Study on Investigation and Assessment Techniques of Tropical Forest Ecotourism Resources in Diaoluoshan National Forest Park

HUANG Qinglin, HUANG Jingcheng and MA Zhibo

Technical Report of ITTO Project

ITTO RED-SPD 075/12 Rev. 1 (F)
Demonstration on Investigation and Assessment of Tropical Forest Ecotourism Resources in Hainan Province, China

TECHNICAL REPORT OF THE ITTO PROJECT

Title of the ITTO Project:	Demonstration on Investigation and Assessment of Tropical Forest Ecotourism Resources in Hainan Province, China
Title of the Report:	Study on Investigation and Assessment Techniques of Tropical Forest Ecotourism Resources in Diaoluoshan National Forest Park
Authors name:	Huang Qinglin, Huang Jingcheng and Ma Zhibo

Additional technical and scientific staff that worked on the topic of the report:	Li Hua, Zhuang Chongyang, Luo Hong, He Chulin, Peng Wencheng
Relevant institutions' full name, address:	Full Name: Research Institute of Forest Resource Information Techniques, Chinese Academy of Forestry (CAF) Address: Box 33, Chinese Academy of Forestry (CAF), Wan shou shan, Beijing 100091, P. R. China Full Name: Hainan Forestry Bureau Address: 80 Haifu Road, Meilan District, Haikou City, Hainan Province 570203, P. R. China Full Name: Diaoluoshan National Forest Park Address: Lingshui County, Hainan Province 572433, P. R. China
The place and date the report was issued:	Beijing, China 29 September 2015

Title of the ITTO Project or Pre-project:	Demonstration on Investigation and Assessment of Tropical Forest Ecotourism Resources in Hainan Province, China
Project number:	RED-SPD 075/12 REV. 1 (F)
Host Government:	The People's Republic of China
Name of the Executing Agency:	Research Institute of Forest Resource Information Techniques, Chinese Academy of Forestry (CAF)
Project Coordinator	Huang Qinglin
Starting date of the Project:	1 May 2013
Duration of the Project (month)	18 months

Table of contents

Summary

There is not specific method of investigation and assessment for tropical forest ecotourism resources in China. The existing methods are simple, extensive and no specific. They are introduced from universal methods, mainly from "*Classification, Investigation and Evaluation of Tourism Resources*" (GB/T 18972-2003, National Standard of the People's Republic of China) developed by National Tourism Administration and "*China Landscape Resources Grade Evaluation of Forest Park in China*" (GB/T 18005-1999, National Standard of the People's Republic of China) developed by State Forestry Administration. There are 3 main problems in the existing method of investigation and assessment of tropical forest ecotourism resources in Hainan Province: (1) The ecotourism attractions in tropical forests are not specific. (2) The ecotourism attractions inventory is not conducted in all subcompartments in the Forest Management Unit (FMU). (3) The Recreation Opportunity Spectrum (ROS) inventory and visual resources (in landscape level) inventory are not included. Lacks of Recreation Opportunity Spectrum (ROS) (in landscape level), visual resources (in landscape level) and forest ecotourism attractions in individual and stand level in tropical forests are the main problems in existing techniques of investigation and assessment for tropical forest ecotourism resources in China.

Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN), Rural (R) and Urban (U) are the six classes of the Recreation Opportunity Spectrum (ROS) in tropical forest ecotourism resources (in landscape level) . The scenic attractiveness, scenic integrity, landscape visibility and scenic classes etc. are the main indicators of visual resources (in landscape level) in tropical forest ecotourism resources (in landscape level). The buttress, garden in the air, cauliflory, strangler, dangling liana, special tree and animal etc. are the main tropical forest ecotourism attractions in individual level.

Case study on Recreation Opportunity Spectrum (ROS) and visual resources in Diaoluoshan National Forest Park (in Lingshui County) in 2014 showed: the total area of Diaoluoshan National Forest Park (in Lingshui County) was 2 2279.48 ha in 2014; the Primary Forest, Degraded Primary Forest, Secondary Forest and Degraded Forest Land accounted for 10.83%, 42.61%, 37.98% and 1.05% respectively; the Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN) and Rural (R) of existing ROS classes accounted for 41.82%, 23.68%, 10.17%, 9.82% and 13.64% respectively; the Class A-Distinctive, Class B-Typical and Class C-Indistinctive of existing scenic attractiveness accounted for 39.40%, 31.91% and 26.96% respectively; the Very High, High, Moderate, Low and Very Low of existing scenic attractiveness accounted for 10.83%, 28.16%, 31.91%, 20.52% and 6.85% respectively; the Foreground Concern 1, Middleground Concern 1, Background Concern 1, Foreground Concern 2 and Middleground Concern 2 of existing landscape visibility accounted for 12.18%, 40.41%, 21.77%, 13.51% and 12.13% respectively; the Scenic Class 1, Scenic Class 2, Scenic Class 3 and Scenic Class 4 of existing scenic classes accounted for 40.67%, 41.95%, 9.40% and 6.25% respectively.

There were 228 buttress tree species in Diaoluoshan National Forest Park in 2014, which belong to 87 genera and 42 families. There were 24 buttress tree species with big buttress (buttress height ≥ 1.5 m) in Diaoluoshan National Forest Park, which belong to 17 genera and 13 families. There were about 37 big tree species (DBH ≥ 100 cm) in Diaoluoshan National Forest Park, which belong to 29 genera and 21 families.

Neottopteris nidus and *Pseudodrynaria coronans* were two typical epiphytic ferns that formed garden in the air in Diaoluoshan National Forest Park. There were 79 host tree species (except *Tetrastigma planicaule*, a vine of Vitaceae) which belong to 53 genera and 31 families in sample plots. *Neottopteris nidus* and *Pseudodrynaria coronans* presented together on 37 tree species. Except, *Neottopteris nidus* presented on another 25 tree species, and *Pseudodrynaria coronans* presented on another 17 tree species. There were 24 host tree species were found in primary forests (PFs), 48 host tree species in degraded primary forests (DPFs) and 7 host tree species in both of them in sample plots.

The living height of the epiphytic ferns did not distributed in normal pattern or other common distribution functions. The diameter and density distribution of the epiphytic ferns, the density distribution of epiphytic ferns' hosts and the distribution of epiphytic fern number per host met the negative exponential function. Both tree hosts in primary forests (PFs) and degraded primary forests (DPFs) were clumped distribution patterns.

The buttress length did not distributed in normal pattern or other common distribution functions. The buttress height distribution, the distribution of buttress density and the distribution of buttress trees density met the negative exponential function. The buttress number per buttress tree distributed in Poisson distribution. Both buttress trees in primary forests (PFs) and degraded primary forests (DPFs) were clumped distribution patterns.

There are 3 levels of ecotourism attractions for investigation and assessment of tropical forest ecotourism resources in Hainan Province: individual level, stand (forest community) level and forest landscape level. The buttress, garden in the air, cauliflory, strangler, dangling liana, special tree and animal etc. should be the main ecotourism attractions in individual level and should be inventoried in each subcompartment when conduct the traditional forest management inventory in FMU. The density and distribution of individual ecotourism attractions, species diversity and structure of stand (forest community) etc. should be the main ecotourism attractions in stand (forest community) level and should be inventoried in each subcompartment when conduct the traditional forest management inventory in FMU. The Recreation Opportunity Spectrum (ROS) and visual landscape characters (including scenic attractiveness, scenic integrity, landscape visibility and scenic classes etc.) should be the main ecotourism attractions in forest landscape level and should be analyzed and assessed after the traditional forest management inventory and assessment in FMU.

Keywords: Forest Ecotourism Resources; Tropical Forest; Investigation; Assessment; Techniques; Diaoluoshan National Forest Park; Hainan Province; China

1 Introduction

1.1 The background and purpose

The construction of Hainan International Tourist Island became a national strategy after *Several Suggestions on the Advancement of Construction and Development for Hainan International Tourism Island* issued by State Council in December 2009. The government of Hainan Province developed *outline of Construction and Development for Hainan International Tourism Island* in June 2010 and issued *Decisions on Accelerating Development of Hainan Tropical Forest Tourism* in July 2011. In the *Decisions*, the development of Hainan tropical forest tourism was recognized as an important measure to ensure the ecological security of Hainan Province and an important approach to improve local livelihoods in central and west part of Hainan Province, because of important ecological and economic values and unique tourism values of tropical forest resources. Forest ecotourism is an important part of the construction of Hainan International Tourism Island. Forest ecotourism is an important and effective effort to enhance environmental services and local livelihoods in Hainan Province. Investigation and assessment of typical forest ecotourism resources in Hainan Province is the most important step for implementing and promoting forest ecotourism in Hainan Province.

The forest ecotourism in Hainan Province is still weak, but should have great potential because of 60.2% of tropical forest coverage (especially 0.659 million hectare of natural tropical forests) and unique minorities cultures etc. Besides weakness in the infrastructure for forest ecotourism, there main problem for forest ecotourism in Hainan Province was that tourists visited Hainan were not interests in tropical forests (including rain forest). In other words, the results and their dissemination from existing extensive investigation and assessment of forest ecotourism resources in Hainan Province have not obviously attracted the tourists and public. The important and unique ecotourism values of tropical forest ecotourism resources in Hainan Province should be introduced to public by sound investigation and assessment methods.

There is not specific method of investigation and assessment for tropical forest ecotourism resources in China. The existing methods are simple, extensive and no specific. They are introduced from universal methods, mainly from "*Classification, Investigation and Evaluation of Tourism Resources*" (GB/T 18972-2003, National Standard of the People's Republic of China) developed by National Tourism Administration and "*China Landscape Resources Grade Evaluation of Forest Park in China*" (GB/T 18005-1999, National Standard of the People's Republic of China) developed by State Forestry Administration. Lacks of tropical forest ecotourism attractions, Recreation Opportunity Spectrum (ROS) (in landscape level) and visual resources (in landscape level) in tropical forests are the main problems in existing methods of investigation and assessment for tropical forest ecotourism resources in China.

The techniques of investigation and assessment for Recreation Opportunity Spectrum (ROS) (in landscape level) and visual resources (in landscape level) and ecotourism attractions in tropical forests based on the case study in Diaoluoshan National Forest Park (in Lingshui County) are studied and demonstrated in this report. Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN), Rural (R) and Urban (U) are the six classes of the Recreation Opportunity Spectrum (ROS) in tropical forest ecotourism resources (in landscape level) . The scenic attractiveness, scenic integrity, landscape visibility and scenic classes etc. are the main indicators of visual resources (in landscape level) in tropical forest ecotourism resources (in landscape level). The buttress, garden in the air, cauliflory, strangler, dangling liana, special tree and animal etc. are the main tropical forest ecotourism attractions in individual level.

1.2 Progress of domestic and foreign research and practice

The comprehensive contents and methods of investigation and assessment of forest ecotourism resources were summarized as follows (Figure 1) after relative national and international literature review (Bao and Chu 1999; Brass 1996; Chen 2006; Chen et al. 2007; Clawson and Knetsch 1969; Dowling, 1993; Fu and Wu 2006; Getz 1986; Liang and Ding 2002; Gutierrez et al. 2005; Goeldner and Ritchie 2011; Guo et al. 2000; Gunn 1972; Lascuráin 1996; Lawton 2005; Leiper 1990; Lew 1987; Luo et al. 2014; Ma et al. 2014; Ministry of Forestry 1996; National Tourism Administration 2003; Pearce 1991; Pigram1983; Qiu 2000; Qi 2013; State Forestry Administration 2000; State Forestry Administration 2011; The Resource Inventory Committee, 1998; USDA Forest Service 1974, 1982, 1995, 2007; USDA Soil Conservation Service 1978; USDOT Federal Highway Administration 1981; Wang et al. 2008; Wu et al. 2001; Wu C. 2003; Wu Z 2003; Xing and Wang 1987; Yang 1997; Zhang 1999; Zhong 1998).

Garden in the air is a most typical characteristic and an important tourism attraction of tropical forests. As the "skeleton" of garden in the air, epiphytic ferns like baskets with efficiently intercepts and retains falling leaf litter, giving habitats for insects, invertebrates, arthropods and other plants, such as mosses, lichens. Besides those functions of supporting forest community diversity and dynamic focused by Ecology (Fayle et al. 2008; Watkins et al. 2008; Ellwood et al. 2009), they are also research objects of Palaeobotany and Palynology (Galtier and Christenhusz 2014; Sundue and Rothfels 2014), Physiology (Hietz and Briones 2001; Minardi et al. 2014), Botany (Moran et al. 2003; Dubuisson et al. 2009; Fayle et al. 2009; Christenhusz and Chase 2014; Wagner et al. 2015), Conservation Biology (Soria-Auza and Kessler 2008), and climate changing (Hsu et al.2014). In China, researchers have mainly focused on montane rain forests, and mainly considered selected groups of flower plants. Studies on epiphytic ferns only include their flora and diversity (Dong et al. 2003; Liao et al. 2003; Qin et al. 2007; Zhang et al. 2007; Luo et al. 2010), medicinal ferns (Yang, et al. 2010; Chen and Zhong 2014), and few considering their ecological characteristics (Xu 2013).

“*Classification, Investigation and Evaluation of Tourism Resources*” (GB/T 18972-2003, National Standard of the People's Republic of China) developed by National Tourism Administration focuses on object of tourism resource and ignores the inventory of forest ecotourism attractions. “*China Landscape Resources Grade Evaluation of Forest Park in China*” (GB/T 18005-1999, National

Standard of the People's Republic of China) developed by State Forestry Administration focuses on overall evaluation on Forest Management Unit (FMU) level and ignores forest ecotourism attractions in individual level and stand (forest community) level. And *Technical Regulations for Inventory for Forest Management Planning and Design* (GB/T 26424-2010, National Standard of the People's Republic of China) developed by State Forestry Administration focuses on forest mensuration characteristics and ignores the characteristics of forest ecotourism attractions. Recreation Opportunity Spectrum (ROS) (in landscape level) and visual resources (in landscape level) were ignored in above three guides relative to investigation and assessment of forest ecotourism resources.

In brief, lacks of Recreation Opportunity Spectrum (ROS) (in landscape level), visual resources (in landscape level) and forest ecotourism attractions in individual and stand level in tropical forests are the main problems in existing techniques of investigation and assessment for tropical forest ecotourism resources in China.

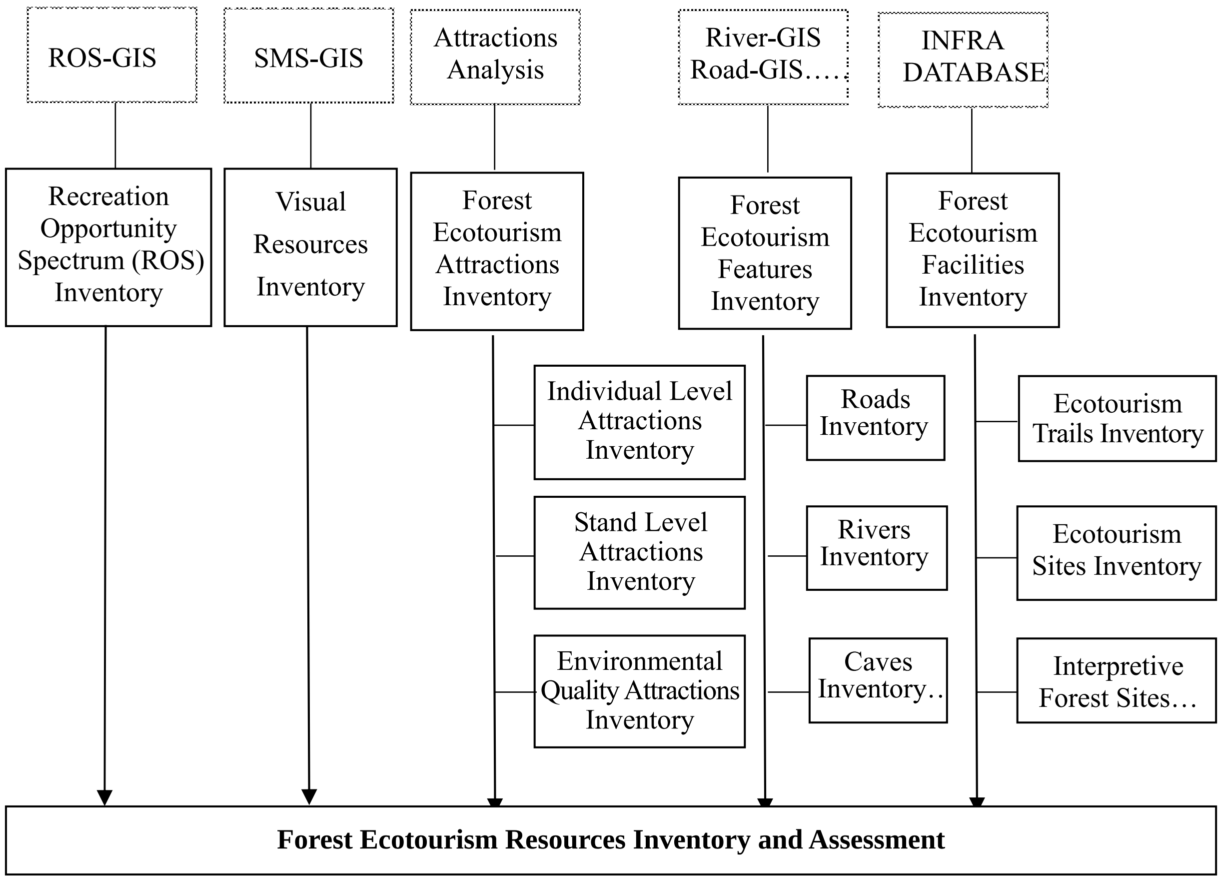


Figure 1 Frame of investigation and assessment techniques of forest ecotourism resources

2 Applied methodology

Diaoluoshan National Forest Park (in Lingshui County) of Hainan Province was selected as a case study area. The remote sensing data processing, subcompartments information analysis, GIS analysis, ROS analysis, visual resources analysis, sample plots inventory, species diversity, size and density distribution analysis of the epiphytic ferns (garden in the air) and buttress and the distribution pattern of host of epiphytic ferns and buttress tree were the main methods applied in this study.

2.1 Remote sensing data processing

The RS data (SPOT5 image, SPOT2 images, LANDSAT-ETM images and LANDSAT-TM images) of Diaoluoshan National Forest Park were the source of baseline information in vegetation pattern analysis of case study area. Selected clear ground points from 1:10 000 topographic maps as coordinates for image correction and then fused the images. Information extraction was carried out using methods of automatic classification in combination with visual interpretation.

