

**THE MINISTRY OF EDUCATION AND TRAINING  
THAI NGUYEN UNIVERSITY**

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**NGUYEN THI YEN**

**RESEARCH ON PLANT DIVERSITY IN FOREST  
ECOSYSTEMS OF XUAN SON NATIONAL PARK  
IN PHU THO PROVINCE AS A BASIS FOR PLANNING  
AND CONSERVATION WORK**

**SPECIALITY: ECOLOGY**

**Code: 62 42 01 20**

**SUMMARY OF Ph.D. DISSERTATION IN BIOLOGY**

**THAI NGUYEN – 2015**

The study has fulfilled at the Department of Botany  
The Faculty of Biology, College of Education - Thai Nguyen University

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Reviewer 1.....

Reviewer 2.....

Reviewer 3.....

*The dissertation will be defended at College of Education,  
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Dissertation can be found in:

- National library of Viet Nam;
- Learning Resource Center - Thai Nguyen University;
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## FOREWORDS

### 1. The necessity of the research

Xuan Son National Park located in the territory of Tan Son district, Phu Tho Province has a relatively abundant and diversified forest ecosystem of the North of Viet Nam in particular and Vietnam in general. With the tropical and subtropical forests here, there are quite a lot of rare plant and animal species existing and typical for the northern mountainous region. They are not only valuable for scientific research, preservation of genetic sources, but also have implications for economic development, exploitation of natural resources (especially biological resources) and education of environmental protection.

So far, there have been numerous studies about Xuan Son National Park. Especially, there were a number of research works on biodiversity and flora in Xuan Son National Park. However, most research works were only the discovery of species of animals and plants, and studied on flora species of conservation value.

Specifically, there were not any study to evaluate the diversity of the flora and vegetation under elevations and under human impacts.

Therefore we choose the research topics, namely “***Research on plant diversity in forest ecosystems of Xuan Son National Park in Phu Tho Province as a basis for planning and conservation work***”. This will provide the scientific bases for planning policies and applying silvicultural measures for the conservation and development of diversity the flora of and vegetation in Xuan Son National Park, Phu Tho Province.

### 2. The research objectives

#### 2.1. Overall objective

It evaluates the diversity of vegetation and flora and determines species composition, distribution of soil animals in vegetation types that contribute to provide scientific and practical bases for work of planning and conservation of biodiversity in Xuan Son National Park, Phu Tho Province

#### 2.2. Specific objectives

- It evaluates the diversity of flora and vegetation of Xuan Son National Park under altitude, topography and extent of various human impacts.

- It determines species composition, distribution of soil animals in vegetation types of Xuan Son National Park

- It proposes some measures for conservation and development of vegetation and several rare plant species in Xuan Son National Park

### **3. The scientific and practical meaning**

#### **3.1. In term of science**

It studied plant diversity, determines rare plant species, classification, describes structures, analyzes changes of vegetation types according to elevation zones (below 700m and above 700m), terrain and extent of human impacts.

#### **3.2. In terms of practice**

A number of conservation measures vegetation development and some precious and rare plant species in the study site were proposed from the research results of the diversity and the value of the vegetation and the flora in Xuan Son National Park.

### **4. Novel contribution of the dissertation**

- Research results have added 2 families, 5 genera and 16 species of flora for Xuan Son National Park

- The dissertation has provided data on the diversity of plant taxa and vegetation the park. It has identified the use of 948 useful plant species and 47 rare plant species that are at risk of extinction in Xuan Son National Park.

- Analyse was quite detailed, completed and comprehensive in terms of species, the structure of the flora and the vegetation in organic relationship with some environmental factors such as elevations, terrain, modes and different extent of human impacts.

### **5. Structure of the dissertation**

The dissertation consists of 132 pages. Apart from the foreword part with 4 pages and two pages of conclusions and recommendations. The main contents of the dissertation are presented in four chapters: Chapter 1. Literature review of research including 32 pages; Chapter 2. Research objects of contents and methods consisting of 9 pages; Chapter 3. Conditions on nature and society at studies area including 5 pages; Chapter 4. Research results and discussion including 80 pages. There are 18 tables, 5 figures and 7 appendixes.

The list of scientific research works published by the author (9 research works), references (109 documents) and the appendix include: Appendix 1. List of the flora of Xuan Son National Park, Phu Tho Province, Appendix 2. List of rare plants species in Xuan Son National Park, Appendix 3. The sample tables for survey and questionnaires, Appendix 4. Information on the sample plots, Appendix 5. Added information on 16 species of the flora of Xuan Son National Park, Phu Tho Province, Appendix 6. Pictures on activities of the research duration, Annex 7. Pictures of some rare plant species in the study site and their ecological characteristics.

## **Chapter 1**

### **LITERATURE REVIEW ON RESEARCH ISSUES**

To achieve the purpose of study and successful implementation of research contents set forth, there are 110 Vietnamese and foreign research literatures referred in the dissertation. These research papers were focused on the following major issues:

#### **1.1. Studies on the flora**

Research on the species composition of plant species is one of the contents had been carried out quite early in the World and Vietnam . The studies were focused in the 19th and 20th centuries

#### **1.2. Studies on the vegetation**

In the World, some researchers were the forefront at people in research on the forest vegetation such as Negri (Italy), Gleason, Curtis (USA), Whittaker, Brown (UK), Fournier, Lenoble (France), etc. In Vietnam, the research works on the vegetation were mainly done by foreign scientists such as Chevalier (1918), Maurand (1943), Duong Ham Hy (1956), Rollet, Ly Van Hoi, etc. (1958), Thai Van Trung (1970), Tran Ngu Phuong (1970), etc.

#### **1.3. Soil animals in relation to the ecological environment**

The role and activity of soil biota groups have long been of interest to many researchers. Soil animals include many functional groups (soil tectonic animals, animals with resolution of decayed vegetation, etc.) and many taxonomic groups (nematodes, earthworms, phyllostreta striolata, arachnida, arthropoda, larvae and mature insects, etc.). They plays an important role in the mineralization process of humus and organic derbies making the soil fertile and well-structured soil.

#### **1.4. The cause of degradation of biodiversity and solutions to improve management efficiency**

The major causes of biodiversity decline are change or loss of habitat ( destroyed and divided habitat, etc.), the loss of species and genetic diversity. The loss of species and erosion of genetic resources and the degradation of natural ecosystems have been interested by scientists in the world and in Vietnam.

