The NEF Bio-ecological Nature Conservation Project in Mountainous Region of North Vietnam

GIS-RS GROUP RESEARCH REPORT FOR PERIOD 10/2018 – 9/2021 (FINAL REPORT)

Ha Noi, 12/2021

CONTENT

1. GENERAL INFORMATION

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2. RESEARCH

2.1. Abstract

The GIS and Remote Sensing group has the objective to study land cover/land use change and ecosystem services for 4 representative sites in the limestone ecosystems in Mountainous Region of North Vietnam. This report summarizes the research results in Bac Me Nature Reserve and Phia Oac-Phia Den National Park, while the research results for Nam Xuan Lac Nature Reserve has been completed after conducting 2nd field trip in November 2021.

Regarding land use changes, during the period of 1988/1989 – 2007/2009, Bac Me and Cham Chu Reserves and Phia Oac-Phia Den National Park, face the decline of forest ecosystems (Close forest), while the area of secondary forest (Open forest), bushes and bare land are increased rapidly, concentrated mainly in the elevation zone of 200 m - 1000 m, in Yen Thuan and Phu Luu communes (Cham Chu), in Minh Ngoc and Thuong Tan communes (Bac Me) and in Quang Thanh and Phan Thanh (Phi Oac-Phia Den NP). However, during last 10 years (2007/2009 – 2017/2019), the forest area (Close forest) has increased, mainly due to the conversion of secondary forest and bushland, probably due to the natural process of forest vegetation rehabilitation and reforestation. Nam Xuan Lac Reserve witnesses the increase in forest cover during the period 1989-1998 and has trend to decrease while open forest and bush increase (1998-2007) or agricultural land /shifting cultivation land increase (2007-2017). The rehabilitation of forest cover and land use / land cover change can be explained by

adoption of the conservation and development policies and increase in local livelihood development.

Regarding ecosystem services, according to preliminary assessment, the total value of ecosystem services (provisioning, regulating, cultural and supporting) ranges from 173 – 179 millions USD for Cham Chu Reserve, from 90.3 – 93.1 million USD for Bac Me Reserve, from 126,2 – 129.4 million USD for Phia Oac – Phia Den National Park, and from 87 – 91 million USD for Nam Xuan Lac Reserve. Thus, the value of ecosystem services per hectare is ranged from 4,427 - 4,279 USD; 4,282 - 4,416 USD; 6,292 - 6,419 USD; and 2,990 – 3,151 USD, accordingly.

Regarding the publication, the research team has submitted one paper to international journal in the SCOPUS system and this paper has been published online.

2.2. Background of the study

The Central Institute for Natural Resources and Environmental Studies (VNU-CRES), Vietnam National University, Hanoi, is implementing "The NEF Bio-ecological Nature Conservation Project in Mountainous Region of North Vietnam", with financial and technical support from the Nagao Environment Foundation (Japan). The Institute has worked closely with scientists from the Institute of Ecology and Biological Resources, Hanoi National University of Education and a number of research institutions. GIS-Remote Sensing Research Group is one of 10 research groups of the Project. Other research groups are Mammals, Birds, Amphibian-Reptiles, Fish, Insects, Plants, Soil Invertebrates, Macro-Invertebrates, Aquatic and Social Group.

The project has been implemented for 3 years (10/2018-9/2021) with the goal "To contribute to nature conservation and sustainable development policies in the mountainous region of Northern Vietnam".

Project purposes are:

a) To deepen scientific knowledge of natural ecosystem, biodiversity in particular, at limestone zone in the northern part of Vietnam, such as ecological situations (ecosystem, biodiversity, habitat, population density/distribution, etc.) in relation with land-use change, large-scale regional development and other human activities on the one hand and, on the other hand, with environmental or developmental policies,

b) To elucidate the facts and causes of environmental degradation in recent days due primarily to economic development represented by land use/land cover changes and search for practical solution or mitigation, and

c) To enhance young scientists' research capabilities, i.e., research personnel who are sufficiently skilled and trained to plan, conduct, and publicize research.

The North-Eastern part of Vietnam consists of many limestone ecosystems with high biodiversity richness. Thousands of vascular plants, animals have been found and described since French time. Nevertheless, there is very little systematically survey has been carried out since.

Four representative areas for mountainous region of Northern Vietnam have been selected, including: 1) Cham Chu Reserve of Tuyen Quang province; 2) Bac Me Reserve of Ha Giang province; 3) Phia Oac-Phia Den National Park of Cao Bang province and; 4) Nam Xuan Lac Reserve of Bac Kan province.

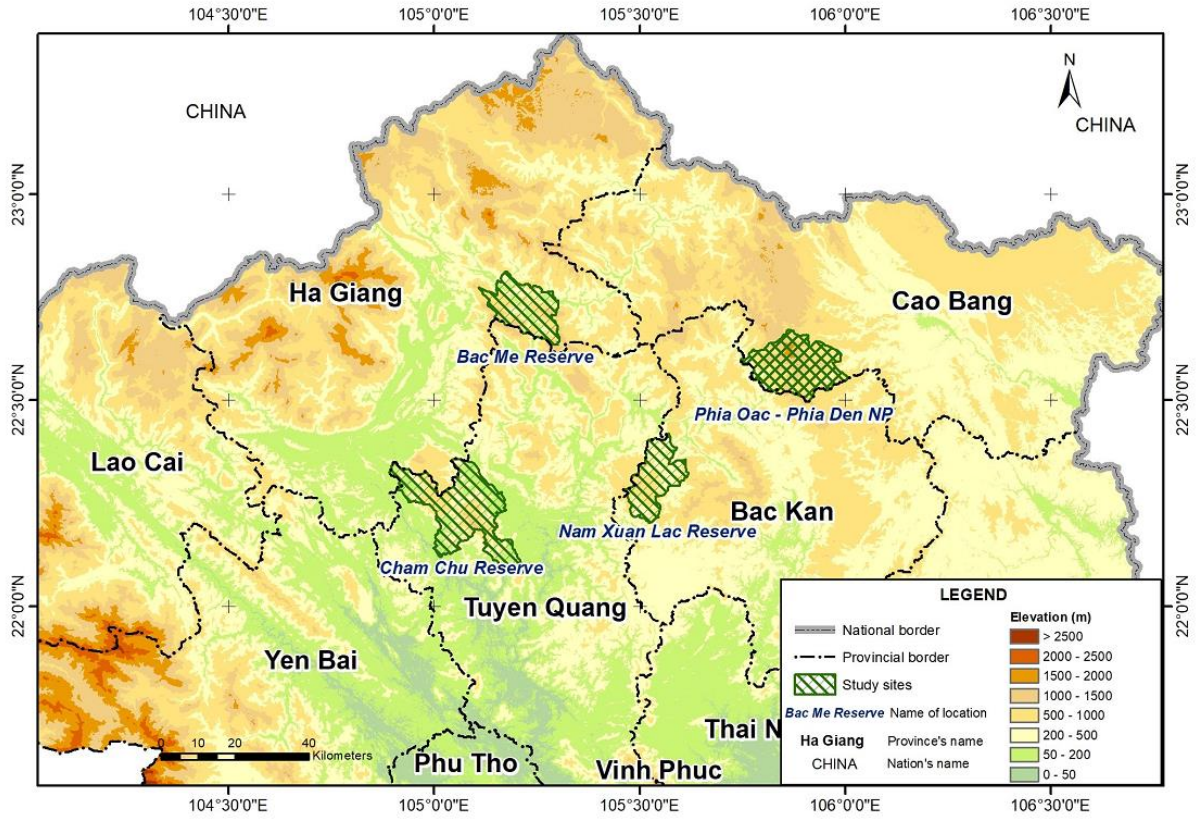


Figure 1. *Location of study sites in Mountainous Region of North Vietnam*

After conducting preliminary field research in April 2018, the project has selected 4 protected areas in 4 representative provinces in the northern mountainous region for the study, namely Cham Chu (Tuyen Quang), Bac Me (Ha Giang), Phia Oac - Phia Den (Cao Bang) and Nam Xuan Lac (Bac Kan). These protected areas are all characterized by high potential for biodiversity but they have not been comprehensive studied.

Some key information about the study sites is shown in Table 1 below.

Table 1. *Basic information of the study areas*

Characteristic	***Cham Chu***	***Bac Me***	***Phia Oac-Phia Den***	***Nam Xuan Lac***
Geographical coordinates	22°04' - 22°21' North latitude; 104°53' - 105°14' East longitude	$22^0$34'00 - $22^0$55'00" North latitude; $105^0$00'00 - $105^0$30'12" East longitude	$22^0$31'44" - $22^0$39'41" North latitude; $105^0$49'53 - $105^0$56'24" East longitude	$22^0$17’12’’ - $22^0$19’45’’ North latitude; $105^0$28’31’’ - $105^0$33’20’’ East longitude
Elevation	From 30 m to 1587 m	From 66 m to 1463 m	From 163 m to 1935 m	From 46 m to 1346 m
Administrative units/ communes	Yen Thuan, Phu Luu (Ham Yen district), Ha Lang, Trung Ha, Hoa Phu (Chiem Hoa district) (Tuyen Quang province) (5 communes)	Lac Nong, Minh Ngoc, Thuong Tan (Bac Me district) (Ha Giang province) (3 communes)	Thanh Cong, Quang Thanh, Phan Thanh, Hung Dao, Tinh Tuc (Nguyen Binh district) (Cao Bang province) (5 communes/towns)	Ban Thi, Dong Lac, Xuan Lac (Cho Don district) (Bac Kan province) (3 communes)

2.3. Literature review

2.3.1. Natural characteristics of study areas

(1) Characteristics of limestone mountain ecosystems

Limestone mountain ecosystems play a very important role in biodiversity conservation and socio-economic development. According to the Ministry of Agriculture and Rural Development (2006), Vietnam's limestone mountain ecosystem has an area of 1,152,200 ha, of which the forest cover area reaches 396,200 ha, in 24 provinces and cities but mainly concentrated in the provinces of Northern mountainous region such as Dien Bien, Lai Chau, Son La, Hoa Binh, Tuyen Quang, Ha Giang, Cao Bang, Bac Kan, Lang Son, Quang Ninh, Hai Phong and some provinces in North Central of Vietnam.

(2). Landscape

The Northeast region consists of hills and mountains on the left bank of the Red River with common topographical features of low hills below 1,000m and arc-shaped mountain ranges in the northeast such as those of Song Gam, Ngan Son and Dong Trieu, clustering towards the Tam Dao mountain range to form the slopes of the mountains. The study sites are mainly located in the areas between two arc-shaped mountain ranges of the Song Gam and Ngan Son, in the Northeast region (See Figure 2).

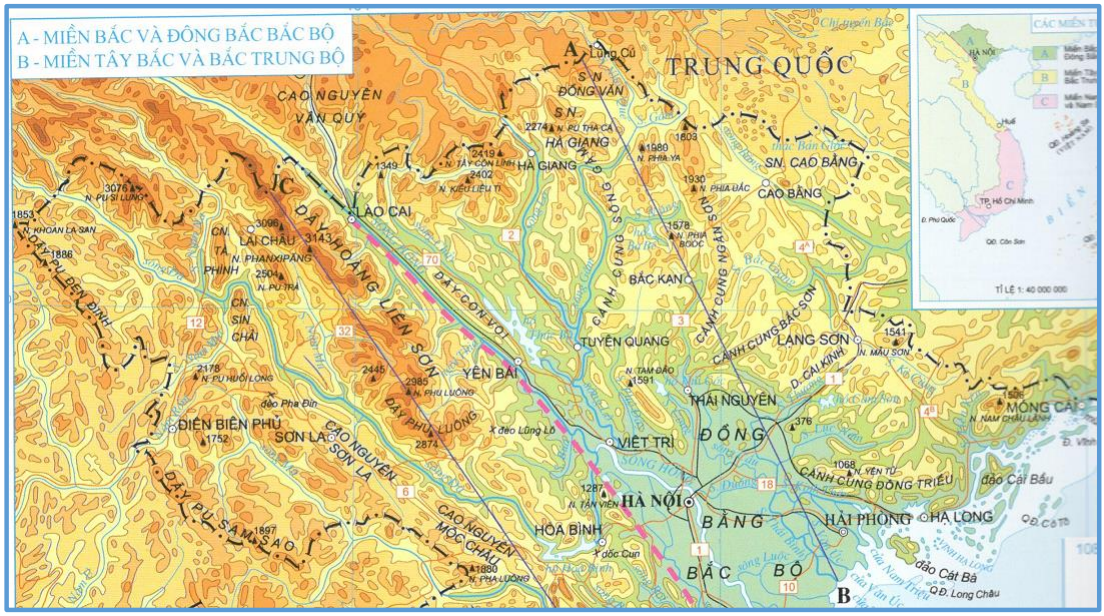


Figure 2. *Topographic map of the studies areas.*

The average elevation of the study sites ranges from 200 to 1000 m, of which the highest point is Phia Oac mountain (Phia Oac peak) with an altitude of 1935 m, highest point m in Cham Chu is 1.587 (Cham Chu peak), highest point in Bac Me is 1463 m and the highest point in Nam Xuan Lac is 1346 m.

(3). Climate

Located in both a temperate and a tropical zone, Vietnam's climate is characterized by strong monsoon influences but has a considerable amount of sun, a high rate of rainfall, and high humidity. In the north, the climate is monsoon-influenced humid subtropical climate (Koppen: Cwa) with four distinct seasons (spring, summer, autumn, and winter).

The Northeast region includes the northern and northeastern provinces such as Lao Cai, Yen Bai, Hoa Binh, Ha Giang, Tuyen Quang, Phu Tho, Cao Bang, Lang Son, Bac Kan, Thai Nguyen, and Quang Ninh. The climate in this region is strongly influenced by the northeast monsoon. Winters are cold, cloudy (little sunshine) that is characterized by drizzle. The cold comes earlier than other provinces. Summers are hot and rainy that coincide with the rainy season. However, unlike the northwest, dry conditions are rare due to a low frequency of westerly winds. The rainy season usually

lasts from May–September although its duration can vary from 4 to 10 months. In the Hoang Lien Son mountains, winters are cold where snowfall and hoarfrost can occasionally occur. These mountains have the highest rainfall in the country. Mean annual temperatures are around 23 °C in which the coldest month has a mean temperature of 16 °C and the hottest month has a mean temperature of 28 °C. Average annual rainfall is approximately 1,800 mm

Table 2. *Climate characteristics according to meteorological stations in the study area* and study sites (According to Nguyen Quang Truong, 2021 and statistics)

Name	Elevation (m a.s.l.)	Temperature (°C)		Rainfall (mm)		Average annual humidity (%)
		Annual average	Range monthly average	Annual average	Range monthly average	
Ha Giang	118	22.7	15.4–27.8	2430.1	31.5–515.6	84
Nguyen Binh	208	20.3	12.3–26.1	1763.0	34.7–312.1	82
Cao Bang	258	21.6	14.0–27.3	1442.7	16.1–267.1	81
Trung Khanh	520	19.9	11.7–26.0	1646.4	31.6–301.5	81
Cho Ra	210	22.0	14.1–27.5	1343.5	18.2–249.4	83
Ngan Son	566	20.1	12.3–25.7	1593.1	24.8–314.8	81
Dinh Hoa	220	22.6	15.3–28.1	1666.9	14.8–315.1	83
Lang Son	258	21.2	13.3–27.0	1391.9	23.0–255.0	82
Cham Chu Reserve (Tuyen Quang)		24.5	16.8-29.7	1789.7	15.6-308.5	81

(4) Hydrology

The monsoon-influenced humid subtropical climate regime with sloping and heavily cut terrain has created a fairly dense hydrological system, with the main river basin system in the study area being the Gam River - Lo River belonging to Red River System. In the study sites, only small rivers and streams flow through, except Bac Me NR with a part of Na Hang hydropower reservoir (Tuyen Quang).

(5) Soils

The soil of limestone mountains with heavy mechanical composition is tropical red soil, mainly ferarit soils formed on rock of limestone (low belt, below 700 m above sea level) or limestone - dolomite (altitudes over 700 m). In the steep and eroding places, the soil cover is alternated by red soil and black soil on limestone mountains (rendzina soil) (MARD, 2006).

Table 3. *Characteristics of soil types in the study area*

Cham Chu	***Bac Me***	***Phia Oac-Phia Den***	***Nam Xuan Lac***
+ Red and yellow feralit soil on medium and high mountains (700-1700m) +Yellow feralit soil on low mountains (300-700m) + Limestone valley soil +Soil on basin and valleys	+ Group of light yellow humus soils on sandstone (>900m) +Red-brown soil group on limestone + Group of red and yellow soil on clay and metamorphic rocks + Group of pale yellow soil on sandstone + Alluvial soil group mainly distributed along the Gam river	+Red-brown feralit soil on limestone mountains (700-1700m) +Feralite soil is light yellow in the high mountains +Red yellow soil in low mountain +Soil on basin and valleys	+Soil on basin and valleys +Red-brown soil group on limestone

Sources: DARD Tuyen Quang, 2014; DARD Ha Giang, 2016; DARD Cao Bang, 2017;. UBND Bac Kan, 2013.

(6) Flora

In terms of species composition, the flora of the limestone mountains is a mixture of many flora, but the main characteristic is the native flora of North Vietnam - South China, and is also influenced by many different types of flora in the region. Vegetation on limestone mountains of Vietnam is distributed discontinuously, concentrated in the belt 300 – 1200 m above sea level (MARD, 2006).

The flora of the limestone mountains is a mixture of many vegetation streams, but the main characteristic is the indigenous flora of North Vietnam - South China, and at the same time, it is also influenced by other vegetation streams. Vegetation on limestone mountains of Vietnam is distributed discontinuously, concentrated in the belt 300 – 1200 m above sea level (MARD, 2006). In general, the limestone forest ecosystem structure includes: (i) Evergreen humid tropical monsoon rainforest; (ii) Evergreen humid subtropical monsoon rainforest; (iii) Subtropical monsoon semi-deciduous rainforest; (iv) Evergreen humid tropical shrubland; (v) Evergreen humid subtropical shrubland.

Among the limestone ecosystems, there are many rare and endemic plant species that are being assessed at the conservation levels CR (critically endangered), EN (endangered) and VU (Vulnerable), especially especially gymnosperms and orchids. The valuable species, both economically and for conservation, can be mentioned, such as Nghien (*Excentrodendron tonkinense*) and Trai *(Garcinia fagraeoides*), Kim Giao *(Podocarpus fleuryi)* and *Ngoc Am (Cupressus torulosus, C. funebris)*, Po mu *(Fokienia hodginsii)*, Thong Pa co *(Pinus kwangtungensis)*, Bach vang *(Cupressus vietnamensis)*, Tue *(Cycas spp.)*, Lan hai *(Paphiopedilum spp.)*, Binh voi *(Stephania spp.)…*

(7). Fauna

Due to the diversity and special topography, the fauna on limestone mountains also has many unique characteristics. As for the fauna, due to the difficult and complex terrain, the fauna also has its own characteristics, especially the species capable of moving independent of the ground such as primates, squirrels, birds, bats, etc. ... and species whose life depends heavily on caves and crevices created on limestone such as bats, snakes, swallows,...

According MARD (2006), the richest biodiversity is bats of the order Chiroptera with about 50 species living in large caves; The order Primates has 16 species and subspecies, including endemic species on limestone mountains such as: Douc langur (*Trachypethucus trancoisii delacouri*), langur (*Trachypithecus trancoisii phicephalus*), snub-nosed monkey (*Rhinopithecus avunculus*), gibbon (Hylobates concolor); The order Carnivora has 8 species such as sun bears, civets and wildcats; The order Even-toed clogs (Artiodactyla) have 5 species such as musk deer, gills, chamois, wild boar and salamander; The most diverse order of bird is the Passeriformes and endangered species such as white pheasant (*Lophura nycthemera*), wild boar owl (*Phodilus badius*), magpie (*Pica pica*), white-tailed blue-tailed chicken (*Lophura hatinhensis*); There are 17 species of amphibians and reptiles, of which the king cobra (*Ophiophagus hannah*) is endemic and has high economic value, and the yellow-fronted box turtle (*Cistoclemmys galbinifrons*), and the golden mountain turtle (*Indotestudo elongata*) are species of endangered species. In the endangered status, all 17 species are rare species listed in the Red Book and CITES; The four major insect orders are the order Lepidoptera, the order Coleoptera, the order Orthoptera and the order Diptera, in which the indicator species belong to the subfamily of Ladybugs (Cassidinae), Family leaf beetles (Chrysomelidae - Coleoptera) and mantises (Mantis religiosa).

The flora and founa in the study sites is shown in the Table 4.