2.2 Subcompartments information analysis

The subcompartments information in Diaoluoshan National Forest Park were collected from the results of forest management inventory in Lingshui County conducted in 2011 based on *Technical Regulations of Forest Management Inventory* issued by the State Forestry Administration in 2003 and *Operation Rules for Forest Resource Inventory in Hainan Province* issued by Hainan Provincial Forestry Bureau in 2008.

2.3 GIS analysis

GIS analysis in Diaoluoshan National Forest Park was conducted based on the topographic data, results of remote sensing data processing and subcompartments information.

2.4 ROS analysis

ROS analysis in Diaoluoshan National Forest Park was conducted mainly based on the *ROS Users Guide* issued by USDA Forest Service in 1982.

2.5 Visual resources analysis

Visual resources analysis in Diaoluoshan National Forest Park was conducted mainly based on the *Handbook for Scenery Management* issued by USDA Forest Service in 1995 and 2007.

2.6 Sample plots inventory

The sample plots investigation for forest ecotourism attractions in individual level was conducted in April and May 2014 in Diaoluoshan National Forest Park. The garden in the air and buttress were main important forest ecotourism attractions in individual level and were analyzed in this report. The area of each sample plot was mainly 2,500 m^2 (Table 1). Sample plot number 1 to 11 were degraded primary montane rain forests (DPFs) and the sample plot number 12 to 16 were primary montane rain forests (PFs). Their altitude were between 755 m to 1 055 m. The species name, diameter at breast height (DBH) and height of the trees with DBH ≥ 5.0 cm were inventoried and recorded. The species name, quantity, height and diameter of epiphytic ferns (garden in the air) and the species name, quantity, height and diameter of buttress were measured respectively.

2.7 Species diversity

Species Richness, Species Diversity Index, Species Evenness and Ecological Dominance Index were chosen to measure species diversity. Species Richness (R) was the number of species that was the species richness in communities (S). Shannon-Wiener index (SW) was used to express the Species Diversity Index, Shannon-Wiener evenness to express the Species Evenness (E) and Simpson dominance index to express the Ecological Dominance (ED) (Wang et al. 1996). The formulas are as follows:

$$\mathrm{SW} = \sum_{\mathrm{i}=1}^{S} P_i \cdot \log_2 P_i = 3.3219(\lg N - \sum_{i=1}^{S} n_i \lg n_i / N)$$

$$E = SW / \log_2 S$$

$$ED = \sum_{i=1}^{S} n_i (n_i - 1) / (N(N-1))$$

Where, SW is Shannon-Wiener index, S is the number of species, n_i is the number of species i, N is the total number of individuals of the community (sample plot), P_i is the percentage of the number of species i in the total number of species, E is Species Evenness，ED is Simpson Ecological Dominance.

2.8 Size and density distribution analysis of epiphytic ferns (garden in the air) and buttress

The distributed pattern was firstly explored from histogram. And then, either the normality or other distribution tests were implemented, which based on Kolmogorov-Smirnov (with Lilliefors significance correction) and Shapiro-Wilk methods (Wu and Zhao 2009), or to fit the distribution functions. Distribution analysis objects were epiphytic ferns' and buttress' height, diameter and density. Density was analyzed by separating the sample plots (those area bigger than 700 m^2) into sample subplots with the area of 600 m^2 or 700 m^2.

2.9 Distribution pattern of the epiphytic ferns' host and buttress tree

The diffusion coefficients (C) was calculated to decide the distribution pattern of epiphytic ferns' host and buttress trees (Zhang 2004; Ma 2009). And the formula is:

$$C = S^2/\overline{x}$$

where $\overline{x}$ is the mean of individuals quantity in samples of 10m×10m, and S^2 is the variance. The patterns of the distribution was decided by the C-value:

$$\begin{cases} \text{uniform/regular distribution} & C<1 \\ \text{random distribution} & C=1 \\ \text{aggregated distribution} & C>1 \end{cases}$$

The student's t-test can be used to decide if the observed samples value deviated the random distribution (Possion distribution). The deviated was significance if the calculated t-value (by formula as follows) bigger than the critical value in table of t-test. All the sample plots with area of 2 500 m^2 was tested in that paper.

$$t = (C-1)/\sqrt{2/(n-1)}$$

3 Presentation of the data

3.1 Basic information of sample plots in Diaoluoshan National Forest Park

Basic information of sample plots in Diaoluoshan National Forest Park (in Lingshui County) in 2014 is shown in Table 1. Sample plots number 1 to 11 were degraded primary montane rain forests (DPFs) and the sample plots number 12 to 16 were primary montane rain forests (PFs). The degraded primary forests (DPFs) evenness (*E*) was as same as primary forests (PFs) in the mean, therefore, the mean of abundance (*S*), biodiversity index (*SW*), and ecological dominant index (*ED*) were lower than that of PFs (Table 2). The mean of stand *DBH* and *H* of DPFs were higher than that of PFs, but the stand volume (*V*) was lower than PFs because of their relative lower stand density.

Table 1 Basic information of sample plots in Diaoluoshan National Forest Park

Sample Plot Number	$\overline{DBH}$ (cm)	$\overline{H}$ (m)	Density (N/hm^2)	V (m^3/hm^2)	*S*	*SW*	*ED*	*E*	Area (m^2)
1	26.8	18.9	496.0	236.8	34	4.52	17.31	0.89	2 500
2	27.7	20.8	488.0	272.1	33	4.47	16.11	0.89	2 500
3	23.3	17.2	704.0	229.8	37	4.00	8.06	0.77	2 500
4	20.0	16.5	712.0	166.3	48	4.38	10.52	0.78	2 500
5	19.8	17.7	1 204.0	299.3	58	4.94	18.99	0.84	2 500
6	23.2	18.7	1 184.0	423.1	58	5.20	25.78	0.89	2 500
7	25.2	19.0	960.0	407.8	59	5.24	26.08	0.89	2 500
8	25.8	18.6	844.4	363.3	42	4.58	15.03	0.85	1 800
9	26.0	17.6	1 340.0	572.0	43	4.87	20.16	0.90	1 000
10	50.1	22.5	456.3	841.6	36	4.65	14.44	0.90	1 600
11	29.5	16.5	333.3	163.6	14	3.62	10.88	0.95	900
12	23.0	13.8	1 384.0	355.1	118	6.16	44.41	0.89	2 500
13	22.2	13.7	1,416.0	335.0	92	5.51	22.40	0.84	2 500
14	15.3	12.0	2 204.0	231.8	66	4.94	17.98	0.82	2 500
15	21.9	12.9	1 028.0	229.1	73	5.50	30.92	0.89	2 500
16	37.1	18.6	971.4	858.0	33	4.59	17.92	0.91	700
Mean (*DPFs*)	**27.0**	**18.5**	**792.9**	**373.9**	**42**	**4.59**	**16.67**	**0.87**	**-**
Mean (*PFs*)	**23.9**	**14.2**	**1 400.7**	**401.8**	**76**	**5.34**	**26.73**	**0.87**	**-**
Total Mean	**26.1**	**17.2**	**982.8**	**383.2**	**53**	**4.82**	**19.81**	**0.87**	**-**

3.2 Basic information of vegetation types in Diaoluoshan National Forest Park

The result and map of existing vegetation types in Diaoluoshan National Forest Park (in Lingshui County) in 2014 are shown in Table 2 and Annex 4. The total area of Diaoluoshan National Forest Park (in Lingshui County) was 22 279.48 ha in 2014. The Primary Forest, Degraded Primary Forest, Secondary Forest and Degraded Forest Land in Diaoluoshan National Forest Park (in Lingshui County) accounted for 10.83%, 42.61%, 37.98% and 1.05% respectively in 2014.

Table 2 The result of Existing Vegetation Types in Diaoluoshan National Forest Park

Vegetation Types	Number of patches	Area/ha	Area Percent/%
Primary Forest	8	2 412.86	10.83
Degraded Primary Forest	43	9 493.88	42.61
Secondary Forest	33	8 461.94	37.98
Degraded Forest Land	23	234.05	1.05
Rubber Plantation	1	22.99	0.10
Other Plantation	31	764.57	3.43
Garden plots	7	504.29	2.26
Agricultural Land	4	12.54	0.06
Residential Quarters	1	5.73	0.03
Other Land	11	366.63	1.65
Total	162	22 279.48	100.00

4 Analysis and interpretation of the data and results

The results of Recreation Opportunity Spectrum (ROS) (in landscape level), visual resources (in landscape level) and ecotourism attractions in individual level in tropical forests in Diaoluoshan National Forest Park (in Lingshui County) were as follows.

4.1 The result of Recreation Opportunity Spectrum (ROS) in Diaoluoshan National Forest Park

Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN), Rural (R) and Urban (U) are the six classes of the Recreation Opportunity Spectrum (ROS) in tropical forest ecotourism resources (in landscape level) .

While the goal of the recreationist is to obtain satisfying experiences, the goal of the recreation resource manager becomes one of providing the opportunities for obtaining these experiences. By managing the natural resource settings, and the activities which occur within it, the manager is providing the opportunities for recreation experiences to take place. Therefore, for both the manager and the recreationist, recreation opportunities can be expressed in terms of three principal components: the activities, the setting, and the experience. For management and conceptual convenience possible mixes or combinations of activities, settings, and probable experience opportunities have been arranged along a spectrum, or continuum. This continuum is called the Recreation Opportunity Spectrum (ROS) and is divided into six classes: Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN), Rural (R) and Urban (U).

Criteria used for ROS class delineation include physical, social and managerial setting Component. Mapping criteria for ROS class delineation include remoteness, size, evidence of humans, user density, managerial regimentation and noticeability. Remoteness criteria for Primitive (P) is an area designated at least 1200 m from all roads, railroads or trails with motorized use. Remoteness criteria for Semi-Primitive Non-Motorized (SPNM) is an area designated at least 400 m but not further than 1200 m from all roads, railroads or trails with motorized use; can include the existence of primitive roads and trails if usually closed to motorized use. Remoteness criteria for Semi-Primitive Motorized (SPM) is an area designated within 400 m of primitive roads or trails used by motor vehicles; but not closer than 400 m from better than primitive roads. Remoteness criteria for Roaded Natural (RN) is an area designated within 400 m from better than primitive roads and railroads. Remoteness criteria for Rural (R) is no distance criteria. Remoteness criteria for Urban (U) is no distance criteria.

The result and map of existing Recreation Opportunity Spectrum (ROS) in Diaoluoshan National Forest Park in 2014 are shown in Table 3 and Annex 5. The Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN) and Rural (R) of existing ROS classes in Diaoluoshan National Forest Park accounted for 41.82%, 23.68%, 10.17%, 9.82% and 13.64% respectively in 2014.

Table 3 The area result of Existing ROS classes in Diaoluoshan National Forest Park

ROS Classes	**Area/ha**	**Area Percent/%**
Primitive (P)	9 316.33	41.82
Semi-Primitive Non-Motorized (SPNM)	5 276.40	23.68
Semi-Primitive Motorized (SPM)	2 266.61	10.17
Roaded Natural (RN)	2 188.46	9.82
Rural (R)	3 039.48	13.64
Urban (U)	0.00	0.00
Others	192.19	0.86
Total	22 279.48	100.00

4.2 The results of visual resources in Diaoluoshan National Forest Park

The scenic attractiveness, scenic integrity, landscape visibility and scenic classes etc. are the main indicators of visual resources (in landscape level) in tropical forest ecotourism resources (in landscape level).

4.2.1 The Scenic Attractiveness of Diaoluoshan National Forest Park

Scenic attractiveness measures the scenic importance of a landscape based on human perceptions of the intrinsic beauty of landform, water characteristics, vegetation pattern, and cultural land use. Scenic attractiveness is the primary indicator of the intrinsic scenic beauty of a landscape d of the positive responses it evokes in people. It helps determine landscapes that are important for scenic beauty, based on commonly held perceptions of the beauty of landform, vegetation pattern, composition, surface water characteristics, and land use patterns and cultural features.

Scenic attractiveness, in its purest definition, exhibits the combined effects of the natural and cultural forces in the landscape. People value all landscapes, but they regard those having the most positive combinations of variety, vividness, mystery, intactness, coherence, harmony, uniqueness, pattern, and balance as having the greatest potential for high scenic attractiveness. Scenic attractiveness indicates varying levels of long-term beauty of the landscape character. Scenic attractiveness is ordinarily very stable. The combination of valued landscape elements such as landform, water characteristics, vegetation, and cultural features, are used in determining the measure of Scenic Attractiveness.

Scenic attractiveness classifications are: (1) Class A-Distinctive; (2) Class B-Typical; (3) Class

C-Indistinctive.

Class A-Distinctive: Areas where landform, vegetation patterns, water characteristics, and cultural features combine to provide unusual, unique, or outstanding scenic quality. These landscapes have strong positive attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance. Class B-Typical: Areas where landform, vegetation patterns, water characteristics, and cultural features use combine to provide ordinary or common scenic quality. These landscapes have generally positive, yet common, attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance. Normally they would form the basic matrix within the ecological unit. Class C-Indistinctive: Areas where landform, vegetation patterns, water characteristics, and cultural land use have low scenic quality. Often water and rockform of any consequence are missing in class C landscapes. These landscapes have weak or missing attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance.

The result and map of existing Scenic Attractiveness in Diaoluoshan National Forest Park in 2014 are shown in Table 4 and Annex 6. The Class A-Distinctive, Class B-Typical and Class C-Indistinctive of existing scenic attractiveness in Diaoluoshan National Forest Park accounted for 39.40%, 31.91% and 26.96% respectively in 2014.

Table 4 The result of Existing Scenic Attractiveness in Diaoluoshan National Forest Park

Scenic Attractiveness	Number of patches	Area/ha	Area Percent/%
Class A (Distinctive)	43	8 777.95	39.40
Class B (Typical)	40	7 109.09	31.91
Class C (Indistinctive)	63	6 007.54	26.96
Others	16	384.90	1.73
Total	162	22 279.48	100.00

4.2.2 The Scenic Integrity of Diaoluoshan National Forest Park

Scenic Integrity indicates the degree of intactness and wholeness of the landscape character. Human alterations can sometimes raise or maintain integrity. More often it is lowered depending on the degree of deviation from the character valued for its aesthetic appeal.

In its purest definition, "integrity" means perfect condition. However, in managing scenery degrees of integrity are defined as very high to very low. Scenic integrity is a continuum ranging over five levels of integrity from very high to very low. The scenic integrity levels are shown below.

VERY HIGH scenic integrity refers to landscapes where the valued landscape character "is' act with only minute if any deviations. The existing landscape character and sense of place is expressed at the highest possible level.

HIGH scenic integrity refers to landscapes where the valued landscape character "appears" act. Deviations may be present but must repeat the form, line, color, texture, and pattern common to the landscape character so completely and at such scale that they are not evident. MODERATE scenic integrity refers to landscapes where the valued landscape character pears slightly altered." Noticeable deviations must remain visually subordinate to the landscape character being viewed. See section below on meeting integrity levels.

LOW scenic integrity refers to landscapes where the valued landscape character "appears moderately altered." Deviations begin to dominate the valued landscape character being viewed but they borrow valued attributes such as size, shape, edge effect and pattern of natural openings, vegetative type changes or architectural styles outside the landscape being viewed. They should not only appear as valued character outside the landscape being viewed but compatible or complimentary to the character within.

VERY LOW scenic integrity refers to landscapes where the valued landscape character "appears heavily altered." Deviations may strongly dominate the valued landscape character. They may not borrow from valued attributes such as size, shape, edge effect and pattern of natural openings, vegetative type changes or architectural styles within or outside the landscape being viewed. However deviations must be shaped and blended with the natural terrain (landforms) so that elements such as unnatural edges, roads, landings, and structures do not dominate the composition.

UNACCEPTABLY LOW scenic integrity refers to landscapes where the valued landscape character being viewed appears extremely altered. Deviations are extremely dominant and borrow little if any form, line, color, texture, pattern or scale from the landscape character. Landscapes at this level of integrity need rehabilitation. This level should only be used to inventory existing integrity. It must not be used as a management objective.

The result and map of existing Acenic Integrity in Diaoluoshan National Forest Park in 2014 are shown in Table 5 and Annex 7. The Very High, High, Moderate, Low and Very Low of existing scenic attractiveness in Diaoluoshan National Forest Park accounted for 10.83%, 28.16%, 31.91%, 20.52% and 6.85% respectively in 2014.

Table 5 The result of Existing Scenic Integrity in Diaoluoshan National Forest Park

Scenic Integrity	Number of patches	Area/ha	Area Percent/%
Very High	8	2 412.86	10.83
High	26	6 274.15	28.16
Moderate	40	7 109.09	31.91
Low	10	4 572.58	20.52
Very Low	62	1 525.90	6.85
Others	16	384.90	1.73
Total	162	22 279.48	100.00

4.2.3 The Landscape Visibility of Diaoluoshan National Forest Park

Landscape visibility is a function of many essential, interconnected considerations, including: (1) context of viewers; (2) duration of view; (3) degree of discernible detail; (4) seasonal variations; and (5) number of viewers. Landscape visibility addresses the relative importance and sensitivity of what is seen and perceived in the landscape. Landscape viewing can be subdivided into distance zones for classification, analysis, and simplification of inventory data.

Portions of landscapes visible from travelways and use areas are important to constituents for their scenic quality, aesthetic values, and landscape merits. Landscape Visibility consists of three elements: (1) Travelways and Use Areas; (2) Concern Levels; (3) Distance Zones.

Existing travelways and use areas are identified and classified in order to determine which existing observer positions to use in the landscape visibility analysis. People utilize **travelways and use areas** throughout the national forests. In addition, they utilize travelways and use areas located outside of national forest boundaries that provide views into national forests. Travelways represent linear concentrations of public-viewing, including freeways, highways, roads, railroads, trails, commercial flight paths, rivers, canals, and other waterways. Use areas are spots that receive concentrated public-viewing use. They include national forest visitor centers, vista points, trailheads, campgrounds, picnic grounds, swim beaches, marinas, resorts, ski areas, and other recreation sites. Use areas also include urban and suburban areas, towns and villages, subdivisions, parks and golf courses on private lands, or other public lands within or adjacent to national forests.

