Investigation Report on Community Forest Resources in Bos Thom, Siem Reap, Cambodia

1 Basic information

1.1 Study area

The study area is located in the community forest of Bos Thom village, Siem Reap, Cambodia. It is about 32km from Siem Reap. The latitude and longitude are 13°26′35″N and 104°11′40″E, respectively. The forest type is a natural mixed forest of evergreen and deciduous forest, with a total area of 445 hectares, of which there are 194 hectares of forest with growing stock, 207 hectares of sparse young forest land, and 44 hectares of grassland / open land.

The climate is a tropical monsoon climate with an average annual temperature of 28.2℃ and an annual precipitation of 1500 to 200 mm. The rainy season is from May to October accounting for about 75% of the total annual rainfall. The dry season is from November to April next year. The landform is a plain platform with an altitude of 50-80m. The soil belongs to red-yellow podzols of plain alluvial soil. The soil layer is thick, sandy, and has poor water and fertilizer retention.

1.2 History of forest management

The forest is very close to the community settlements, with a straight distance of about 1 km, and it is very convenient to enter the forest area. Due to the lack of forest management technology and weak awareness of forest protection, a large number of trees were fell, in exchange for wood economic income and fuelwood needed for living. The community's forests have been developed and used disorderly, therefore the forest quality gradually declined, some huge forest windows were formed in some forests, half of the forests were free of wood for logging, and biodiversity declines seriously. In some areas, soil dryness or desertification occurred, and forest ecosystem functions were significantly degraded.

2 Methods

2.1 Classification of forest types

Combining history data and on-site investigation, according to the forest appearance, stand structure and the degree of human disturbance on the forest, the forest is divided into three types: severely degradation type (Type A), moderately degradation type (Type B), and slightly degradation type (Type C). The characteristics of each forest type are as follows:

A Severely degraded forest type (Type A): The forest is the most strongly disturbed by humans. The trees in the community have been cut down and the forest canopy density is less than 0.2. The existing main vegetation is composed of low bush and weeds. The height of the sprouting tree layer is less than 5m, the number of species is small, and the herbaceous layer occupies a larger area (Figure 1).

Figure 1 Severely degraded forest

B Moderately degraded forest type (Type B): The forest is subject to greater human disturbance and there are no tall trees in the forest. It is a sparse forest land formed after forest destruction. The community is composed of small, sprouting or natural regenerated trees and shrubs. The vegetation is richer, and the herb coverage is significantly smaller than that of the severely degradation forest, and the canopy density is 0.2-0.6 (Figure 2).

C Slightly degraded forest type (Type C): The forest is lightly disturbed by humans. The tree species are abundant and the forest structure is similar to the level of the natural forest. There are more developed vines in the forest, and there are only a few woods in the community. Tall and large trees are cut down, and the proportion of large-diameter trees is smaller than that of natural forest. The canopy density is 0.6-0.9.

Figure 3 Lightly degraded forest

Figure 2 Moderately degraded forest

2.2 Measurement of plant and soil characteristics

In each forest type, a representative stand was selected for plot survey during 21-23 December, 2018. There were 3 plots in each forest type with a total of 9 fixed plots (Table 1). The plot was a circular plot with a radius of 13.8m and an area of 600m^2. A PVC pipe was inserted at the center of the plot to mark the plot. In the plot, the community structure, tree growth and soil physical and chemical properties were investigated, respectively.

Table 1 Geographical coordinates of plots

Plot no.	Type of forest	Longitude	Latitude
A1	Severely Degraded Forest	104°6'20"	13°25'54"
A2	Severely Degraded Forest	104°6'26.46"	13°26'16.45"
A3	Severely Degraded Forest	104°6'30.09"	13°26'16.58"
B1	Moderately Degraded Forest	104°6'23"	13°26'31"
B2	Moderately Degraded Forest	104°6'18.58"	13°26'41.42"
B3	Moderately Degraded Forest	104°6'07.25"	13°26'12.05"
C1	Slightly Degraded Forest	104°6'09.14"	13°26'34.12"
C2	Slightly Degraded Forest	104°6'10.6"	13°26'29.2"
C3	Slightly Degraded Forest	104°6'15.22"	13°26'40.05"

--Arbor layer: The DBH and tree height were determined for the trees with a DBH ≥5cm and the tree name was also recorded. Before the end of the survey, In the slightly degraded forest, the tall, straight, good branching trees with high economic value in the upper forest layer were selected as the target tree. Red paint draws a circle at the breast height as a permanent mark, and then the target tree number in the plot was recorded. The calculation formula of standing wood volume is defined as $V=0.667054\times10^{-4}D^{1.84795450}H^{0.96657509}$.