Table 4. *Summary of flora and founa in the study site*

	Cham Chu	***Bac Me***	***Phia Oac-Phia Den***	***Nam Xuan Lac***
Flora	906 species belonging to 425 genera, 136 families, 5 phyla (2009)	625 species belonging to 388 genera, 141 families, 5 phyla (2015)	1287 species belonging to 786 genera, 163 families, 6 phyla (2013 and 2016)	653 species belonging to 440 genera, 142 families, 4 phyla
Endangered plant species	+58 Endangered species belonging to 55 genera, 36 families +VN Red Book 2007: 43 species, 40 genera, 30 families	+VN Red Book 2007: 36 species (EN=12; VU=24); +IUCN 2015: 23 species (EN=2; VU=3; LR=3; LC=14; NT=1);	+VN Red Book 2007: 88 species (CR=4; EN=33; VU=48; LC=3); +IUCN 2015: 23 species (EN=2;	+ VN Red Book 2007: 50 species (Animals 15; Birds 9+; Reptiles 4+) +IUCN 2015: 9 species (Reptiles 2+)

	+IUCN 2009: 23 species belonging to 25 genera, 16 families; +ND32/CP/2006: 16 species belonging to 15 genera, 15 families	+ Decree 32/CP/2006: 22 species (IA=5; IIA=17)	VU=3; LR=3; LC=14; NT=1); +Decree 32/CP/2006: 23 species (IA=11; IIA=12)	+ND32/CP: 54 species
Fauna	91 species, 45 families, 15 orders	194 species, 64 families, 23 orders	496 species, 95 families, 27 orders (2016)	88 species, 39 families (2016)
Mammal	33 species belonging to 15 families, 5 orders	44 species belonging to 18 families, 7 orders	108 species belonging to 27 families, 8 orders	29 species belonging to 12 families, 4 orders
Bird	47 species belonging to 19 families, 8 orders	104 species belonging to 29 families, 12 orders	302 species belonging to 51 families, 15 orders	47 species belonging to 21 families, 9 orders
Reptile	11 species belonging to 11 families, 2 orders	22 species belonging to 9 families, 2 orders	52 species belonging to 10 families, 2 orders	12 species belonging to 6 families
Amphibian	-	24 species belonging to 8 families, 2 orders	34 species belonging to 7 families, 2 orders	-
Fish	-	-	-	-
Endangered animals	+VN Red Book 2007: 31 species (Mammal 20; Bird 3; Reptile 8); +IUCN 2015: 18 species (Mammal 18; Bird 1; Reptile 4);	+VN Red Book 2007: 22 species (Mammal 15; Birds 1; Reptiles 5; Amphibian 1); +IUCN 2015: 18 species (Mammal 10; Bird 0; Reptiles 4; Amphibian 4); +ND32/CP: 22 species (Mammal 15; Bird 2; Reptile 5);	+VN Red Book 2007: 51 (Mammal 30; Bird 6; Reptile 12; Amphibian 3) +ND32/CP: 41 species (Mammal 22; Bird 9; Reptile 10);	+VN Red Book 2007: 23 (Mammal 12; Bird 6; Reptile 5) +ND32/CP: 21 species (Mammal 13, Bird 3, Reptile 5); +IUCN: 21 species (Mammal 13; Bird 5; Reptile 3);

Note:

+ IUCN: EX: Extinct; EW: Extinct in the wild; CR: Critically endangered; EN: Endangered; VU: Vulnerable; LR: Lower risk; DD: Thiếu dữ liệu (Data dificient); NE: Not evaluated.

+ Vietnam Red Book + NĐ/32-CP: CR (Critically endangered); EN (Endangered); VU (Vulnerable); LC.

Sources: DARD Tuyen Quang, 2014; DARD Ha Giang, 2016; DARD Cao Bang, 2017;. UBND Bac Kan, 2013.

The main characteristics of species diversity for Cham Chu NR, Bac Me NR, Phia Oac-Phia Den NP and Nam Xuan Lac NR are presented as follows:

1). Flora: In terms of species, Phia Oac-Phia Den NP has the largest number of species (1287 species belonging to 786 genera, 163 families, 6 phylums), equal to 140% of those in Cham Chu NR (906 species belonging to 425 genera, 136 families, 5 phylums) and about 545% of those in Bac Me NR (91 species, 45 families, 15 orders) and nearly 564% of those in Nam Xuan Lac NR (906 species belonging to 425 genera, 136 families, 5 phyla). PO-PD has up to 6 phyla, including gymnosperm (alpine regions), compared with 5 phyla (Cham Chu, Bac Me) and 4 phyla (Nam Xuan Lac). Regarding the number of endangered species: Phia Oac-Phia Den NP has the largest number of species (90 species) significantly larger than Cham Chu (58 species), Nam Xuan Lac (50 species) and Bac Me (36 species).

2). Fauna: Regarding the number of species, Phia Oac-Phia Den NP has the largest number of species (496 species, 95 families, 27 orders), equal to 256% of those in Bac Me NR (194 species, 64 families, 23 orders), and 545% of those in Cham Chu NR (91 species, 45 families, 15 orders) and nearly 564% of those in Nam Xuan Lac NR (88 species, 39 families). Regarding the number of endangered species, according to the Vietnam Red Book, Phia Oac-Phia Den NP has the largest number of species (51 species) significantly larger than Cham Chu NR (31 species), Nam Xuan Lac NR (23 species) and Bac Me NR (22 species).

2.3.2. Socio-economic condition of study areas

(1). Protected areas system in Vietnam

According to the Vietnam Environment Administration (MONRE, 2020), the system of protected areas in Vietnam can be divided into three groups: (i) The system of special-use forests (according to the 2017 Forestry Law); (ii) System of Nature Reserves (according to the BD Law); (iii) The system of marine Nature Reserve (according to the Law on Fisheries 2017 and the Law on Biodiversity 2008); (iv) Wetland Nature Reserve system according to Decree No. 66/2019/ND-CP (July 29, 2019) and the Law on Biodiversity.

According to the national master plan on special-use forests to 2020, with a vision to 2030 (Prime Minister/Thu tuong, 2014), the special-use forest system covers 2,462,592.33 hectares out of a total of 14.6 million hectares of forested land, with 176 special-use forests, including 34 national parks, 133 nature reserves (nature preserves, species and habitat conservation areas and landscape protection areas) and 9 scientific research and experimental forests (See Table 6). Vietnam's special-use forest system is distributed over all local ecological zones and the study sites (Cham Chu, Bac Me, Phia Oac-Phia Den and Nam Xuan Lac) are part of this Special-use Forest system.

Table 5. *The special-use forest system divided by type in Vietnam*

No	Region	National park (number)	Nature Reserve (number)	Research Forest Sites (number)	Total
1	North West		12	1	13
2	**North East**	**7**	**40**	**3**	**50**
3	Red River Delta	4	9	2	15
4	Central North	5	22	1	28
5	Central Coasts		18		19
6	Tay Nguyen	6	9	1	16
7	South East	6	9	1	16
8	Mekong Delta	6	13		6
	Total	**34**	**133**	**9**	**176**

Source: Thủ tướng (Prime Minister), 2014.

The development history of protected areas in the study sites is presented in Table 6. The process of establishing a protected area usually includes the following steps; i). The project proposal for developing a protected area, including the biodiversity value; ii). Adjustment of protected areas/special-use forests in the planning of 3 types of forests (special-use forests, protection forests and production forests); iii). Planning and sustainable development of the protected areas, including consolidating the entire management apparatus. In fact, since 2012, the organization and management board are been improved, so the works of forest protection and biodiversity conservation are implemented.

Table 6. *Development history of protected areas for study sites*

	Cham Chu	***Bac Me***	***Phia Oac-Phia Den***	***Nam Xuan Lac***
Decision on establishment of protected areas	+2001: Project proposal to develop Cham Chu special-use forest (1536/QD-UBND) + 2008: Establishment of Forest Ranger District for Cham Chu Special-use (408/QD-UBND) +2012: Adjusting forest protection and development planning,	+1994: Establishment of Bac Me Nature Reserve by Ha Giang province (648/QD) +2013: Adjusting the planning for 3 types of forests,	+2013: Establishment of PO-PD NR by Cao Bang province (10,261 ha) (1502/QD) +2015: Adjusting the planning of 3 types of forests, including NR	+2004: Project proposal to develop Nam Xuan Lac NR (342/QD-UB) +2007: Establishment of Management Board of Nam Xuan Lac NR (core 1,788 ha, buffer

	including Cham Chu special-use forest (1770/QD)	including NR (area: 9,016.3 ha in 3 communes) (1981/2013)	(10,593 ha) (415/QD)	7,508 ha) (342/QD-UB) +2007: Adjusting the planning of 3 types of forests in Bac Kan province, including the NR (757/2007/QD-UBND)
Conservation Planning and sustainable development	+2014: Report for Planning for conservation and sustainable development of Cham Chu NR until 2020 (734/QD-UBND) (total 15,262.3 ha (Ham Yen district: 6,168.4 ha, Chiem Hoa district: 9,093.9 ha).	+2016: Report on conservation and sustainable development planning of Bac Me natural reserve until 2020	+2017: Report on the detailed planning of transforming PO-PD natural reserve into PO-PD NP (5 communes/towns)	2012: Report on Conservation and Sustainable Development Planning of Nam Xuan Lac NR for the period 2013-2020

In terms of functional zoning, these study sites have a small area, from more than 8,000 hectares (Bac Me), to more than 10,000 hectares (Phia Oac - Phia Den), up to more than 15,000 hectares (Cham Chu) and the largest is more than 18,000 ha (Nam Xuan Lac) and they are divided into functional zones such as Strictly Protected, Ecological Restoration and Administrative-service Areas (See Table 7). However, this boundary is often not clearly defined in the field, so people have easy access to them that make the management and protection of forests in the protected areas difficult.

Table 7. *Some main characteristics of protected areas in the study sites*

Features	***Cham Chu (Tuyen Quang)***	***Bac Me (Ha Giang)***	***Phia Oac-Phia Den (Cao Bang)***	***Nam Xuan Lac (Bac Kan)***
Official name and year of establishment	Cham Chu Reserve of Species and Habitat Conservation (2001/2014)	Bac Me Nature Reserve, (1994/2016)	Phia Oac-Phia Den National Park (1994/2018)	Nam Xuan Lac Reserve of Species and Habitat Conservation (2003/2018)
Area (ha) (strictly protected/Ecological Restoration/Administration)	**15,590.9** (10,757.6/3,862.2/642.5)	**8,791.80**	**10.593,4** (4.035,5/6.417,1/140,9)	**18,504** (2.547,04/1.586,12/9,04

Administrative unit (commune/district)	Yen Thuan, Phu Luu (Ham Yen district), Ha Lang, Trung Ha, Hoa Phu (Chiem Hoa district) (5 communes)	Lac Nong, Minh Ngoc, Thuong Tan (Bac Me district) (3 communes)	Thanh Cong, Quang Thanh, Phan Thanh, Hung Dao, Tinh Tuc (Nguyen Binh district) (5 communes/town)	Ban Thi, Dong Lac, Xuan Lac (Cho Don district) (3 communes)
Population (people)	15.913 (year 2014)	9.198 (year 2014)	8.289 (year 2016)	7.608 (11/2012)
Main ethnic group	Tay (60%), Dao (22%), Kinh (12%) Khác (6%) (year 2014)	Tay (42%), H'môngg (41%), Dao (10%), Kinh (3%), others (1%) (year 2014)	Dao (47,2%), Nung (20,3%), Kinh (17,8%), Tay (13,8%), H'mong (0,9%)	Dao, H'mong, Tay, Nung, Hoa (90%), Kinh (10%) (11/2012)

Sources: DARD Tuyen Quang, 2014; DARD Ha Giang, 2016; DARD Cao Bang, 2017;. UBND Bac Kan, 2013.

In terms of administrative management, these protected areas are usually located in the administrative areas of 3 communes (Bac Me, Nam Xuan Lac) or 5 communes/towns (Cham Chu, Phia Oac - Phia Den). The local authority directly managing these Nature Reserves and National Park is the People's Committees of communes and towns in the sites, in which the Commune People's Committee is the lowest administrative unit in Vietnam (there are 4 levels, including national and provincial, district and commune). The villages are considered as extention of the commune and the village heads are responsible for administrative works to support the inhabitants of the villages.

In terms of population, in principle there are no people living in the protected areas, but people only live in residential areas of the communes outside the protected areas boundary. Population and population density are quite low because most protected areas are located in mountainous and remote areas. The main ethnic groups in these communes are ethnic people, which are mainly Tay, Mong, Dao and some other ethnic minorities.

2.3.3. Landuse

The current land use status for the study sites is presented in Table 8. Most of the protected areas are covered by forests, respectively 97.0%, 75.6%, 83.9% and 77.4% in Cham Chu Reserve, Bac Me Reserve, Phia Oac-Phia Den National Park and Nam Xuan Lac Reserve. Of these sites, the largest areas of forest on limestone mountains is in Nam Xuan Lac NR (7,219 ha), in Cham Chu NR (2,145.9 ha) and Bac Me NR (1,014.45 ha).

Table 8. *Landuse in the study sites*

Land use/Forest types	Cham Chu	Bac Me	Phia Oac-Phia Den	Nam Xuan Lac
I. Forested land	**15,119.7**	**6,649.81**	**8883.9**	**14,316**
1. Natural forest in terrestrial mountains	**12,923.8**	**4,620.30**	**7841.7**	**6,389**
Mixed wood forest + bamboo		12.89	1791.3	1,761
Rich forest			1280.0	
Medium forest		812.94	331.2	600
Poor forest		2,543.00	-	96
Rehabilitated forest		1,251.47	4439.2	3,932
2. Forest on limestone	**2,145.9**	**2,014.45**	**278.1**	**7,219**
Rich forest on limestone				1,864
Medium forest on limestone		62.11		264
Poor forest on limestone		825.19		4,903
Rehabilitated forest on limestone		1,127.15		188
3. Forested plantation	**49.9**	**15.06**	**764.1**	**708**
Young plantation	49.9	15.06	764.1	708
II. No-forest land	**143.1**	**1,771.91**	**1678.6**	
1.No-forest land in terr. mountains	**90.1**	**1,661.78**	**1,678.6**	**2,552**
Bareland with bushes (Ia, Ib)	90.1	702.51	1085.7	916
Bareland with wood regrowth (Ic)		959.27	592.9	756
2. No-forest land on limestone	**53.0**	**110.13**		**60**
Bareland with bushes (Ia, Ib)	53.0	25.67		60
Bareland with wood regrowth (Ic)		84.46		
III. Other land	**328.7**	**370.08**	**30.9**	**1,636**
Other land	92.9	7.11		367
Agriculture	235.8	362.97		1,269
Total	**15,590.9**	**8,791.80**	**10593.4**	**18,504**

Sources: DARD Tuyen Quang, 2014; DARD Ha Giang, 2016; DARD Cao Bang, 2017;. UBND Bac Kan, 2013.

Table 9. *National conservation and development policies*

Main policy	***Law***	***Strategy***	***Planning***	***Plan/Action plan***
1.Sustainable development	Planning Law (2018)	Agenda 21 (2004); Sustainabale development strategy for 2011-2020 (2011); Social-Economic Development Stratgy		Implementation plan for the 2030 Agenda for Sustainable Development (17 SDG) (2017)

		for 2011-2020; Green Growth Stratgy (2013)		
2.Biodiversity conservation	Biodiversity Law (2008)	Biodiversity Strategy	National Biodiversity Planning (2013)	Reforestation Program (327/661, 5 million ha of forest)
3.Forest protection and utilization	Forestry Law (2018)	Strategy for development of National Parks (2006)		Decree for payment of forest environmental services (NĐ 99)

Table 10. *Conservation and development policies for the study sites*

Main policies	***Cham Chu (Tuyen Quang)***	***Bac Me (Ha Giang)***	***Phia Oac-Phia Den (Cao Bang)***	***Nam Xuan Lac (Bac Kan)***
1.Sustainable development	Action plan for implementation of National action plan for implementation of the 2030 Agenda for Sustainable Development (2017)	Action plan for implementation of National action plan for implementation of the 2030 Agenda for Sustainable Development (2017)	Action plan of Cao Bang Provincial People's Committee to implement the 2030 Agenda for Sustainable Development (2018)	
2.Biodiversity conservation	Biodiversity conservation planning of Tuyen Quang province in the period of 2013-2020 and orientation to 2030 (2013)	Biodiversity conservation planning of Ha Giang province to 2020, orientation to 2030 (2015)	Biodiversity conservation planning in Cao Bang province to 2020, orientation to 2030 (2014)	Biodiversity conservation planning of Bac Kan province to 2020, orientation to 2030 (2017)

3.Forest protection and utilization	Adjustment of the planning for forest protection and development in Tuyen Quang province for the period 2011-2020, supplementing the planning up to 2025 (2016)	Planning for conservation and sustainable development of special-use forests in Ha Giang province until 2020 (2016)	Forest protection and development planning in Cao Bang province in the period of 2013 -2020 (2015)	-Forest protection and development planning in Bac Kan province for the period 2009-2015, orientation to 2020 (2009) -Plan to implement the 3-year program of sustainable forestry development in Bac Kan province (2018-2020) (2018)
4. Policy for nature reserve and national park	Planning for conservation and sustainable development of Cham Chu habitat and species conservation reserve (2014)	Planning for conservation and sustainable development of special-use forests, including Bac Me Nature Reserve (2016)	Decision to establish Phia Oac-Phia Den National Park, Nguyen Binh district, Cao Bang province (2018)	-Planning for conservation and sustainable development of Nam Xuan Lac Species and Habitat Conservation Reserve, Bac Kan province in the period of 2013 - 2020 (2018). -Decision on establishment of Nam Xuan Lac Species and Habitat Conservation Reserve (324/QD-UBND, March 17, 2004)

2.4. Group's purpose and subjects

- To provide and manage baseline spatial database for all other research groups with purpose to integrate their results;

- To study land cover/land use change and its causes derived from socio-economic development in the northern mountain region of Vietnam;

- To develop the maps of ecosystem services to support policies for biodiversity conservation and sustainable development in the region;

- To technically support biological groups for managing their spatial data for species distribution maps upon their requirements and needs.

2.5. Materials and methods and time frame

2.5.1. Document, materials, data, map and remote sensing images acquirement

(1) Document and secondary data collection

Documents and data needed to be collected related to the study sites include: 1). Local (provincial, district) policies and legal documents on socio-economic development, land use, biodiversity conservation/forest protection, payment for forest environmental services; 2). Scientific reports related to local socio-economic development (province, district, commune), land use, biodiversity conservation/forest protection, payment for forest environmental services; 3). Documents relating to, socio-economic planning, conservation, use and exploitation of natural resources related to the study area; 4). Statistical data on socio-economic situation, forest protection, afforestation and forest exploitation, payment for forest environmental services related to the study area.

(2) Collection and acquirement of digital maps for study sites

Digital maps relevant to the study site are collected and purchased, including: 1). Land use maps/forest status maps of the 4 provinces (Tuyen Quang, Ha Giang, Cao Bang, Bac Kan) corresponding to the NRs/National Parks in the study area; Land use maps, forest maps of study areas, especially digital maps of the forest database of Vietnam managed by the Ministry of Agriculture and Rural Development (e.g. Sector Data System forestry at http://maps.vnforest.gov.vn/vn); 2). Planning and conservation maps for the NRs/National Parks in the study area; 3). Other relevant background maps (administration, topography, climate, soil, hydrology ...).

This information supports satellite image mapping and analysis of landuse and changes for the study site.

(3) Collection and acquirement of remote sensing images

Data sources for land cover-land use mapping in this research are US Landsat images taken over the area of the 4 sites. These images are free and downloaded from the United States Geological Survey (USGS) website: https://earthexplorer.usgs.gov. A series of 24 Landsat scenes since 1980s was downloaded for quality evaluations. For each research site, a set of 4 Landsat scenes (Table 11) at 10 years interval was finalized for land cover-land use interpretation and analysis. These images have least effects of atmospheric conditions (haze, cloud cover) to ensure quality, and have similar times/seasons of acquisition for compatible identification of land cover – land use types.

Table 11. *Basic information of Landsat images obtained for the research*

Year	Satellite	Scene/ Image ID	Spatial resolution	No. of bands
Cham Chu and Nam Xuan Lac Reserve				
1986	Landsat 5	LT05_L1TP_127045_19860701_20170221_01_T1.tar (for Cham Chu Reserve)	30m	7
1989	Landsat 5	LT05_L1TP_127045_19891130_20170201_01_T1.tar (for Nam Xuan Lac Reserve)	30m	7
1998	Landsat 5	LT05_L1TP_127045_19981107_20161220_01_T1.tar	30m	7
2007	Landsat 5	LT05_L1TP_127045_20070524_20161115_01_T1.tar	30m	7
2017	Landsat 8	LC08_L1TP_127045_20170604_20170615_01_T1.tar	30m	7
Bac Me Nature Reserve and Phia Oac-Phia Den National Park				
1988	Landsat 5	LT05_L1TP_127044_19881111_20170221_01_T1	30m	7
1998	Landsat 5	LT05_L1TP_127044_19981022_20161222_01_T1	30m	7
2009	Landsat 5	LT05_L1TP_127044_20091105_20161018_01_T1	30m	7
2019	Landsat 8	LC08_L1TP_127044_20190930_20191018_01_T1	30m	7

(Sources: https://earthexplorer.usgs.gov)

These Landsat scenes have been subsetted for the area of study sites.

2.5.2. Methods used

2.5.2.1. Desk study

To facilitate the study on land use/land cover change and ecosystem services, all documents and data collected are classified and used according to the content, timeline and type as follows: 1). Policy system on biodiversity/forest resource conservation, environmental protection, socio-economic development and response to climate change; 2). Reports on ecosystems and biodiversity at local protected areas; 3). The documents directly related to study sites.