Landscape are viewed to varying degrees from different locations and subsequently differ in their importance. To assist scenic inventory and analysis, this importance can be ranked by concern levels. Concern levels are a measure of the degree of public importance placed on landscapes viewed from travelways and use areas. Divide concern levels into three categories: levels 1, 2, and 3. At the inventory stage, the type of area and its level of use is an adequate indicator of the level of interest that people are likely to have in the surrounding landscape. Base concern levels on past experience and existing planning data. Supplement this data as new constituent information becomes available.

Generally three distance zones for forest planning and four distance zones are needed for project level planning. The fourth zone is **immediate foreground.** Because of its limited depth, immediate foreground should never be used as a separate zone in forest planning but rather combined with the balance of the foreground area. All four distance zones are defined and described in the following section.

Immediate foreground: 0 to 90 m. At an immediate foreground distance, people can distinguish individual leaves, flowers, twigs, bark texture, small animals (chipmunks and songbirds), and can notice movement of leaves and grasses in light winds. They can also receive other sensory messages at an immediate foreground distance, such as sounds of small animals, birdcalls, wind whispering through leaves and grasses, and pungent odors or sweet smells. Texture is made up of individual leaves, needle clusters, bark patterns, and twig patterns. Details are important.

Foreground (Fg): 0–400 m. At a foreground distance, people can distinguish small boughs of leaf clusters, tree trunks and large branches, individual shrubs, clumps of wildflowers, medium-sized animals (squirrels and rabbits), and medium-to-large birds (hawks, geese, and ducks). At this distance, people can also distinguish movement of tree boughs and treetops in moderate winds. At a foreground distance, people receive other sensory messages, such as sounds of medium-sized animals, birdcalls, a moderate wind whistling through branches, and smells of the forest. Texture is largely made up of boughs, large branches, and visible portions of trunks. Individual forms are dominant.

Middleground (Mg): 400 m to 3 km. Middleground is usually the predominant distance zone at which national forest landscapes are seen, except for regions of flat lands or tall, dense vegetation. At this distance, people can distinguish individual treeforms, large boulders, flower fields, small openings in the forest, and small rock outcrops. Treeforms typically stand out vividly in silhouetted situations. Form, texture, and color remain dominant, and pattern is important. Texture is often made up of repetitive treeforms. In steeper topography, a middleground landscape perspective is similar to an aerial one. Because the viewer is able to see human activities from this perspective in context with the overall landscape, a **middleground** landscape having steep topography is often the most critical of all distance zones for scenery management.

Background (Bg): 3 km to horizon. At a background distance, people can distinguish groves or stands of trees, large openings in the forest, and large rock outcrops. Texture has disappeared and color has flattened, but large patterns of vegetation or rock are still distinguishable, and landform ridgelines and horizon lines are the dominant visual characteristic. As a result, the landscape has been simplified. The role of background in providing scenic quality lies mainly in its capacity as a contrastingly softened backdrop, a pleasantly distant vista, or a strikingly beautiful focal point.

Distance zones are mapped for travelways and use areas. Distance zone and concern level combinations are determined through the use of the matrix below.

	fg1	mg1	bg1	fg2	mg2	bg2	fg3	mg3	bg3
bg3	fg1	mg1	bg1	fg2	mg2	bg2	fg3	mg3	bg3
mg3	fg1	mg1	bg1	fg2	mg2	mg3	fg3	mg3	
fg3	fg1	mg1	bg1	fg2	mg2	fg3	fg3		
bg2	fg1	mg1	bg1	fg2	mg2	bg2			
mg2	fg1	mg1	mg2	fg2	mg2				
fg2	fg1	mg1	fg2	fg2					
bg1	fg1	mg1	bg1						
mg1	fg1	mg1							
fg1	fg1								

The result and map of existing Landscape Visibility in Diaoluoshan National Forest Park in 2014 are shown in Table 6 and Annex 8. The Foreground Concern 1, Middleground Concern 1, Background Concern 1, Foreground Concern 2 and Middleground Concern 2 of existing landscape visibility in Diaoluoshan National Forest Park accounted for 12.18%, 40.41%, 21.77%, 13.51% and 12.13% respectively in 2014.

Table 6 The result of Existing Landscape Visibility in Diaoluoshan National Forest Park

Landscape Visibility	Number of patches	Area/ha	Area Percent/%
Foreground Concern 1	62	2 713.91	12.18
Middleground Concern 1	52	9 002.63	40.41
Background Concern 1	14	4 849.26	21.77
Foreground Concern 2	21	3 010.23	13.51
Middleground Concern 2	13	2 703.46	12.13
Total	162	22 279.48	100.00

4.2.4 The Scenic Classes of Diaoluoshan National Forest Park

Scenic classes measure the relative importance, or value, of discrete landscape areas having similar characteristics of scenic attractiveness and landscape visibility.

The components of Scenic Classes are **Scenic Attractiveness** and **Landscape Visibility.** Scenic Attractiveness measures the scenic importance of a landscape based on human perceptions of the intrinsic beauty of landform, water characteristics, vegetation pattern, and cultural land use. It is the primary indicator of the scenic beauty of a forest or wildland landscape and of the positive responses scenic beauty evokes in humans. Scenic Attractiveness is divided into three classes: A-distinctive, B-typical or common, and C-indistinctive. Landscape Visibility uses three distance zones (foreground, middleground, and background), abbreviated "fg", "mg", and "bg", and three concern levels for scenery (1-high, 2-moderate, and 3-low).

Scenic classes arc determined and mapped by combining the three classes of scenic attractiveness with the distance zones and concern levels of landscape visibility (Table below). They are a product of the inventory process that is used for analysis and planning purposes. Scenic classes are used during the forest planning process to compare the value of scenery to other resource values. Generally Scenic Classes 1 -2 have high public value, Classes 3-5 have moderate value, and Classes 6 and 7 have low value.

Scenic Classes

	Distance Zones & Concern Levels									
Scenic Attractiveness		Fg1	Mg1	Bg1	Fg2	Mg2	Bg2	Fg3	Mg3	Bg3
	A	1	1	1	2	2	2	2	3	3
	B	1	2	2	2	3	4	3	5	5
	C	1	2	3	2	4	5	5	6	7

The result and map of existing Scenic Classes in Diaoluoshan National Forest Park in 2014 are shown in Table 7 and Annex 9. The Scenic Class 1, Scenic Class 2, Scenic Class 3 and Scenic Class 4 of existing scenic classes in Diaoluoshan National Forest Park accounted for 40.67%, 41.95%, 9.40% and 6.25% respectively in 2014.

Table 7 The result of Existing Scenic Classes in Diaoluoshan National Forest Park

Scenic Classes	Number of patches	Area/ha	Area Percent/%
Scenic Class 1	72	9 061.82	40.67
Scenic Class 2	61	9 345.46	41.95
Scenic Class 3	8	2 094.95	9.40
Scenic Class 4	5	1 392.35	6.25
Others	16	384.90	1.73
Total	162	22 279.48	100.00

4.3 Tree species' list of buttress, big buttress, big tree and features of flower and color leaf in Diaoluoshan National Forest Park

The buttress, garden in the air, cauliflory, strangler, dangling liana, special tree and animal etc. are the main tropical forest ecotourism attractions in individual level. The garden in the air and buttress were important forest ecotourism attractions in individual level in Diaoluoshan National Forest Park (in Lingshui County) and were analyzed in this report.

Tree species' list of buttress, big buttress (buttress height ≥ 1.5 m), big tree (DBH ≥ 100 cm) and feature of flower and color leaf in Diaoluoshan National Forest Park in 2014 are shown in Table 8. There were 228 buttress tree species with buttress in Diaoluoshan National Forest Park, which belong to 87 genera and 42 families. There were 24 buttress tree species with big buttress (buttress height ≥ 1.5 m) in Diaoluoshan National Forest Park, which belong to 17 genera and 13 families. There were about 37 big tree species (DBH ≥ 100 cm) in Diaoluoshan National Forest Park which belong to 29 genera and 21 families.

Table 8 Tree species' list of buttress, big buttress, big tree and feature of flower and color leaf in Diaoluoshan National Forest Park

No.	Name of Family	Name of Species	Buttress	Big Buttress	Big Tree	Feature of flower and color leaf
1	Podocarpaceae	*Dacrydium pierrei*			●	
		Podocarpus imbricatus			●	
2	Cephalotaxaceae	*Cephalotaxus hainanensis*	●		●	
3	Magnoliaceae	*Magnolia albosericea*	●			
		Manglietia hainanensis	●	●	●	
		Michelia balansae	●		●	
		Michelia fulgens	●		●	
		Michelia mediocris	●		●	White flower in May
		Michelia shiluensis	●		●	
		Tsoongiodendron odorum	●		●	
4	Annonaceae	*Polyalthia consanguinea*	●			
		Polyalthia laui	●			
		Polyalthia nemoralis	●			
5	Lauraceae	*Actinodaphne glaucina*	●			
		Actinodaphne paotingensis	●			
		Actinodaphne pilosa	●			
		Alseodaphne hainanensis	●			Red leaf in Aug-Oct
		Alseodaphne rugosa	●			Red leaf in Aug-Oct
		Beilschmiedia glauca	●			
		Beilschmiedia intermedia	●			
		Beilschmiedia longepetiolata	●			
		Beilschmiedia macropoda	●			
		Beilschmiedia percoriacea	●			
		Beilschmiedia wangii	●			
		Cinnamomum bejolghota	●			
		Cinnamomum burmanni	●			
		Cinnamomum porrectum	●			
		Cryptocarya chinensis	●			
		Cryptocarya chingii	●			
		Cryptocarya concinna	●			
		Cryptocarya hainanensis	●			
		Lindera kwangtungensis	●			
		Lindera kwangtungensis fo.	●			
		Lindera nacusua	●			
		Lindera robusta	●			
		Lindera tonkinensis	●			
		Litsea acutivena	●			
		Litsea atrata	●			
		Litsea baviensis	●			
		Litsea cubeba	●			
		Litsea elongata	●			
		Litsea lancifolia	●			
		Litsea lancilimba	●			
		Litsea litseifolia	●			
		Litsea variabilis	●			
		Litsea variabilis var. variabilis fo . chinensis	●			
		Litsea verticillata	●			

		Machilus cicatricosa	●			
		Machilus foonchewii	●			
		Machilus grijsii	●			
		Machilus monticola	●			
		Machilus nakao	●			
		Machilus pomifera	●			
		Machilus robusta	●			
		Neolitsea oblongifolia	●			
		Litsea veitchiana	●			
		Neolitsea pulchella	●			
		Syndiclis chinensis	●			
6	Polygalaceae	*Xanthophyllum hainanense*	●			
7	Proteaceae	*Helicia hainanensis*	●			
		Helicia longipetiolata	●			
		Helicia obovatifolia	●			
		Helicia obovatifolia var. mixta	●			
		Heliciopsis lobata	●			
		Heliciopsis terminalis	●			
8	Dilleniaceae	*Dillenia pentagyna*	●			
		Dillenia turbinata	●			
		Dillenia indica	●			
9	Flacourtiaceae	*Hydnocarpus hainanensis*	●			
10	Samydaceae	*Casearia membranacea*	●			
		Homalium cochinchinense	●			
		Homalium hainanense	●	●	●	
		Homalium kainantense	●			
		Homalium mollissimum	●			
		Homalium paniculiflorum	●			
		Homalium cochinchinense	●			
11	Theaceae	*Adinandra hainanensis*	●			
12	Pentaphylacaceae	*Pentaphylax euryoides*	●			
13	Dipterocarpaceae	*Hopea reticulata*	●			
		Hopea hainanensis	●			
		Vatica mangachapoi	●	●	●	
14	Myrtaceae	*Acmena acuminatissima*	●			
		Cleistocalyx operculatus	●			
		Decaspermum albociliatum	●			
		Decaspermum cambodianum	●			Red and white flower in Oct
		Rhodamnia dumetorum var. hainanensis	●			
		Rhodomyrtus tomentosa				Red flower in May
		Syzygium araiocladum	●			
		Syzygium austrosinense	●			
		Syzygium brachyantherum	●			
		Syzygium championii	●			
		Syzygium chunianum	●			
		Syzygium claviflorum	●			
		Syzygium cumini	●	●	●	
		Syzyglum hancei	●			
		Syzygium jambos	●			
		Syzygium levinei	●			

		Syzygium myrsinifolium	●			
		Syzygium rysopodum	●			
		Syzygium tephrodes	●			
15	Melastomataceae	*Melastoma candidum*				Red flower in May
		Melastoma intermedium				Red flower in May
		Melastoma normale				Red flower in May
		Melastoma penicillatum				Red flower in May
		Melastoma sanguineum				Red flower in May
		Osbeckia chinensis				Red flower in May
		Phyllagathis hainanensis				Red flower in May
		Phyllagathis melastomatoides				Red flower in May
16	Elaeocarpaceae	*Elaeocarpus dubius*	●			
		Elaeocarpus limitaneus	●			
		Elaeocarpus petiolatus	●		●	
		Elaeocarpus sylvestris	●	●	●	
		Elaeocarpus decipiens	●			
		Sloanea hainanensis	●	●	●	
		Sloanea sinensis	●	●	●	
17	Sterculiaceae	*Firmiana hainanensis*	●			White flower in Mar
		Firmiana pulcherrma	●			Red flower in Apr-May
		Heritiera parvifolia	●	●	●	
		Pterospermum heterophyllum	●			
		Pterospermum lanceaefolium	●			
		Pterygota alata	●			
		Reevesia botingensis	●			
		Reevesia longipetiolata	●			
		Reevesia thyrsoidea	●			
18	Bombacaceae	*Bombax ceiba*	●			Red flower in Jan-Mar
19	Ixonanthaceae	*Ixonanthes chinensis*	●	●	●	
20	Euphorbiaceae	*Baccaurea ramiflora*	●			
		Endospermum chinense	●	●	●	
		Macaranga denticulata	●			
		Ostodes paniculata	●			
21	Bischofiaceae	*Bischofia polycarpa*	●		●	
22	Daphniphyllaceae	*Daphniphyllum paxianum*	●			
23	Polyosmataceae	*Polyosma cambodiana*	●			
24	Mimosaceae	*Albizia chinensis*	●		●	
		Albizia procera	●			
25	Caesalpiniaceae	*Peltophorum tonkinense*				Yellow flower in Jan-Mar
26	Papilionaceae	Dalbergia hainanensis	●			
27	Hamamelidaceae	*Altingia obovata*	●		●	
		Altingia chinensis	●			
		Liquidambar formosana				Red leaf in Nov
28	Fagaceae	*Castanopsis fissa*	●			
		Castanopsis formosana	●			
		Castanopsis hainanensis	●	●		
		Castanopsis jucunda	●			
		Castanopsis carlesii	●			
		Castanopsis carlesii var hainanica	●			
		Lithocarpus amygdalifolius	●	●	●	
		Lithocarpus brachystachyus	●			

		Lithocarpus corneus	●			
		Lithocarpus elmerrillii	●			
		Lithocarpus fenzelianus	●			
		Lithocarpus hancei	●			
		Lithocarpus handelianus	●	●	●	
		Lithocarpus howii	●			
		Lithocarpus litseifolius	●			
		Lithocarpus longipedicellatus	●	●		
		Lithocarpus obvatilimbus	●			
		Lithocarpus psedudovestitus	●			
		Lithocarpus silvicolarum	●			
		Lithocarpus skanianus	●			
		Lithocarpus ternaticupulus	●	●		
		Cyclobalanopsis blakei	●			
		Cyclobalanopsis championii	●	●	●	
		Cyclobalanopsis edithae	●			
		Cyclobalanopsis fleuryi	●			
		Cyclobalanopsis hui	●			
		Cyclobalanopsis insularis	●			
		Cyclobalanopsis nemoralis	●			
		Cyclobalanopsis patelliformis	●	●	●	
		Cyclobalanopsis phanera	●			
		Cyclobalanopsis tiaoloshanica	●			
		Cyclobalanopsis bambusaefolia	●			
		Quercus acutissima	●			
29	Moraceae	*Antiaris toxicaria*	●	●	●	
		Artocarpus styracifolius	●			
		Artocarpus tonkinensis	●			
		Ficus altissima	●	●	●	
		Ficus esquiroliana	●			
		Ficus glaberrima	●			
		Ficus heterophylla	●			
		Ficus langkokensis	●			
		Ficus microcarpa	●			
		Ficus nervosa	●	●		
		Ficus variegata	●			
		Ficus virens	●	●	●	
30	Aquifoliaceae	*Ilex ficoidea*	●			
		Ilex kwangtungensis	●			
		Ilex nuculicava	●			
		Ilex revoluta	●			
31	Rutaceae	*Acronychia oligophlebia*	●			
		Acronychia pedunculata	●			
		Evodia lepta	●			
		Evodia glabrifolia	●			
32	Burseraceae	*Canarium album*	●	●	●	
33	Meliaceae	*Amoora dasyclada*	●		●	

		Aglaia odorata	●			
		Aglaia roxburghiana	●			
		Aglaia tetrapetala	●			
		Amoora tsangii	●			
		Aphanamixis grandifolia	●		●	
		Aphanamixis polystachya	●			
		Aphanamixis sinensis	●			
		Chukrasia tabularis	●			
		Dysoxylum binectariferum	●			
		Dysoxylum hongkongense	●			
		Walsura robusta	●			
34	Sapindaceae	*Amesiodendron chinense*	●			Red leaf in May-Jun
		Litchi chinensis	●	●	●	
		Litchi chinensis var. cuspontanea	●		●	
		Nephelium topengii	●			
		Sapindus mukorossi	●			
35	Staphyleaceae	*Turpinia montana*	●			
36	Anacardiaceae	*Choerospondias axillaris*	●		●	
		Toxicodendron vernicifluum	●			
37	Juglandaceae	*Engelhardtia colebrookiana*	●			
		Engelhardtia roxburghiana	●			
		Engelhardia fenzelii	●			
38	Alangiaceae	*Alangium faberi var. platyphyllum*	●			White flower in Mar-Apr
		Alangium salviifolium	●			
39	Araliaceae	*Brassaiopsis glomerulata*	●			
		Heteropanax fragrans	●			
		Schefflera octophylla	●			
40	Ericaceae	*Rhododendron hainanense*				Red flower in Oct-Nov
41	Ebenaceae	*Diospyros cathayensis*	●			
		Diospyros howii	●			
		Diospyros maclurei	●			
42	Sapotaceae	*Madhuca hainanensis*	●		●	
		Sarcosperma laurinum	●			
43	Styracaceae	*Alniphyllum fortunei*	●			
		Styrax agrestis	●			
44	Symplocaceae	*Symplocos chunii*	●			
		Symplocos glauca	●			
		Symplocos hainanensis	●			
		Symplocos lancilimba	●			
45	Oleaceae	*Olea hainanensis*	●			
		Olea neriifolia	●			
		Osmanthus didymopetalus	●			
		Osmanthus hainanensis	●			
		Osmanthus marginatus	●			
46	Apocynaceae	*Winchia calophylla*	●	●	●	
47	Bignoniaceae	*Dolichandrone cauda-felina*	●			

4.4 Characteristics of epiphytic ferns in montane rain forests in Diaoluoshan National Forest Park

There were two main typical epiphytic ferns (garden in the air) in montane rain forests in Diaoluoshan National Forest Park in 2014, *Neottopteris nidus* and *Pseudodrynaria coronan*s.