## Chapter 2

### RESEARCH SUBJECTS, CONTENTS AND METHODS

#### 2.1 Research subjects and contents

##### 2.1.1 *Research subjects*

- The flora and vegetation in forest ecosystems of Xuan Son National Park in Phu Tho Province.
- Earthworms and other mesofauna groups in some vegetation types.
- Causes of decline of plant biodiversity in Xuan Son National Park

##### 2.1.2 *Research contents*

###### 2.1.2.1. *Research on diversity of the flora*

- Studying on the diversity of plant species composition according to the different taxa systems.
- Analyzing the flora in the study area according to elements of plant geography.
- Assessing the diversity on the value of plant resources according to different use groups.
- Determining the value of conservation of the flora in Xuan Son National Park.
- Analyzing changes of plant species component on the elevation.

###### 2.1.2.2. *Research on diversity of vegetation*

- Classifying systematically vegetation types according to elevation zones (below 700m and above 700m).
- Describing the structure of the vegetation types in Xuan Son National Park through studying sample plots.
- Analyzing transformation of the vegetation types at altitudes.

###### 2.1.2.3. *Research on the relationship between soil animals and the vegetation*

- Determining composition and distribution of earthworms and other mesofauna groups in the study area.
- Analyzing changes the species composition and distribution of soil animals according to vegetation types.

###### 2.1.2.4. *Proposal for measures of conservation and development of the vegetations and rare and precious plant species in the study area*

- Studying the current state of the management, conservation of biodiversity in Xuan Son National Park.

- Identifying risk of decline of biodiversity in the study area.
- Proposing measures of biodiversity conservation in the study area

## **2.2. Research method**

### **2.2.1. The approach of the dissertation**

\* *The ecosystem approach*: For high mountain ecosystems that are susceptible and suffered many impacts, it is only to implement the conservation work of plant diversity in particular and biodiversity in general in a comprehensive way by using the ecosystem-based approach.

\* *The approach on interdisciplinary synthesized perspective*: During development process of natural, nature, function and values of any ecosystem, it depends on both natural factors and influenced by human activities. Hence, a certain ecosystem should be viewed from many different perspectives on the natural, social, economic aspects.

### **2.2.2. The inherited method**

It is selective inheritance and development of data, results of investigations, surveys, previous studies on climate, soil, landscape ecology, map databases, diversity of plant communities of the study area including reports of research works, action plans, reports on natural and socioeconomic conditions, research papers, projects, etc.

### **2.2.3. The field research methodology on plant diversity**

Processes of field survey were applied according Nguyen Nghia Thin's method and were introduced via "*A manual for Research on Biological Diversity*" (1997) and "*The Tropical Forest Ecosystem*."

- *Determination of study routes*: it was based on topographic maps, status maps of land use to determine survey routes passing through the different habitat types in the study area. transecting

The survey routes have established as follows:

- *Route I: Du Hamlet – Ten Hill– Dinh Hamlet (600m – 1200m).*
- *Route II: Du Hamlet– Lang Hamlet– Lung Mang Hamlet (350m–600m)*
- *Route III: Ben Than Hamlet – Can (600m - 900m).*
- *Route IV: Coi Hamlet – Can Hamlet (300m – 1300m).*
- *Route V: Du Hamlet– Lap Hamlet – Ngoc Waterfall– To Spring – Ga Spring (400m – 700m)*
- *Route VI: Office of XSNP – Ha Bang Hamlet – Tan Ong Hamlet – 9- Layer Waterfall (270m – 600m).*

- *Selection of study sites*: it uses the compass, GPS and topographic maps, satellite images to determine the position of the representative field points in order to define boundaries of plant communities as well as to analyze bioclimatic and soil characteristics of the study area.

- *Creation of sample plots*: they have areas with the dimensions of  $40 \times 50$  m ( $2000\text{m}^2/\text{plot}$ ) on elevation zones. The sample plots selected are representative of vegetation types that are characteristic of the study area.

- *It is measurement of diameter, height* of timber trees in sample plots and estimation coverage. Indicators such as number of species per ha, species composition, numbers of floors of timber trees, the dominant species, canopy cover etc. are used to analyze diversity and to compare the vegetation types.

- *Methods of sample collection and preliminary treatment samples at the study field*: samples are collected for all parts of nutrition, reproduction and tykes fixed to take note with preliminary information at the study field (after writing in the book of sample collection). The small samples are put in plastic bags clamped edges, while other samples are wrapped in newspaper sheets and arranged in piles and put in larger plastic bags containing alcohol for preservation.

- *Taking photos*: it is to take images of species (writing code number of samples and the order of pictures in the manual for convenient in further lookup) and creatures habitats in the process of sample collection and fieldwork.

#### **2.2.4. The analysis methods of plant diversity in the laboratory**

##### *2.2.4.1. Analysis and treatment of plant samples and assessment vegetation*

*\*Determination of scientific names and development of lists Kormobionta vascular plants distributed in elevation zones in the study area*

- Preliminary Classification: samples are processed (compressed, soaked with chemicals and drying), preliminarily classified upon morphological characteristics, particularly reproductive organs and species features according to the existing documents and consultation of botany experts.



- *Comparison of samples and determination of species names:*

The samples were compared with the standard samples available at the Museum of the Institute of Ecology and Biology Resource (IEBR); analysis of samples, research of the key to classification, study of existing literature, consultation from experts, etc. to determine the scientific names.

- *Check of scientific names* : To ensure the systematic feature, to avoid confusion and errors, they were adjusted under Brummitt system in "Vascular Plants. Families and Genera", names of species were adjusted under the "Flora of Vietnam" and "Checklist of Plant Species of Vietnam."

- *Establishment of the checklist of the flora in the study area:*

The information obtained in the analysis of samples was compiled in plant checklist in the study area. This information was compiled from the literature on botany at IEBR and databases opened on plant resources of Museums and websites in the World.

\* *Vegetation analysis and assessment*

- *Preliminary description of vegetation types:* Names and description of vegetation types in the study area were applied according to the 1973 UNESCO framework for plant taxonomy applied in Vietnam by Phan Ke Loc.