--Shrub and herb layer: Three representative subplots (2 m × 2 m) were set up in each plot. The species name, height, abundance, and coverage of all shrubs and herbs were investigated. The Margalef richness index, Shannon-Wiener diversity index, Simpson dominance index and Pielou evenness index were further calculated using the survey data.

--Soil sample: In each plot, 1m-deep soil profile was divided into five levels: 0-10cm, 10-20cm, 20-30cm, 30-50cm and 50-100cm. The soil samples from different levels were determined for soil physical properties (bulk density, porosity, moisture content, water holding capacity, texture) and chemical properties (pH, organic matter, total nitrogen, phosphorus and potassium, available nitrogen, phosphorus, potassium and soluble carbon and nitrogen content, soil microbial biomass carbon and nitrogen content).

3 Results and analysis

3.1 Tree layers

--Forest resource status analysis: There were significant differences in the number of trees per hectare, mean DBH, tree height and stock volume in three different forest types (Table 2). The numbers of trees per hectare, average DBH, tree height, and stock volume of type C were significantly greater than those of type A and type B, although there was no significant difference in the average DBH and tree height between type A and type B.

Table 2 Growth status of three forest types

Indicators	Type A	Type B	Type C
Numbers of trees per hectare	139c	656b	1328a
Mean DBH (cm)	10.69b±6.55	8.86b±4.74	12.28a±7.41
Average tree height (m)	8.38b±3.62	8.11b±3.37	13.85a±4.90
Average stock volume (m^3/ha)	5.77c	18.64b	115.73a

--Diameter distribution and stand volume: The three types of forests are more disturbed by humans. The trees in the arbor layer have a higher proportion of small trees, while the proportion of the large diameter trees is lower. Among them, the average DBH and average stock volume of type A are 12.28 cm and 115.73 m^3/ha, respectively. The proportion of large diameter trees (DBH greater than 26 cm) is about 40 trees/ha (Figure 4), indicating that there are few high-value, large-diameter trees can be harvested at least 20 years in this type of forest.

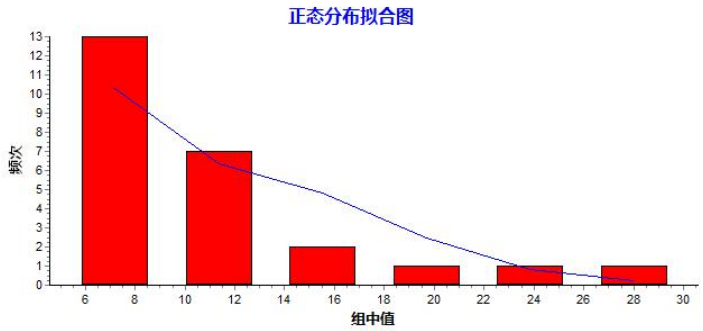

Figure 4 The distribution of tree diameter in lightly degraded forest type (Type C)

--Selection of target trees in type C forest: A total of 17 target trees were selected in 3 plots, about 94 target trees per hectare, with an average DBH of 22.2 cm and average tree height of 22.0 m. Among them, there are 7 species of high-value timber species, such as *Peltophorum dasyrrhachis* (code 19), *Eugenia spp.* (Code 18), *Garcinia schomburgkiana* (code 11), *Sindora cochinchinensis* (Code 14), *Phyllanthus amarus* (code 32), etc. The tree species code 19 and 18 accounted for a higher proportion.

3.2 Plant diversity

The Margalef richness index, Shannon-Wiener index and other indicators are significantly different among three forest types (Table 3). The lightly degraded forest (type C) has a relatively stable and reasonable community structure, with strong natural regeneration ability and long-term succession potential. The species diversity of the slightly degraded forest (type C) are better than those of the moderately degraded forest (type B) and the severely degraded forest (type A). Severely degraded forest (type A) is more affected by the human and natural disturbances, resulting in declines in the stability, biodiversity and natural restoration of forest communities.