4.4.1 The host species of the epiphytic ferns

There were 79 host species of epiphytic ferns which belong to 53 genera and 31 families (Table 9).

Table 9 Name list of family, genus and species of epiphytic ferns' hosts in sample plots

Name of Family	Name of Genus	Name of Species	*N.*	*P.*	PFs	DPFs
Podocarpaceae	Dacrydium	*Dacrydium pierrei*	●	●		●
	Podocarpus	*Podocarpus imbricatus*	●	●	●	●
Magnoliaceae	Manglietia	*Manglietia hainanensis*	●	●		●
	Michelia	*Michelia mediocris*	●	●	●	●
Lauraceae	Actinodaphne	*Actinodaphne glaucina*		●	●	
	Alseodaphne	*Alseodaphne hainanensis*		●		●
	Beilschmiedia	*Beilschmiedia intermedia*	●	●		●
	Cinnamomum	*Cinnamomum porrectum*	●	●		●
	Cryptocarya	*Cryptocarya densiflora*	●		●	
	Lindera	*Lindera robusta*	●	●		●
	Litsea	*Litsea litseaefolia*		●		●
		Litsea variabilis		●	●	
	Machilus	*Machilus monticola*		●	●	
	Phoebe	*Phoebe hungmaoensis*	●	●		●
		Phoebe tavoyana	●			●
	Syndiclis	*Syndiclis chinensis*	●	●		●
Polygalaceae	Xanthophyllum	*Xanthophyllum hainanense*	●		●	
Samydaceae	Homalium	*Homalium cochinchinense*	●			●
Theaceae	Adinandra	*Adinandra hainanensis*	●	●		●
	Eurya	*Eurya ciliata*	●	●	●	
	Gordonia	*Gordonia axillaris*	●	●		●
	Schima	*Schima superba*	●	●		●
Pentaphylacaceae	Pentaphylax	*Pentaphylax euryoides*		●		●
Myrtaceae	Syzygium	*Syzygium buxifolium*	●		●	
		Syzygium chunianum		●	●	
		Syzygium hancei	●	●	●	●
		Syzygium latilimbum	●	●		●
		Syzygium rysopodum	●	●		●
Guttiferae	Garcinia	*Garcinia oblongifolia*	●			●
Elaeocarpaceae	Elaeocarpus	*Elaeocarpus decipiens*		●		●
		Elaeocarpus sylvestris	●	●		●
Sterculiaceae	Heritiera	*Heritiera parvifolia*		●	●	
	Reevesia	*Reevesia thyrsoidea*	●		●	●
Euphorbiaceae	Antidesma	*Antidesma maclurei*	●			●

		Antidesma montanum	●			●
	Bridelia	*Bridelia balansae*	●		●	
Rosaceae	Eriobotrya	*Eriobotrya deflexa*	●	●		●
	Photinia	*Photinia benthamiana*	●	●		●
Hamamelidaceae	Altingia	*Altingia chinensis*	●	●		●
		Altingia obovata	●	●	●	
Fagaceae	Castanopsis	*Castanopsis carlesii*		●		●
		Castanopsis carlesii var. hainanica	●	●	●	●
		Castanopsis hainanensis		●		●
		Castanopsis jucunda	●	●		●
	Lithocarpus	*Lithocarpus amygdalifolius*	●		●	
		Lithocarpus fenzelianus	●		●	
		Lithocarpus handelianus	●	●		●
	Cyclobalanopsis	*Cyclobalanopsis championii*	●	●		●
		Cyclobalanopsis patelliformis		●	●	
		Cyclobalanopsis phanera	●		●	
Ulmaceae	Gironniera	*Gironniera subaequalis*	●			●
Moraceae	Artocarpus	*Artocarpus tonkinensis*	●			●
	Ficus	*Ficus altissima*	●	●		●
		Ficus fistulosa	●			●
		Ficus hainanensis	●	●		●
		Ficus henryi	●			●
Aquifoliaceae	Ilex	*Ilex hainanensis*		●		●
		Ilex nuculicava	●	●		●
		Ilex revoluta	●		●	
Vitaceae	Tetrastigma	*Tetrastigma planicaule*	●		●	
Sapindaceae	Nephelium	*Nephelium topengii*	●	●		●
Sabiaceae	Meliosma	*Meliosma squamulata*		●	●	
Staphyleaceae	Turpinia	*Turpinia montana*	●	●	●	●
Anacardiaceae	Toxicodendron	*Toxicodendron vernicifluum*	●	●		●
Juglandaceae	Engelhardtia	*Engelhardtia fenzlii*	●		●	
		Engelhardtia roxburghiana	●	●		●
Araliaceae	Schefflera	*Schefflera octophylla*	●	●		●
Ebenaceae	Diospyros	*Diospyros hainanensis*	●	●		●
		Diospyros howii	●	●	●	
		Diospyros morrisiana	●			●
		Diospyros tutcheri	●		●	
Sapotaceae	Sarcosperma	*Sarcosperma laurinum*	●	●	●	●
Myrsinaceae	Rapanea	*Rapanea linearis*	●		●	
		Rapanea neriifolia		●	●	
Styracaceae	Alniphyllum	*Alniphyllum fortunei*	●			●
Rubiaceae	Nauclea	*Nauclea officinalis*		●		●
	Tarenna	*Tarenna mollissima*		●	●	
Cyatheaceae	Alsophila	*Alsophila gigantea*	●			●
Daphniphyllaceae	Daphniphyllum	*Daphniphyllum paxianum*	●	●		●

Note：N.-*Neottopteris nidus*; P.-*Pseudodrynaria coronans*. PFs-primary forests; DPFs-degraded primary forests.

Neottopteris nidus and *Pseudodrynaria coronans* were two typical epiphytic ferns that formed garden in the air in Diaoluoshan National Forest Park. There were 79 host tree species (except *Tetrastigma planicaule*, a vine of Vitaceae) which belong to 53 genera and 31 families in sample plots. *Neottopteris nidus* and *Pseudodrynaria coronans* presented together on 37 tree species. Except, *Neottopteris nidus* presented on another 25 tree species, and *Pseudodrynaria coronans* presented on another 17 tree species. There were 24 host tree species were found in primary forests (PFs), 48 host tree species in degraded primary forests (DPFs) and 7 host tree species in both of them in sample plots.

4.4.2 The living height distribution of the epiphytic ferns

The living height of all *Neottopteris nidus* and *Pseudodrynaria coronans* was in the range of 0.5 to 25.0 m. The mean was 8.4 m with standard deviation 5.3 m. All the living height of epiphytic ferns were divided into 13 classes by distance of 2.0 m (Figure 2). The numbers of those living height were varied largely in each class, and its appearance was distributed in a nearly normal pattern. But it was rejected the hypothesis that the epiphytic height distributed in normal pattern because of the *sig*. < 0.05 (Table 10). The other distribution models were also fitted but results were not satisfied according to the goodness-of-fit.

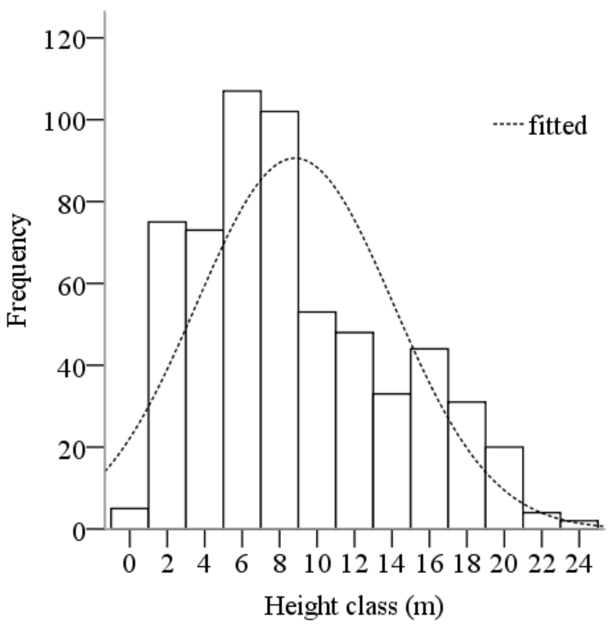


Figure 2 The living height distribution of the epiphytic ferns

Table 10 Normality tests

Kolmogorov-Smirnov test[a]			**Shapiro-Wilk test**		
statistic	*df*	*Sig.*	statistic	*df*	*Sig.*
0.226	597	0.000	0.912	597	0.000

[a] Lilliefors significant level correction

The epiphytic height of epiphytic ferns could be classified in 3 levels by dividing cumulative percentage of height groups into 3 equal pieces:

Low: the height of epiphytic ferns < 5.5 m
Medium: 5.5 m ≤ the height of epiphytic ferns < 10.0 m
High: the height of epiphytic ferns ≥ 10.0 m

4.4.3 The diameter distribution of the epiphytic ferns

The diameter of all *Neottopteris nidus* and *Pseudodrynaria coronans* was in the range of 0.2 to 5.0 m. The mean diameter was 1.0 m with standard deviation 0.7 m. All the epiphytic ferns were divided into 10 classes by distance of 0.5 m (Figure 3). Obviously, it did not distribute in normal pattern and the results of normality tests supported that conclusion. The diameter (*di*) was bigger, the numbers of epiphytic ferns (*Nf*) was fewer. That tendency could be well described by negative exponential function:

$$Nf = 510.125 \cdot e^{-1.255di}, R^2=0.944.$$

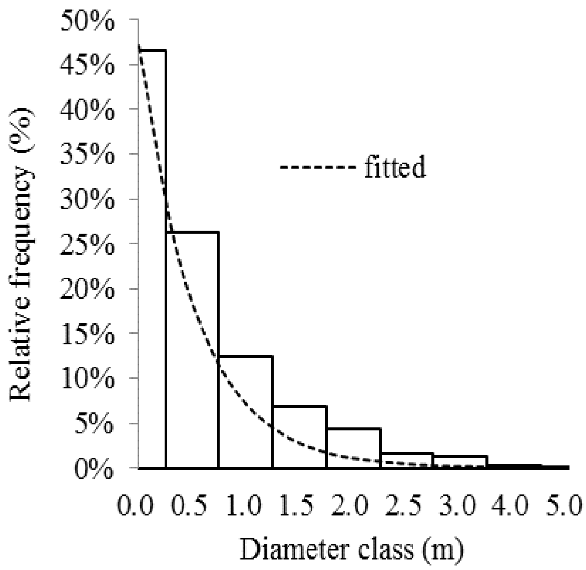


Figure 3 The diameter distribution of the epiphytic ferns

Table 11 Normality tests

Kolmogorov-Smirnov test[a]			**Shapiro-Wilk test**		
statistic	*df*	*Sig.*	statistic	*df*	*Sig.*
0.228	597	0.000	0.822	597	0.000

[a] Lilliefors significant level correction

The diameter of epiphytic ferns could be classified in 3 levels:

Small: the diameter of epiphytic fern < 0.6 m
Medium: 0.6 m ≤ the diameter of epiphytic fern < 1.0 m
Large: the diameter of epiphytic fern ≥ 1.0 m

4.4.4 The density distribution of the epiphytic ferns

Epiphytic ferns' density was in the range of 0.0 to 616.7 N/hm^2. The mean density was 179.9 N/hm^2 with standard deviation 155.2 N/hm^2. Epiphytic ferns' density of all sample subplots was divided into 10 classes by the distance of 50 N/hm^2 (Figure 4). It did not distribute in normal pattern according to the histogram and the results of normality tests (Table 12).

Table 12 Normality tests

Kolmogorov-Smirnov test[a]			**Shapiro-Wilk test**		
statistic	*df*	*Sig.*	statistic	*df*	*Sig.*
0.168	52	0.001	0.895	52	0.000

[a] Lilliefors significant level correction

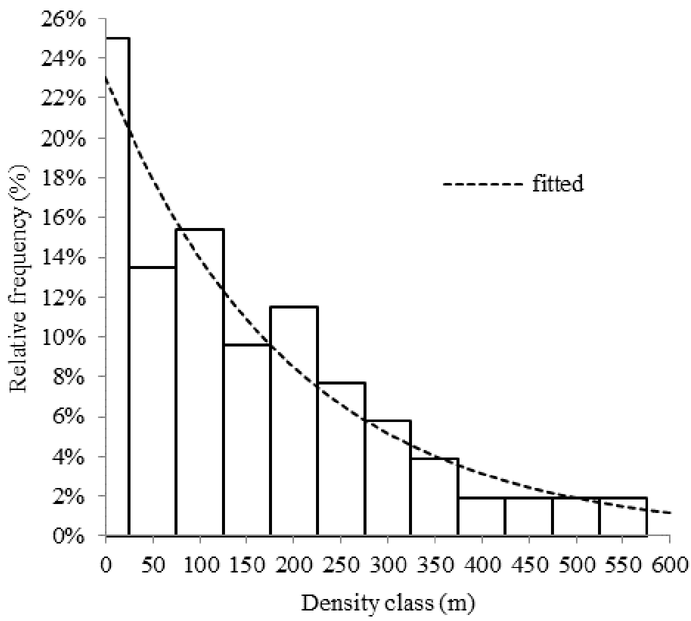


Figure 4 The density distribution of the epiphytic ferns

The tendency that sample subplots numbers (*N*s) variation with epiphytic ferns' density (*fd*) was similar with Figure 3 and the fitted model was:

$Ns = 13.462 \cdot e^{-0.005fd}$, R^2=0.933

The density of epiphytic ferns could be classified in 3 levels:

Low: the density of epiphytic ferns < 77 N/hm^2
Medium: 77 N/hm^2 ≤the density of epiphytic ferns < 230 N/hm^2
High: the density of epiphytic ferns ≥ 230 N/hm^2

4.4.5 The density distribution of epiphytic ferns' hosts

The density of epiphytic ferns' hosts was in the range of 0.0 to 333.3 N/hm^2. The mean density was 100.0 N/hm^2 with standard deviation 76.0 N/hm^2. It did not distribute in normal pattern according to results of normality tests (Table 13). 11 classes of hosts' density were divided by distance of 50 N/hm^2 (Figure 5). The tendency that sample subplots numbers (*N*s) variation with hosts density (*hd*) was similar with Figure 3 and the fitted model was:

$Ns = 13.761 \cdot e^{-0.009hd}$, R^2=0.739.

Table 13 Normality tests

Kolmogorov-Smirnov test [a]			**Shapiro-Wilk test**		
statistic	*df*	*Sig.*	statistic	*df*	*Sig.*
0.110	52	0.165	0.930	52	0.004

[a] Lilliefors significant level correction

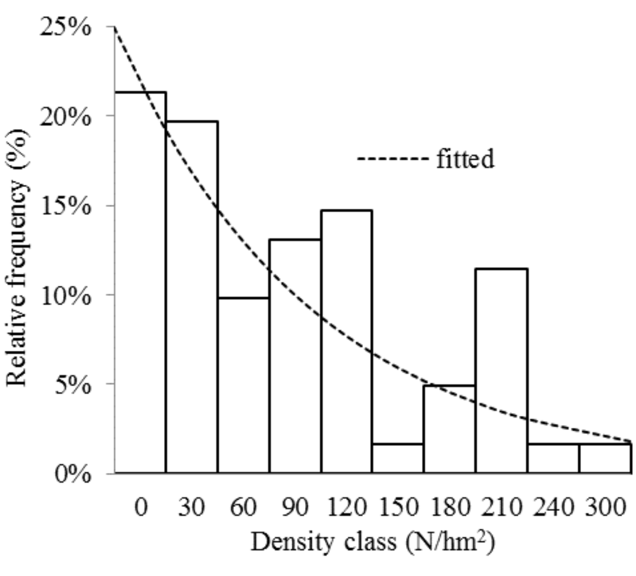


Figure 5 The density distribution of epiphytic ferns' hosts

The hosts' density could be classified in 3 levels:

Low: the density of epiphytic ferns' hosts < 50 N/hm^2
Medium: 50 N/hm^2 ≤ the density of epiphytic ferns' hosts < 116 N/hm^2
High: the density of epiphytic ferns' hosts ≥ 116 N/hm^2

4.4.6 The distribution of epiphytic fern number per host

The distribution of epiphytic fern number per host was in the range of 1.0 to 10.0. The mean number was 1.8 with standard deviation of 1.3. All the results were divided into 10 classes by distance of 1.0 (Figure 6). Frequency of each class obviously did not distribute in normal but in exponential pattern. The fitted negative exponential function of numbers (*N*) of each class and ratio (*r*) was:

$$N = 203.662 \cdot e^{-0.997r}, R^2=0.997.$$

The epiphytic fern number per host could be classified in 3 levels:

Low: the epiphytic fern number per host < 1
Medium: 1 ≤ the epiphytic fern number per host < 2
High: the epiphytic fern number per host ≥ 2

Theoretically, the medium of the epiphytic fern number per host was between 0.6 and 1.3.

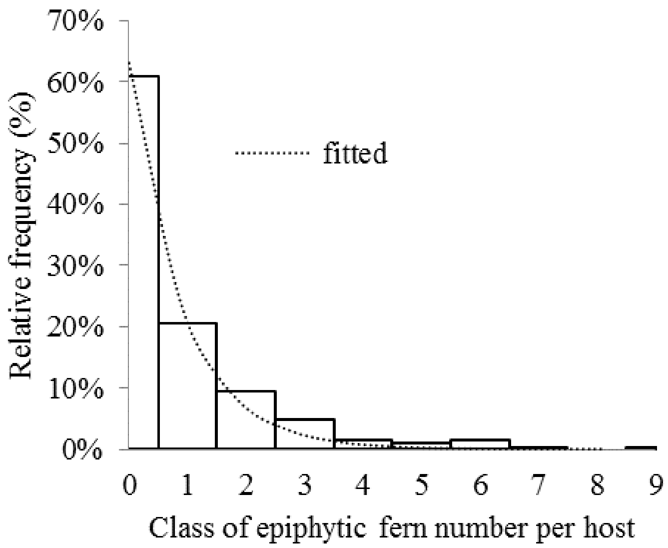


Figure 6 The distribution of epiphytic fern number per host

4.4.7 The distribution pattern of the epiphytic ferns' hosts

The diffusion coefficients (*C*) were calculated for sample plots with area of 2 500 m^2. Both epiphytic ferns' hosts in PFs (sample plot number 12-15) and DPFs (sample plot number 1-7) were clumped distribution patterns because all those *C*-values larger than 1 and statistics were significant (α=0.05) larger than "*t*-value" of *t*-test (Table 14).