- *Assessment of vegetation transformation with altitude:* in terms of aspects, it is the change in quantity of species and species composition; the change in vegetation status; distribution of species characterized by elevation zones; the correlation among elevation zones. It used Sorensen's formula (1911) to record under the Nguyen Nghia Thin for comparing the relationship among elevation zones.

$S = \frac{2c}{a+b}$  , where: S is Sorensen index (values from 0 to 1); a is the number of species of the community A ; b is the number of species of the community B, and c are the number of species together of two communities (A and B). The closer to 1 the S value is, the more closely the relationship of two communities is, whereas, the closer to 0 the S value is, the further the relationship of two communities is.

2.2.4.2. *Methods of data treatment and analysis on the flora*

- Data collected in the fieldwork were processed by Excel software.

- Groups of high tree species were applied by the formula:  $NTB = N/m$

Where, NTB is the average number of individuals per species surveyed; N is the number of individuals of each species; m is the total number of individual surveyed.

- Primary documents were used to evaluate the endangered extent of plant species, namely:

- + The Appendix of The Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora in the International Union for Conservation of Nature (IUCN).

- + The Vietnam Red Book, 2007 (Part II-Plant), the IUCN Red List Criteria (2012) and the provisions of the law of Vietnam.

- + The Decree No. 32/2006/ND-CP dated March 30th, 2006 of the Government and the Decision No. 74/2008/QĐ-BNN dated June 20<sup>th</sup>, 2008 of the Ministry of Agriculture and Rural Development issued the checklist of species of wild animals and plants.

### **2.2.5. Methods of Research in Soil Zoology**

*\* The method of collection of Earthworm samples and other mesofauna groups.*

Quantitative samples for earthworms and other Mesofauna groups were collected in some sample plots in 5 representative vegetation types (under the method of Ghilarov, 1975). A samples has an area with dimensions of 50x50 cm. Specimens were collected in each layer under soil depths (a 10 cm layer) until a depth of 40cm.

*\* Analysis of specimens and determination of specimen types*

Analysis and identification of soil animal group was based on specialized documents. The quantitative data was attributed on the area of 1m<sup>2</sup>. Biomass was calculated under weight of shaping earthworms, including food in the gut.

### **2.2.6. Method of interview and sociological survey**

To get more database serving orientation of plant biodiversity conservation and sustainable tourism development, we used methods of interviews and Participatory Rural Appraisal (PRA).

- It is to interview residents, local government leaders, the management staffs of national parks, protected zones; the individual function forces such as rangers, scientific officials at locality, etc to collect information and necessary data.

- It is based on local resident community to conduct additional surveys of plant diversity, environmental conditions, infrastructures - technology, residents' lives and incomes in the study area. The method was performed including steps of consultation and authentication of information

While studying at the National Park, we have conducted directly interviews with and collection of data from some local officials and people (the president of the Commune, forest management officials and some households of the hamlets in the core area such as Du, Lap, Lang. People interviewed were in the working age from 27 to 41 years old for men and from 26 to 38 years old for women).

## **Chapter 3**

### **NATURAL AND SOCIO-ECONOMIC CONDITIONS IN THE STUDY AREA**

#### **3.1. Natural conditions**

Xuan Son National Park (XSNP) is located to the west of Thanh Son District, on the triangle bounded among 3 provinces of Phu Tho, Hoa Binh and Son La. The terrain of Xuan Son National Park has large steep slopes, soil mountains interspersed limestone mountains gradually raising from east to west and from south to north.

The climate in the area of Xuan Son National Park is the monsoon tropics; every year there are two seasons: the rainy and dry seasons. The river and stream systems of Xuan Son National Park are rather thick. Total length of rivers is 120 km and the average width of rivers is 150m.

#### **3.2. Socio-economic features**

The average income per capita in the core zone and buffer zone is about VND 7,900,000 per person per year. Main income source of the people in the area are mainly from agricultural production, livestock husbandry, etc. Xuan Son National Park and the buffer zone, according to the statistical results of 2012, include 29 villages/hamlets having 12,559 people with 2908 households; in which, there are 2,984 people with 794 households in the core zone of the National Park.

## **Chapter 4**

### **RESEARCH RESULTS AND DISCUSSION**

#### **4.1. Analysis of the flora of Xuan Son National Park**

##### ***4.1.1. The diversity of plant taxa***

In the vegetations in Xuan Son National Park, it was identified 1232 well-developed vascular plant species belonging to 685 genera, 182 families of 6 classes, including Magnoliophyta that has the largest number of species (1,141 species accounting for 92.61%). There were not many species of the rest classes (91/1232 species). The distribution of well-developed vascular plant taxa in Xuan Son National Park is shown in Table 4.1.

**Table 4.1. The distribution of the taxa in the flora in XSNP**

STT	Ngành	Tên khoa học	Số họ		Số chi		Số loài	
			Số họ	%	Số chi	%	Số loài	%
1	Ngành Quyết lá thông	Psilotophyta	1	0,55	1	0,15	1	0,08
2	Ngành Thông đất	Lycopodiophyta	2	1,10	3	0,45	6	0,50
3	Ngành Cỏ tháp bút	Equisetophyta	1	0,55	1	0,15	1	0,08
4	Ngành Dương xỉ	Polypodiophyta	22	12,09	38	5,55	74	6,08
5	Ngành Thông	Pinophyta	5	2,75	6	0,87	9	0,41
6	Ngành Mộc lan	Magnoliophyta	151	82,96	636	92,83	1.141	92,61
<b>Tổng</b>			<b>182</b>	<b>100</b>	<b>685</b>	<b>100</b>	<b>1.232</b>	<b>100</b>

The study has added 2 new families, 5 novel genera and 16 novel species for the flora in Xuan Son National Park (Table 4.2).