2.5.2.2. Methods of remote sensing, GIS and cartography

Remote sensing method is used to acquire the remote sensing imagery, interprete and analyse and develop map of land use change. Specifically, this method will apply

for Cham Chu, Bac Me, Nam Xuan Lac Nature Reserves and Phia Oct- Phia Den National Park.

For each study site, 4 times of remote sensing image were selected, namely years of 1986, 1998, 2007 and 2017 for Cham Chu and Nam Xuan Lac Nature Reserves, and years of 1988, 1998, 2009 and 2019 for Bac Me Nature Reserve and Phia Oac-Phia Den with a time interval of about 10 years to be able to assess land use changes for 30 years.

GIS and cartography methods are also used to present the resulted map.

Land cover mapping for Cham Chu, Bac Me, Nam Xuan Lac Reserves and Phia Phia Oac-Phia Den national park from remote sensing images

The methodology that was used to create the baseline land-cover map of the reserve is divided into two parts, a methodology for carrying out the ground surveys and a methodology for classifying the satellite imagery into the land-cover classes.

a) Ground survey data collection

Two field surveys were carried out in each study site by a team of scientists consisting of GIS specialists, and geographers. During the field surveys, a Garmin GPS receiver was used to record coordinates of survey points and tracks. These points and tracks were imported to ArcView GIS software for the purpose of mapping visited areas.

At each survey point picture(s) of the survey location was taken, and vegetation in the area was identified. The aim of the ground surveys was to collect land cover data over the area. This data was used to classify the satellite imagery into the different land-cover classes and also to verify the accuracy of the land-cover maps produced.

b) Remote sensing land cover map development

In order to develop a land cover map of the area from the satellite image and the ground survey data, a number of steps were followed. The steps are briefly described below:

- The ground survey data was organized into a database with the following fields: the point identification, the location of the GPS point (in easting and northing) and distanced point(s) (calculated from distant from GPS location and bearing to the North), a description of the land-cover in the immediate vicinity of the point and the distanced point(s), a picture of the point and distanced point(s).
- A base map of the area was collected and transformed to UTM Zone 48, WGS84 datum.
- The satellite images were rectified to the base map, so that the ground survey data can be located on the images.
- Examples of each land-cover class were identified on the image and "training

sets" for the computer to use in classifying the image were created.

- A supervised classification of the satellite images was done. This divided the area on the satellite image into the land-cover categories decided upon during the field survey.
- An accuracy assessment of the classified satellite image was done.
- Land-cover maps for the area were created.
- A statistical analysis of the land cover for the area was completed. This analysis acts as a baseline for any future monitoring of land-cover change within the area.

c) Remote sensing imagery classification

The classification of land-cover in the study area is based both on the structural appearance of the vegetation and on ecological processes. The classification is dependent on the experience of the researchers and on technical limitations, such as the satellite image resolution.[1] These two variables ultimately define the detail of the classification.

During fieldwork, it was recognized that the land-cover could be divided six classes. These classes are (1) Close forest; (2) Open forest; (3) Bush mixed with small woody tree and grass; (4) Open bare land; (5) Irrigated rice paddy; and (6) Water. A short description of each of these classes follows:

Class 1: Close forest: this is both primary forest (such as tropical humid evergreen forest and subtropical humid subtropical evergreen forest on terrestrial land and limestone), which is only found within the reserve, and secondary, or disturbed forest which has human impacts (swiddening and/or selected logging) long time ago. In most places where this type of forest exists it has multi-stories woody trees, large canopy and cover most of ground surface.

Class 2: Open forest: this is regenerated forest as results of human exploitation of evergreen broad-leaved forest. This type of forest has only one story and is dominated by medium woody tree mixed with bushes and low coverage. It can be found in former upland areas or clear-cut areas after 7-10 years, and in low hills closed to residential area in the form of well-developed plantation.

Class 3: Bush mixed with small woody tree, vines and grass. This land-cover type can be found everywhere in the buffer zone of the reserve. This is resulted from the continuous impact of humans on primary forest or regenerated forest.

Class 4: Open bare land. This type of land cover associates with human agro-forestry activities. As a result it has no vegetation coverage. This land-cover type can

[1] As an example, because the final land-cover map will be derived from satellite imagery with a resolution of 30 meters on the ground, there are limitations regarding how detailed the final land-cover map can be, and only land-cover patches of greater than 60 x 60 meters will be reliably classified.

be found in areas where are newly harvested agriculture field, and forest/plantation has been clear cut or burned down.

The other land-cover classes are class 5 (paddy - irrigated rice paddy) and class 6 (water – lakes, large streams and rivers).

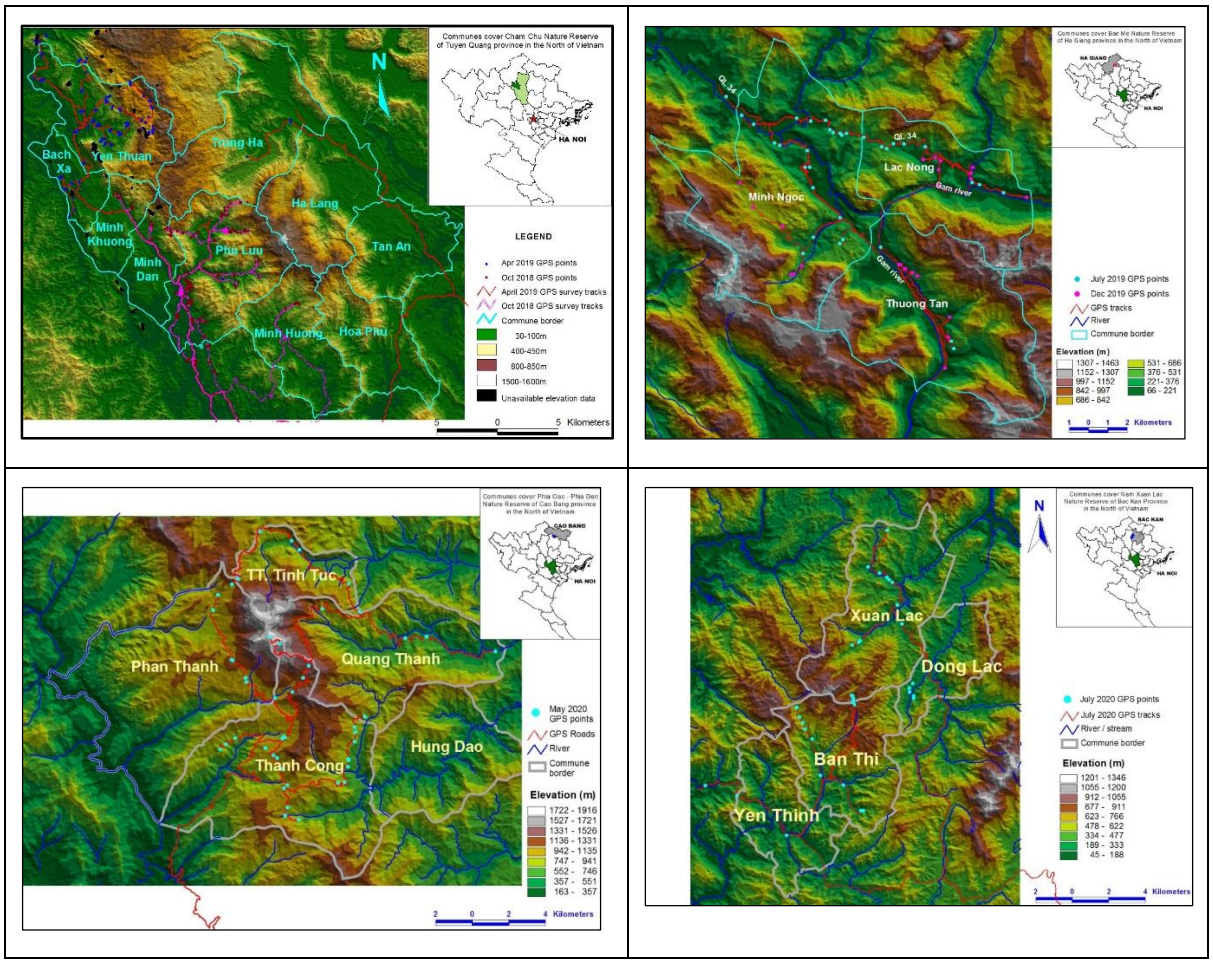


Figure 3. *GPS points and tracks collected during the field research for study sites (Cham Chu Reserve, Bac Me Reserve, Phia Oac-Phia Den National Park and Nam Xuan Lac Reserve)*

2.5.2.3. Benefits transfer method for ecosystem service estimation

The general methodology to estimate ecosystem services (provisioning, regulating, supporting and cultural) is to combine methods of remote sensing, GIS and value transfer method and descriptive statistical methods, used for research sites.

One of the methods of evaluating ecosystem services, which are applied to the assessment of an overall ecosystem service, in the context of limited data and resources, is the value transfer method or benefits transfer method [2]. Benefits transfer method (BT) is short-cut method for generating economic value estimates for

[2] See http://www.aboutvalues.net/method_database/

ecosystem services based on the use of appropriately adjusted primary valuation estimates from other studies.

This method can be applied to estimate all the ecosystem services, but the use of this method depends on the location of the study site and the objective of the evaluation. The strength of this approach is generally lower cost with quantitative studies that collect primary data, which are conducted relatively quickly and can be used as a pre-evaluation technique before carrying out larger studies. The limitation of this method is that it depends much on the results of available studies, which are suitable or similar to your study site, as with the nature reserve or national park.

The linkage between ecosystem services being (provisioning, regulating, supporting and cultural) and human well-being are presented in Figure 4 below.

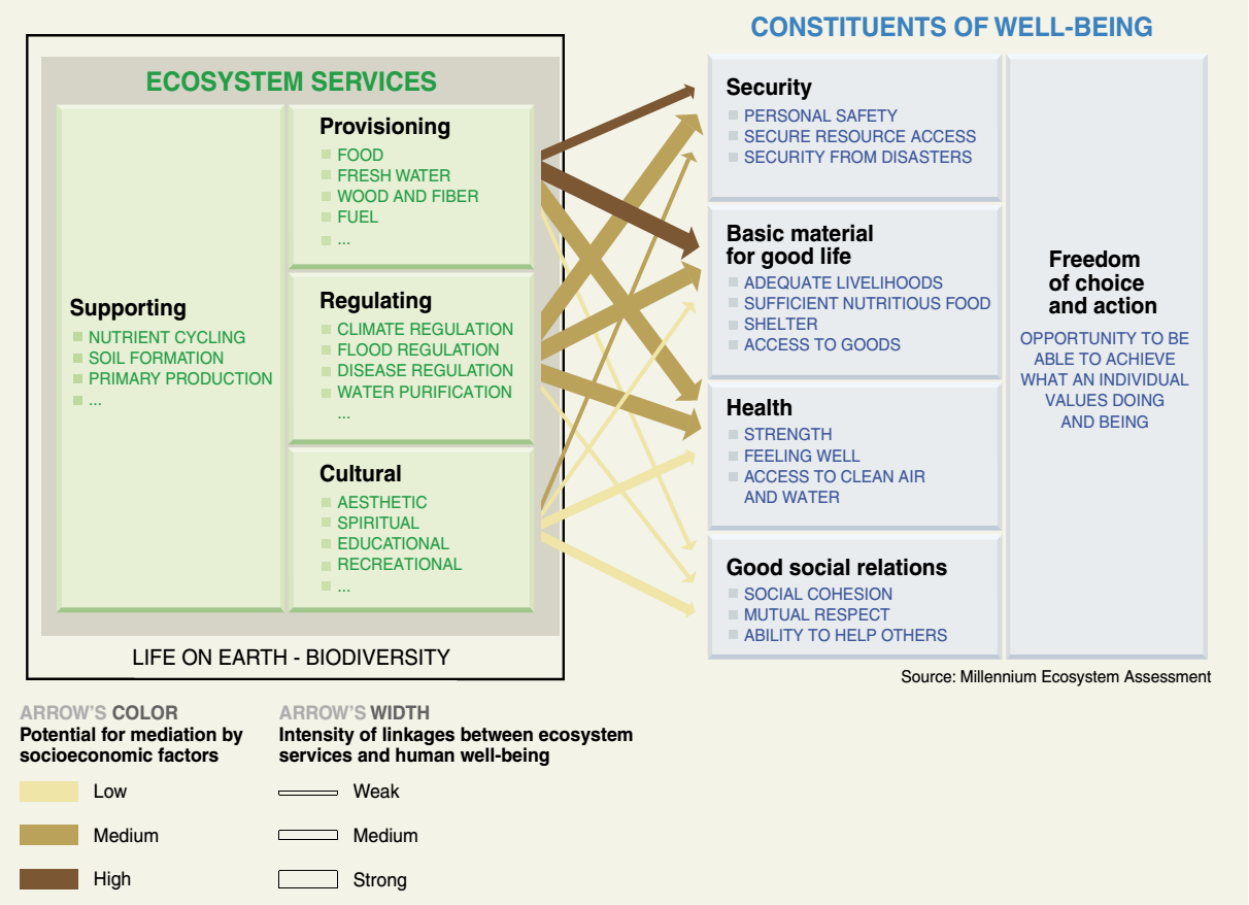


Figure 4. *The linkage between Ecosystem Service and Human Well-being (MA, 2005)*

The method of value transfer (Rudolf de Groot et al., 2012, Table 1, page 55) is used to calculate the Indexes of ecosystem services (provisioning, regulating, cultural and supporting) for different types of land use (Close Forest, Open Forest, Bush, Agricultural land/Paddy, Fresh water) for study sites (Cham Chu NR, Bac Me NR, Phia Oac-Phia Den NP and Nam Xuan Lac NR). Some indexes/functions not defined by de Groot et al., (2012) were added from the methodology developed by Costanza et al.,

(1997: Table 2, p 256) for Function for Pollination (regulating ecosystem service) for the land use type is Agricultural land/Paddy. The index/function of the ecosystem service provided by the agricultural land/Paddy land use type is estimated from the statistics of production value (VND converted to USD) per 1 hectare of arable land.

Table 12 presents monetary values for provisioning ecosystem service per land use type (Close forest, Open forest, Bushes/Grassland, Bushes/Grassland, Bareland, Agricultural land / Paddy, Fresh water) derived from analysis of remote sensing image for study sites.

Table 12. *Summary of monetary values for provisioning ecosystem service (in USD/ha/year) by land use type for study sites*

No	**Provisioning Ecosystem services by landuse type**	***Value (USD/ha/year)***	***Source***
1	**Close forest,** including + Food + Water + Raw materials + Genetic resources + Medicinal resources	**1828** 200 27 84 13 1504	Rudolf de Groot et al., 2012: Table 1, p 55
2	**Open forest,** including + Food + Water + Raw materials + Genetic resources + Medicinal resources	**1828** 200 27 84 13 1504	Rudolf de Groot et al., 2012: Table 1, p 55
3	**Bushes/Grassland,** including + Food + Water + Raw materials	**1305** 1192 60 53	Rudolf de Groot et al., 2012: Table 1, p 55
4	**Bareland**	**0**	
5a	**Agricultural land/Paddy (Cham Chu NR)**	**3290***	Estimated for Cham Chu Reserve from Statistical yearbooks of Ham Yen and Chiem Hoa districts in 2017 (Tuyen Quang province)
5b	**Agricultural land/Paddy (Bac Me NR)**	**1340.8****	Estimated for Bac Me Reserve from Statistical yearbooks of Bac Me distric (Ha Giang province)
5c	**Agricultural land/Paddy (Phia Oac-Phia Den NP)**	**270*****	Estimated for PO-PD national park from Statistical yearbooks of Cao Bang province)

5d	**Agricultural land/Paddy (Nam Xuan Lac)**	**2333,2**	Estimated for Bac Me Reserve from Statistical yearbooks of Cho Don district for 2017) (53.5 million VND/ha huyện Chợ Đồn) (1USD=22930VNĐ) (2333.2USD)
6	**Fresh water** (River, lake), including + Food + Water	**1914** 106 1808	Rudolf de Groot et al., 2012: Table 1, p 55

** Values of cropland per hectare per year for 2017 are mean values for Ham Yen and Chiem Hoa districts.*

Table 13 presents monetary values for regulating ecosystem service per land use type (Close forest, Open forest, Bushes/Grassland, Bushes/Grassland, Bareland, agricultural land / Paddy, Fresh water) derived from analysis of remote sensing image for study sites.

Table 13. *Summary of monetary values for regulating ecosystem service (in USD/ha/year) by land use type for study sites*

No	**Regulating Ecosystem services by landuse type**	***Value (USD/ha/year)***	***Source***
1	**Close forest,** including	**2529**	Rudolf de Groot et al., 2012: Table 1, p 55
	(i) Air quality regulation	12	
	(ii) Climate regulation	2044	
	(iii) Disturbance moderation	66	
	(iv) Regulation of water flow	342	
	(v) Waste treatment	6	
	(vi) Erosion prevention	15	
	(vii) Nutrient cycling	3	
	(viii) Pollination	30	
	(ix) Biological control	11	
2	**Open forest,** including	**2529**	Rudolf de Groot et al., 2012: Table 1, p 55;
	(i) Air quality regulation	12	
	(ii) Climate regulation	2044	
	(iii) Disturbance moderation	66	
	(iv) Regulation of water flow	342	
	(v) Waste treatment	6	
	(vi) Erosion prevention	15	
	(vii) Nutrient cycling	3	
	(viii) Pollination*	30	
	(ix) Biological control	11	
3	**Bushes/Grassland,** including	**184**	Rudolf de Groot et al., 2012: Table 1, p 55; Costanza et al., 1997: Table 2, p 256,
	(ii) Climate regulation	40	
	(v) Waste treatment	75	
	(vi) Erosion prevention	44	
	(viii) Pollination*	25	

4	**Bareland**	**NA**	
5	**Agricultural land/Paddy**, including (viii) Pollination*	**25** 25	Costanza et al., 1997: Table 2, p 256,
6	**Fresh water** (River, lake), including (iv) Regulation of water flow	**187** 187	Rudolf de Groot et al., 2012: Table 1, p 55

*Source: Costanza et al., 1997: Table 2, p 256,

Table 14 presents monetary values for supporting ecosystem service per land use type (Close forest, Open forest, Bushes/Grassland, Bushes/Grassland, Bareland, agricultural land / Paddy, Fresh water) derived from analysis of remote sensing image for study sites.

Table 14. *Summary of monetary values for supporting ecosystem service (in USD/ha/year) by land use type for study sites*

No	**Supporting Ecosystem services by landuse type**	***Value (USD/ha/year)***	***Source***
1	**Close forest,** including + Nursery service + Genetic diversity	**39** 16 23	Rudolf de Groot et al., 2012: Table 1, p 55
2	**Close forest,** including + Nursery service + Genetic diversity	**39** 16 23	Rudolf de Groot et al., 2012: Table 1, p 55;
3	**Bushes/Grassland,** including + Nursery service + Genetic diversity	**1214** - 1214	Rudolf de Groot et al., 2012: Table 1, p 55;
4	**Bareland**	**NA**	
5	**Agricultural land/Paddy**	**NA**	Costanza et al., 1997: Table 2, p 256,
6	**Fresh water** (River, lake)	**NA**	Rudolf de Groot et al., 2012: Table 1, p 55

*Source: Costanza et al., 1997: Table 2, p 256,

Table 15 presents monetary values for cultural ecosystem service per land use type (Close forest, Open forest, Bushes/Grassland, Bushes/Grassland, Bareland, agricultural land / Paddy, Fresh water) derived from analysis of remote sensing image for study sites.

Table 15. *Summary of monetary values for cultural ecosystem service (in USD/ha/year) by land use type for study sites*

No	**Cultural Ecosystem services by landuse type**	**Value (USD/ha/year)**	**Source**
1	**Close forest,** including Recreation	**867** 867	Rudolf de Groot et al., 2012: Table 1, p 55

2	**Open forest,** including Recreation	**867** 867	Rudolf de Groot et al., 2012: Table 1, p 55;
3	**Bushes/Grassland,** including Recreation	**26** 26	Rudolf de Groot et al., 2012: Table 1, p 55;
4	**Bareland**	**NA**	
5	**Agricultural land/Paddy**, including Recreation	**NA**	
6	**Fresh water** (River, lake), including Recreation	**2166** 2166	Rudolf de Groot et al., 2012: Table 1, p 55

*Source: Costanza et al., 1997: Table 2, p 256,

Thus, the monetary values for the entire ecosystem services (provisioning regulating, cultural, supporting) by land use types for the study sites are presented in the tables 16, 17, 18 and 19.