Table 3 Plant diversity in three forest types

Indicators	Type A		Type B		Type C	
	Tree layer	Shrub/grass layer	Tree layer	Shrub/grass layer	Tree layer	Shrub/grass layer
Margalef richness index	11	12	26	22	34	31
Shannon-Wiener index	2.21	0.70	2.84	2.05	2.94	2.73
Simpson dominance index	0.87	0.27	0.92	0.82	0.93	0.89
Pielou evenness index	0.92	0.28	0.87	0.66	0.83	0.80
Rl/Species richness index	3.11	1.74	5.24	2.98	6.03	5.97
λ/Ecological dominance	0.09	0.73	0.07	0.18	0.07	0.11

3.3 Soil conditions

--Soil parent material and soil type: The soil belongs to plain alluvial and red-yellow gray soil.

--Soil physical properties: The soil texture is sandy loam or light loam. The average content of clay and fine particles (less than 0.02mm) in the active root layer is 25.6%-30.2%. The moisture content is 7.1%-8.3%. However, there were no significant differences among forest types in these two indicators.

--Soil chemical properties: The total N content of type C was significantly higher than those of type A and type B, while there were no significant differences in other indicators (Table 4).

--Evaluation of soil fertility: The soil belongs to strong acid soil, light sandy loam soil or light loam soil with high sand content (Table 4). The soil moisture in the dry season is relatively low, but plants grow normally. According to the traditional classification of nutrient grades, the organic matter content is in medium level, the total N and available P contents are in the medium to high level. Overall, the forest is disturbed by human activities to a certain extent. Although the contents of organic matter and macro-nutrients have declined, the soil fertility is still in the middle-high level and has better productivity.

Table 4 Soil physicochemical analysis in 0-40 cm soil depth in three forest types

Indicators	Type A	Type B	Type C
Content of clay and fine particles (<0.02mm) (%)	30.2±7.59	25.6±5.19	25.9±6.67
Moisture content (%)	8.3±0.40	7.1±0.61	7.7±0.39
pH	5.05±0.22	4.97±0.20	4.76±0.10
Organic Matter (%)	3.01±0.37	2.26±0.26	3.03±0.29
Total Nitrogen (%)	0.12b±0.01	0.13b±0.01	0.16a±0.01
Total Phosphorus (%)	0.04±0.00	0.03±0.01	0.03±0.00
Available Phosphorus (ppm)	31.81±6.31	28.00±0.86	28.50±0.50

4 Recommendations of forest management

4.1 Strengthening the protection of forest resources

Establish or improve the community forest resource management mechanism, formulate practical regulations and rules, conscientiously implement the responsibilities and rights of managers, strengthen the protection of forest resources, and prevent all phenomena of disorderly development and destruction of forests.

4.2 Classified operations

According to the degree of forest degradation, ecological restoration and forest resource management are carried out according to three different types of forests.

(1) For severely degraded forest land, artificial afforestation is carried out with fast-growing, nitrogen-fixing precious tree species that are beneficial for rapid improvement of the forest structure and high economic value, so that bare land can quickly form forest vegetation. The complex forest structure not only gives full play to the ecological service function, but also greatly improves the economic benefits, eventually achieving the purpose of sustainable forest management and utilization.

(2) For moderately degraded forest, through a series of measures, such as open forest windows and replant target trees in moderately degraded forests, adjust the species composition of low-quality and low-efficiency forests, to achieve the purpose of increasing forest economic value and forming a mixed-age forest with more complex structures to further improve stand stability, stand quality, and productivity.

(3) For lightly degraded forest, the natural resilience is fully used to restore forest functions. The main measures include the conservation of the dominant and target tree species, and reduction of non-target tree species those affecting the direction of forest succession. It aims to shorten the forest cultivation circle, promote the restoration of degraded forest ecosystems and increase their economic value.

4.3 Develop local economy and improve people's livelihood.

It is suggested that the local government vigorously develop the local economy, seek multiple sources of economic income, and improve material living conditions, thereby reducing the pressure on the use of forest resources by people's livelihood needs.