Table 14 Distribution patterns of the hosts in sample plots

Sample Plot Number	*C*	statistics
1	7.5547	22.7061
2	11.2207	35.4057
3	11.1401	35.1262
4	6.6103	19.4346
5	9.1574	28.2581
6	7.4904	22.4834
7	7.3512	22.0012
12	4.8333	13.2791
13	5.4167	15.2998
14	6.9386	20.5719
15	6.2157	18.0677

Note：$t_{(0.05, 24)}$= 2.0639

4.5 Characteristics of buttress in montane rain forests in Diaoluoshan National Forest Park

4.5.1 The buttress trees species

There were 52 tree species with buttress in sample plots which belong to 33 genera, 25 families (Table 15). Most species belong to Fagaceae, such as *Castanopsis carlesii*, *Lithocarpus amygdalifolius*, and *Cyclobalanopsis blakei*. The common species both in PFs and DPFs were 11 species. Species only presented in PFs and DPFs are 18 and 23 species respectively.

Table 15 Name list of family, genus and species of buttress trees in sample plots

Name of Family	Name of Genus	Name of Species	PFs	DPFs
Podocarpaceae	Dacrydium	*Dacrydium pierrei*	●	
	Podocarpus	*Podocarpus imbricatus*	●	●
Magnoliaceae	Manglietia	*Manglietia hainanensis*		●
	Michelia	*Michelia mediocris*		●
Lauraceae	Lindera	*Lindera robusta*		●

	Litsea	*Litsea litseaefolia*		●
	Machilus	*Machilus monticola*	●	
Polygalaceae	Xanthophyllum	*Xanthophyllum hainanense*	●	●
Dilleniaceae	Dillenia	*Dillenia indica*	●	
Flacourtiaceae	Hydnocarpus	*Hydnocarpus hainanensis*		●
Theaceae	Adinandra	*Adinaudra hainanensis*		●
Pentaphylacaceae	Pentaphylax	*Pentaphylax euryoides*		●
Myrtaceae	Syzygium	*Syzygium chunianum*	●	
		Syzygium hancei		●
Elaeocarpaceae	Elaeocarpus	*Elaeocarpus dubius*	●	
		Elaeocarpus sylvestris	●	●
		Elaeocarpus decipiens		●
	Sloanea	*Sloanea sinensis*	●	
Sterculiaceae	Heritiera	*Heritiera parvifolia*	●	
	Pterygota	*Pterygota alata*		●
Euphorbiaceae	Bischofia	*Bischofia polycarpa*	●	
Polyosmataceae	Polyosma	*Polyosma cambodiana*		●
Hamamelidaceae	Altingia	*Altingia obovata*	●	
		Altingia chinensis	●	●
Fagaceae	Castanopsis	*Castanopsis carlesii*	●	●
		Castanopsis carlesii var hainanica	●	●
		Castanopsis hainanensis		●
		Castanopsis jucunda		●
	Lithocarpus	*Lithocarpus amygdalifolius*	●	
		Lithocarpus amygdalifolius var. praecipitiorum	●	●
		Lithocarpus fenzelianus	●	
		Lithocarpus handelianus	●	●
	Cyclobalanopsis	*Cyclobalanopsis blakei*	●	
		Cyclobalanopsis championii		●
		Cyclobalanopsis phanera	●	
		Cyclobalanopsis patelliformis		●
		Cyclobalanopsis bambusaefolia	●	
		Cyclobalanopsis tiaoloshanica	●	
Moraceae	Ficus	*Ficus altissima*	●	●
		Ficus glaberrima		●
		Ficus variegata		●
Aquifoliaceae	Ilex	*Ilex nuculicava*	●	●
		Ilex revoluta	●	
Sapindaceae	Nephelium	*Nephelium topengii*		●
Anacardiaceae	Toxicodendron	*Toxicodendron vernicifluum*		●
Juglandaceae	Engelhardtia	*Engelhardia roxburghiana*		●
		Engelhardia fenzelii		●
Alangiaceae	Alangium	*Alangium salviifolium*		●
Araliaceae	Schefflera	*Schefflera octophylla*	●	●
Sapotaceae	Sarcosperma	*Sarcosperma laurinum*	●	
Styracaceae	Alniphyllum	*Alniphyllum fortunei*		●

Note： PFs-primary forests; DPFs-degraded primary forests.

4.5.2 The buttress height distribution

All recorded 129 buttresses were in a relative large height range of 0.3 to 5.0 m because of the differences of tree species and buttress trees age. The mean height was 1.19 m, with a standard deviation 0.97 m. It could be divided into 10 height classes by distance of 1.0 m (Figure 7). The height distributed obviously in exponential pattern when seeing the histogram and the fitted negative exponential function of numbers (*N*) of each class and height (*h*) was:

$N = 56.596 \cdot e^{-0.851h}$, R^2=0.953

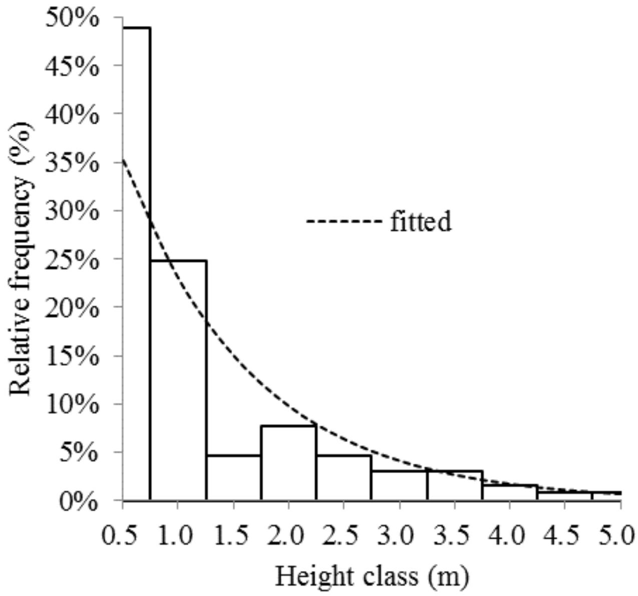


Figure 7 The buttress height distribution

4.5.3 The buttress length distribution

All buttresses were in a length range of 0.5 to 7.0 m. The mean height was 2.37 m, with a standard deviation 1.10 m. The length also could be divided into classes with distance of 1.0 m (Figure 7). It distributed in normal like, but test of normality did not support that (Table 16). Other continuous distributions also did not pass the tests.

Table 16 Distribution test

Distribution type	Kolmogorov-Smirnov		Shapiro-Wilk	
	Statistic	***Sig.***	***Statistic***	***Sig.***
Normality	0.153[a]	0.000	0.904	0
Beta	0.949	0.000	-	-
Gamma	0.686	0.000	-	-
Weibull	0.875	0.000	-	-

[a] Lilliefors Significance Correction; *df*=526

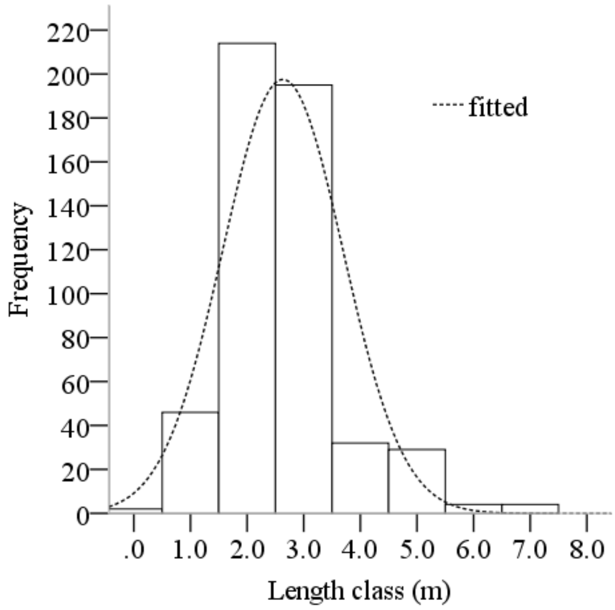


Figure 7 The buttress length distribution

4.5.4 The relationship between buttress height and length

The following was the fitted simple linear model of buttress height (in meter) and length (in meter):

$$Height = -1.0795 + 0.8689\ Length,\ R^2 = 0.74195$$

The correlation between buttress height and length was significant ($\alpha = 0.01$) and their correlation coefficient was 0.86137. The linear correlation was hold based on the result of F-test (F-value = 1460.6> $F_{(0.01,\ 508)}$=6.69). So buttress root height could be expressed by length according to the fitted model, i.e. the length could simply represent root size.

The shape of buttress is approximated to right triangle, and buttress height and length are similar as the right angled sides of a right triangle. In view of this and based on the correlation of height and length, the buttress size could be classified in 3 levels simply by buttress height by dividing cumulative percentage of buttress height into 3 equal pieces:

Small: the buttress height < 0.6 m
Medium: 0.6 m ≤ the buttress height < 1.5 m
Large: the buttress height ≥ 1.5 m

4.5.5 The distribution of buttress number per buttress tree

Buttress number per buttress tree was in a range of 1 to 8. The mean was 4.1 with a standard deviation 1.5. It distributed in a normal like pattern (Figure 8), but the passed test-distribution was Poisson (Table 17). That was reasonable because count itself was discrete.

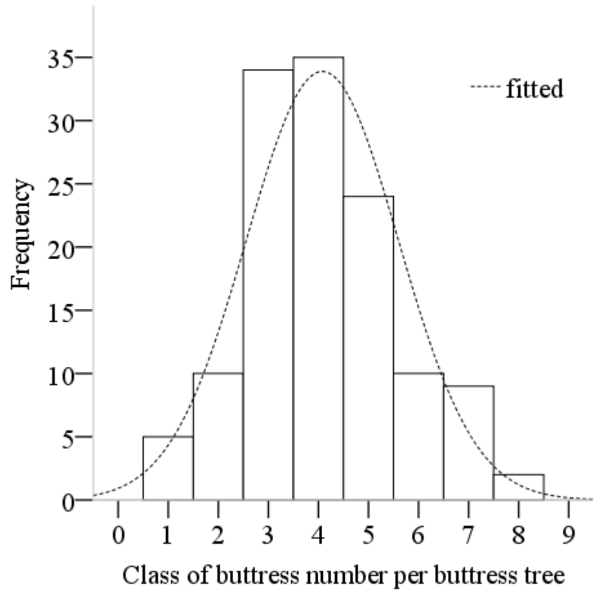


Figure 8 The distribution of buttress number per buttress tree

Table 17 Distribution test

Distribution type	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	***df***	***Sig.***	***Statistic***	***df***	***Sig.***
Normality	0.172[a]	129	0.000	0.947	129	0.000
Poisson	1.257	129	0.085	-	-	-

[a] Lilliefors Significance Correction

The Buttress number per buttress tree could be classified in 3 levels:

Low: the buttress number per buttress tree < 3
Medium: 3 ≤ the buttress number per buttress tree < 5
High: the buttress number per buttress tree ≥ 5

4.5.6 The distribution of buttress density

The buttress density of all sample subplots were in a range of 0.0 to 666.7 N/hm^2. The mean was 160 N/hm^2, with a standard deviation 159 N/hm^2. It could be divided into 13 density classes by distance of 50 N/hm^2 (Figure 9). It distributed in exponential pattern, and the fitted negative exponential function of numbers (*Ns*) of each class and density (*dr*) was:

$Ns = 9.419 \cdot e^{-0.004dr}$, R^2=0.828

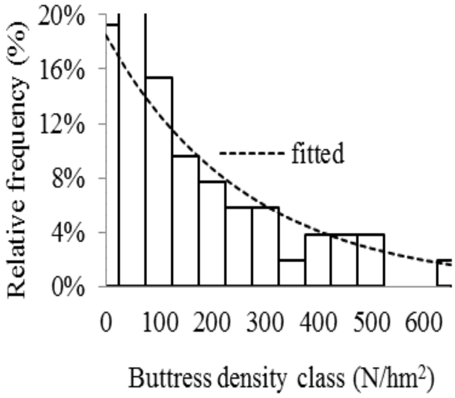


Figure 9 The distribution of buttress density

The buttress density could be classified in 3 levels:

Low: the buttress density < 67 N/hm^2
Medium: 67 ≤ the buttress density < 184 N/hm^2
High: the buttress density ≥ 184 N/hm^2

4.5.7 The distribution of buttress trees density

The buttress trees density of all sample subplots were in a range of 0.0 to 133.3 N/hm^2. The mean was 38.9 N/hm^2, with a standard deviation 37.0 N/hm^2. It could be divided into 7 density classes by distance of 20 N/hm^2 (Figure 10). It distributed in exponential pattern, and the fitted negative exponential function of numbers (*Ns*) of each class and density (*dt*) was:

$Ns = 17.709 \cdot e^{-0.016dt}$, R^2=0.836

The density of buttress trees could be classified in 3 levels:

Low: density: the buttress trees density < 16 N/hm^2
Medium: density: 16 ≤ the buttress trees density < 50 N/hm^2
High: density: the buttress trees density≥ 50 N/hm^2

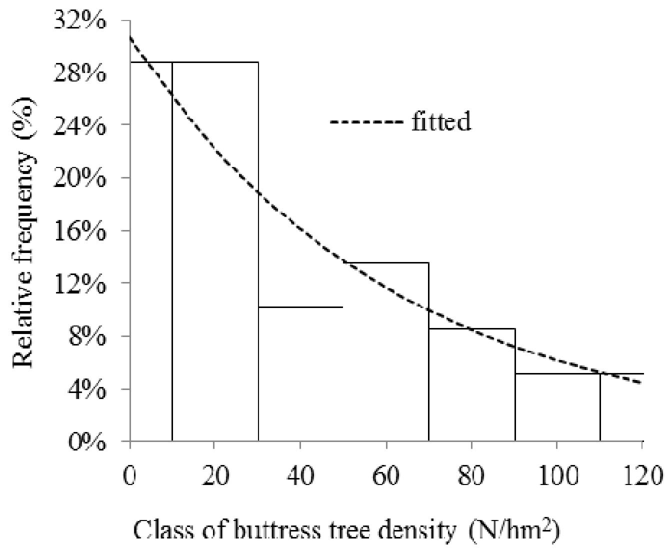


Figure 10 The distribution of buttress trees density

4.5.8 The distribution pattern of buttress trees

The diffusion coefficients (*C*) were calculated for sample plots with area of $2500m^2$. Both buttress trees in PFs (sample plot number 12-15) and DPFs (sample plot number 1-7) were clumped distribution patterns because all those *C*-values larger than 1 and statistics were significant (α=0.05) larger than "*t*-value" of *t*-test (Table 18).

Table 18 Distribution patterns of the buttress trees

Sample Plot Number	*C*	Statistics
1	8.3466	25.4493
2	5.4554	15.4338
3	6.3102	18.3950
4	4.3704	11.6753
5	8.3333	25.4034
6	12.0313	38.2134
7	7.9545	24.0913
12	8.3333	25.4034
13	10.0348	31.2976
14	6.0000	17.3205
15	7.5034	22.5285

Note: $t_{(0.05,\ 24)}$= 2.0639

5 Conclusions

Lacks of Recreation Opportunity Spectrum (ROS) (in landscape level), visual resources (in landscape level) and forest ecotourism attractions in individual and stand level in tropical forests are the main problems in existing techniques of investigation and assessment for tropical forest ecotourism resources in China. Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN), Rural (R) and Urban (U) are the six classes of the Recreation Opportunity Spectrum (ROS) in tropical forest ecotourism resources (in landscape level) . The scenic attractiveness, scenic integrity, landscape visibility and scenic classes etc. are the main indicators of visual resources (in landscape level) in tropical forest ecotourism resources (in landscape level). The buttress, garden in the air, cauliflory, strangler, dangling liana, special tree and animal etc. are the main tropical forest ecotourism attractions in individual level.

Case study on Recreation Opportunity Spectrum (ROS) and visual resources in Diaoluoshan National Forest Park (in Lingshui County) in 2014 showed: the total area of Diaoluoshan National Forest Park (in Lingshui County) was 2 2279.48 ha in 2014; the Primary Forest, Degraded Primary Forest, Secondary Forest and Degraded Forest Land accounted for 10.83%, 42.61%, 37.98% and 1.05% respectively; the Primitive (P), Semi-Primitive Non-Motorized (SPNM), Semi-Primitive Motorized (SPM), Roaded Natural (RN) and Rural (R) of existing ROS classes accounted for 41.82%, 23.68%, 10.17%, 9.82% and 13.64% respectively; the Class A-Distinctive, Class B-Typical and Class C-Indistinctive of existing scenic attractiveness accounted for 39.40%, 31.91% and 26.96% respectively; the Very High, High, Moderate, Low and Very Low of existing scenic attractiveness accounted for 10.83%, 28.16%, 31.91%, 20.52% and 6.85% respectively; the Foreground Concern 1, Middleground Concern 1, Background Concern 1, Foreground Concern 2 and Middleground Concern 2 of existing landscape visibility accounted for 12.18%, 40.41%, 21.77%, 13.51% and 12.13% respectively; the Scenic Class 1, Scenic Class 2, Scenic Class 3 and Scenic Class 4 of existing scenic classes accounted for 40.67%, 41.95%, 9.40% and 6.25% respectively.

There were 228 buttress tree species with buttress in Diaoluoshan National Forest Park (in Lingshui County) in 2014, which belong to 87 genera and 42 families. There were 24 buttress tree species with big buttress (buttress height ≥ 1.5 m) in Diaoluoshan National Forest Park, which belong to 17 genera and 13 families. There were about 37 big tree species (DBH ≥ 100 cm) in Diaoluoshan National Forest Park, which belong to 29 genera and 21 families.