**Table 4.2. Novel families, genera and species added for the flora in XSNP**

Ord	Scientific names	Name in Vietnamese	Notes
	<b>CYCADACEAE</b>	<b>HỌ TUẾ</b>	<b>HMXS</b>
1.	<i>Cycas chevalieri</i> Leandri	Nghèn	CMXS
2.	<i>Cycas pectinata</i> Buch.-Ham.	Tuế lược	LMXS
	<b>CUPRESSACEAE</b>	<b>HỌ HOÀNG ĐÀN</b>	<b>HMXS</b>
3.	<i>Fokienia hodginsii</i> (Dunn) A. Henry & H. H. Thomas	Phơ Mu	CMXS
	<b>GNETACEAE</b>	<b>HỌ DÂY GẮM</b>	
4.	<i>Gnetum latifolium</i> Blume	Gắm lá rộng	LMXS
	<b>BIGNONIACEAE</b>	<b>HỌ ĐINH</b>	
5.	<i>Markhamia cauda-felina</i> (Hance) Craib	Kè đuôi dồng	LMXS
6.	<i>Fernandoa brilletii</i> (P.Dop) Steenis	Đinh thối	CMXS
	<b>BURSERACEAE</b>	<b>HỌ TRÁM</b>	
7.	<i>Canarium tonkinensis</i> L.	Trám chim	LMXS
	<b>CAESALPINIACEAE</b>	<b>HỌ VẠNG</b>	
8.	<i>Senna siamea</i> Lam.	Muồng đen	LMXS
	<b>DIPTEROCARPACEAE</b>	<b>HỌ DẦU</b>	
9.	<i>Hopea chinensis</i> (Merr.) Hand.-Mazz.	Sao hòn gai	CMXS
10.	<i>Hopea mollissima</i> C.Y. Wu	Tầu mặt quỷ	LMXS
11.	<i>Hopea odorata</i> Roxb.	Sao đen	LMXS
	<b>LAURACEAE</b>	<b>HỌ LONG NÃO</b>	

12.	<i>Cinnamomum bejolghota</i> (Buch.-Ham.) Sweet	Quế lộn	LMXS
13.	<i>Cinnamomum iners</i> Reinw. ex Blume*	Re hương	LMXS
	<b>MAGNOLIACEAE</b>	<b>HỌ MỘC LAN</b>	
14.	<i>Manglietia confiera</i> Dandy	Mỡ	LMXS
15.	<i>Michelia mediocris</i> Dandy	Giổi xanh	LMXS
	<b>SAPINDACEAE</b>	<b>HỌ BỒ HÒN</b>	
16.	<i>Paviesia annamensis</i> Pierre	Trùng mật	CMXS

Notes:

- HMXS: Novel families added for the flora of XSNP
- CMXS: Novel genera added for the flora of XSNP
- LMXS: Novel species added for the flora of XSNP

#### 4.1.1.1. Diversity of plant families

In total of 1,232 plant species, there were 10 plant families having the largest number of species (Table 4.3).

**Table 4.3. Ten plant families having the largest number of species**

Ord	Names of families	No. species	Rate% compared with number of plants of 10 families	Rate% compared with number of species of the flora
1	Euphorbiaceae	60	17.34	4.77
2	Rubiaceae	50	14.45	3.97
3	Fabaceae	38	10.98	3.02
4	Moraceae	35	10.12	2.78
5	Asteraceae	35	10.12	2.78
6	Orchidaceae	32	9.25	2.54
7	Poaceae	27	7.80	2.14
8	Myrsinaceae	24	6.94	1.91
9	Lauraceae	24	6.94	1.91
10	Cyperaceae	21	6.06	1.67
	<b>Total</b>	<b>346</b>	<b>100.00</b>	<b>28.06</b>

The largest total number of species of 10 plant families In the Xuan Son National Park are 346 species accounting for 28.06% compared with total species of the National Park. That means that the flora in the study area evaluated is diversity on plant families.

#### 4.1.1.2. Diversity of plant genera

Considering the diversity of genera, we also selected 10 genera that have the largest number of species shown in Table 4.4.

**Table 4.4. Genera having the largest number of species of XSNP**

Ord	Names of genera	Names of families	No. species	Rate% compared with number of species of the 10 largest genera
1	<i>Ficus</i>	Moraceae	24	24.25
2	<i>Ardisia</i>	Myrsinaceae	13	13.13
3	<i>Polygonum</i>	Polygonaceae	9	9.09
4	<i>Piper</i>	Piperaceae	9	9.09
5	<i>Alpinia</i>	Zingiberaceae	8	8.08
6	<i>Limnophila</i>	Scrophulariaceae	8	8.08
7	<i>Diospyros</i>	Ebenaceae	7	7.07
8	<i>Elaeocarpus</i>	Elaeocarpaceae	7	7.07
9	<i>Hedyotis</i>	Rubiaceae	7	7.07
10	<i>Dendrobium</i>	Orchidaceae	7	7.07

The largest number of species in 10 genera was 99 species and account for 8.02% of the total number of species in XSNP

#### 4.1.1.3. Plant geographic factor

Because of the topography and climate available distinct characteristics, Xuan Son National Park has become the convergence of migrating floristic flows along with native flora to create the face of plant abundance and diversity for this area.

#### 4.1.2. Value of natural resources of useful plants

In total of 1,232 species of the NP, 948 species were identified benefits and 284 remaining species were not defined their uses. The result has 9 main effect groups (Table 4.5).

**Table 4.5. Main plant effect groups in XSNP**

Ord	Effects	Signs	No. species
1	Medicinal Plants	T	678
2	Timber trees	G	208
3	Ornamental plants	Ca	93
4	Edible plants (fruits, vegetables)	A,Q,R	78
5	Aromatic plants	TD	48
6	Plants as food for livestock	Tags	24
7	Plants used for knitting	Đa	19
8	Poisonous plants	Đ	10
9	Plants for fatty oil	D	9

#### ***4.1.3. The rare and endangered plant species***

The results have identified that Xuan Son National Park has 47 rare and endangered plant species available their name in Vietnam Red Book. There are 14 endangered species (EN), 32 vulnerable species (VU) and one species with little concern (LC). The number of species in danger of extinction named in the World Red List was 17 species that include 4 endangered species (EN), 11 vulnerable species (VU) and one species with little concern (LC), etc.

### **4.2. The differentiation of vegetation types in XSNP on the elevation**

#### ***4.2.1. Tropical zone (at elevations below 700 m high).***

##### ***4.2.1.1. Closed evergreen tropical rainforest***

This forest type is distributed relatively large arrays at elevations below 700 m in the southern area of XSNP. Although, it is more or less affected, the structure and biodiversity of the forest is basically retained. The structure of the 5-layer forest is quite apparent.