Table 16. *Summary of monetary values for entire ecosystem services (in USD/ha/year) by land use type for Cham Chu Reserve*

No	Entire ecosystem services by landuse type	Value (USD/ha/year)				
		Provisioning	*Regulating*	*Suppoting*	*Cultural*	*Total*
1	**Close forest**	1,828	2,529	39	867	5,263
2	**Open forest**	1,828	2,529	39	867	5,263
3	**Bushes/Grassland**	1,305	184	1,214	26	2,729
4	**Agricultural land/Paddy**	**3,290**	25	-	-	**3,315**
5	**Bareland**	-	-	-	-	-
6	**Fresh water/River**	1,914	187	-	2,166	**4,267**

Table 17. *Summary of monetary values for entire ecosystem services (in USD/ha/year) by land use type for Bac Me Nature Reserve*

No	Entire ecosystem services by landuse type	Value (USD/ha/year)				
		Provisioning	*Regulating*	*Suppoting*	*Cultural*	*Total*
1	**Close forest**	1,828	2,529	39	867	5,263
2	**Open forest**	1,828	2,529	39	867	5,263
3	**Bushes/Grassland**	1,305	184	1,214	26	2,729
4	**Agricultural land/Paddy**	**1,340.8**	25	-	-	**1,365.8**
5	**Bareland**	-	-	-	-	-
6	**Fresh water/River**	1,914	187	-	2,166	4,267

Table 18. *Summary of monetary values for entire ecosystem services (in USD/ha/year) by land use type for Phia Oac-Phia Den National Park*

No	Entire ecosystem services by landuse type	Value (USD/ha/year)				
		Provisioning	*Regulating*	*Suppoting*	*Cultural*	*Total*
1	**Close forest**	1,828	2,529	39	867	5,263
2	**Open forest**	1,828	2,529	39	867	5,263
3	**Bushes/Grassland**	1,305	184	1,214	26	2,729
4	**Agricultural land/Paddy**	**270**	25	-	-	**295**
5	**Bareland**	-	-	-	-	-

Table 19. *Summary of monetary values for entire ecosystem services (in USD/ha/year) by land use type for Nam Xuan Lac Nature Reserve*

No	Entire ecosystem services by landuse type	Value (USD/ha/year)				
		Provisioning	*Regulating*	*Suppoting*	*Cultural*	*Total*
1	**Close forest**	1,828	2,529	39	867	5,263
2	**Open forest**	1,828	2,529	39	867	5,263
3	**Bushes/Grassland**	1,305	184	1,214	26	2,729
4	**Agricultural land/Paddy**	**2,333.2**	25	-	-	**2,358**
5	**Bareland**	-	-	-	-	-
6	**Fresh water/River**	1,914	187	-	2,166	4,267

2.6. Results

2.6.1. Landuse and landcover change

2.6.1.1. Landuse and landcover change in Cham Chu Reserve during 1986-2017

(1). Landuse/landcover in the communes of Cham Chu Reserve during period 1986-2017

Cham Chu Nature Reserve is located in the administrative boundaries of 5 communes: Trung Ha, Ha Lang and Hoa Phu in Chiem Hoa district; Yen Thuan and Phu Luu Ham Yen district, Tuyen Quang province.

The total area of the reserve is 15,262.3 ha, including 6,168.4 ha in Ham Yen district and 9,093.9 ha in Chiem Hoa district. The information related to forest cover is shown in Table 5.

Table 20 shows a breakdown of the land-cover in hectares and by percent for the classes described above for the whole area.

Table 20. *Area of land cover-land use of Cham Chu Nature Reserve*

Land cover type	1986		1998		2007		2017	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Close forest	24,410	60.4%	23,962	59.2%	23,230	57.4%	25,786	63.8%
Open forest	6,199	15.3%	6,581	16.3%	5,806	14.4%	5,122	12.7%
Bush	4,017	9.9%	3,791	9.4%	4,573	11.3%	1,489	3.7%
Open bare land	3,456	8.5%	4,070	10.1%	4,165	10.3%	6,161	15.2%
Paddy	1,905	4.7%	1,854	4.6%	2,471	6.1%	1,775	4.4%
Water	160	0.4%	188	0.5%	115	0.3%	113	0.3%
Cloud cover	297	0.7%	-	0.0%	86	0.2%	-	0.0%
Total area	40,445	100.0%	40,445	100%	40,445	100%	40,445	100%

The results for the land-cover classification of Cham Chu Reserve during the last 40 years (1986-2017) indicate forest cover has not been changed much. It suggests that there are large areas of the reserve, about 60%, that are still in evergreen forest, either primary evergreen forest or secondary or disturbed evergreen forest. The areas of evergreen forest that are far into the core of the reserve are most likely primary forest, probably some of the last primary forest left in Vietnam. The evergreen forest that is closer to the edge of the reserve or in the buffer area has most likely been selectively logged, or may even, in some cases, be secondary forest that has grown back after a swiddening cycle. Looking at the derived vegetation maps, it is easily seen that the amount of evergreen forest decreases as one moves into the buffer area around the reserve.

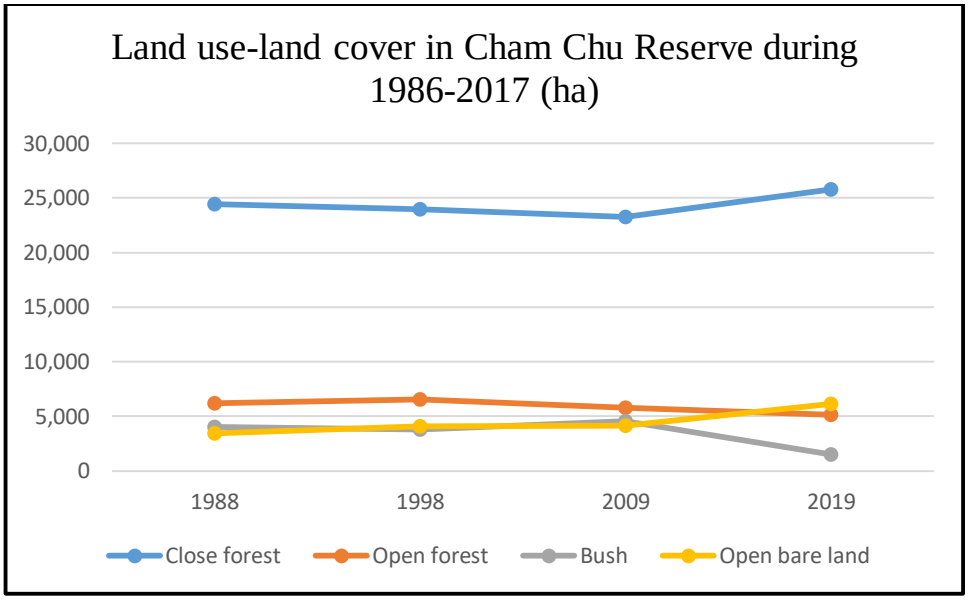


Figure 5. *Land use-land cover in Cham Chu Reserve during 1988-2019 (ha)*

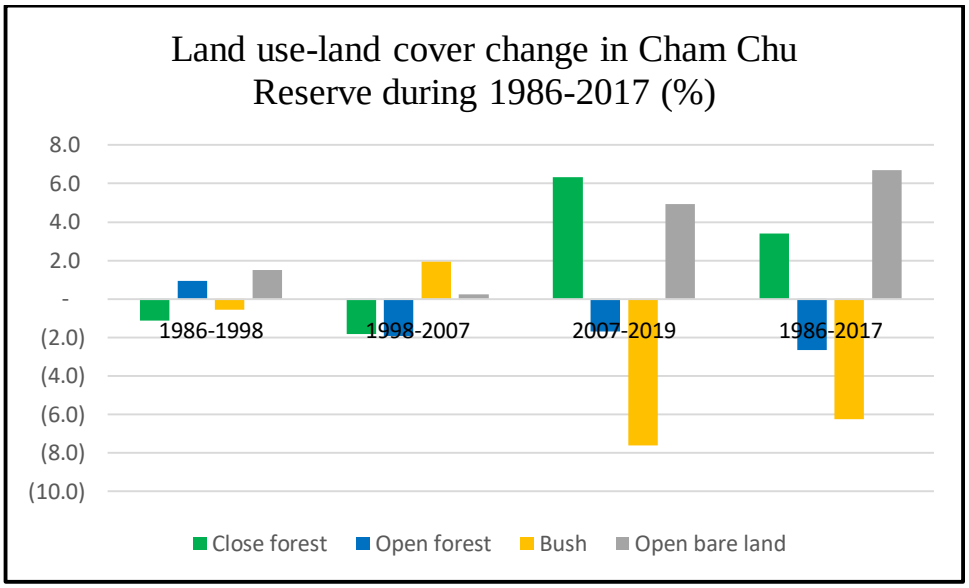


Figure 6. *Land use-land cover change in Cham Chu Reserve during 1988-2019 (%)*

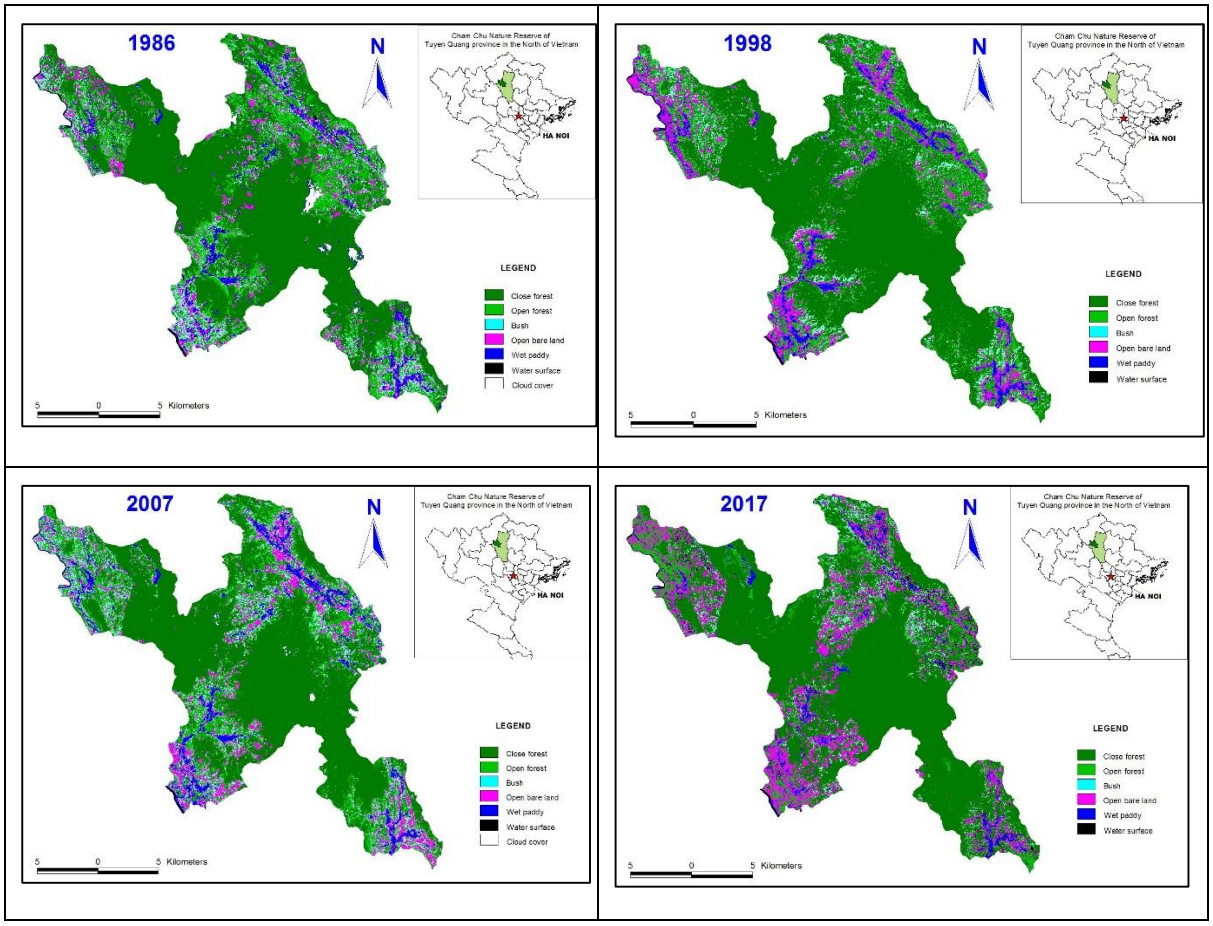


Figure 7. *Evolution of land use and land cover change for Cham Chu Reserve during 1986 – 2017*

(2). Landuse and landuse/landcover change by communes of Cham Chu Reserve during period 1986-2017

Tables 21, 22, 23 and 24 show the current landuse/landcover for 5 communes in Cham Chu Reserve for 1986, 1998, 2007 and 2007, extracted from analysis of satellite images.

Table 21. Land use / Land cover for communes of Cham Chu Reserve in 1986.

Unit: Ha

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)						
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	Others
I	***Ham Yen district***	***16445.7***	***9883.26***	***2304.81***	***1807.83***	***1506.87***	***818.01***	***124.83***	***0,09***
1	Phu Luu	8913.87	5163.12	1357.83	1030.41	761.13	536.49	64.8	0,09
2	Yen Thuan	7531.83	4720.14	946.98	777.42	745.74	281.52	60.03	0
II	***Chiem Hoa district***	***23999.49***	***14526.45***	***3894.66***	***2209.59***	***1949.31***	***1086.66***	***35.55***	***297,27***
1	Trung Ha	10285.29	6546.15	1645.29	753.21	842.22	440.91	20.34	37,17
2	Ha Lang	7818.57	4805.55	1335.78	628.92	566.37	229.05	10.8	242,1
3	Hoa Phu	5895.63	3174.75	913.59	827.46	540.72	416.7	4.41	18

Total	**40445.19**	**24409.71**	**6199.47**	**4017.42**	**3456.18**	**1904.67**	**160.38**	**297.36**

Table 22. Land use / Land cover for communes of Cham Chu Reserve in 1998.

Unit: Ha

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)						
			Close forest	Open forest	Bushes	Bare land	Agricultural land/ Paddy	Water	Others
I	***Ham Yen district***	***16445.7***	***9243.45***	***2338.83***	***1636.47***	***2144.61***	***931.41***	***150,93***	**-**
1	Phu Luu	8913.87	5211.99	1249.38	743.4	1046.88	599.31	62,91	-
2	Yen Thuan	7531.83	4031.46	1089.45	893.07	1097.73	332.1	88,02	-
II	***Chiem Hoa district***	***23999.49***	***14718.06***	***4241.97***	***2154.78***	***1925.10***	***922.41***	***37,17***	**-**
1	Trung Ha	10285.29	6489.18	1681.56	867.6	865.08	365.4	16,47	-
2	Ha Lang	7818.57	5219.1	1290.78	590.94	505.35	198.63	13,77	-
3	Hoa Phu	5895.63	3009.78	1269.63	696.24	554.67	358.38	6,93	-
Total		**40445.19**	**23961.51**	**6580.80**	**3791.25**	**4069.71**	**1853.82**	**188.10**	**-**

Table 23. Land use / Land cover for communes of Cham Chu Reserve in 2007.

Unit: Ha

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)						
			Close forest	Open forest	Bushes	Bare land	Agricultural land/ Paddy	Water	Others
I	***Ham Yen district***	***16445.7***	***8515.71***	***2705.22***	***2116.08***	***1859.13***	***1166.04***	***82.17***	***1,35***
1	Phu Luu	8913.87	4638.87	1376.37	975.24	1194.03	686.70	42.21	0,45
2	Yen Thuan	7531.83	3876.84	1328.85	1140.84	665.10	479.34	39.96	0,90
II	***Chiem Hoa district***	***23999.49***	***14714.01***	***3100.68***	***2456.82***	***2306.07***	***1305.00***	***32.40***	***84,51***
1	Trung Ha	10285.29	6131.97	1341.72	1125.54	1032.57	628.20	15.39	9,90
2	Ha Lang	7818.57	5223.15	979.38	641.79	534.87	355.23	9.90	74,25
3	Hoa Phu	5895.63	3358.89	779.58	689.49	738.63	321.57	7.11	0,36
Total		**40445.19**	**23229.72**	**5805.90**	**4572.90**	**4165.20**	**2471.04**	**114.57**	**85.86**

Table 24. Land use / Land cover for communes of Cham Chu Reserve in 2017.

Unit: Ha

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)						
			Close forest	Open forest	Bushes	Bare land	Agricultural land/ Paddy	Water	Others
I	***Ham Yen district***	***16445.7***	9514.17	2376.45	452.25	3222.45	788.76	91,62	-
1	Phu Luu	8913.87	5249.34	942.57	264.42	1949.40	466.74	41,40	-

2	Yen Thuan	7531.83	4264.83	1433.88	187.83	1273.05	322.02	50,22	-
II	***Chiem Hoa district***	***23999.49***	16271.46	2745.63	1037.07	2938.32	986.13	20,88	-
1	Trung Ha	10285.29	6208.38	1359.72	629.82	1624.41	455.58	7,38	-
2	Ha Lang	7818.57	5893.92	769.68	260.73	662.67	223.83	7,74	-
3	Hoa Phu	5895.63	4169.16	616.23	146.52	651.24	306.72	5,76	-
Total		**40445.19**	25785.63	5122.08	1489.32	6160.77	1774.89	112.50	-

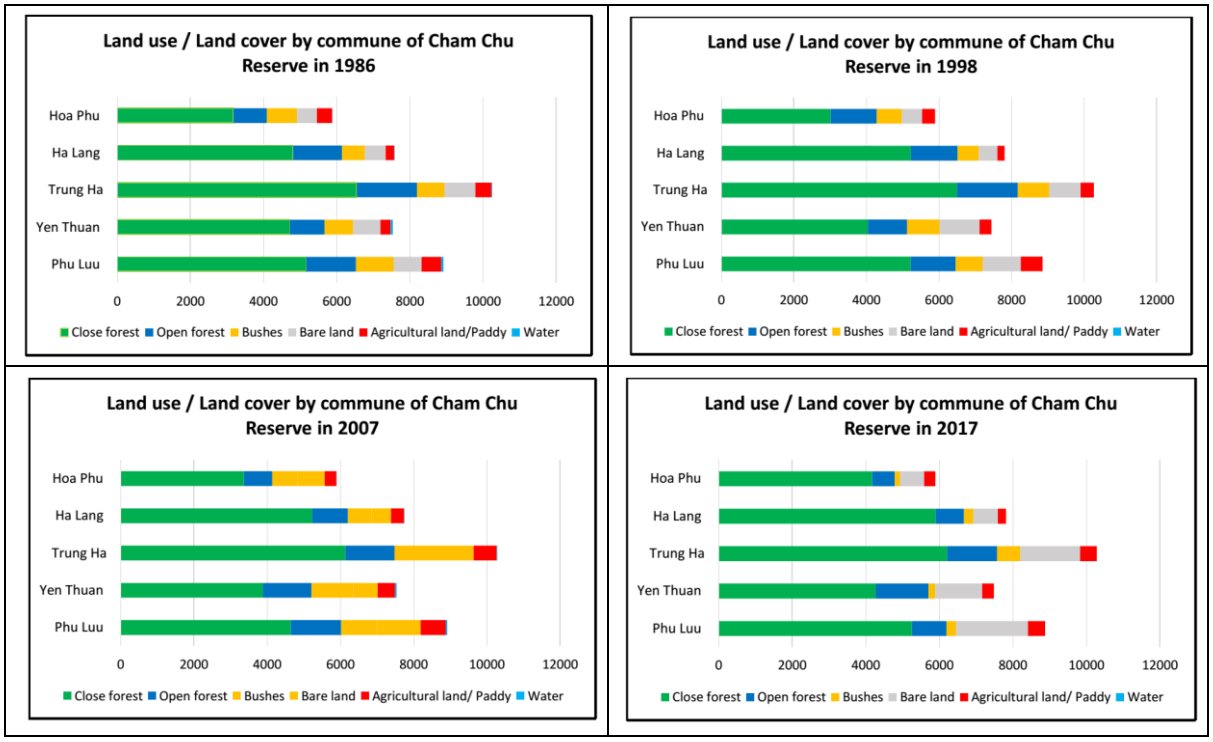


Figure 8. *Land use-land cover in Cham Chu Reserve by commune during 1986-2017 (ha)*

(3). Landuse and landuse/landcover change by altitude of Cham Chu Reserve during period 1986-2017

The landuse and landcover by altitude in Cham Chu Reserve for the years of 1998, 1998, 2009, 2019 is presented in Tables 25, 26, 27 và 28 and the topographic map is presented in Figure 9.