Neottopteris nidus and *Pseudodrynaria coronans* were two typical epiphytic ferns that formed garden in the air in Diaoluoshan National Forest Park. There were 79 host tree species (except *Tetrastigma planicaule*, a vine of Vitaceae) which belong to 53 genera and 31 families in sample plots. *Neottopteris nidus* and *Pseudodrynaria coronans* presented together on 37 tree species. Except, *Neottopteris nidus* presented on another 25 tree species, and *Pseudodrynaria coronans* presented on another 17 tree species. There were 24 host tree species were found in primary forests (PFs), 48 host tree species in degraded primary forests (DPFs) and 7 host tree species in both of them in sample plots.

The living height of the epiphytic ferns did not distributed in normal pattern or other common distribution functions. The diameter and density distribution of the epiphytic ferns, the density distribution of epiphytic ferns' hosts and the distribution of epiphytic fern number per host met the negative exponential function. Both tree hosts in primary forests (PFs) and degraded primary forests (DPFs) were clumped distribution patterns.

The buttress length did not distributed in normal pattern or other common distribution functions. The buttress height distribution, the distribution of buttress density and the distribution of buttress trees density met the negative exponential function. The buttress number per buttress tree distributed in Poisson distribution. Both buttress trees in primary forests (PFs) and degraded primary forests (DPFs) were clumped distribution patterns.

The main contents and methods of investigation and assessment of forest ecotourism resources could be as follows (Figure 11).

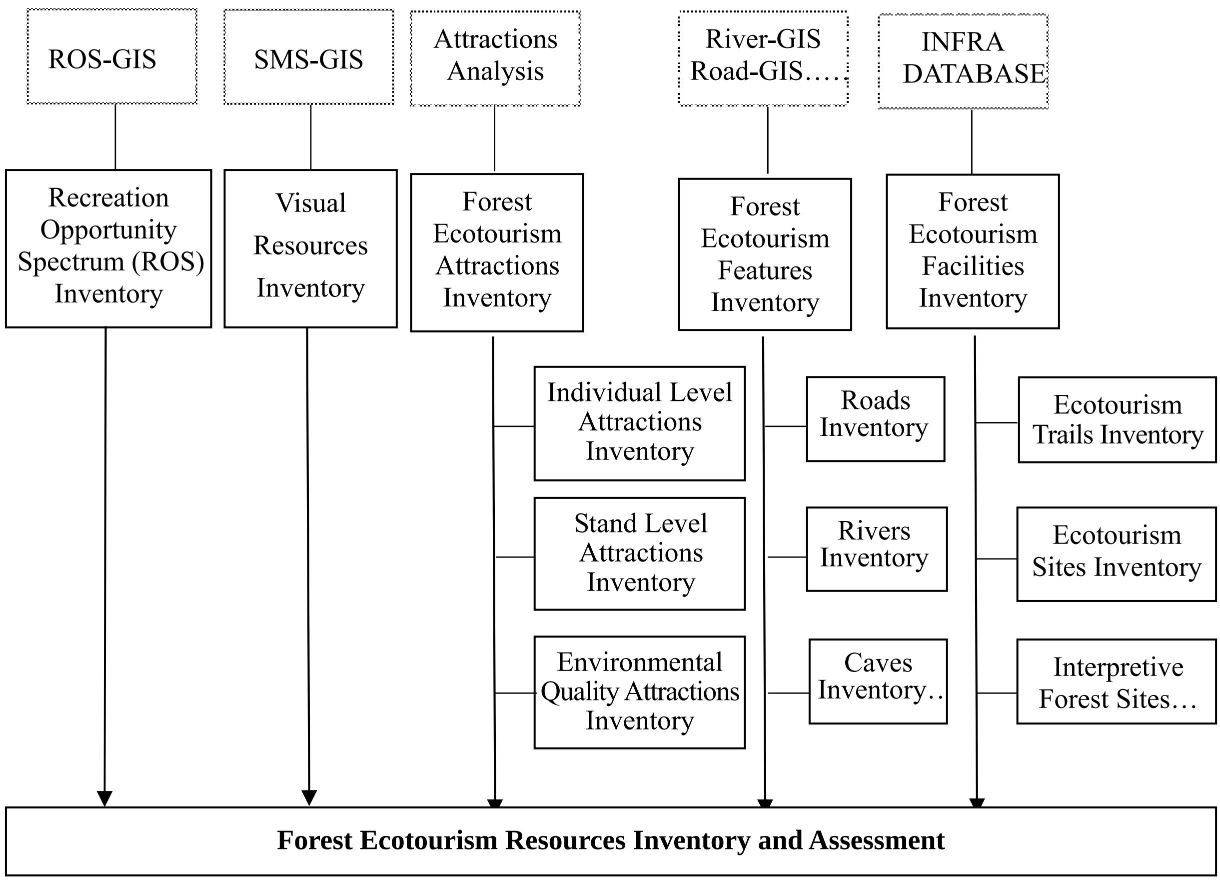


Figure 11 Contents and methods of investigation and assessment of forest ecotourism resources

6 Recommendations

There are 3 levels of ecotourism attractions for investigation and assessment of tropical forest ecotourism resources in Hainan Province: individual level, stand (forest community) level and forest landscape level. The buttress, garden in the air, cauliflory, strangler, dangling liana, special tree and animal etc. should be the main ecotourism attractions in individual level and should be inventoried in each subcompartment when conduct the traditional forest management inventory in FMU. The density and distribution of individual ecotourism attractions, species diversity and structure of stand (forest community) etc. should be the main ecotourism attractions in stand (forest community) level and should be inventoried in each subcompartment when conduct the traditional forest management inventory in FMU. The Recreation Opportunity Spectrum (ROS) and visual landscape characters (including scenic attractiveness, scenic integrity, landscape visibility and scenic classes etc.) should be the main ecotourism attractions in forest landscape level and should be analyzed and assessed after the traditional forest management inventory and assessment in FMU.

7 Implications for practice

Sketch Map of Existing buttress in Diaoluoshan National Forest Park (Annex 10) demonstrated the distribution result of the existing buttress and its density after inventory in each subcompartment. Sketch Map of Existing 'gardens in the air' in Diaoluoshan National Forest Park (Annex 11) demonstrated the distribution result of the existing buttress and its density after inventory in each subcompartment.

When conduct the forest ecotourism attractions inventory in each subcompartment, the following indicators and standards could be considered.

The standard of living height of epiphytic ferns:

Low: the height of epiphytic ferns < 5.5 m

Medium: 5.5 m ≤ the height of epiphytic ferns < 10.0 m

High: the height of epiphytic ferns ≥ 10.0 m.

The standard of diameter of epiphytic ferns:

Small: the diameter of epiphytic fern < 0.6 m

Medium: 0.6 m ≤ the diameter of epiphytic fern < 1.0 m

Large: the diameter of epiphytic fern ≥ 1.0 m

The standard of density of epiphytic ferns:

Low: the density of epiphytic ferns < 77 N/hm^2

Medium: 77 N/hm^2 ≤the density of epiphytic ferns < 230 N/hm^2

High: the density of epiphytic ferns ≥ 230 N/hm^2

The standard of hosts' density of epiphytic ferns:

Low: the density of epiphytic ferns' hosts < 50 N/hm^2

Medium: 50 N/hm^2 ≤ the density of epiphytic ferns' hosts < 116 N/hm^2

High: the density of epiphytic ferns' hosts ≥ 116 N/hm^2

The standard of epiphytic fern number per host:

Low: the epiphytic fern number per host < 1

Medium: 1 ≤ the epiphytic fern number per host < 2

High: the epiphytic fern number per host ≥ 2

Theoretically, the medium of the epiphytic fern number per host was between 0.6 and 1.3.

The standard of buttress size:

Small: the buttress height < 0.6 m

Medium: 0.6 m ≤ the buttress height < 1.5 m

Large: the buttress height ≥ 1.5 m

The standard of buttress number per buttress tree:

Low: the buttress number per buttress tree < 3

Medium: 3 ≤ the buttress number per buttress tree < 5

High: the buttress number per buttress tree ≥ 5

The standard of buttress density:

Low: the buttress density < 67 N/hm^2

Medium: 67 ≤ the buttress density < 184 N/hm^2

High: the buttress density ≥ 184 N/hm^2

The standard of density of buttress trees:

Low: the buttress trees density < 16 N/hm^2

Medium: density: 16 ≤ the buttress trees density < 50 N/hm^2

High: the buttress trees density≥ 50 N/hm^2.

Bibliography

Bao Jigang, Chu Yifang. Tourist geography (in Chinese). Beijing: Higher Education Press (HEP), 1999: 15-20.

Bolker B M. Ecological models and data in R. Princeton University Press, 2008.

Brass J L. Community tourism assessment handbook. Ballard Hall: Western rural development center, 1996.

Chen Cai, Wang Haili, Jia Hong. Thoughts on the relations among tourism attractions, tourism resources and tourism products (in Chinese). Journal of Guilin Institute of Tourism, 2007, 18(1): 1-4.

Chen Neng, Zhong Qiongxin. Inventory and Development of Medicinal Ferns at the Jianfengling Nature Reserve in Hainan, China (in Chinese). Journal of tropical biology, 2014, 5(4): 381-387.

Chen Xiaoqin. Analyzing on the concept of forest tourism resources (in Chinese). Problems of Forestry Economics, 2006, 26(2): 146-149.

Christenhusz M J M, Chase M W. Trends and concepts in fern classification. Annals of botany, 2014, 113(4): 571-594.

Clawson, M. and Knetsch, J. L. Economics of outdoor recreation resources for the future (2nd edition). Washington D.C. 1969.

Dong Shiyong, Chen Zhengchuan, Zhang Xinchun. Biodiversity and conservation of pteridophytes from Diaoluo Mountain, Hainan Island (in Chinese). Biodiversity science, 2003, 11(5): 422-443.

Dowling R K. An environmentally based approach to tourism planning. Western Australia: Murdoch University, 1993.

Dubuisson J Y, Schneider H, Hennequin S. Epiphytism in ferns: diversity and history. Comptes rendus biologies, 2009, 332(2): 120-128.

Ellwood F, Manica A, Foster W A. Stochastic and deterministic processes jointly structure tropical arthropod communities. Ecology Letters, 2009, 12(4): 277-284.

Fayle T M, Chung A Y C, Dumbrell A J, et al. The effect of rain forest canopy architecture on the distribution of epiphytic ferns (Asplenium spp.) in Sabah, Malaysia. Biotropica, 2009, 41(6): 676-681.

Fayle T M, Ellwood M D F, Turner E C, et al. Bird’s nest ferns: islands of biodiversity in the rainforest canopy. Antenna, 2008, 32(1):34-37.

Fu Xia, Wu En. The development and application of recreation opportunity spectrum theory (in Chinese). Journal of Guilin Institute of Tourism, 2006，17(6): 691-694.

Getz D. Models in tourism planning. Tourism Management, 1986, 7: 332-344.

Galtier J, Phillips T L. Evolutionary and ecological perspectives of Late Paleozoic ferns. Part III. Anachoropterid ferns (including Anachoropteris, Tubicaulis, the Sermayaceae, Kaplanopteridaceae and Psalixochlaenaceae). Review of Palaeobotany and Palynology, 2014, 205: 31-73.

Goeldner C R., Ritchie J R B. Tourism: principles, practices, philosophies (12 edition). Wiley, 2011.

Gunn C. Vacationscape: designing tourist regions. Austin: University of Texas, 1972.

Guo L, Wu B, Liu F, et al. Study on the tourist resources classification system and types evaluation in China (in Chinese). Acta Geographica Sinica, 2000, 55(3): 294-301.

Gutierrez E., Lamoureux K., Matus S., et al. Linking communities, tourism & conservation: a tourism assessment process. 2005.

Hietz P, Briones O. Photosynthesis, Chlorophyll Fluorescence and Within-Canopy Distribution of Epiphytic Ferns in a Mexican Cloud Forest. Plant Biology, 2001, 3(3): 279-287.

Hsu R C C, Oostermeijer J G B, Wolf J H D. Adaptation of a widespread epiphytic fern to simulated climate change conditions. Plant Ecology, 2014, 215(8): 889-897.

Lascuráin H C. Tourism, ecotourism, and protected areas: the state of nature-based tourism around the world and guidelines for tits development. Island Press, 1996.

Lawton L J. Resident perception of tourist attractions on the gold coast of Australia. Journal of Travel Research, 2005, 44(2): 188-200.

Leiper N. Tourist attraction systems. Annals of Tourism Research, 1990, 17(3): 367-384.

Lew A. A framework of tourist attraction research. Annals of Tourism Research, 1987, 14: 533-575.

Liao Wenbo, Jin Jianhua, Wang Bosun et al. Biodiversities and their continental features of the fern floras in Hainan and Taiwan island, China (in Chinese). Acta botanica boreali-occidentalia sinica, 2003, 23(7): 1237-1245.

Liang Xiucun, Ding Dengshan. Trends of overseas studies of tourism resources evaluation (in Chinese). Journal of Natural Resources, 2002, 17(2): 253-260.

Luo Feng, Huang Qinglin, Zhang Yin et al. Research progress on classification, investigation and evaluation of forest tourism resource (in Chinese). World Forestry Research, 2014, 27(6): 8~13.

Luo Wen, Song Xiqiang, Xu Han et al. Floristic analysis of pteridophytes in Jianfengling Nature Reserve, Hainan Island (in Chinese). Journal of Wuhan botanical Research, 2010, 28(3): 294-302.

Ma Qinyan. Analysis of the negative binomial distribution and test of population pattern (in Chinese). Journal of Beijing Forestry University, 2009, 31(3): 1-5.

Ma Zhibo, Sun Wei, Huang Qinglin. Valuation and payments for forest ecosystem service: concepts, principles and indicators (in Chinese). Journal of China Agriculture University, 2014, 19(5): 263~268.

Minardi B D, Voytena A P L, Santos M, et al. Water stress and abscisic acid treatments induce the CAM pathway in the epiphytic fern *Vittaria lineata* (L.) Smith. Photosynthetica, 2014, 52(3): 404-412.

Ministry of Forestry. Standard for overall design of forest parks (LY/T5132-95) (in Chinese). Beijing: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 1996.

National Tourism Administration. Classification, investigation and evaluation of tourism resources (GB/T 18972-2003, National Standard of the People's Republic of China) (in Chinese). Beijing: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2003.

Pearce P. Analysing tourist attractions. Journal of Tourism Studies, 1991, 2(1): 46-55.

Pigram J. Outdoor recreation and resource management. Beckenham: Croom Helm, 1983.

Qi Tong, Wang Yajuan, Wang Weihua. A Review on visual landscape study in foreign countries (in Chinese). Progress in Geography, 2013, 32(6): 975-983.

Qin Xinsheng, Yan Yuehong, Zhang Rongjing et al. Resources of pteridophytes in limestone regions in Hainan Island (in Chinese). Journal of South China Agricultural University, 2007, 28(4): 122-124.

Qiu Yaorong. Technical points and study of forest tourist resources investigation (in Chinese). Forest

Resources Management, 2000(4): 62-65.

Rößler R, Galtier J. The first evidence of the fern Botryopteris from the Permian of the Southern Hemisphere reflecting growth form diversity. Review of Palaeobotany and Palynology, 2003, 127(1): 99-124.

Roulin A, Bersier L F. Nestling barn owls beg more intensely in the presence of their mother than in the presence of their father. Animal Behaviour, 2007, 74(4): 1099-1106.

Soria-Auza R W, Kessler M. The influence of sampling intensity on the perception of the spatial distribution of tropical diversity and endemism: a case study of ferns from Bolivia. Diversity and Distributions, 2008, 14(1): 123-130.

State Forestry Administration. China forest park landscape resources grade evaluation (GB/T 18005-1999, National Standard of the People's Republic of China) (in Chinese). Beijing: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2000.

State Forestry Administration. Technical regulations for inventory for forest management Planning and design (GB/T 26424-2010) (in Chinese). Beijing: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2011.

Sundue M A, Rothfels C J. Stasis and convergence characterize morphological evolution in eupolypod II ferns. Annals of botany, 2014, 113(1): 35-54.

The Resource Inventory Committee. Recreation features inventory: procedures and standards manual. Canada British Columbia Province, 1998.

USDA Forest Service. *National Landscape Management Volume 2 Chapter 1: The Visual Management System*. Agriculture Handbook Number 462. USDA Forest Service, Washington D. C, 1974.

USDA Forest Service. ROS users guide. USDA Forest Service, Washington D. C, 1982.

USDA Forest Service. Landscape aesthetics: a handbook for scenery management, Agriculture Handbook No.701. USDA Forest Service, Washington D. C, 1995.

USDA Forest Service. Appendix J, Recommended Refinements to the Scenery Management System. USDA Forest Service, Washington D. C, 2007.

USDA Soil Conservation Service. Procedure to establish priorities in landscape architecture. USDA, SCS Technical Release No. 65, Washington, D. C.: U.S. Government Printing Office, 1978.

USDOT Federal Highway Administration. Visual impact assessment of highway projects. USDOT FHWA, Washington D. C.: Office of Environmental Policy, 1981.

Wagner K, Mendieta-Leiva G, Zotz G. Host specificity in vascular epiphytes: a review of methodology, empirical evidenceand potential mechanisms. AoB PLANTS, 2015, 7: plu092 (doi:10.1093/aobpla/plu092).

Wang Bosun, Yu Shixiao, Peng Shaolin. Experiment handbook of plant community (in Chinese). Guangzhou: Guangdong higher education press, 1996.

Wang Chuanwei, Guo Feng, Jiang Zeping, et al. Resource management of outdoor recreation in America (in Chinese). World Forestry Research, 2008, 21(2): 64-68.

Watkins J E, Cardelús C L, Mack M C. Ants mediate nitrogen relations of an epiphytic fern. New Phytologist, 2008, 180(1): 5-8.

Wu Chucai, Zheng Qqunming, Zhong Linsheng. A Study of the aero-anion concentration in forest recreation area (in Chinese). Scientia Silvae Sinicae, 2001, 37(5): 75-81.