*a. Closed evergreen tropical rainforest on less affected sloping land:*

#### **\* Distribution of the closed evergreen tropical rainforest on tropical sloping lowland**

The distribution of this closed forest is located in the tropical belt of 700m. In average, in a sample plot, there are at least 32 species involved in the group structures creating floor layers with an average height of 12 - 15m. In the forest parts exploited, the forest is poor and restored forest, changes single preferential structure and forms new dominant group (from 5 to 7 species).

#### **\* Secondary forest stable and mature on limestone mountains**

Secondary forests are mature, stable without abused exploitation (often called the jungle) on the remaining principal limestone mountains in rugged headwaters. Overall, the majority of plant components are like state of the primary forest.

#### **\* The mature secondary forests selectively exploited on limestone mountains.**

Trees are distributed concentrated mainly in the diameter range from 20 to 30 cm, unevenly distributed, open forest canopy, usually availability of 2 distinct floors . Storey of trees with high canopy is not closed and frequently interrupted immediately. Upstairs are mainly *Burretiodendron hsienmu*, *Selaginella tamariscina*, *Fagraea fragrans*, accounting for 25- 30% of grouping standing trees, etc.

The understorey is relatively clear formation, they are often *Acanthus ilicifolius*, etc. and accounting for 30 to 40% grouping standing trees.

*b. Closed evergreen tropical rainforest on significant affected lowland:*

**\* Secondary forest of restoration after selected exploitation and after milpa farming on lowland**

Secondary forest is sparsely distributed throughout the National Park. It includes secondary forests of restoration after milpa farming on tropical and subtropical low mountains. Though two forest types are formed from different bioclimatic features, they are all products after milpa farming, there are not many differences in their forest structures.

Species composition and forest structure are simple. The forest is only to have one storey of timber trees with even canopy but quite sparse forest. Thus, fresh vegetation understorey is relatively well developed by tall grass species belonging to the family Poaceae and the family Cyperaceae.

**\* Distribution of mixed evergreen rainforest after selected exploitation on lowland**

This forest is the result of human impacts on natural forest causing destroyed succession and then the revitalization.

Each plot in average has 25 species (2000m<sup>2</sup> per plot) and 40 species (2500m<sup>2</sup> per plot), 20 genera of 15 families of timber trees. The average number of species of timber trees per plot is 110 trees (2000m<sup>2</sup> per plot) to 163 trees (2500m<sup>2</sup>). If there are up to 626 individual timber trees in average per hectare. The canopy coverage of vegetation reaches 62% and canopy index reaching a low value is 0.62.

**\* Distribution of the mixed evergreen rainforest after milpa farming on lowland**

The storey structure is clearly distinguished in these communities. There are usually 2 to 3 storeys of main timber trees. In this structure, the appearance of dominant species are namely: *Castanopsis annamensis*, *Canarium pimela*, *Pterospermum heterophyllum*, *Schizostachyum dullooa*. Timber trees in the 3-storey structure have reached the high level of 5 - 6m, etc.



c. *Secondary forest on limestone stony soil intensively exploited:*

**\* Secondary forests abusively exploited on limestone mountains**

This is the state that forests have been selected exploited many times and sparse plant density. The key composition group of species of uperstorey reduces and loses gradually such as *Parashorea chinensis*, *Chukrasia tabularis*, etc. However, *Fagraea fragrans* in some places are quite large proportion, even though up to 15 % in some sites. Some species of light-demanding plants began to appear, etc. *Parashorea*

**\* Depleted secondary forest on limestone mountains**

This shows that forest state is the most impoverished in the study area. In plots counted and measured, there are usually only 7-10 species and 8 species in average in a plot. It appeared some light-demanding plant species such as *Sterculia lanceolata*, *Cinamomum sp* *Pahudia cochinchinensis* Pierre, etc.

**\* The bamboo secondary forest**

Bamboo forest is located in the zone of closed evergreen tropical rainforest in the eastern area of the National Park. It is also the secondary subtype formed after fallow milpa or timber tree forests exploited exhaustly.

*4.2.1.2. Shrubby vegetation, grassland vegetation*

This vegetation type is quite popular with 1604.4 hectares, accounting for 10.7% of total natural area of the Park and sparsely distributed throughout the areas in both elevation zones. The majority of this vegetation is high grasslands such as *Imperata cylindrica*, *Erianthus arundinaceus*, *Saccharum spontaneum*, *Themeda gigantea*, *Thysanolaema maxima*, etc.

*a. The tropical evergreen shrubby vegetation at low elevation zone*

**\* Broadleaved evergreen shrubby vegetation on the zonal land**

This vegetation is distributed often in forest fringe areas on land strongly affected. Plant community consist mostly of light - demanding and fast growing species, shrubs or small timber shrubs pioneered short-life. The dominant species are *Aporosa dioica*, *Euodia lepta*, *Trema orientalis*, *Rhus javanica*, *Macaranga denticulate*, etc

**\* Broadleaved evergreen shrubby vegetation on limestone land**

The vegetation on calcareous soils here is non-zonal feature, most stratified structure with a single-storey. The typical plant communities of sample plots in the areas of limestone mountains are

as follows *Streblus ilicifolius*, *Taxotrophis macrophylla*; *Sterculia sp.*, *Streblus ilicifolius*, *Murraya paniculata*, etc. The vegetation in limestone mountains has low canopy coverage, reaches only 30-40%. Most of trees in this condition are light demanding trees and simple secondary stratified structure with an average height of timber trees from 7 - 9 meters and less abundant species composition.

*b. The tropical secondary grassland vegetation at low elevation zone*

**\* The tropical high grassland vegetation at low elevation zone**

This vegetation type is quite popular to most herbaceous species over 1 meter in height, including species of rice-leaf weeds such as *Thysanolaena maxima*, *Saccharum arundinaceum*, *Miscanthus nepalensis*, *Miscanthus japonica*, *Miscanthus japonica*, *Saccharum spontaneum*, *Sasa spp.*, *Neyraudia reynaudiana*, etc.

together some non- rice-leaf weeds such as *Chromolaena odorata*, etc. and Polypodiophyta.

