lushong District, Shifeng District, Shigu District, Shuangqing District, Wangcheng District, Wuling District, Yanfeng District, Yongding District, Yuhu District, Yuelu District, Yuetang District, Yueyanglou District, Zhengxiang District, Zhuhui District, Ziyang District
Key metropolitan counties (cities and districts) (8)	Furong District, Hetang District, Kaifu District, Louxing District, Tianxin District, Tianyuan District, Yuhua District, Changsha County

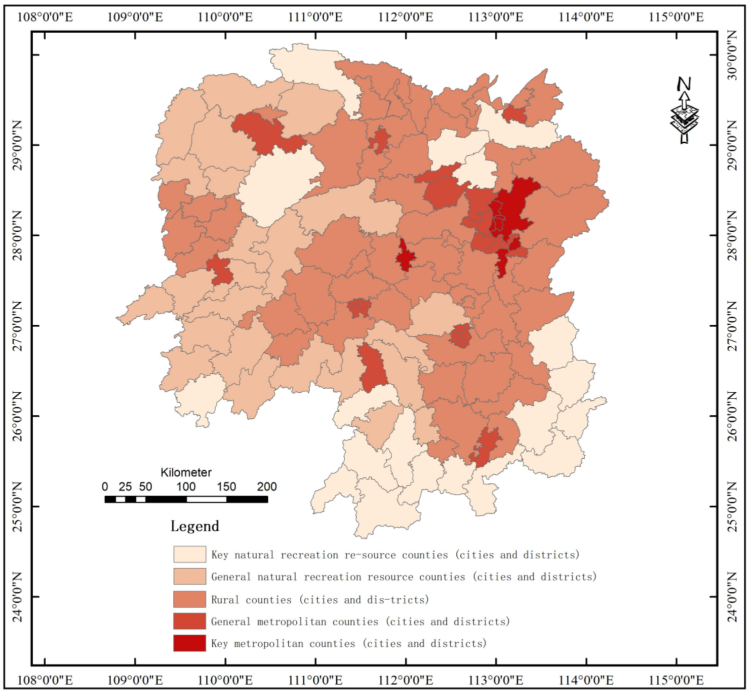

Figure 4. Results of the zoning of 122 counties.

4. Discussion

In reality, it is difficult to obtain permanent population data through technical means. Previous studies have shown that the distribution of population size has a strong correlation with the night-time light intensity characterization [37]. Night-time light data have great advantages in the application of urban expansion and population spatialization, and light data as an indicator data of human social activity also have guiding significance [38–42]. In this paper, light data are used as an indicator data of human activity in the physical environment. Compared with the expression of building density in other research, the use of night light data has the advantages of convenient acquisition, small data volume, wide coverage, and fast data update [43]. This paper uses POI data as an indicator of the social setting, signaling the opportunities for contact between individuals and groups. POI data have characteristics such as a large amount of information, high location accuracy, and strong real-time performance, which can fully and effectively reflect the urban spatial structure. POI data are widely used in the identification and analysis of urban functional areas, improving the accuracy of urban public service format space research with a reduced research cost [44,45]. Some scholars have studied population spatialization based on night-time light data and POI, and other multivariate data [46]. Therefore, the use of night-time light data and POI data to determine evidence of human activity and opportunity for contact between individual groups enables the research results to be more objective and scientific.

Within a certain region, the population density and the degree of human disturbance are different, and the corresponding primitive and developed degrees in the region are also relative. Because this research is based on the production of a large-scale ROS within the province, it cannot take into account certain socio-economic conditions in extreme areas. Therefore, the concept of factor dominance is introduced to calculate the factor dominance of the ROS at all levels in the provincial and county areas, namely the control degree of the ROS in the provincial and county areas. The relative level of the ROS in the county can be reflected by calculating the ratio of the advantages of the ROS at all levels in the county and the province.

Spatial heterogeneity is the spatial distribution relationship and variation degree of patches with different land cover types, which is an important factor affecting spatial geographic data research [47]. It is believed that heterogeneity can be defined according to two components, namely the system properties researched and their complexity or variability, which emphasizes the observability and quantitative analysis of spatial structure characteristics and spatial scale dependence. Landscape spatial heterogeneity is not only derived from the natural geographical characteristics and geological process of spatial units in the landscape, but is also affected by natural disturbance, human activities, biological community settlement and endogenous succession, and the historical accumulation process of these three [48,49]. Landscape spatial heterogeneity directly affects the distribution and dissemination of resources, species, and disturbances in the landscape, affects the biodiversity and productivity of the landscape, and plays an important role in controlling the overall function and ecological process of the landscape [50,51]. The study of landscape spatial heterogeneity and its dynamics helps to reveal the source and control factors of the heterogeneity of research objects, clarifies the characteristics and dynamics of spatial heterogeneous mosaics, and provides a basis for the effective management and sustainable utilization of landscapes [52].

The dominance of landscape elements is the direct embodiment of landscape spatial heterogeneity. The higher the dominance of a certain type of landscape element in the landscape, the higher the degree of control of the landscape by this type of landscape element. If there is no significant advantage of landscape elements in the landscape, it indicates that the landscape heterogeneity is high [35]. According to the classification results of the ROS in Hunan, semiprimitive motorized is the dominant type of ROS in Hunan, which indicates that the level of ROS in Hunan is highly controlled by semi-primitive motorized regions, followed by semi-developed natural regions. Therefore, Hunan is rich in natural recreational resources and low in landscape heterogeneity.