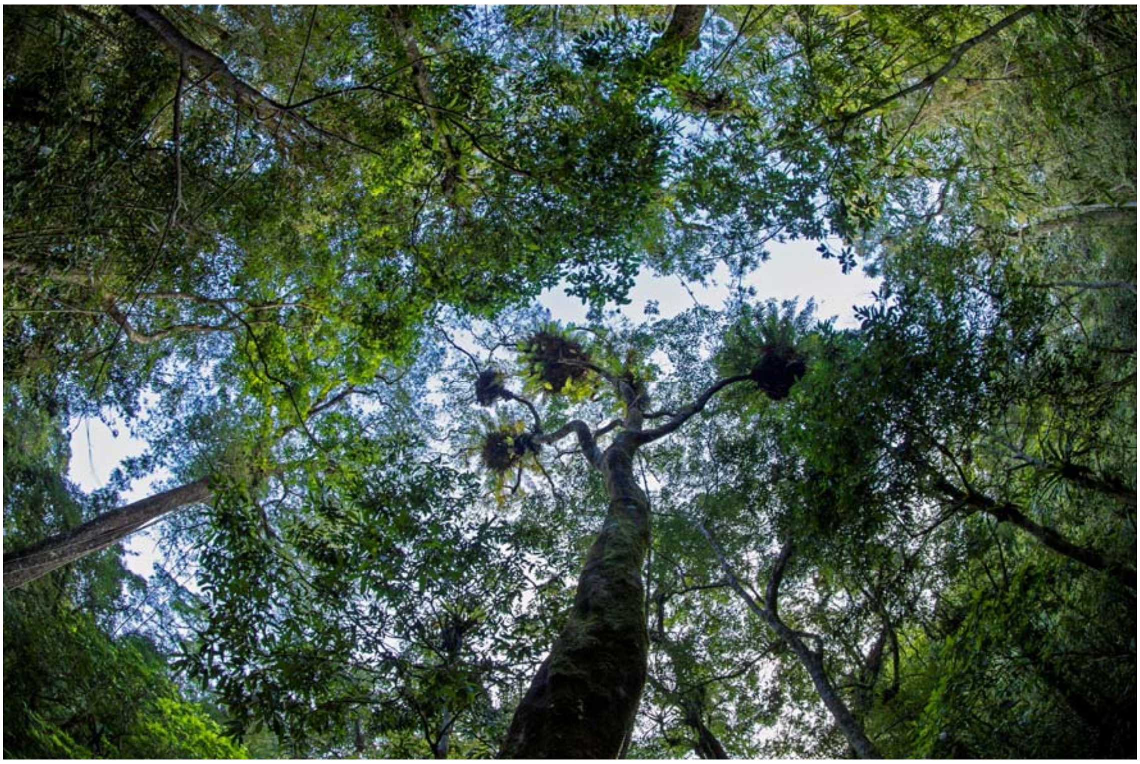
Wu Chucai. Ranking of forest tourism resources (in Chinese). Journal of Central South Forestry

University, 2003, 23(2): 33-38.
Wu Xizhi, Zhao Bojuan. Nonparametric statistics (in Chinese). Beijing: Statistics Press of China, 2009, 150-152.
Wu Zhangwen. Characteristics and classification of forest tourism resources (in Chinese). Journal of Central South Forestry University, 2003, 23(2): 39-42.
Xing Daolong, Wang Mei. Some basic problems of tourism resources evaluation (in Chinese). Tourism Tribune, 1987, 2(3): 13-19.
Xu Shitao. Epiphytic characteristics of *Asplenium nidus* L. (Aspleniaceae) complex in tropical montane rain forest, Hainan Island (in Chinese). Hainan University, 2013.
Yang Fenchun, Huang Huaping, Niu Liming et al. Diversity and habitat of pteridophyte herbs in Hainan Island (in Chinese). Journal of Hainan Normal University (Natural Science), 2010, 23(3): 314-319.
Yang Zhenzhi. Systematic analyses of the tourist resources (in Chinese). Tourism Tribune, 1997, 12(3): 25-29.
Zhang Jintun. Quantitative ecology (in Chinese). Beijing: Science Press, 2004.
Zhang Lingyun. Market Evaluation: A new outlook of tourism resources (in Chinese). Tourism Tribune, 1999，14(2): 47-52，99.
Zhang Yongxia, Chen Hongfeng, Hu Xueqiang et al. Fern flora and its characteristics of the lowland rainforest in Tongtieling, Hainan Island (in Chinese). Acta botanica boreali-occidentalia sinica, 2007, 27(4): 805-812.
Zhong Linsheng, Wu Chucai, Xiao Duning. Aeroanion researches in evaluation of forest recreation resources (in Chinese). Chinese Journal of Ecology, 1998, 17(6): 56-60.
Zuur A F, Ieno E N, Walker N, *et al*. Mixed effects models and extensions in ecology with R. Springer Science & Business Media, 2009.

.

Annex 1 Typical photos of forest ecotourism attractions in individual level in Diaoluoshan National Forest Park

Buttress



'Gardens in the air' and epiphytic fern (*Pseudodrynaria coronan*s)

Cauliflory

Cauliflory and epiphytic fern (*Neottopteris nidus*)

Strangler

Dangling lianas

Special tree (spirit tree)

Special tree (tea tree)

Special tree (tree fern)

Special tree

Special tree (tree fern)

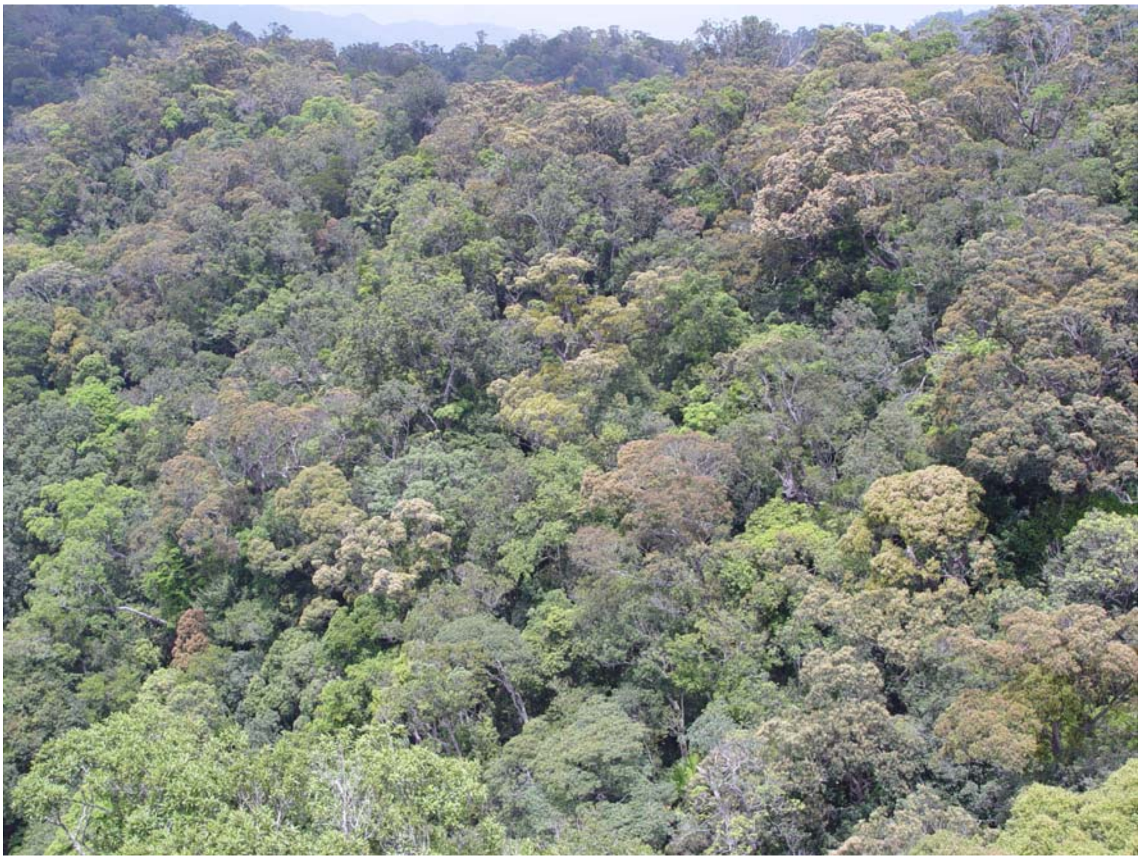
Special tree

Special tree

Special tree

Annex 2 Typical photos of forest ecotourism attractions in stand (forest community) level in Diaoluoshan National Forest Park

Stand (forest community) level



Stand (forest community) level

Annex 3 Typical photos of forest ecotourism attractions in landscape level in Diaoluoshan National Forest Park

Landscape level

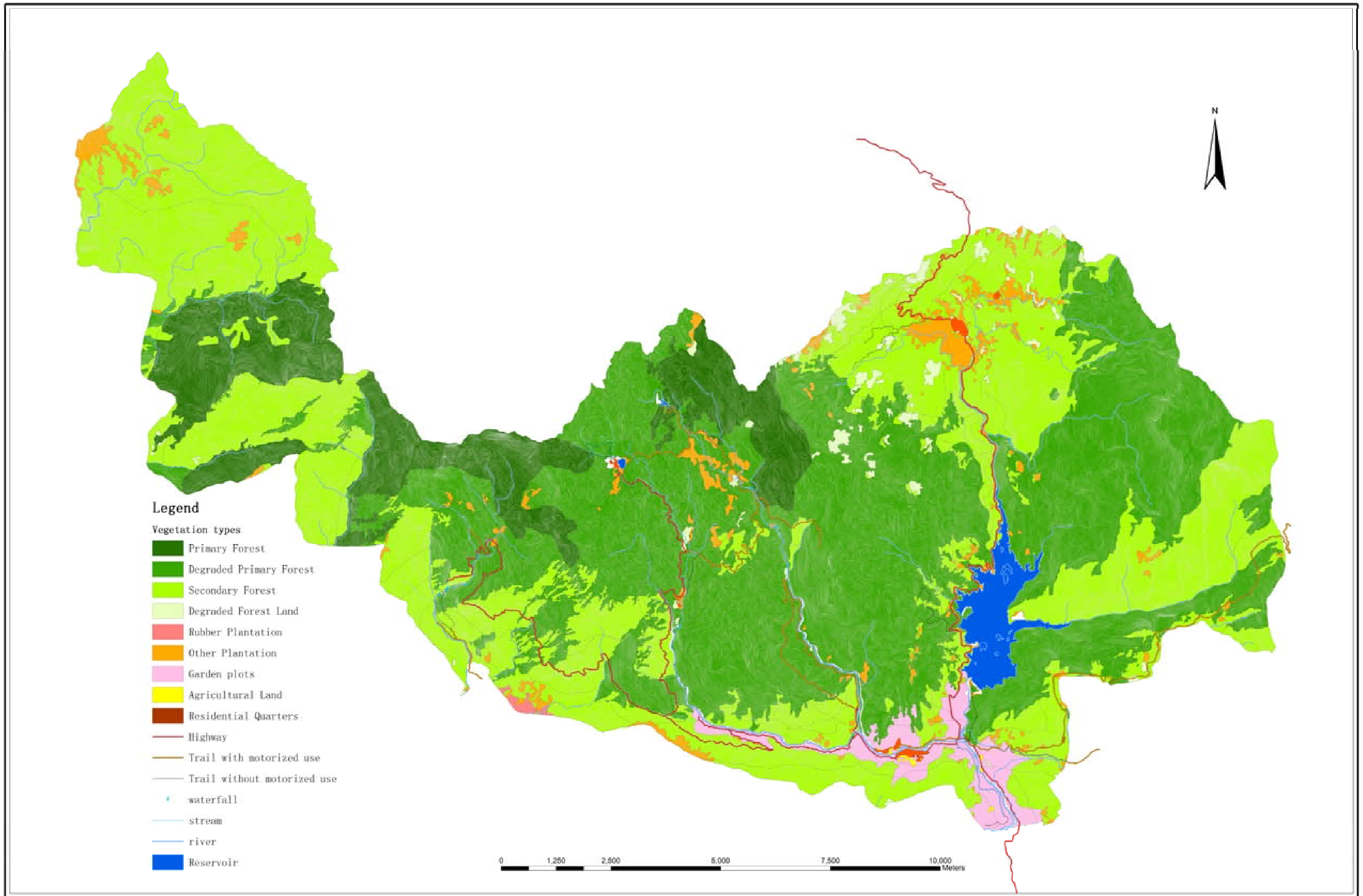
Landscape level

Landscape level

Landscape level

Annex 4 Map of Existing Vegetation types in Diaoluoshan National Forest Park

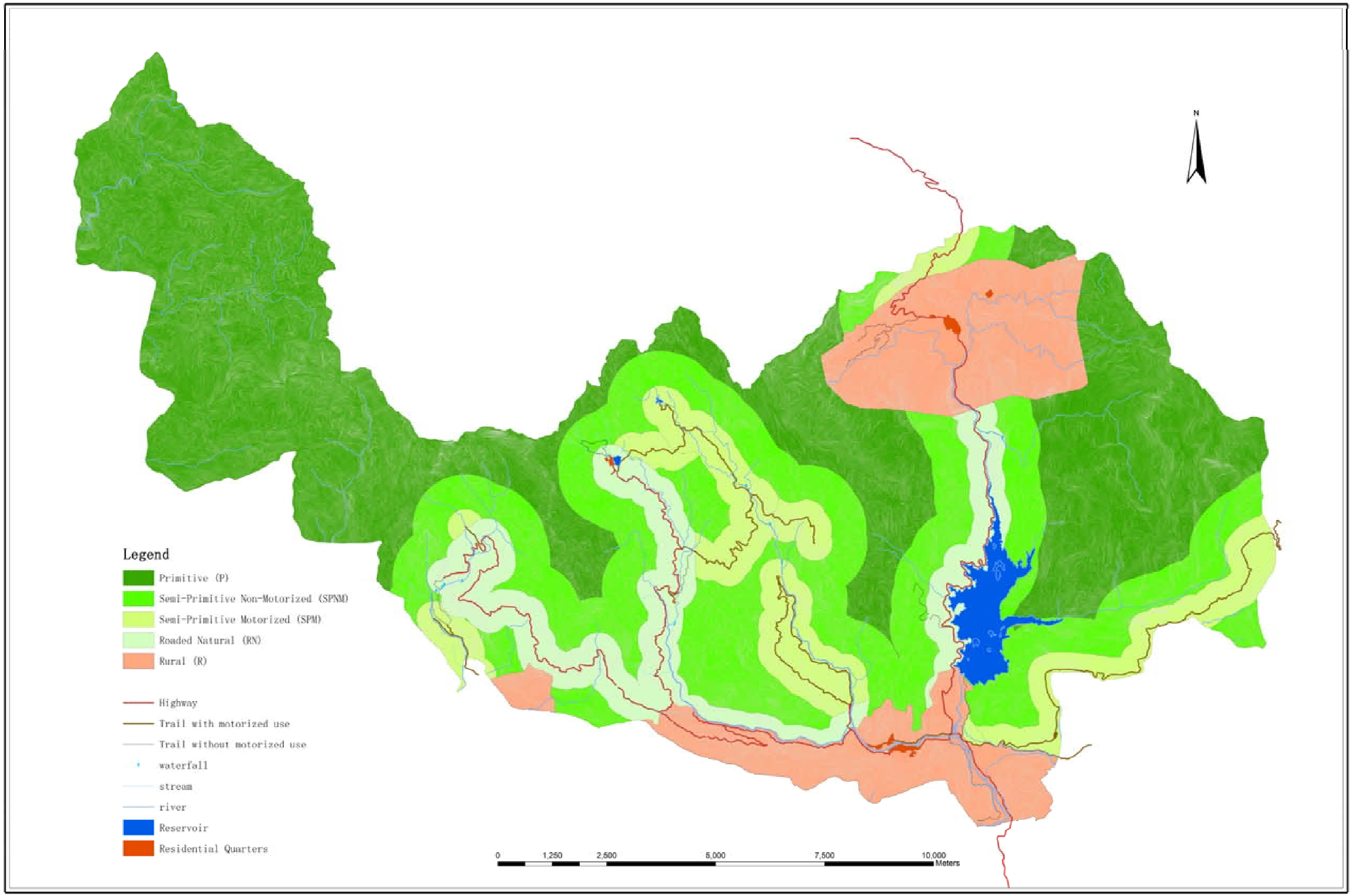
Map of Existing Vegetation types in Diaoluoshan National Forest Park



ITTO RED-SPD 075/12 Rev. 1 (F)
Project on Investigation and Assessment of Tropical Forest Ecotourism Resources
2015-05-31

Annex 5 Map of Existing Recreation Opportunity Spectrum (ROS) in Diaoluoshan National Forest Park

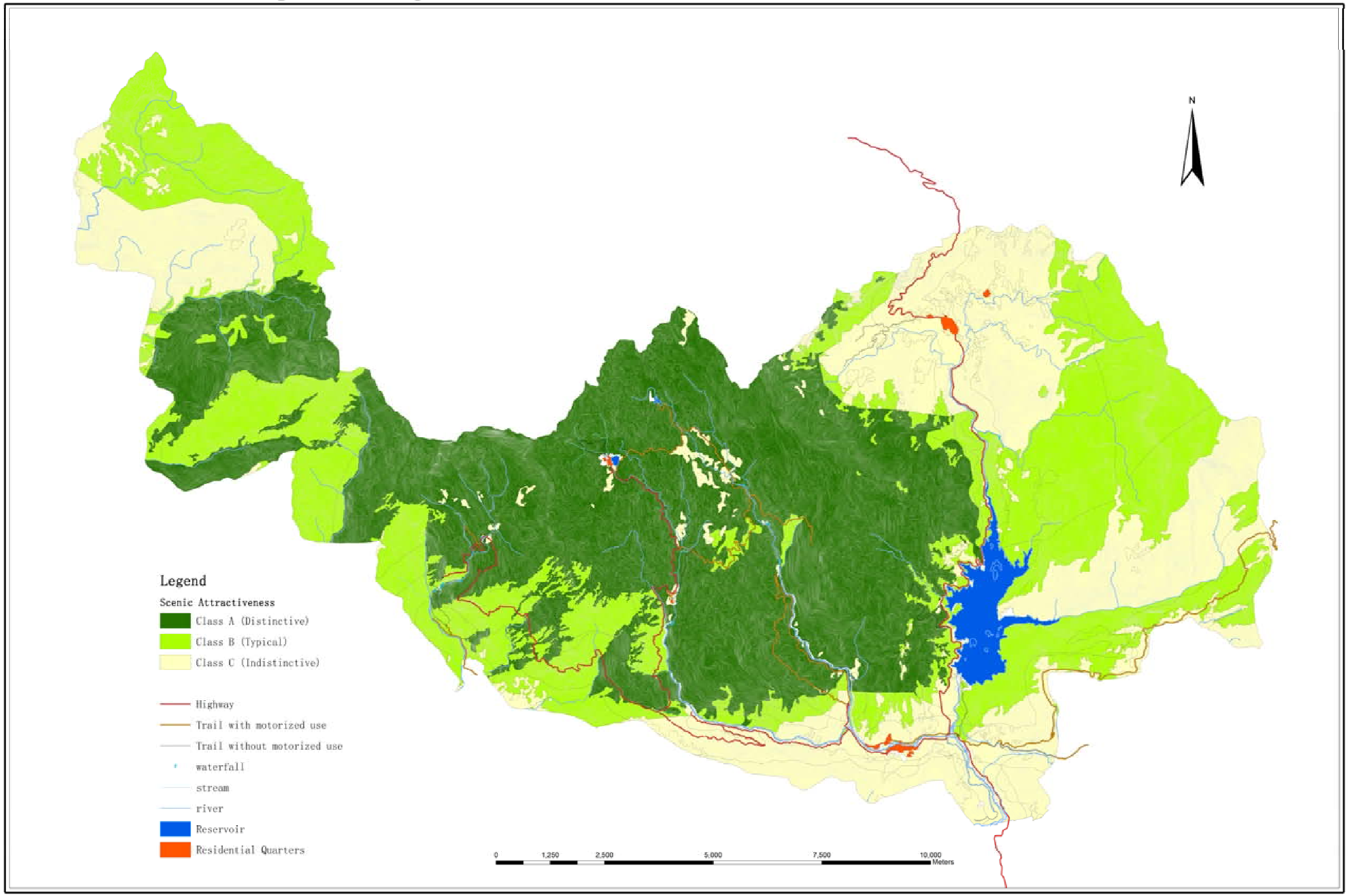
Map of Existing Recreation Opportunity Spectrum (ROS) in Diaoluoshan National Forest Park