**\* The tropical low grassland vegetation at low elevation zone**

Representatives for this grassland types are herbaceous species under 1m belonging to the rice leaf types such as *Imperata cylindrical*, *Panicum*, *Paspalum*, *Ischaemum*, *Setaria*, *Cymbopogon spp.*, *Eleusine indica*, etc. and non- rice-leaf weeds such as *Hedyotis capitellata*, *Canithum*, *Alpinia*, *Amaranthus spinosus*, etc., and Polypodiophyta.

**4.2.2. Subtropical zones (above 700m of elevation)**

*4.2.2.1. Closed subtropical evergreen rainforest with a low mountain less affected*

The distribution is concentrated in Ten mountain area and the land part of the West of the NP at a height from 700m

Overall, this forest type has also affected with various levels. However, more or less the structure of the primary forest is retained with sizable canopy. Plant species composition are mainly broad-leaf trees belonging to families of Fagaceae, Magnoliaceae, Lauraceae, Euphorbiaceae, Myrtaceae, Aceraceae, Theraceae, Sapotaceae, etc. Particularly, tree species of family Dipterocarpaceae do not found in this forest type.

*4.2.2.2. Closed subtropical evergreen rainforest affected*

This forest type is mainly composed of vegetation types formed after exploitation and after milpa farming. Canopy coverage reaches 78% in average.

**\* Closed subtropical evergreen rainforest formed after exploitation**

Vegetation structure includes 4 - storeys and may be 5 - storeys with state of mixed secondary forest affected lightly, excludes woody vines, etc.

**\* Closed subtropical evergreen rainforest formed after milpa farming**

Size of the forest vegetation after milpa farming in high elevation zone has much smaller than that of the vegetation after exploitation. The forests often have 3 storeys.

**4.2.2.3. Closed subtropical evergreen forest on limestone bony land**

There is a quite wide distribution in Can mountain area, with elevations above 700m. The ecological dominance storey (A2): it is approximately 18 to 20 meters high and consists of species of *Pometia pinnata*, *Cinnamomum spp.*, *Garcinia fagraeoides*, *Garcinia sp.* The forest understorey (A3): it is about 7 -15m high. Apart from the small trees forest upperstorey, in this floor, there are often species of *Alphonsea squamosa*, *Saurauia tristyla*, *Camellia spp.*, *Eurya spp.etc.* Bushes storey (B): it is under 5m high and mostly bush species of *Psychotria montana*, *Lasianthus dinhensis*, *Randia tomentosa*, *Clausena duniana*, *Micromelum falcatum*, etc. Fresh vegetation storey (C): The density of the species in this storey changed quite obviously by the ability to provide water to trees.

**4.2.2.4. Shrubby vegetation formed after exploitation and after milpa farming**

Shrubby vegetation is derived from after exploitation and after milpa farming. However, it is not protected from collecting continuously firewoods and grazing by the local residents. It is dried, infertile, rocky soil. Plant coverage generally is very low (40%). Simple spatial structure is with shrubs. Scattered trees are appeared, do not form a separate storey (average 293 trees per ha), and mostly small-sized species.

**4.3. Analysis of the diversity of vegetation in Xuan Son National Park**

**4.3.1. The difference of vegetation in XSNP by altitudes**

According to altitude, natural vegetation has highly fragmented in terms of both vegetation types and plant species composition.

At an altitude below 700 meters, there are the main vegetation types as follows:

*The closed tropical evergreen rainforest:* The structure of plant species creates relatively abundant forest, the popular species are in families of Dipterocarpaceae, Sapindaceae, Mimosaceae,

Caesalpiniaceae, etc.

*The closed tropical evergreen forest on limestone bony soil:* It distributes mainly at both ends of Can Mountain range. The key representatives of species are as follows *Excentrodendron tonkinense*, *Garcinia fagraeoides*, *Streblus spp.*, *Chukrasia tabularis*, *Pometia pinnata*, etc.

*The secondary forest of restoration after milpa farming:* In this vegetation type, there are relatively abundant species, except timber trees often less abundant and light demanding species growing fast are *Liquidambar formosana*, *Symplocos laurina*, *Albizia sp.*, *Peltophorum dasyrrachis*, *Engelhardtia sp.*, *Rhus javanica*, etc.

*Vegetations of grassland, shrubs, and scattered timber trees:* they distribute scatterly throughout the region at two elevation zones, but are still more concentration in the tropical forest belt of the eastern land portion of the Park. Plants forming forests are mainly species of *Schizostachyum pseudolima* and some scattered trees, etc.

At an altitude above 700 meters, there are mainly vegetation types, namely:

*The closed evergreen subtropical rainforests on medium-high mountains:* Plants are mostly broadleaved trees belonging to families of Fagaceae, Lauraceae, Magnoliaceae, Aceraceae, Theraceae, etc.

*The closed evergreen subtropical rainforests on skeletal calcareous soils:*

Species of the oil family are no longer seen and a number of coniferous- leaf tree species are appeared such as *Amentotaxus argotaenia*, *Podocarpus neriifolius* and the increase of sub-tropical plants such as Fagaceae, *Camellia sinensis*

*The secondary forest of restoration after exploitation: species* are often *Castanopsis armata*, *C. tessellata*, *Lithocarpus elegans*, *Aglaia gigantea*, *Vatica odorata*, *Machilus odoratissima*, *Pterospermum heterophyllum*, *Dillenia heterosepala*, *Canarium album*, etc.

*The bamboo secondary forest:* Plants forming forests are mainly species of *Schizostachyum pseudolima* and some scattered timber trees, etc.

To assess the relationship among plant communities on species composition between the zones, we calculated Sorensen index. The results are shown at Table 4.8.

**Table 4.8. Sorensen Index between elevation zones in XSNP**

	<b>The elevation zone below 700m</b>	<b>The elevation zone above 700m</b>
Sorensen Index	0.49	0.75

Results at the 4.8 show that species composition of plant communities distributed at elevations below 700m in XSNP is more different more than that at elevations above 700 m.

The reason of this phenomenon, beyond the fragmentation of the species composition between plant communities, is decided by natural factors. The plant communities distributed at elevations below 700m are affected by human more diversity both in impact form and extent of affected level, fragmentation of plant communities under species composition is also more complex and more diverse.