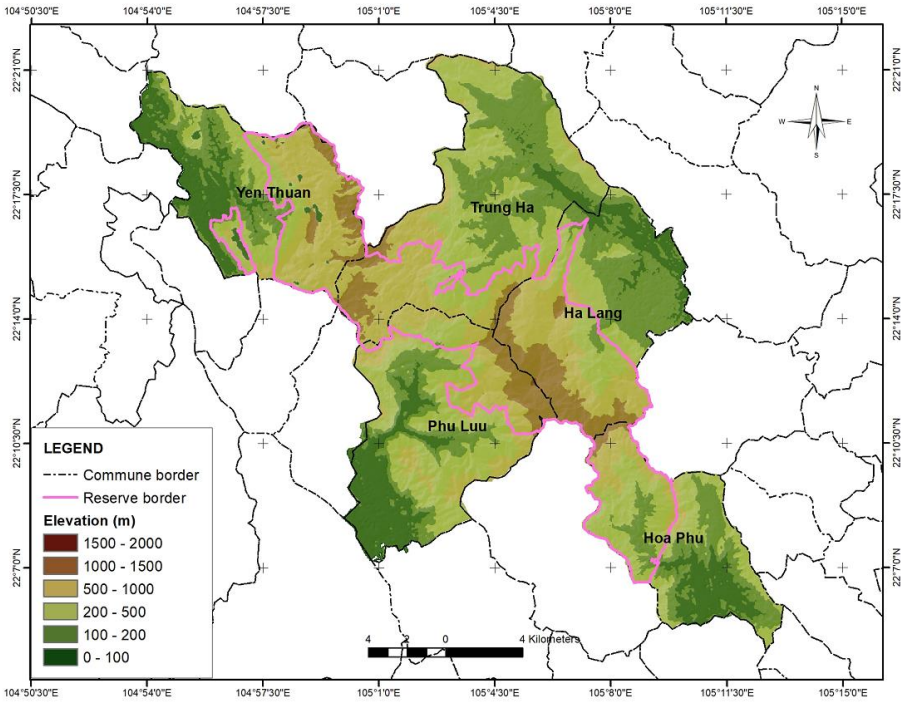


Figure 9. *Topographic map of Cham Chu Reserve*

Table 25. *Land use / Land cover by altitude of Cham Chu Reserve in 1986*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	Others	Total
0 - 100	885.82	806.09	1,538.35	1,042.98	1,050.63	130.8	8.54	5,463.22
100 - 200	3,602.55	2,727.10	1,545.81	1,049.39	507.22	26.3	14.63	9,472.99
200 - 500	8,233.05	2,358.49	797.62	1,121.15	208.98	9.04	43.66	12,772.00
500 - 1000	8,584.55	261.92	76.27	206.08	130.43	9.35	238.3	9,506.91
1000 - 1500	3,147.42	9.51	8.7	12.3	14.42		23.09	3,215.45
1500 - 2000	14.63							14.63
Total	24,468.02	6,163.12	3,966.76	3,431.89	1,911.69	175.49	328.22	40,445.19

Table 26. *Land use / Land cover by altitude of Cham Chu Reserve in 1998*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Others*	*Total*
0 - 100	453.94	1,050.63	379.03	2,014.76	1,396.42	168.63		5,463.41
100 - 200	3,364.45	2,494.41	1,586.94	1,601.11	403.54	22.62		9,473.05

200 - 500	8,433.29	2,354.03	1,520.46	422.91	30.76	10.45		12,771.91
500 - 1000	8,659.70	513.18	210.35	82.89	31.24	9.8		9,507.16
1000 - 1500	3,133.00	39.71	20.87	12.84	7.73			3,214.15
1500 - 2000	15.52							15.52
Total	24,059.89	6,451.96	3,717.65	4,134.50	1,869.69	211.5	-	40,445.19

Table 27. *Land use / Land cover by altitude of Cham Chu Reserve in 2007*

Unit: ha

Altitude (m)	**Close forest**	**Open forest**	**Bushes**	**Bare land**	**Agricultural land/Paddy**	**Water**	***Others***	***Total***
0 - 100	316.33	930.52	1,263.21	1,254.03	1,598.61	94.98	8.64	5,466.31
100 - 200	2,463.88	2,485.83	2,024.79	1,750.42	719.34	23.73	8.26	9,476.25
200 - 500	8,450.54	1,978.40	1,167.96	1,057.02	103	9.14	9.23	12,775.27
500 - 1000	8,866.30	245.04	118.35	91.24	89.84	8.59	91.13	9,510.51
1000 - 1500	3,177.80	8.43	7.1	8.89				3,202.22
1500 - 2000	14.62							14.62
Total	23,289.47	5,648.21	4,581.41	4,161.60	2,510.79	136.44	117.26	40,445.19

Table 28. *Land use / Land cover by altitude of Cham Chu Reserve in 2017*

Unit: ha

Altitude (m)	**Close forest**	**Open forest**	**Bushes**	**Bare land**	**Agricultural land/Paddy**	**Water**	***Others***	***Total***
0 - 100	675.3	1,673.90	140.84	1,953.29	923.79	98.04		5,465.16
100 - 200	4,266.05	1,780.18	600.42	2,300.94	505.5	21.91		9,475.00
200 - 500	8,847.90	1,285.30	671.73	1,800.61	158.66	9.73		12,773.93
500 - 1000	8,866.48	237.96	62.5	172.31	159.46	10.45		9,509.15
1000 - 1500	3,177.01	11.52	7.76		10.13			3,206.43
1500 - 2000	15.52							15.52
Total	25,848.27	4,988.86	1,483.25	6,227.15	1,757.54	140.13	-	40,445.19

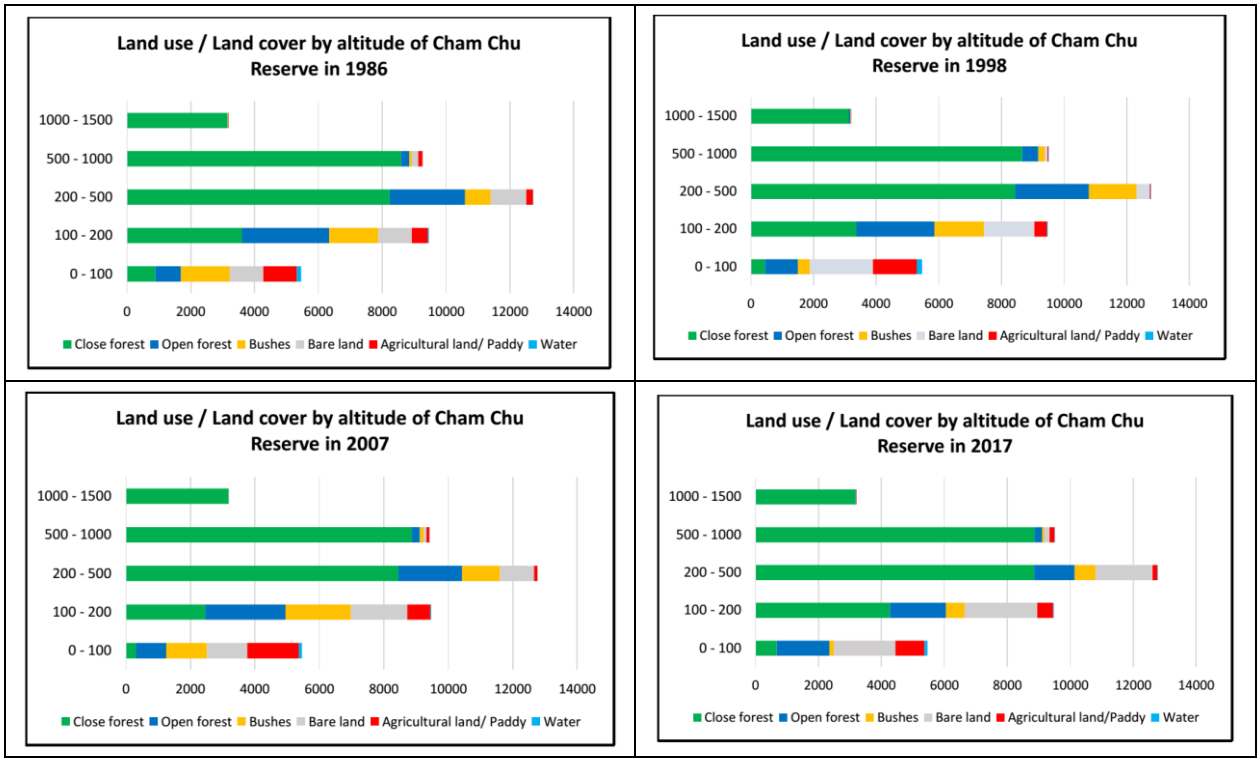


Figure 10. *Land use-land cover in Cham Chu Reserve by altitude during 1986-2017 (ha)*

In summary, the characteristics of land use and land cover of Cham Chu Reserve are the followings:

i). In general, the area of close forest (or closed-canopy forest as such evergreen broad-leaved tropical forest...) has a large coverage, accounting for more than 60% of the area in the communes of the Reserve; Open forest, or the form of degraded close forest at different levels, accounting for a certain percentage, about 15%, but this land use type has a decreasing trend, mainly due to the process of natural regeneration of forests;

In the period 1986-1998 and 1998-2007, the types of land use have not changed much, but in the period 2007-2017, the area of close forest is increased rapidly due to a decrease in the area of bushes, mainly due to the natural restoration of the forest and reforestation programs and increased bare land, probably due to the expansion of agricultural crops (orange trees). Thus, in the period 1986-2017, the area of close forest and bare land also increased, on the basis of a decrease in bush area and open forest.

ii). By commune, the area of close forest is distributed fairly evenly in the communes of the Cham Chu Reserve, but 2 communes in Chiem Hoa district (Ha Lang and Trung Hoa) have the dominant area; The large areas of bare land, bushes and

agricultural land (including shifting cultivation) are concentrated in 2 communes Phu Luu, where the area for oranges is the largest in the Reserve, Yen Thuan commune (Ham Yen district) and Trung Ha commune (Chiem Hoa district).

iii). By altitude, most of close forest are concentrated in the elevation zones ranging from 200m - 1500m, in which the elevation zone greater than 1500m is covered mainly by close forest.

Areas of open forest and bushes are concentrated in the high elevation zones ranging from 100 m – 500 m, where reforestation activities, forest exploitation and agricultural activities are interlinked. The zone ranging from 0m - 100m is mainly agricultural land and bare land.

2.6.1.2. Landuse and landcover change Bac Me Nature Reserve during 1988-2019

Bac Me Nature Reserve is located in the administrative areas of 3 communes (Minh Ngoc, Lac Nong and Thuong Ta) in Bac Me district, with a total natural area of 8,791.8 ha, of which the forest area is 6,649.81, accounting for 75.6% of the natural area; Non-forested land 1,771.91 ha, accounting for 20.2%, the remaining land is water surface, agricultural land and other land is 370.08 ha (See Figure 11).

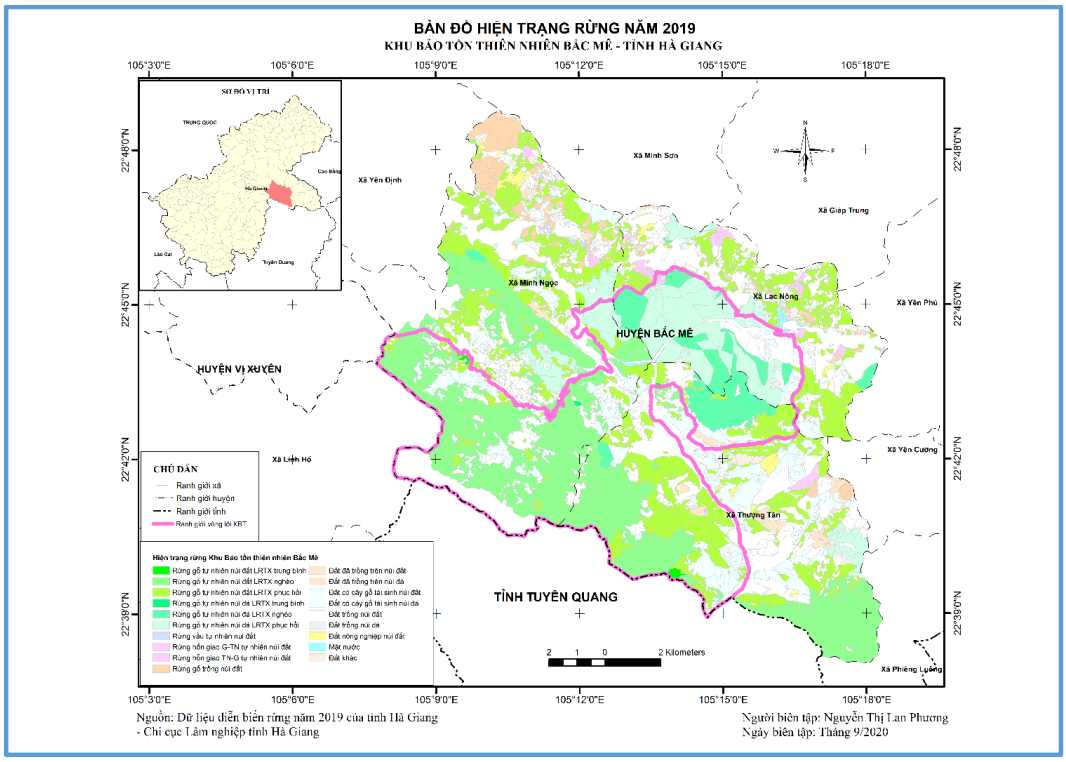


Figure 11. *Forest cover of Bac Me Nature Reserve (MARD, 2019)*

(1). Landuse and landuse/landcover change in the communes of Bac Me Nature Reserve during period 1988-2019

Table 29 shows a breakdown of the land-cover for the 3 communes covering Bac Me Nature Reserve.

Table 29. *Area of land use/land cover-for communes of Bac Me Nature Reserve during 1988-2019*

Land cover type	1988		1998		2009		2019	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Close forest	13,071	62.0	10,242	48.6	11,134	52.8	9,847	46.7
Open forest	2,748	13.0	4,676	22.2	4,210	20.0	4,660	22.1
Bush	2,989	14.2	3,544	16.8	2,818	13.4	3,395	16.1
Open bare land	1,481	7.0	1,588	7.5	2,122	10.1	1,132	5.4
Paddy	581	2.8	830	3.9	331	1.6	1,406	6.7
Water	217	1.0	207	1.0	473	2.2	647	3.1
Total area	**21,087**	**100.0**	**21,087**	**100**	**21,087**	**100**	**21,087**	**100**

Source: Remote sensing image analysis data, 2020

Note:

+ During the period 1988-2019, among 21,087 ha of Bac Me Nature Reserve communes, close forest has the largest area accounting for 62.0%, 48.6%, 52.8% and 47.6% of the total area in the years of 1988, 1998, 2009 and 2019, respectively. Open forest has the second largest area, accounting for 13.0%, 22.2%, 20.0% and 22.1%. Thus, after 30 years, the area of close forest is decreased by 15.3% and the open forest increased by 9.1% (See Figure. Graph of changes in land use). For the entire area of the Nature Reserve's communes, a part of close forest has been degraded and converted into open forest, which is in fact the secondary forest and poor forest.

+ In the period 1988-2019, areas of bush have a trend to increase, accounting for 14.2% to 16.8%, 13.4% and 16.1% of the total areas in 1988, 1998, 2009 and 2019, respectively while the area of bare land is at first increased from 7.0% in 1988, to 7.5% in 1998, and to 10.1% in 2009 and then dropped down to 5.4% in 2019. Thus, some areas of bush have converted into bare land, especially in 2019. Other land use, such as agricultural land/rice fields and water surface, occupy a small percentage and do not change significantly.

+ In summary, during the past 30 years, close forest is decreased by 15.3%, open forest increased by 9.1%, bush increased by 1.9%, bare land decreased by 1.6%, agricultural land increased by 3 .9% and water surface increased by 2.1%.

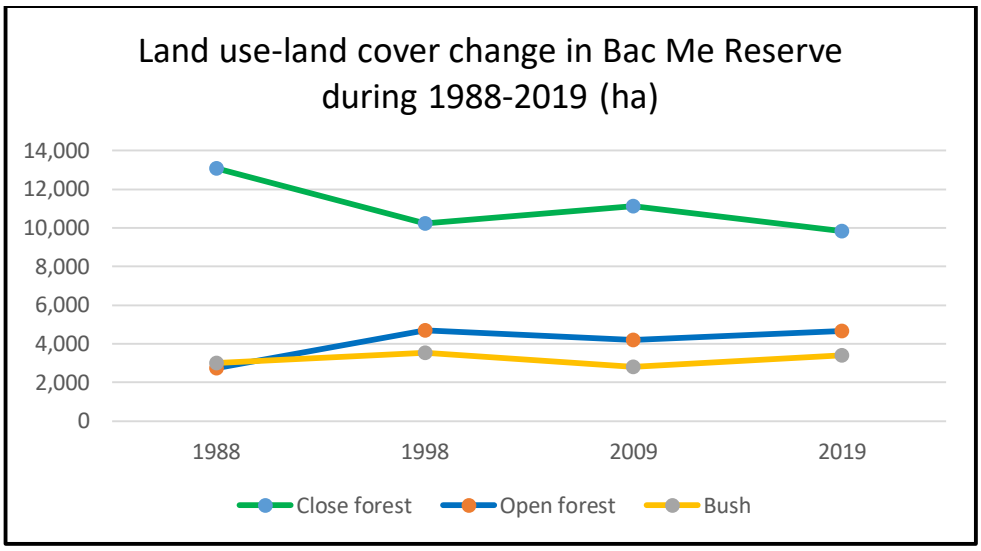


Figure 12. *Land use-land cover in Bac Me Reserve during 1988-2019 (ha)*

Regarding the landuse/landcover changes during 30 years, from 1988 to 2019, close forest decreased sharply (-3224 ha), open forest increased (+1912ha), bush increased a little (+406 ha), showing a serious degradation of close forest in quantity and quality and its conversion into other land use/land cover such as open forest and bush. Bare land has steadily increased over the years (1998: +107 ha; 2007: +641 ha), but decreased in 2019 (-349 ha) and this figure shows the clearing of vegetation during period 1988 to 2007 and natural vegetation recovering in 2019.

The landuse and landcover change for Bac Me Reserve during 1988 – 2019 is presented in the Table 30, Figure 13 and Figure 14.

Table 30. *Land use/land cover change for Bac Me Reserve during 1988 – 2019 (%)*

	1988-1998	***1998-2009***	***2009-2019***	***1998-2019***
Close forest	- 13.4	4.2	- 6.1	- 15.3
Open forest	9.1	- 2.2	2.1	9.1
Bush	2.6	- 3.4	2.7	1.9
Bare land	0.5	2.5	(4.7)	(1.7)
Paddy	1.2	- 2.4	5.1	3.9
Water	0.0	1.3	0.8	2.0

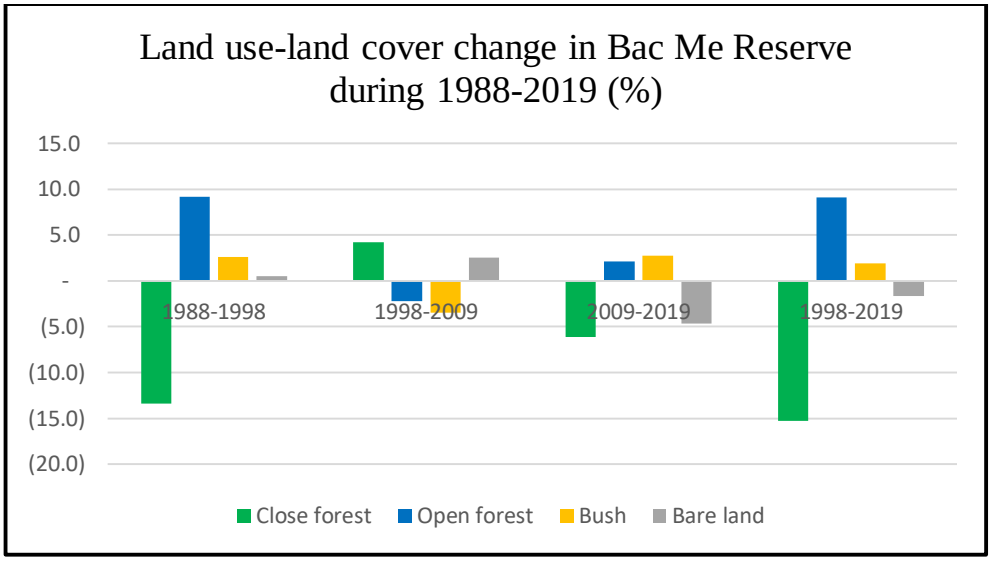


Figure 13. *Land use-land cover change in Bac Me Reserve during 1988-2019 (ha)*

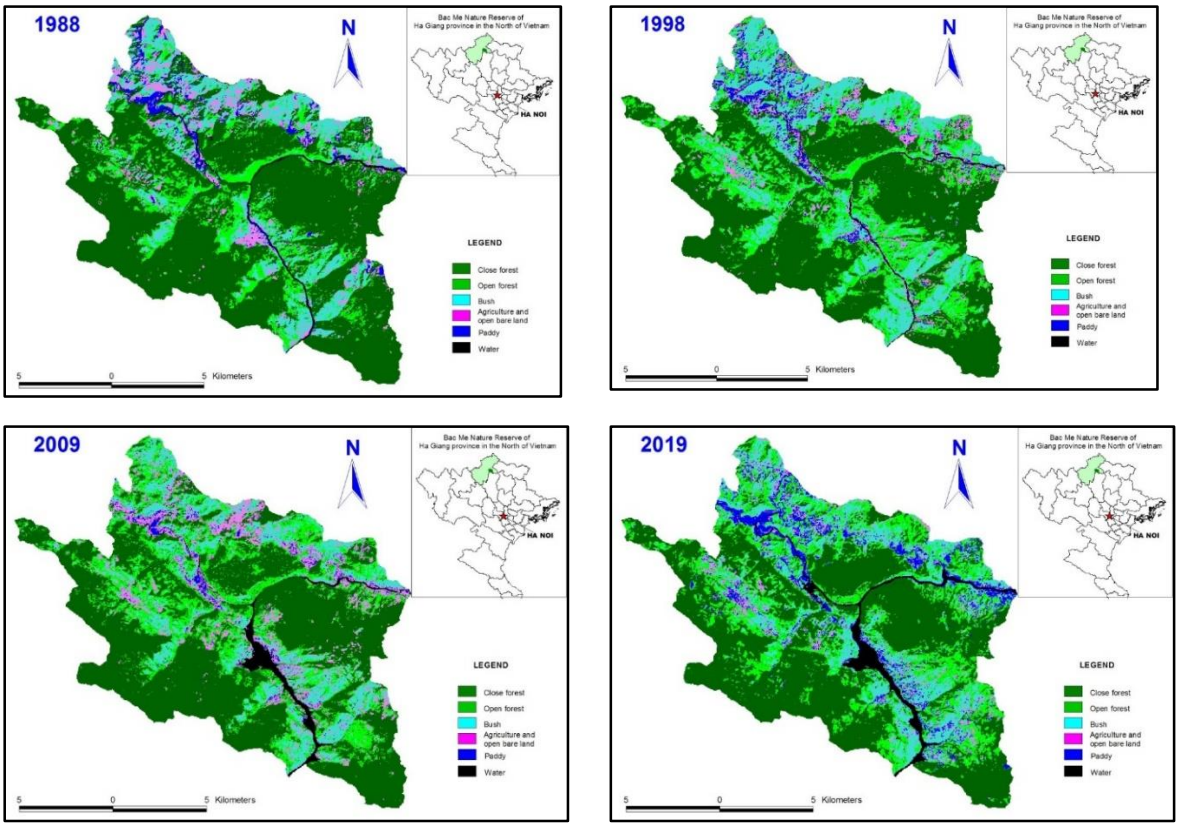


Figure 14. *Evolution of landuse and landcover change for Bac Me Nature Reserve during 1988 – 2019*

Source: Remote sensing image analysis, 2020

(2). Landuse and landuse/landcover change by communes of Bac Me Nature Reserve

during period 1988-2019

Tables 31, 32, 33 and 34 show the current landuse/landcover for 3 communes in Bac Me Nature Reserve for 1988, 1998, 2009 and 2019, extracted from analysis of satellite images.