ITTO RED-SPD 075/12 Rev. 1 (F)
Project on Investigation and Assessment of Tropical Forest Ecotourism Resources
2015-05-31

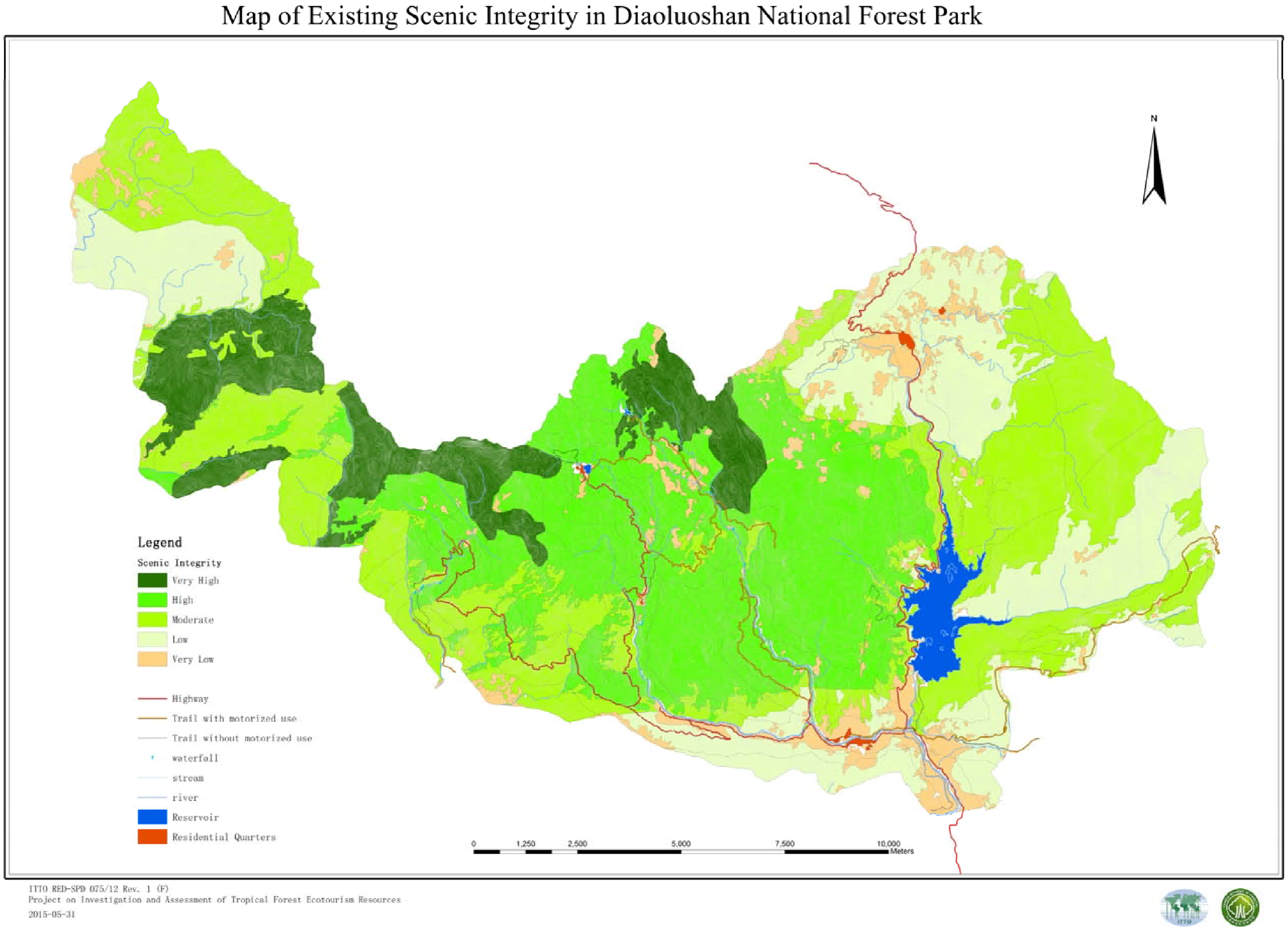
Annex 6 Map of Existing Scenic Attractiveness in Diaoluoshan National Forest Park

Map of Existing Scenic Attractiveness in Diaoluoshan National Forest Park



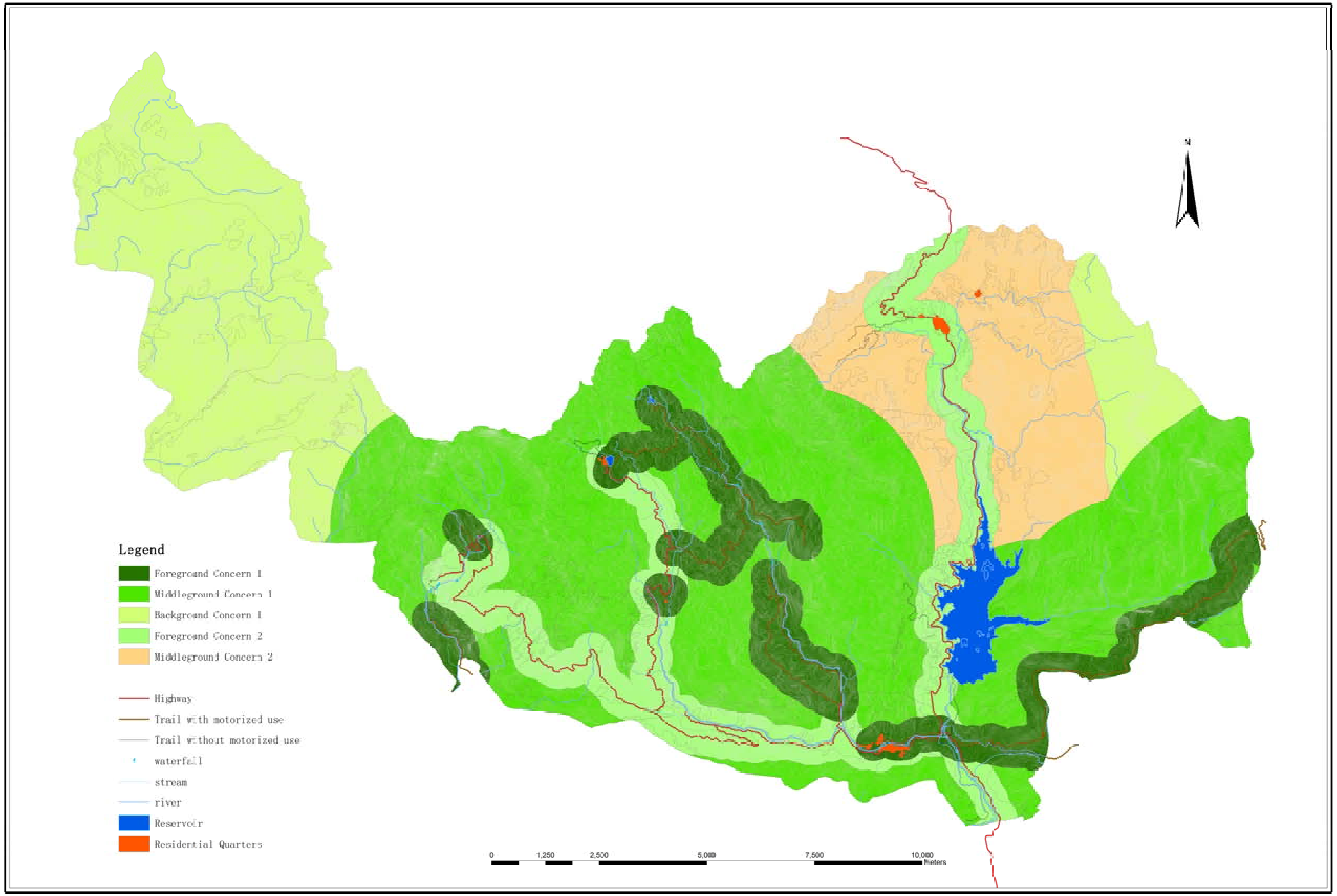
ITTO RED-SPD 075/12 Rev. 1 (F)
Project on Investigation and Assessment of Tropical Forest Ecotourism Resources
2015-05-31

Annex 7 Map of Existing Scenic Integrity in Diaoluoshan National Forest Park



Annex 8 Map of Existing Landscape Visibility in Diaoluoshan National Forest Park

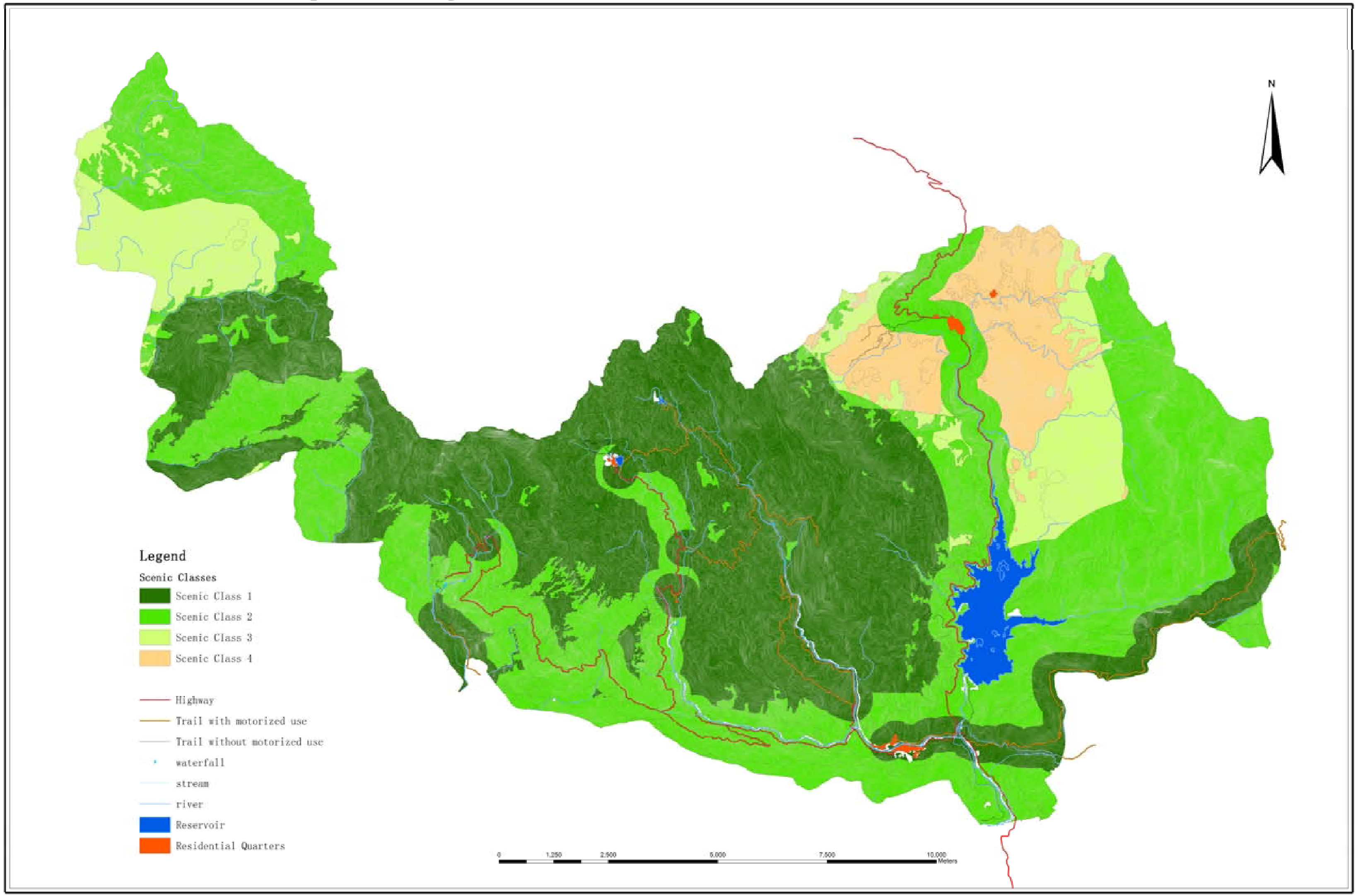
Map of Existing Landscape Visibility in Diaoluoshan National Forest Park



ITTO RED-SPD 075/12 Rev. 1 (F)
Project on Investigation and Assessment of Tropical Forest Ecotourism Resources
2015-05-31

Annex 9 Map of Existing Scenic Classes in Diaoluoshan National Forest Park

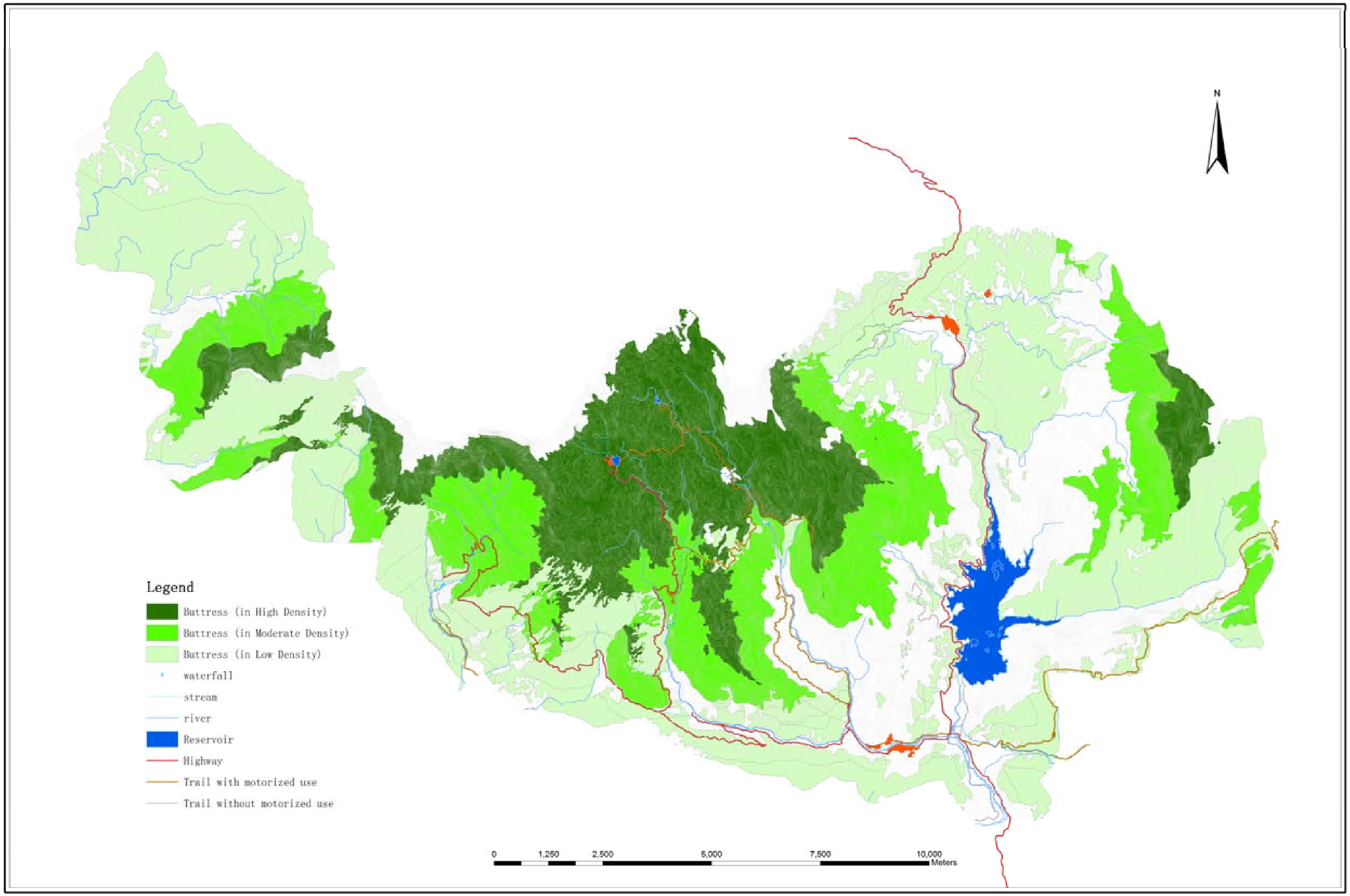
Map of Existing Scenic Classes in Diaoluoshan National Forest Park



ITTO RED-SPD 075/12 Rev. 1 (F)
Project on Investigation and Assessment of Tropical Forest Ecotourism Resources
2015-05-31

Annex 10 Sketch Map of Existing buttress in Diaoluoshan National Forest Park

Sketch Map of Existing buttress in Diaoluoshan National Forest Park



ITTO RED-SPD 075/12 Rev. 1 (F)
Project on Investigation and Assessment of Tropical Forest Ecotourism Resources
2015-05-31

Annex 11 Sketch Map of Existing ‘gardens in the air’ in Diaoluoshan National Forest Park

Sketch Map of Existing ‘gardens in the air’ in Diaoluoshan National Forest Park