#### **4.3.2. The fragmentation of vegetation of XSNP through the method and extent of human impact**

Vegetation of recovered forest formed after exploitation has the four- storey structure. The ecological dominant storey is often to have species of *Hopea hainanensis*, *Syzygium* spp., *Aidia* sp., *Knema conferta*, *Polyalthia* sp., *Madhuca pasquieri*, *Aidia pycnantha*, *Syzygium* sp., *Eberhardtia tonkinensis*.etc.

Meanwhile, the forest vegetation formed after milpa farming has only a maximum of three storeys, with the main tree species: *Polyalthia* sp., *Madhuca pasquieri*, *Aidia pycnantha*, *Syzygium* sp., *Garcinia oblongifolia*, *Lithocarpus* sp., *Eberhardtia tonkinensis*, *Prunus arborea*, *Diospyros* sp., *Nephelium lappaceum*, etc. The timber tree species often have lower average size than that of forest vegetation formed after exploitation.

#### **4.3.3. The fragmentation of vegetation under the geographical factor**

According to terrain location, vegetation on the top of limestone mountains and limestone foothills, especially in the rocky valley is a significant difference. This difference is mainly due to segmentation of soil and climate regimes:

- The top of rock mountain: Plants are colonies of small timber trees in high mountains, with spindly body of trees, and branched at low level and horizontal branches as the species belong to the genera of *Pentaphylax*, *Ilex camanthus*, *Claussena*, *Sideroxylon*, etc. These species have height with significant fluctuations, complicated forest structure, difficult to division storey level. Particularly, a few species grows well ahead such as *Brruetiodendron hsienmu*, *Garcinia fragraeoides*, *Quercus bambusaefolia*, etc.

- The mountain foot is usually light-demanding plants, drought resistant plants like *Abacopteris*, *Trifolium*, *Liriope spicata*, *Pholidola*, *Ardisia*, *Balastus cochinchinensis*, *Seglaginella*, *Pandanus tonkinensis*), etc. They often grow in dense clumps.

- *Slopes of rocky mountains*: composition of plant distributed in this area is very complex, it depends on composition structures and rocky arrangements of ground surface and climate conditions of the region. If there are steep slopes together with large stone blocks, plants here are mainly small trees, vines, trees with thorns and drought tolerance as *Bauhinia sp.*, *Caesalpinia minax*, etc. There are places where slopes are gentle, plants distributed are mainly small low trees with small body and premature branching, namely *Phlogacanthus curviflorus*, *Rhaphis micrantha*, etc.

- Valley located in rocky mountains: Plant composition is more abundant and are mostly wet-loving species such as *Annamocaya chiensis*, *Bischoffia javanica*, *Caryodaphnopsis tonkinensis*, *Saraca dives*, *Hydrocarpus annamensis*, *Amesiodendron chinense*, etc.

#### 4.4. Species composition and distribution of soil animals in the vegetation types (VTs)

##### 4.4.1. Earthworms

##### 4.4.1.1. Species composition and distribution

It was to recognize the presence of 25 species belonging to 5 seeds, 4 families of earthworms in the vegetation types of XSNP. Checklist of species and distribution of earthworms are shown at Table 4.9.

**Table 4.9. Species composition and distribution of earthworms in vegetation types in XSNP**

Ord	Species composition	Nhóm HT-ST	Vegetation types				
			RKTX	RTS	RTN	RT	TCB
<b>Family</b>	<b>Glossoscolecidae (Michelsen)</b>						
1	<i>Pontoscolex corethrurus</i> (Muller)	1		x			x
<b>Family</b>	<b>Megascolecidae (part Rosa)</b>						
2	<i>Pheretima adexilis</i> Thai	1		x	x		
3	<i>Ph. alluxa</i> Thai	3			x		
4	<i>Ph. arrobusta</i> Thai	2	x	Đt			
5	<i>Ph. arrobustoides</i> Thai	2		x			
6	<i>Ph. californica</i> Kinberg	2		x			
7	<i>Ph. corticus</i> (Kinberg)	2	x				x
8	<i>Ph. dawydovi</i> Mich.	1		Đt			

9	<i>Ph. diagna</i> Chen	1	x	x		x	
10	<i>Ph. dongkheana</i> Le	2	x				
11	<i>Ph. exilis</i> Gates	1			x	x	x
12	<i>Ph. exgua austrina</i> Gates	1			x		
13	<i>Ph. falcipapllata</i> Thai	2	x	x	x		
14	<i>Ph. hawayana</i> (Rosa)	3		x			
15	<i>Ph. infantiloides</i> Thai	1	x		x		x
16	<i>Ph. leucocirca</i> Chen	3	x		x		
17	<i>Ph. morrisi</i> Beddard	2				x	
18	<i>Ph. pingi</i> Stepheson	2	x		x		
19	<i>Ph. robusta</i> (Perrier)	2	x	x	x		
20	<i>Ph. tuberculata</i> Gates	3	x				
21	<i>Ph. wui</i> Chen	1				x	
22	<i>Pheretima</i> sp. <sub>1</sub>	1	x	x			
<b>Family</b>	<b>Ocnodrilidae Beddard</b>						
23	<i>Gordiordrilus elegans</i> Beddard	1		x			
24	<i>Ocnodrilus occidentalis</i> Eisen	1		x			
<b>Family</b>	<b>Octochaetidae Gates</b>						
25	<i>Dichogaster modigliani</i> (Rosa)	1		x		x	
Total species according to vegetation types			11	14	9	5	4
The average density (earthworm/m <sup>2</sup> )			36.0	37.6	25.6	34.4	11.2
The average biomass (gr./m <sup>2</sup> )			10.6	11.6	7.0	4.2	1.8

*Note:*

Vegetation types: KTX- closed evergreen forest; RTS-secondary forest; RTN-bamboo forest; RT-planted forest; TCB-scrub vegetation; Group HT-ST: Morphological-ecological group: 1. official land group; 2. Group of vegetation-land; 3-dead vegetation group. Dt-availability in quality samples; X-availability in quantitative samples.

The distribution of earthworms under vegetation types: A number of earthworm species in vegetation types of XSNP are different, and depend on the specific conditions of vegetation type. They are classified clearly into 2 groups: the group including the secondary forest, the closed evergreen forest, the bamboo forest has much more number of species than (14 species >11 species >9 species, respectively) compared with that of 2 remaining vegetation types consisting planted forest (5 species) and scrub vegetation (4 species).