Table 31. *Land use / Land cover for communes of Bac Me Nature Reserve in 1988*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)					
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water
1	Lac Nong	4,632	2,830	522	730	356	122	72
2	Minh Ngoc	9,260	5,555	1,238	1,233	778	378	79
3	Thuong Tan	7,195	**4,686**	988	1,026	347	82	66
Total		**21,087**	**13,071**	**2,748**	**2,989**	**1,481**	**581**	**217**

Table 32. *Land use / Land cover for communes of Bac Me Nature Reserve in 1998*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)					
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water
1	Lac Nong	4,632	2,310	893	736	498	127	67
2	Minh Ngoc	9,260	4,308	1,952	1,592	757	580	70
3	Thuong Tan	7,195	3,624	1,831	1,216	332	122	69
Total		**21,087**	**10,242**	**4,676**	**3,544**	**1,588**	**830**	**207**

Table 33. *Land use / Land cover for communes of Bac Me Nature Reserve in 2009*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)					
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water
1	Lac Nong	4,632	2,466	852	563	607	83	61
2	Minh Ngoc	9,260	4,887	2,094	1,158	901	186	35
3	Thuong Tan	7,195	3,782	1,263	1,097	614	61	377
Total		**21,087**	**11,134**	**4,210**	**2,818**	**2,122**	**331**	**473**

Table 34. *Land use / Land cover for communes of Bac Me Nature Reserve in 2019*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)					
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water
1	Lac Nong	4,632	2,187	995	769	207	358	116

2	Minh Ngoc	9,260	4,462	2,047	1,324	575	743	108
3	Thuong Tan	7,195	3,197	1,618	1,302	350	304	423
Total		**21,087**	**9,847**	**4,660**	**3,395**	**1,132**	**1,406**	**647**

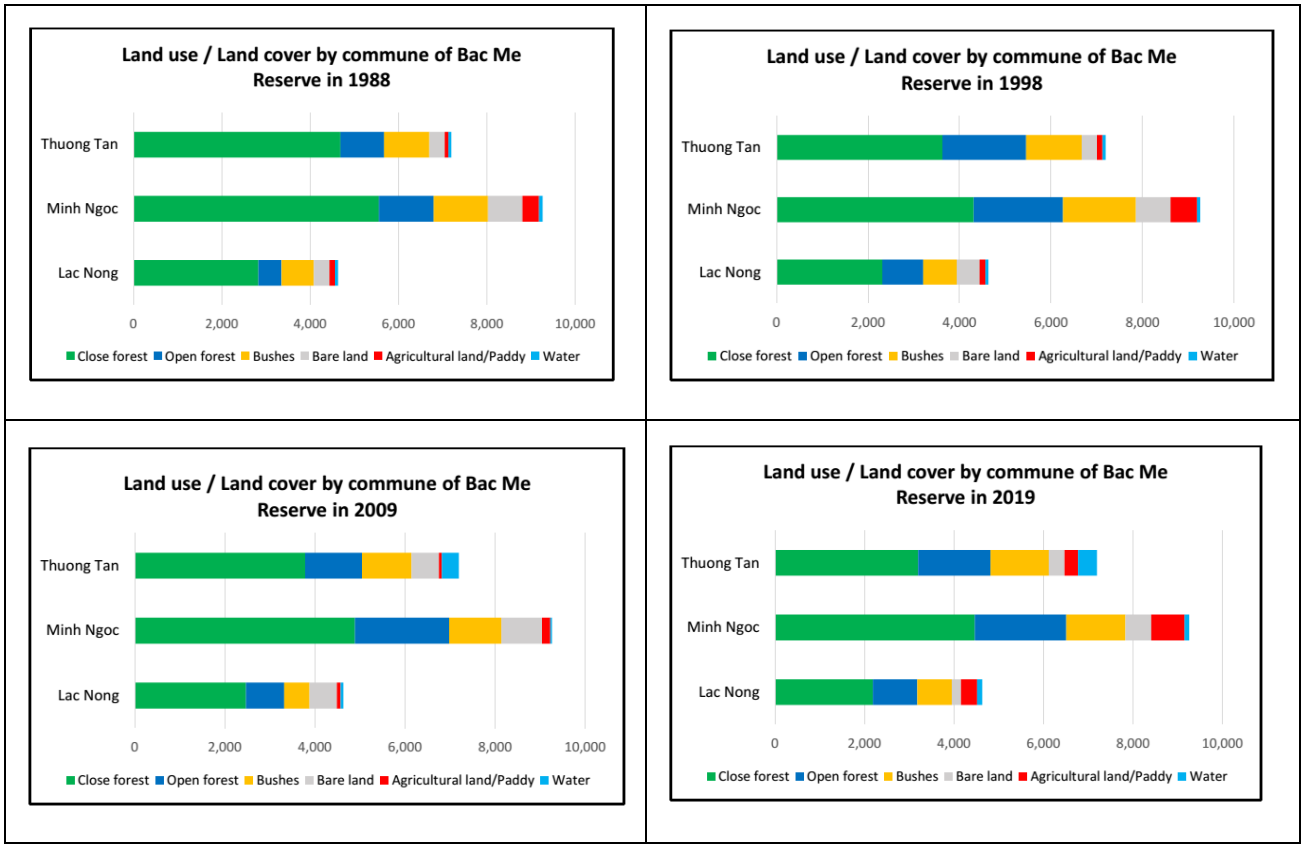


Figure 15. *Land use-land cover in Bac Me Reserve by commune during 1988-2019 (ha)*

The evolution of land use/Land cover during 1988-2009 and 1988-2019 is represented in Tables 35 and 36.

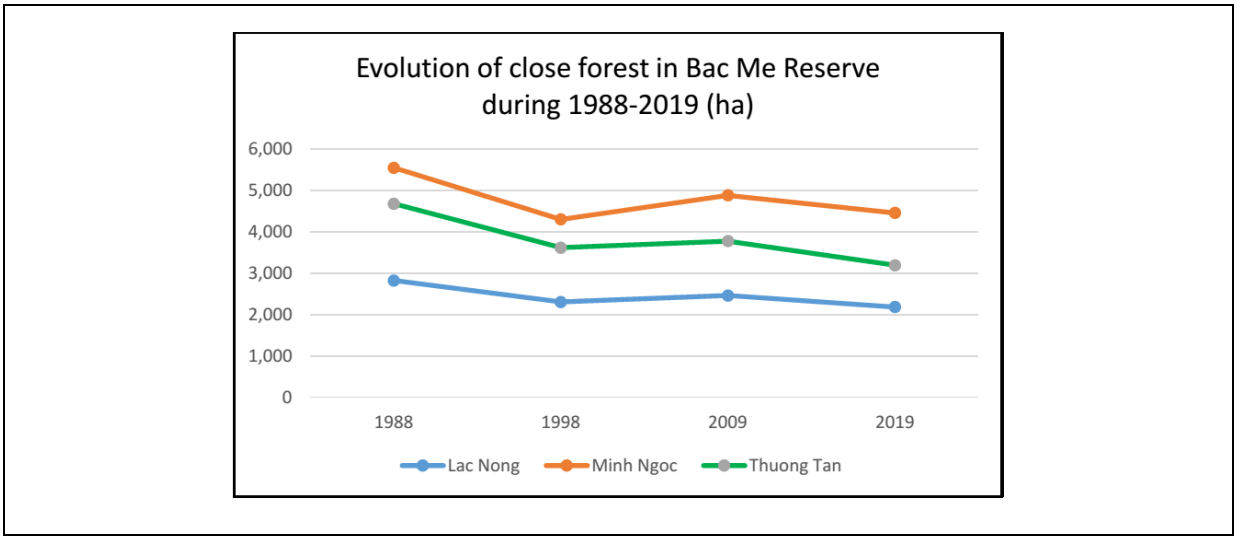
The close forest area of Bac Me Nature Reserve during the period 1988-2019 is decreased sharply, mainly in Thuong Tan commune (-1489 ha), followed by Minh Ngoc commune (-1093 ha), and Lac Nong (- 643 ha). Meanwhile, the area of open forest is increased the most in Minh Ngoc commune (+809 ha) and Thuong Tan commune (+630 ha), and lastly in Lac Nong commune. Furthermore, the largest increase in bush area occurs also in Thuong Tan commune (+276 ha) and Lac Nong commune (+39 ha). Thus, close forests, which are actually tropical evergreen forest, are most degraded in Thuong Tan and Minh Ngoc communes, and they are converted to open forest and bush.

Table 35. *Evolution of Land use / Land cover for communes of Bac Me Nature Reserve in during 1988-2009*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)					
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water
1	Lac Nong	4632	-364	330	-167	251	-39	-11
2	Minh Ngoc	9260	-668	856	-75	123	-192	-44
3	Thuong Tan	7195	-904	275	71	267	-21	311
Total		**21087**	**-1,936**	**1,461**	**-171**	**641**	**-252**	**256**

Table 36. *Evolution of landuse and landcover for communes of Bac Me Nature Reserve during 1988-2019*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)					
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water
1	Lac Nong	4,632	-643	473	39	-149	236	44
2	Minh Ngoc	9,260	-1,093	809	91	-203	365	29
3	Thuong Tan	7,195	-1,489	630	276	3	222	357
Total		**21,087**	**-3,225**	**1,912**	**406**	**-349**	**823**	**430**



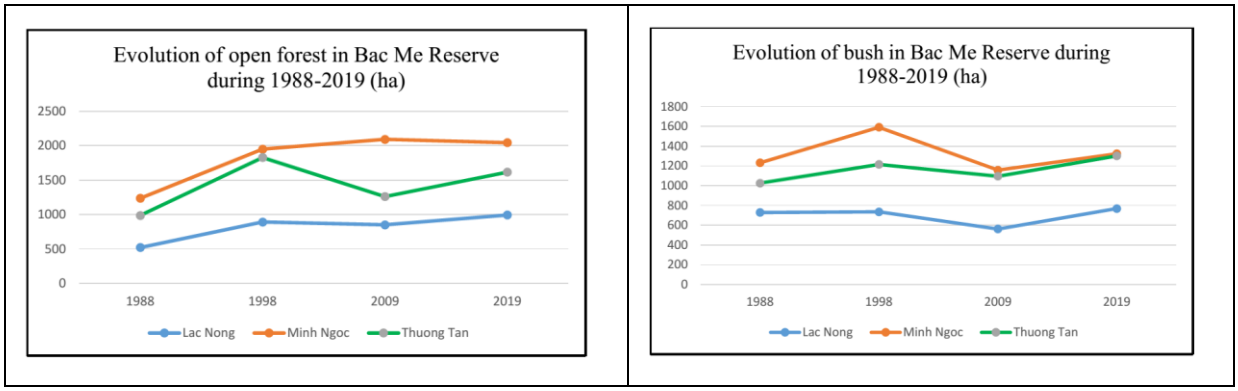


Figure 16. *Evolution of somwe landuse landcover types in Bac Me Reserve during 1988-2019 (ha)*

(3). Landuse and landuse/landcover change by altitude of Bac Me Nature Reserve during period 1988-2019

The topography of Bac Me Nature Reserve is quite diverse and complex, located in the concave area of the Gam river arc-shaped mountainous range to the southeast of Ha Giang province, with high and medium hilly terrain. The lowest elevation with about 120 m is in the reservoir of Tuyen Quang hydropower station and the highest is the Thai Giang Phin peak with 1,465 m.

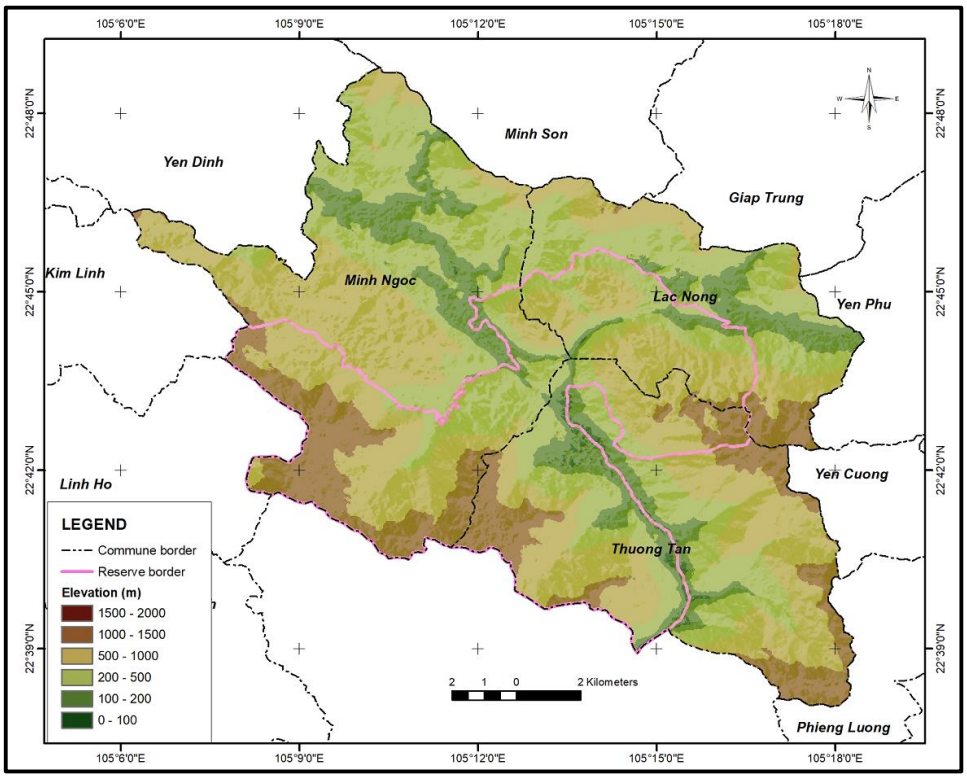


Figure 17. *Topographic map of Bac Me Nature Reserve*

The landuse and landcover by altitude in Bac Me Nature for the years of 1998,

1998, 2009, 2019 is presented in Tables 37, 38, 39, 40.

Among the types of land use and land cover of the Reserve, close forest occupies the largest area, ranging from 10,000 ha to 13,000 ha, accounting for 46-62% of the total area. In which, close forest area is mainly distributed at an altitude belt of 500 m - 1,000 m, accounting for about 45-48% of the total area of close forest of the Reserve.

Based on the classification of Vietnamese forest vegetation by Thai Van Trung (1970), close forest at an altitude belt of over 700m belongs to the type of subtropical humid evergreen broadleaved forest at medium and high mountains. Forests distributed at altitudes below 700m belong to tropical humid evergreen broadleaved forest at low mountains.

Table 37. *Landuse and landcover by altitude for communes of Bac Me Nature Reserve in 1988*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	Total
0 - 100	35.82	7.16	29.56	35.00	14.92	18.80	***141.25***
100 - 200	828.19	376.65	477.69	450.38	334.96	165.77	***2,633.65***
200 - 500	3,232.70	1,295.18	1,595.72	596.32	151.82	20.92	***6,892.65***
500 - 1000	6,010.92	965.21	903.89	339.70	59.39	4.31	***8,283.42***
1000 - 1500	3,058.73	30.19	5.20	31.26	9.65	-	***3,135.02***
1500 - 2000	-	-	-	-	-	0.27	***0.27***
Total	***13,166.35***	***2,674.38***	***3,012.05***	***1,452.66***	***570.74***	***210.07***	***21,086.27***

Table 38. *Landuse and landcover by altitude for communes of Bac Me Nature Reserve in 1998*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Total*
0 - 100	19.52	23.84	25.51	30.88	18.70	20.08	***138.54***
100 - 200	355.53	642.71	571.35	512.73	392.29	163.22	***2,637.83***
200 - 500	2,193.16	2,012.78	1,712.00	621.68	333.91	18.72	***6,892.26***
500 - 1000	4,757.66	1,885.22	1,214.53	356.40	65.31	3.01	***8,282.12***
1000 - 1500	2,950.43	130.03	34.24	17.11	2.42	0.09	***3,134.33***
1500 - 2000	-	-	-	-	-	0.35	***0.35***
Total	***10,276.31***	***4,694.58***	***3,557.63***	***1,538.81***	***812.63***	***205.47***	***21,085.43***

Table 39. *Landuse and landcover by altitude for communes of Bac Me Nature Reserve in 2009*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Total*
0 - 100	18.46	1.49	0.26	5.23	1.10	114.30	***140.85***
100 - 200	420.84	468.06	391.87	775.16	226.13	356.07	***2,638.13***
200 - 500	2,458.68	2,077.13	1,471.19	814.79	66.22	2.57	***6,890.59***
500 - 1000	5,274.83	1,580.45	942.73	470.07	13.59	0.09	***8,281.75***
1000 - 1500	2,989.95	54.88	41.43	47.07	0.47	-	***3,133.81***
1500 - 2000	-	-	-	-	-	0.52	***0.52***
Total	***11,162.76***	***4,182.02***	***2,847.49***	***2,112.32***	***307.52***	***473.55***	***21,085.65***

Table 40. *Landuse and landcover by altitude for communes of Bac Me Nature Reserve in 2019*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Total*
0 - 100	14.92	0.81	0.96	0.13	2.52	120.66	***140.00***
100 - 200	211.49	447.04	587.64	188.94	687.77	514.80	***2,637.69***
200 - 500	2,101.37	1,840.27	1,954.39	481.47	503.67	12.33	***6,893.51***
500 - 1000	4,788.75	2,055.85	852.76	396.21	186.07	0.87	***8,280.51***
1000 - 1500	2,766.15	317.51	15.43	12.84	21.43	-	***3,133.36***
1500 - 2000	-	-	-	-	-	0.53	***0.53***
Total	***9,882.67***	***4,661.47***	***3,411.19***	***1,079.59***	***1,401.47***	***649.20***	***21,085.59***

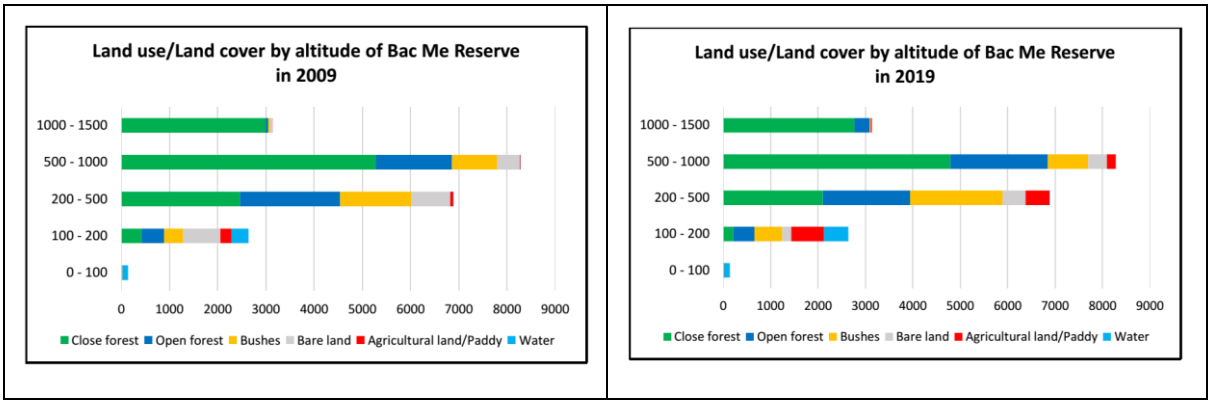


Figure 18. *Land use-land cover in Bac Me Reserve by altitude during 1988-2019 (ha)*

Evolution of Land use / Land cover by altitude for communes of Bac Me Nature Reserve during 1988-2019 is presented in Table 41.