In the results of the division of natural recreational resources, the key natural recreational resources counties (cities and districts) have the primitive area as the dominant ROS, featuring large-scale natural environments without human modifications, with very superior natural recreational resources, a small population, and minimal human intervention, which is a two-way area for reasonable protection and utilization. General natural recreational counties (cities and districts) have semi-primitive regions as the dominant ROS, and the natural ecological environment is the main area, having superior natural recreational resources, with a lower population and minimal human intervention. It is an important area for natural recreational activities. Rural counties (cities and districts) have semi-developed natural and developed natural as the dominant ROS. The natural ecological environment in the region is coordinated with signs of human interference. The natural recreational resources are renovated and utilized by human beings, and the population quantity and management degree are between developed and undeveloped regions, so it is suitable to carry out short-range natural recreational activities around the developed regions. General metropolitan counties (cities, districts) have large natural and small natural as the dominant ROS. The natural recreational resources in the region are changed by human beings. They have a certain scale of artificial facilities. The metropolitan landscape is common and obvious, and it is suitable for non-organized natural recreational activities for the people in the region. The key metropolitan counties (cities, districts) have the area with intensive artificial facilities as the dominant ROS. The natural ecological environment in the area has obvious traces of development, and the artificial facilities are dense and designed, and managed for specific activities, so it is suitable for organized natural recreational activities. The relevant management departments can apply the results of the ROS classification and natural recreational resource zoning in Hunan Province to effectively manage the sustainable use of natural recreational resources in Hunan, so as to realize the non-consumptive use of natural ecological resources.

In this research, in the preparation of the ROS, in addition to the traditional remoteness and size of the area as the physical setting criteria, the night-time light data of Hunan Province in 2019 are innovatively used as evidence of human criteria in the physical environment, and the POI information data of public service resources such as government, schools, hospitals, stations, and public security institutions in Hunan are used as the social setting criteria. Although POI data have the advantages of having strong timeliness, low cost, and easy access, and are representative of various functions and social and economic activities of the city, there are some shortcomings. First, POI data are expressed as point entities, and it is difficult to express the specific location of large information points. Second, managerial setting criteria in the USA mainly focus on the characteristics of land ownership, while in China, they mainly focus on the control requirements of nature reserves. At present, China's nature reserves are in a stage of optimization and integration, so it is difficult to obtain accurate vector boundaries and control zoning. Therefore, there is no vector boundary for any forest parks or nature reserves in Hunan Province, so the managerial setting criteria were not used in the process of compiling the ROS for the province.

Future studies should consider how to incorporate environmental management indicators into ROS construction. Discussion and analysis can be carried out according to the results regarding natural recreational resources, county zoning, and the tourism economy, in order to provide decision-making guidance and reference standards for the relevant management departments.

5. Conclusions

Based on the application of a GIS to compile a ROS for Hunan Province, this research used night-time light data and geographical information POI data as evidence of human activity and user density criteria for the compilation of the ROS on a provincial scale, enriching the application scale and compilation criterion basis for the creation of the ROS and producing a more objective and scientific result. According to the ROS results, primitive areas of natural recreational resources in Hunan Province account for 2.51% of the province, semi-primitive non-motorized areas account for 21.33%, semi-primitive motorized areas and semi-developed natural areas account for, respectively, 38.60% and 30.99%; developed natural areas account for 5.61%; highly developed areas account for 0.96%, of which large natural areas account for 65.63% of the highly developed areas, and small natural areas accounted for 27.95%, and areas with facilities account for 6.42% of the area of highly developed areas. Furthermore, the concept of a natural recreational resource county (city, district) was defined, and subsequently 122 counties (cities, districts) in Hunan Province were divided into key urban counties (cities, districts), general urban counties (cities, districts), rural counties (cities, districts), general natural recreational resource counties (cities, districts), and key natural recreational resource counties (cities, districts) using factor dominance. There are 8, 21, 50, 24, and 19 counties (cities, districts) in the 5 levels of zoning, respectively.

Author Contributions: Conceptualization, W.Z., Y.Z., and D.L.; methodology, Y.Z.; software, W.Z. and D.L.; project administration, Y.Z.; validation, W.Z., Y.Z., and J.D.; visualization, W.Z. and D.L.; original draft writing, W.Z.; writing review and editing, Y.Z. and J.D. funding acquisition, Y.Z. supervision, Y.Z. and J.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by National Key R&D Program: Research on Rural Plant Landscape Construction and Application Technology, grant number 2019YFD1100404. This research was funded by Postgraduate Scientific Research Innovation Project of Hunan Province, the name of the project is Construction of Recreation Opportunity Spectrum for Evaluating Physical and Social Setting With Night Light and POI Data.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Please contact the authors via email for the data.

Acknowledgments: Supported by Scientific Innovation Fund for Post-graduates of Central South University of Forestry and Technology.

Conflicts of Interest: The authors declare no conflict of interest.

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