#### 4.4.1.2. The morphological - ecological groups of earthworms in the vegetation styles

The results of the study have showed that Earthworms in the National Park have full 3-ecological - morphological groups (HT-ST). Of which, the most number of species is the officially land group (12 species accounting for 48% of total species ), number of

species in dead vegetation - soil group and the dead vegetation group decreased (9 species accounting for 36% and 4 species accounting for 16%, respectively).

#### **4.4.2. Other mesofauna groups:**

In the study area, there are 26 other mesofauna groups belonging to different classification hierarchy (at levels of set, family and varieties). Specifically, there are 18 groups, 13 groups, 12 groups, 9 groups and 6 groups seen in the evergreen forests, the secondary forest, the planted forest, the bamboo forest and the scrub vegetations, respectively.

So, quantity of species, distribution and abundance of earthworms, other mesofauna groups in vegetation types tend on increase with duration of forest restoration (from the scrub vegetation, the planted forest to the bamboo forest, the secondary forest, the evergreen forests. This shows that, between the state of vegetation and land animals, there is organic relation with one another.

### **4.5. Causes of impairment and proposals for solutions to conserve plant diversity in Xuan Son National Park**

#### **4.5.1. The causes of impairment of diversity of the flora**

It consists of (1) exploitation and use of illegal wood to build houses; (2). NTFPs exploited illegally; (3) the shortage of arable land and lack of employment; (4) the impact of the increasing population; (5) the awareness of the people; (6) the negative effects of tourism development; (7) poor facilities; (8) not high enough to legal effectiveness.

#### **4.5.2. Proposals for solutions to conserve plant diversity in XSNP**

##### *4.5.2.1. Development of mechanisms to share benefits with the communities in the management of forest protection and biodiversity conservation*

- It is to share interests in the use of natural resources rationally and sustainably through the agreement communities.

- It is to share interests in the development of ecotourism and payments for forest environmental services.

- It is to share interests in the application of scientific advances in manufacturing

##### *4.5.2.2. Raising of awareness of biodiversity protection for communities living in and around the National Park*

It is diversify the forms of propaganda; strengthen management and protection of forests; strengthen scientific studies and conservation of biological diversity.



## CONCLUSIONS AND RECOMMENDATIONS

### 1. CONCLUSIONS

- (1). Xuan Son National Park has the diverse flora. Research results have added 16 species, 5 genera, 2 families that increase the number of flora species namely 1,232 species, 685 genera, 182 families of 6 plant classes. These classes include Magnoliophyta, Pinophyta, Polypodiophyta, Equisetophyta, Lycopodiophyta and Psilotophyta.
- (2). Plant geographic factor: Because of the topography and climate available distinct characteristics, Xuan Son National Park has become the convergence of migrating floristic flows. It is along with native flora to create the face of plant abundance and diversity for this area: Himalayan - Yunnan - Guizhou floristic flow; Malaysia - Indonesia floristic flow; India - Myanmar floristic flow; the native plants of North Vietnam - South China.
- (3). In total of 1,232 species of the NP, 948 species were identified their uses with 9 main effect groups such as medicinal plants, Timber trees, Edible plants (fruits, vegetables), ornamental plants, aromatic plants, plants used for knitting, plants as food for livestock, plants for fatty oil.
- (4). It have identified that the flora of Xuan Son National Park has 48 rare and endangered plant species belonging to three classes of Pteridophyta, Pinophyta and magnoliophyta.
- (5). According to altitudes, components of the plant species of natural vegetation has differentiated extremely high:
  - At an altitude below 700 m, there are typical plant families for the tropical flora area on low mountains of northern Vietnam. Plant families are derived in place and considered the indigenous factor of North Vietnam - China South.
  - From the altitude above 700m, there are plant families derived from subtropical flora. Of which, migration factor in the flora composition is not large. Representatives are often families of Rosaceae, Lauraceae, Apocynaceae, Theaceae, Magnoniaceae, Juglandaceae, Fagaceae, Aceraceae, etc.
- (6). Xuan Son National Park has high differentiation on vegetation types under altitudes
  - At an altitude below 700 meters, there are main vegetation types, namely: The closed evergreen tropical rainforest; the closed evergreen tropical rainforest on skeletal calcareous soils; the secondary forests of restoration after milpa farming; vegetations of grassland, shrubs and scattered timber trees.
  - At an altitude above 700 meters, there are vegetation types,

namely: the closed evergreen subtropical rainforests on medium-high mountains; the closed evergreen subtropical rainforests on skeletal calcareous soils; the secondary forest of restoration after milpa farming and the bamboo secondary forest.

- (7). In addition to elevation factor, the vegetation and the flora of Xuan Son National Park have also differentiated by other factors:
  - With the different intensity and impact methods, the secondary succession vegetations after milpa farming and after exploitation are the significant difference in terms of species composition of plants, as well as vegetation structures.
  - Differentiation of vegetation due to geographical factors has clearly reflected in the vegetations. However, the forest vegetations on limestone mountains have the most obvious difference. This difference is mainly due to differentiation on soil and sub-climate regimes.
- (8). Quantity of species, distribution and abundance of earthworms, and other mesofauna groups in vegetation types tend to increase under duration of forest restoration (from vegetations of scrub, planted forests, bamboo forests, secondary forests and evergreen forests). This shows that, between the state of vegetations and land animals have organic relations with each other.
- (9). It determines 8 groups of causes leading to impairment of diversity of the flora in the study area.
- (10). Based on the study results, two solutions proposed for the management and protection of forests and biodiversity conservation, namely.

## **2. RECOMMENDATIONS**

- It should invest for the protection work and conservation program of plant resources for the National Park by adding force, consolidating management system, forest protection units and guard stations and forest patrol teams.
- It is to invest for the work of organization and management of forest protection and reorganization of production for people in a national park.
- Through investment in infrastructure construction, work of protection and restoration of natural forest ecosystems, the investment for work of forest protection patrols is not only preservation meaning, development of forest resources in Xuan Son National Part, but also contribute to maintain social security, especially in mountainous areas where many ethnic minorities are living.

## **RESEARCH PAPERS PUBLISHED AND RELATED TO THE DISSERTATION**

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