Table 41. *Evolution of landuse and landcover by altitude for communes of Bac Me Nature Reserve during 1988-2019*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water
0 - 100	-20.9	-6.35	-28.6	-34.87	-12.4	101.86
100 - 200	-616.7	70.39	109.95	-261.44	352.81	349.03
200 - 500	-1131.33	545.09	358.67	-114.85	351.85	-8.59
500 - 1000	-1222.17	1090.64	-51.13	56.51	126.68	-3.44
1000 - 1500	-292.58	287.32	10.23	-18.42	11.78	0
1500 - 2000	0	0	0	0	0	0.26
Tổng	***-3,283.68***	***1,987.09***	***399.12***	***-373.07***	***830.72***	***439.12***

During the period 1988-2019, the area of close forest is changed in the direction of decline, corresponding to 13,166.35 ha; 10,276.31 ha; 11,162.76ha; and 9,882.76 ha in the years of 1988, 1998, 2009 and 2019, respectively. The large decrease in area of close forest is at the altitude belt of 500-1000 m (-1,222.17 ha), 200-500m (-1,131.33 ha) and 100-200 m (-616.7 ha) for the whole period 1988-2019.

Meanwhile, the area of open forest tends to increase, corresponding to 2,674.38 ha; 4,694.58 ha; 4,182.02 ha and 4,661.47 ha in the years of 1988, 1998, 2009 and 2019, respectively. The large increase in area is at altitude belt of 500-1000m (+1,090.64 ha),

200-500m (+545.09 ha).) and the altitude belt of 1000-1,500 m (+287.32 ha) for the whole period 1988-2019.

The area of bush tends to increase, corresponding to 3,012.05 ha; 3,557.63 ha; 2,487.49 ha; and 3,411.19 in the years of 1988, 1998, 2009 and 2019, however, year of 2009 witnesses a decrease in area, perhaps due to its conversion to bare land. The large increase in the area is at the altitude belt of 500-1000m (+1,090.64 ha), 200-500m (+545.09 ha) and the altitude belt of 1000-1,500m (+287.32 ha) in the whole period of 1988-2019.

The area of bare land tends to decrease, corresponding to 1,452.66 ha; 1,538.81 ha; 2,112.32 ha; and 1,079.59 ha in the years of 1988, 1998, 2009 and 2019, respectively however year of 2009 witnesses an increase in the area, perhaps due to conversion from bush. The large reduction in area of bare land is at the altitude belt of 100-200m 261.44 ha), 200-500m (-114.85 ha) in the whole period of 1988-2019.

The area of agricultural land/paddy tends to increase, corresponding to 570.74 ha; 812.63 ha; 307.52 ha; and 1,401.47 in 1988, 1998, 2009 and 2019, respectively however, year of 2009 witnesses a decrease in area, perhaps due to its conversion to bare land. The large increase in areas is at the altitude belt of 100-200m (+352.81 ha) and 200-500m (+351.85 ha), as the lowlands are easily converted into arable land, especially when the reservoir of Tuyen Quang hydropower station in Na Hang district (commencing operation in 2008) flooding a large area of the Reserve and also providing water for crops.

The area of water surface tends to increase, corresponding to 210.74 ha; 205.47 ha; 473.55 ha; and 649.20 in the years of 1988, 1998, 2009 and 2019. The water surface area is increased rapidly since 2009 due to the establishment of Tuyen Quang reservoir commencing operation since 2008 and flooding a significant area in the Reserve. The large increase in water surface area is at at the altitude belt of 100-200m (+349.03 ha) and altitude belt of 0-100m (+101.86 ha). The large area of the reservoir also creates favorable conditions for strong aquaculture development in Thuong Tan commune of the Reserve.

In summary, the trend of evolution of land use types by altitude for Bac Me Nature Reserve during the period 1988-2019 is presented in Table 42 below.

Table 42. *Main tendency of evoluation of landuse and landcover by altitude for communes of Bac Me Nature Reserve during 1988-2019*

Altitude (m)	Close forest	Open forest	Bush	Bare land	Agricultural land/Paddy	Water	*Note*
0 - 100	-+	-+	-+	+-	+-	+-	Minor change
100 – 200	--	+-	+-	--	+	++	Moderate change
200 - 500	---	++	+	+-	+	-+	Strong change
500 - 1000	---	+++	-+	+-	+-	-+	Strong change
1000 - 1500	--	+	+-	+-			Moderate change
1500 - 2000							
Total	---	++	+-	+-	+	+	

Note:
+++ : Very strong increase (>1000ha); ++ : Strong increase (500-1000ha); + : Moderate increase (200-500ha); +- : Minor increase (0-200ha)
-+: Minor decrease (0-200ha); - : Moderate decrease (200-500ha); -- : Strong decrease (500-1000ha)'; ---: Very strong decrease (>1000ha)

In summary, the characteristics of landuse and landcover of Bac Me Nature Reserve are the followings:

i). In general, the area of close forest has a large coverage, accounting for more than 60% in the communes of the Reserve in 1988, but it has decreased rapidly, to just over 46% in 2019. Open forest, in contrast to the trend of close forest, accounts for a certain percentage, around 13% in 1988, but tends to increase rapidly, up to more than 22% in 2019, mainly due to close forest degradation.

During the period 1988-1998, the area of close forest is decreased rapidly, and converted to open forest and bushes. In the following periods, this transition is not obvious and the land use patterns do not change much.

ii). By commune, the area of close forest and open is distributed mainly in Minh Ngoc and Thuong Tan communes, where the large area of open forest is increased during 1988-2019, due to the degration of close forest. Meanwhile during this period, the area of agricultural land is increased due to the decrease of bare land.

iii). By altitude, most of close forest are concentrated in the elevation zones ranging from 200m - 1000m, where large are of close forest is converted to open forest during period 1988-2019; The zone ranging from 1000m – 1500m is covered mostly by close forest and has very little change during period 1988-2019.

2.6.1.3. Landuse and landcover change in Phia Oac – Phia Den National Park during 1988-2019

The area of Phia Oac - Phia Den National Park is 10,593.5 ha, situated mainly in 5 communes of Thanh Cong, Quang Thanh, Phan Thanh, Hung Dao and Tinh Tuc, Nguyen Binh district, Cao Bang province, in which the forest land covers 8,914.9 ha, including 8,150.9 ha of natural forest and 764 ha of planted forest and land without forest is 1,678.6 ha.

The total number of people currently living in 05 communes in Phia Oac - Phia Den National Park is 1752 households, 11,452 people, equivalent to 5-6 people/household and distributed in 40 villages. The average population density of the region is 68 people/km^2, but the distribution is uneven. Thanh Cong commune has the highest density of 128 people/km^2 and Hung Dao commune has the lowest density of 33 people/km^2 (See Table 1)

There are 5 ethnic groups living these areas in which Dao ethnic group has 3,912 people, accounting for 47.2%; Nung ethnic group - 1,682 people, accounting for 20.3%, Kinh ethnic group has 1,475 people, accounting for 17.8%, Tay ethnic group has 1,143 people, accounting for 13.8%, the rest are H'Mong ethnic group, accounting for 0.9%.

Table 43. *The population of the communes in Phia Oac – Phia Den National Park in 2020*

No	Commune	Number of villages	Households	Persons	Population density (pers/km^2)
1	Thanh Cong	10	271	2893	128
2	Quang Thanh	7	264	1739	29
3	Phan Thanh	5	300	2974	36
4	Hung Dao	4	124	1152	26
5	Tinh Tuc town	14	793	2694	119
Total		**40**	**1752**	**11452**	**68**

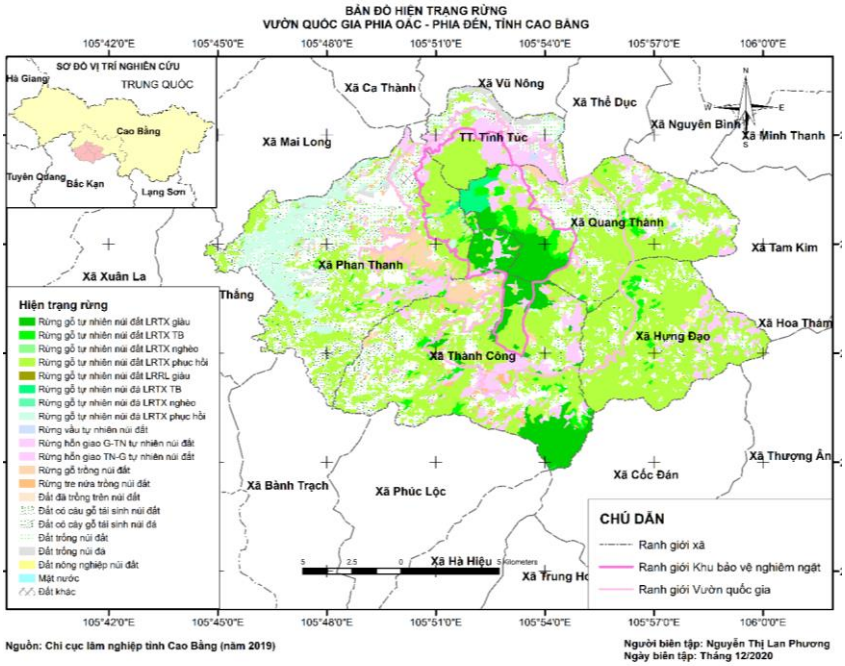


Figure 19. *Forest cover in Phia Oac - Phia Den National Park*

(1). Landuse and landcover in the communes of Phia Oac-Phia Den National Park during period 1988-2019

Interpretation of remote sensing images for land use/land cover types over the past 40 years (1988, 1998, 2010 and 2019) of 5 communes in the National Park shows that the coverage of close forest is relatively high and there is no major change (68.23%, 63.11%, 62.62%, and 67.38%, respectively) while the cover of open forest tends to increase (7.26%, 11.51%, 13.67% and 12.59% respectively).

Table 44. *Land use/land cover types for Phia Oac - Phia Den National Park during 1988 – 2019*

Landuse/ landcover	**1988**		**1998**		**2009**		**2019**	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Close forest	19,826.45	68.23	18,341.25	63.11	18,197.48	62.62	19,582.14	67.38
Open forest	2,110.37	7.26	3,343.84	11.51	3,973.32	13.67	3,658.68	12.59
Bushes	3,550.48	12.22	3,632.78	12.50	2,852.97	9.82	2,185.14	7.52
Agricultural land	3,499.24	12.04	3,657.35	12.59	3,958.48	13.62	3,544.02	12.20
Mining/Bare land	73.77	0.25	85.09	0.29	78.05	0.27	90.30	0.31
Total	29,060.29	100.00	29,060.30	100.00	29,060.29	100.00	29,060.29	100.00

Source: Interpretation of remote sensing imagery, 2021

The characteristics of land use/land cover types for Phia Oac - Phia Den National Park during 1988 – 2019 are presented as follows:

+ During the period 1988-2019, among 29,060.29 ha of communes of Phia Oac-Phia Den National Park, close forest has the largest area, accounting for 68.23%, 63.11%, 62.62% and 67.38% of the total area in the years of 1988, 1998, 2009 and 2019, respectively. Open forest has the second large area, accounting for 7.26%, 11.51%, 13.67% and 12.59%. Thus, after 30 years, the area of close forest is decreased by 1.15% (the lowest reduction in 2009 was 5.61%), while the open forest increased by 5.33%). For the entire area of the National Park' communes, a part of close forest has been degraded and converted into open forest, which is in fact the secondary forest and poor forest.

+ In the period 1988-2019, areas of bush have a trend to decrease, accounting for 12.22%, 12.50%, 9.82% and 7.52%, respectively. Thus, after 30 years, the area of bush are decreased by 4.7%. Bare land and mining land account for a small proportion, less than 0.3% for years. Agricultural land is also relatively stable, at 12.04%, 12.59%, 13.62% and 12.2%, respectively.

+ In summary, over the past 30 years, close forest has decreased by 1.15%, open forest has increased by 5.33%, Bush has decreased by 4.7%, while bare land and agricultural land have not changed much. Thus, a part of close forest and bush have converted into open forest.

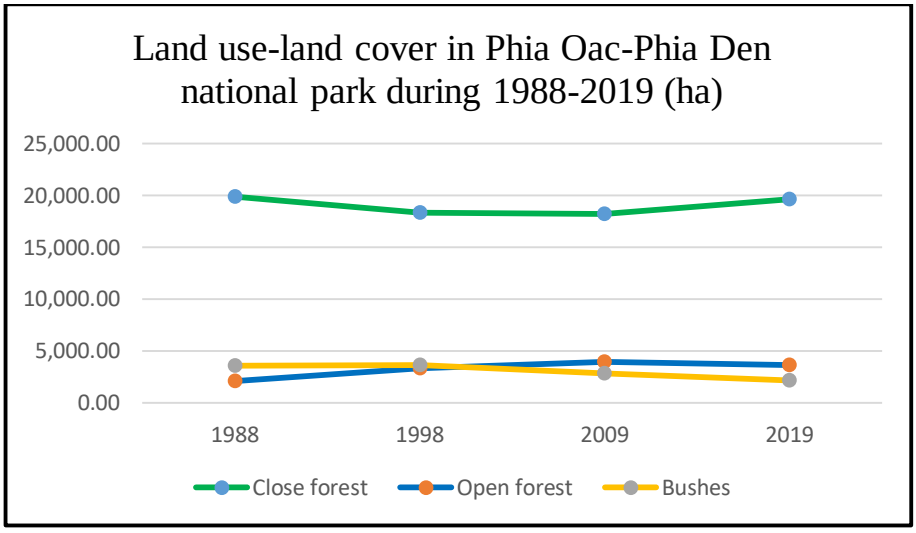


Figure 20. *Land use-land cover in Phia Oac-Phia Den national park during 1988-2019 (ha)*

Thus, regarding the landuse and landcover change during this period, close forest is decreased in area until 2009 (-1,629 ha) and recovered in 2019 (-244 ha); Open forest

is increased rapidly in area, reaching the peak in 2009 (+1,863 ha), then decreased slightly in 2019 (+1,548 ha); Bush is gradually decreased in area, reaching the peak in 2019 (-1,365 ha).

Table 45. *Land use/land cover change in Phia Oac-Phia Den National Park during 1988 – 2019 (%)*

	1988-1998	1998-2009	2009-2019	1998-2019
Close forest	- 5.1	- 0.5	4.8	- 0.8
Open forest	+ 4.2	2.2	- 1.1	+ 5.3
Bushes	+ 0.3	- 2.7	- 2.3	- 4.7
Agricultural land	+ 0.5	+ 1.0	- 1.4	+ 0.2
Mining/Bare land	0.0	(0.0)	0.0	+ 0.1

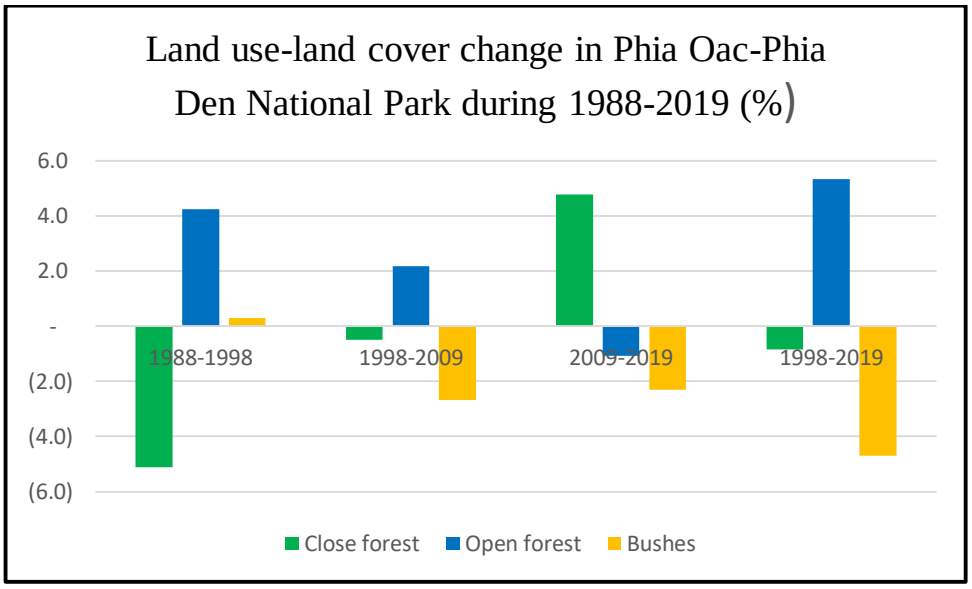


Figure 21. *Land use-land cover change in Phia Oac-Phia Den National Park during 1988-2019 (ha)*

Thus, close forest is decreased in area while open forest is increased rapidly especially in the period 1988-2009. This is to explain the large conversion of close forest into open forest in during this period. Meanwhile, bush is also decreased in size, indicating that some areas of bush is converted into open forest throught the natural process of vegetation regeneration.

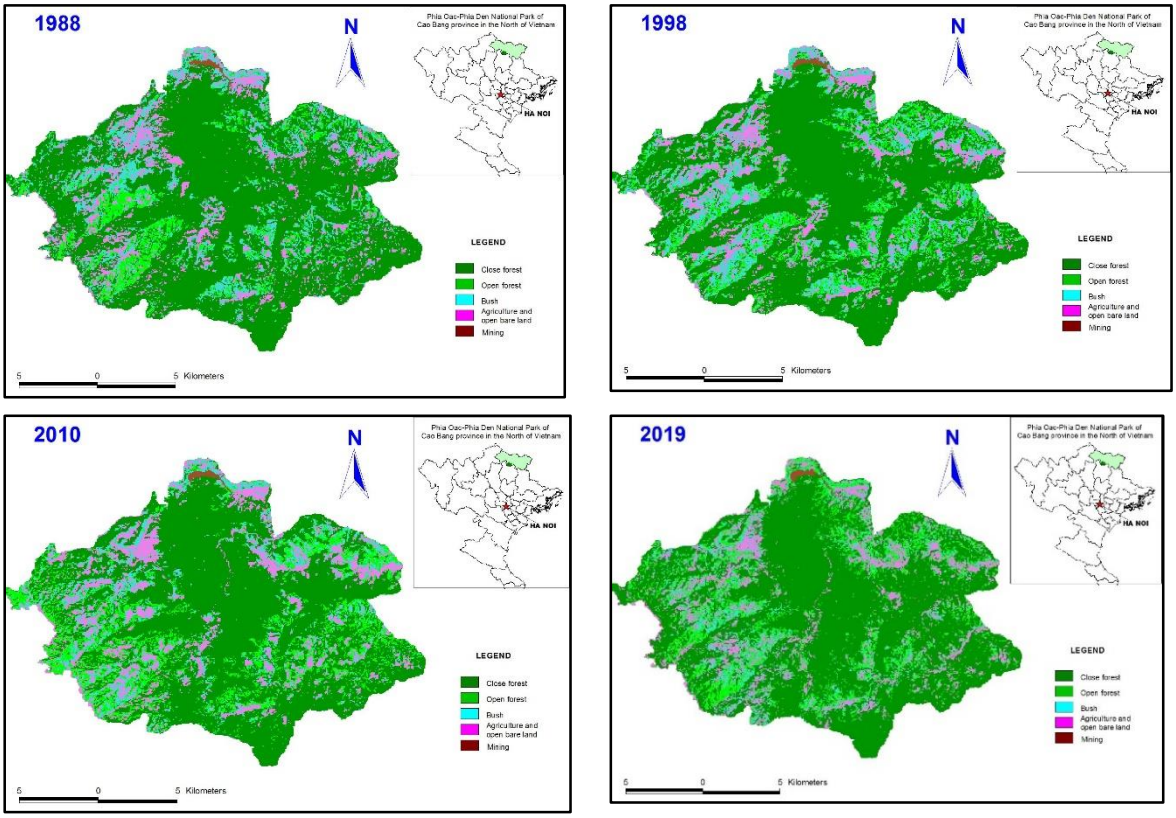


Figure 22. *Evolution of land use / land cover in the communes of Phia Oac – Phia Den National Park*

Source: Interpretation of remote sensing imagery, 2021

(2). Landuse and landcover by communes of Phia Oac-Phia Den National Park during period 1988-2019

Tables 46, 47, 48 and 49 present the land use and land cover for 5 communes in Phia Oac – Phia Den National Park for 1988, 1998, 2010 and 2019, extracted from interpretation of satellite images.

Table 46. *Land use / Land cover for communes of Phia Oac – Phia Den National Park in 1988*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.29	5,803.27	799.24	813.71	732.86	1.21
2	Quang Thanh	5,977.59	4,444.61	347.75	613.55	570.84	0.84
3	Phan Thanh	8,368.66	4,905.87	665.76	1,358.56	1,436.28	2.19
4	Hung Đao	4,408.13	3,343.74	237.07	408.93	417.30	1.08
5	Tinh Tuc town	2,155.63	1,328.96	60.54	355.72	341.96	68.45

Total	**29,060.29**	**19,826.45**	**2,110.37**	**3,550.48**	**3,499.24**	**73.77**

Table 47. *Land use / Land cover for communes of Phia Oac – Phia Den National Park in 1998*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.30	5,272.85	1,048.39	998.82	830.24	-
2	Quang Thanh	5,977.58	4,021.74	702.78	637.40	615.66	-
3	Phan Thanh	8,368.66	4,857.30	788.39	1,217.08	1,505.89	-
4	Hung Đao	4,408.13	2,854.85	688.98	489.69	374.61	-
5	Tinh Tuc town	2,155.63	1,334.50	115.30	289.79	330.94	85.09
Total		**29,060.29**	**29,060.30**	**18,341.25**	**3,343.84**	**3,632.78**	**3,657.35**

Table 48. *Land use / Land cover for communes of Phia Oac – Phia Den National Park in 2010*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.30	5,655.50	1,054.42	585.24	855.14	-
2	Quang Thanh	5,977.59	4,014.98	596.10	592.21	774.29	-
3	Phan Thanh	8,368.66	4,217.36	1,467.75	1,093.45	1,589.72	0.37
4	Hung Đao	4,408.13	2,905.54	762.76	317.08	422.75	-
5	Tinh Tuc town	2,155.63	1,404.10	92.28	265.00	316.57	77.68
Total		**29,060.29**	**29,060.29**	**18,197.48**	**3,973.32**	**2,852.97**	**3,958.48**

Table 49. *Land use / Land cover for communes of Phia Oac – Phia Den National Park in 2019*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.29	5,722.32	952.63	666.44	808.64	0.27
2	Quang Thanh	5,977.58	4,219.37	729.56	322.49	706.16	-
3	Phan Thanh	8,368.65	4,961.65	1,235.97	851.39	1,310.72	8.91

4	Hung Đao	4,408.13	3,415.55	400.39	176.77	415.42	-
5	Tinh Tuc town	2,155.63	1,263.26	340.12	168.05	303.08	81.12
Total		**29,060.29**	**29,060.29**	**19,582.14**	**3,658.68**	**2,185.14**	**3,544.02**

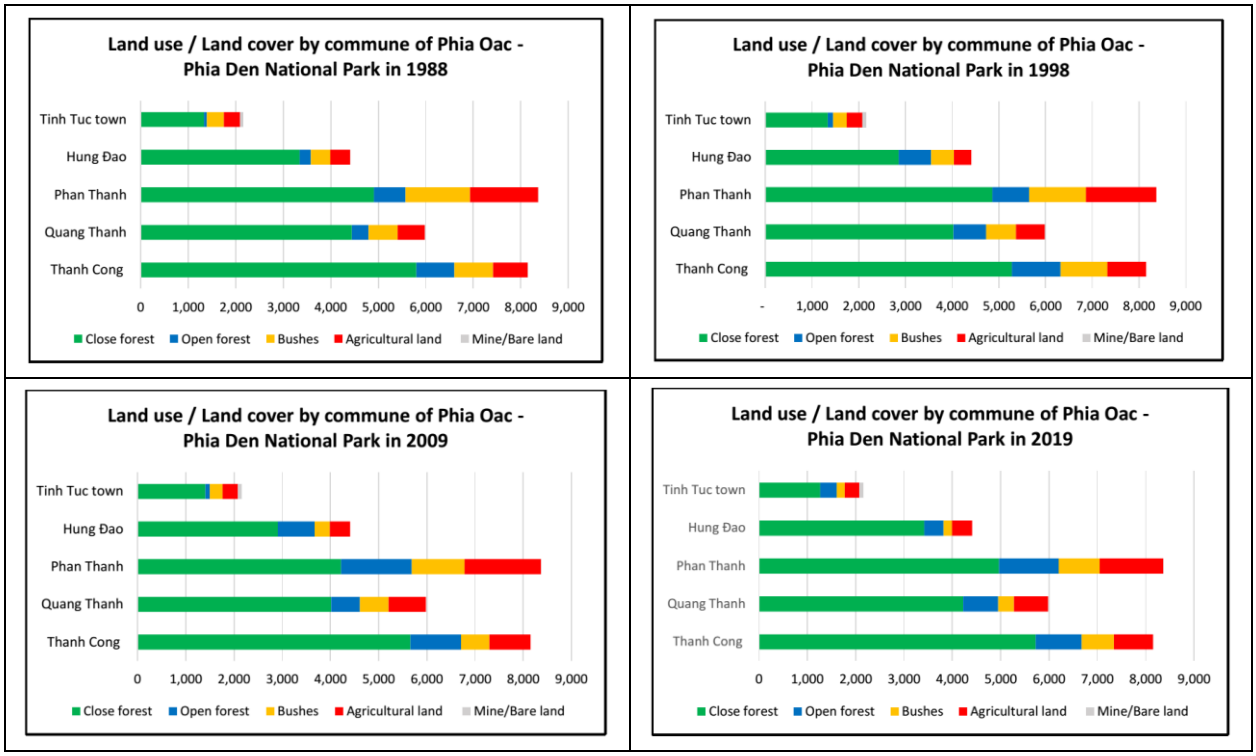


Figure 23. *Land use-land cover in Phia Oac – Phia Den National Park by commune during 1988-2019 (ha)*

Evolution of Land use / Land cover by commune for Phia Oac-Phia Den during period 1988-2009 and 1988-2019 is represented in Table 50 and 51.

Table 50. *Evolution of Land use and Land cover for communes of Phia Oac-Phia Den National Park during 1988-2009*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.3	-147.77	255.18	-228.47	122.28	-1.21
2	Quang Thanh	5,977.59	-429.63	248.35	-21.34	203.45	-0.84
3	Phan Thanh	8,368.66	-688.51	801.99	-265.11	153.44	-1.82
4	Hung Đao	4,408.13	-438.20	525.69	-91.85	5.45	-1.08
5	Tinh Tuc town	2,155.63	75.14	31.74	-90.72	-25.39	9.23
Total		**29,060.29**	**-1,628.97**	**1,862.95**	**-697.49**	**459.23**	**4.28**

Table 51. *Evolution of Land use and Land cover for communes of Phia Oac-Phia Den National Park during 1988-2019*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.29	-80.95	153.39	-147.27	75.78	-0.94
2	Quang Thanh	5,977.58	-225.24	381.81	-291.06	135.32	-0.84
3	Phan Thanh	8,368.65	55.78	570.21	-507.17	-125.56	6.72
4	Hung Đao	4,408.13	71.81	163.32	-232.16	-1.88	-1.08
5	Tinh Tuc town	2,155.63	-65.70	279.58	-187.67	-38.88	12.67
Total		**29,060.28**	**-244.30**	**1,548.31**	**-1,365.33**	**44.78**	**16.53**

For the period 1988-2019, close forest is decreased by large area until 2009 (-1,628.97 ha) and recovered in 2019 (-244.30 ha), especially concentrated for year of 2009 in Phan Thanh (-688.51 ha), Hung Dao (-438.20 ha) and Quang Thanh (-429.63 ha); Open forest is increased rapidly by large area, reaching the peak in 2009 (+1,863 ha), then decreased slightly in 2019 (+1,548 ha), especially concentrated for year of 2009 in Phan Thanh (+801,99 ha), Hung Dao (+525.68 ha), Thanh Cong (+255.18 ha) and Quang Thanh (+248.35 ha); Bush is steadily decreased by large area until 2019 (-1,365.33 ha), especially concentrated for year of 2019 in Phan Thanh (-507.17 ha), Quang Thanh (-291.06 ha) and Hung Dao (-232.16 ha);

3). Landuse and landcover by altitude for Phia Oac – Phia Den National Park during 1988-2019

The landuse and landcover by altitude in Phia Oac – Phia Den National Park for the years 1998, 1998, 2009, 2019 is presented in Tables 52, 53, 54, 55. Topograpgy of Phia Oac – Phia Den National Park is presented in Figure 24.

Among the types of land use and land cover of Phia Oac - Phia Den National Park, close canopy forest occupies the largest area, ranging from 18,000 ha to 19,000 ha, accounting for 62 - 68% of total area of the Park. In which, close forest area is mainly distributed at an altitude belt of 500 m -1,500 m, accounting for about 85-90% of the total area of closed canopy forest of the National Park.

Based on the classification of Vietnamese forest vegetation by Thai Van Trung (1970), close forest at an altitude belt of over 700m belongs to the type of subtropical humid evergreen broadleaved forest at medium and high mountains. Forests distributed at altitudes below 700m belong to tropical humid evergreen broadleaved forest at low mountains.

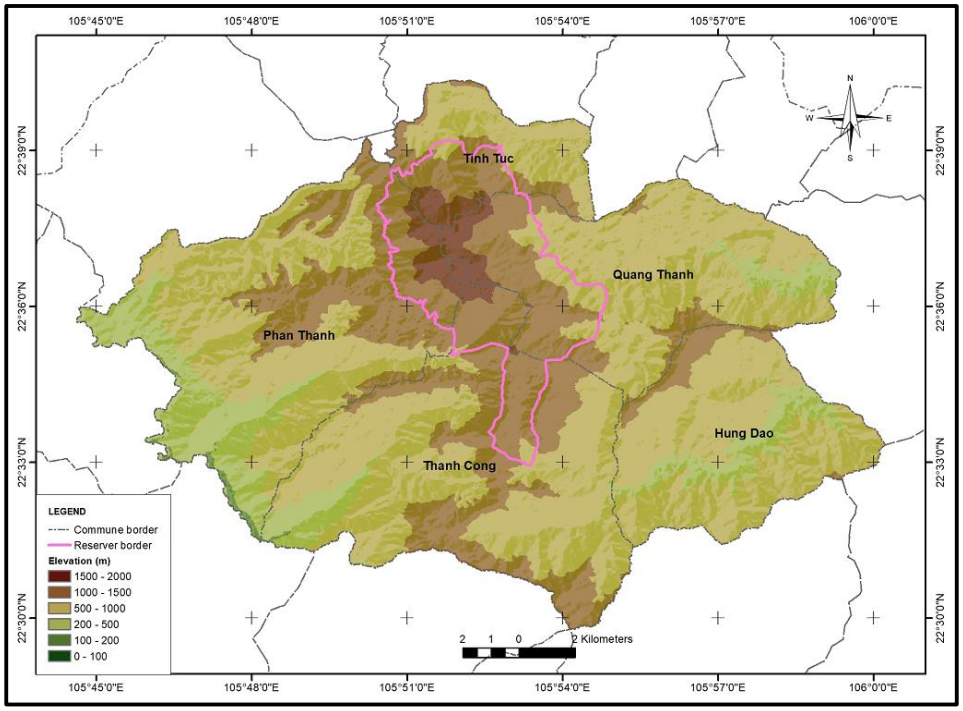


Figure 24. *Topographic map of Phia Oac - Phia Den National Park*

Table 52. *Landuse and landcover by altitude for communes of Phia Oac – Phia Den National Park in 1988*

Unit: ha

Altitude (m)	Close forest	Open forest	Bush	Agricultural land/Paddy	Bare/ mining land	*Total*
0 - 100	42.45	-	-	0.01	-	***42.46***
100 - 200	15.25	1.59	7.42	30.84	-	***55.10***
200 - 500	1,907.54	400.05	338.28	498.56	0.69	***3,145.12***
500 - 1000	10,871.08	1,462.47	2,363.73	2,242.41	71.28	***17,010.98***
1000 - 1500	6,148.44	244.60	838.29	722.31	1.79	***7,955.43***
1500 - 2000	841.70	1.65	2.75	5.11	-	***851.21***
Total	***19,826.46***	***2,110.36***	***3,550.48***	***3,499.24***	***73.77***	***29,060.30***

Table 53. *Landuse and landcover by altitude for communes of Phia Oac – Phia Den National Park in 1998*

Unit: ha

Altitude (m)	Close forest	Open forest	Bush	Agricultural land/Paddy	Bare/ mining land	*Total*

0 - 100	38.72	-	-	0.06	-	***38.78***
100 - 200	17.05	7.75	5.69	27.02	-	***57.51***
200 - 500	1,776.11	488.65	475.81	405.06	-	***3,145.63***
500 - 1000	9,429.84	2,353.00	2,537.69	2,606.17	85.04	***17,011.74***
1000 - 1500	6,234.68	493.44	610.80	616.45	0.05	***7,955.42***
1500 - 2000	844.85	0.99	2.79	2.58	-	***851.21***
Tổng	***18,341.25***	***3,343.84***	***3,632.78***	***3,657.35***	***85.09***	***29,060.30***

Table 54. *Landuse and landcover by altitude for communes of Phia Oac – Phia Den National Park in 2009*

Unit: ha

Altitude (m)	Close forest	Open forest	Bush	Agricultural land/Paddy	Bare/ mining land	*Total*
0 - 100	34.16	-	-	0.06	-	***34.23***
100 - 200	0.18	13.81	6.43	40.00	-	***60.43***
200 - 500	1,026.14	1,066.33	440.21	613.42	0.02	***3,146.12***
500 - 1000	9,542.09	2,582.69	1,943.49	2,866.63	77.99	***17,012.89***
1000 - 1500	6,749.94	309.88	458.85	436.71	0.04	***7,955.42***
1500 - 2000	844.97	0.62	3.98	1.65	-	***851.21***
Total	***18,197.48***	***3,973.32***	***2,852.97***	***3,958.48***	***78.05***	***29,060.30***

Table 55. *Landuse and landcover by altitude for communes of Phia Oac – Phia Den National Park in 2019*

Unit: ha

Altitude (m)	Close forest	Open forest	Bush	Agricultural land/Paddy	Bare/ mining land	*Total*
0 - 100	38.69	-	-	0.06	-	***38.76***
100 - 200	11.88	7.90	2.49	34.10	1.00	***57.38***
200 - 500	1,896.50	535.73	214.82	489.01	8.03	***3,144.09***
500 - 1000	10,057.91	2,598.86	1,723.39	2,552.11	81.09	***17,013.36***
1000 - 1500	6,727.50	515.44	244.30	468.09	0.18	***7,955.51***
1500 - 2000	849.67	0.74	0.15	0.65	-	***851.21***
Total	***19,582.15***	***3,658.68***	***2,185.14***	***3,544.02***	***90.30***	***29,060.30***

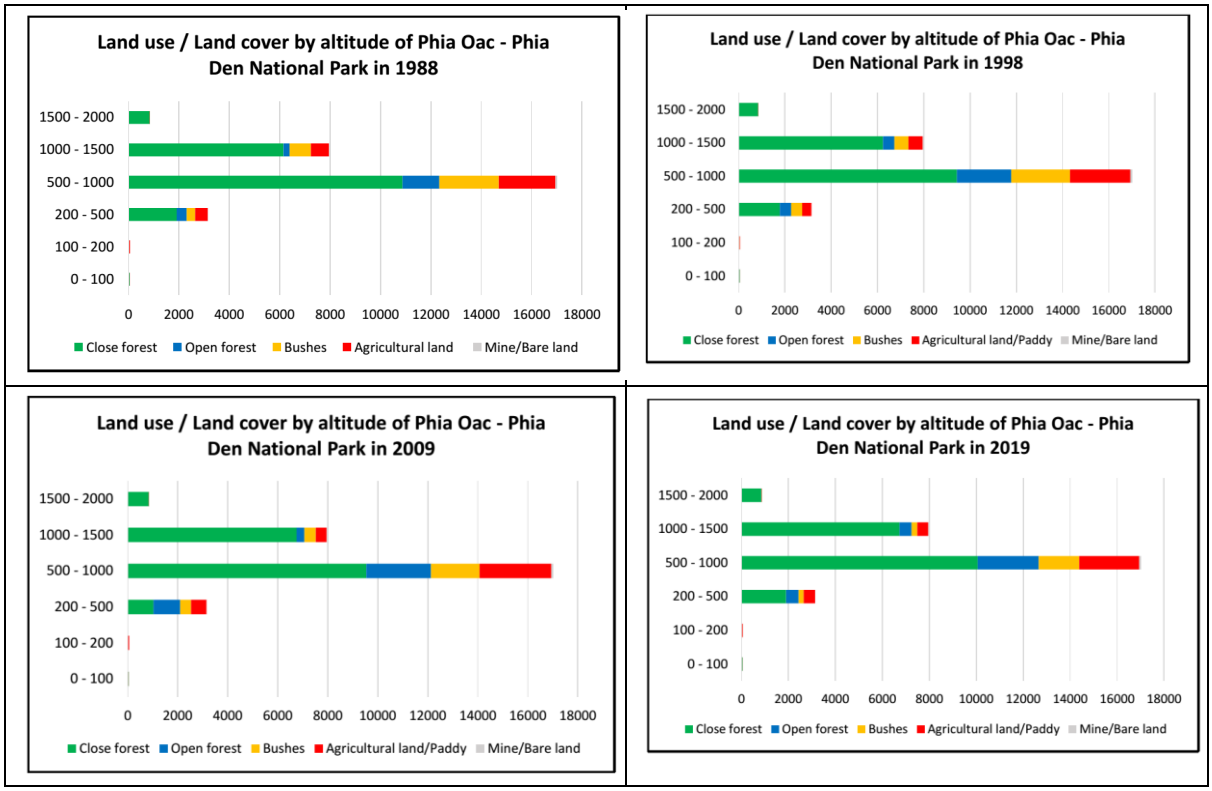


Figure 25. *Land use-land cover in Phia Oac – Phia Den National Park by altitude during 1988-2019 (ha)*

Evolution of Land use / Land cover by altitude for communes of Phia Oac – Phia Den National Park during 1988-2009 and 1988-2019 is presented in Table 56 and 57.

Table 56. *Evolution of Land use and Land cover by altitude for communes of Phia Oac – Phia Den National Park during 1988-2009*

Unit: ha

Altitude (m)	Close forest	Open forest	Bush	Agricultural land/Paddy	Bare/ mining land
0 - 100	-8.28	-	-	0.05	-
100 - 200	-15.06	12.22	-0.99	9.16	-
200 - 500	-881.40	666.27	101.93	114.87	-0.67
500 - 1000	-1,329.00	1,120.22	-420.24	624.22	6.71
1000 - 1500	601.49	65.28	-379.44	-285.60	-1.75
1500 - 2000	3.26	-1.04	1.23	-3.46	-
Total	-1,628.98	1,862.95	-697.50	459.24	4.28

Table 57. *Evolution of Land use / Land cover by altitude for communes of Phia Oac – Phia Den National Park during 1988-2019*

Unit: ha

Altitude (m)	Close forest	Open forest	Bush	Agricultural land/Paddy	Bare/ mining land
0 - 100	-3.76	-	-	0.05	-
100 - 200	-3.36	6.31	-4.93	3.26	1.00
200 - 500	-11.04	135.68	-123.47	-9.55	7.34
500 - 1000	-813.17	1,136.39	-640.35	309.69	9.81
1000 - 1500	579.06	270.84	-593.99	-254.22	-1.61
1500 - 2000	7.96	-0.91	-2.60	-4.46	-
Total	-244.31	1,548.31	-1,365.34	44.78	16.54

Table 58. *Evolution of Land use and Land cover by altitude for communes of Phia Oac – Phia Den National Park during 2009-2019*

Unit: ha

Altitude (m)	Close forest	Open forest	Bush	Agricultural land/Paddy	Bare/ mining land
0 - 100	4.53	-	-	-	-
100 - 200	11.70	-5.91	-3.94	-5.90	1.00
200 - 500	870.36	-530.59	-225.40	-124.41	8.01
500 - 1000	515.83	16.17	-220.11	-314.52	3.10
1000 - 1500	-22.44	205.56	-214.55	31.38	0.14
1500 - 2000	4.70	0.13	-3.83	1.00	-
Total	1,384.67	-314.64	-667.83	-414.46	12.26

Regarding the period 1988-2009: The area of close forest is decreased sharply (-1,628.98 ha), concentrated at the altitude belt of 500-1000m (-1,329 ha) and the altitude belt of 200-500 m (-881.40 ha); Contrary to close forest, the area of open forest is increased strongly, mainly at the altitude belt of 500-1000m (+1,120.22 ha) and the altitude belt of 200-500 m (+666.27 ha). This contrasting trend explains that most of the close forest area has been converted to open forest, the more degraded type of forest. Meanwhile, the area of such is also decreased significantly (-697.50 ha), mainly at the altitude belt of 500-1000m (-420.24 ha) and the altitude belt of 1000-1500 m (-379.44 ha). Agricultural and swidden land are increased significantly (+459.24 ha), but at the same time, is increased at the altitude belt of 500-1000 m (+624.22 ha) and decreased at the altitude belt of 1000-1500 m (-285.60 ha). This explains that most of the area of bush and swidden cultivation at the altitude belt of 1000-1500 m is converted into close forest (+601.49 ha) through natural regeneration or reforestation (See Table 45).

Regarding the period 2009-2019: During this 10-year period, the area of close forest has increased sharply (+1,384.67 ha) on the basis of a decrease in the area of open forest (-314.64 ha), bush (-667.83 ha) and swidden land (-414.46 ha) through natural process of forest vegetation regeneration and reforestation. Specifically, the area of close forest is increased sharply at the altitude belt of 200-500 m (+870.36 ha) and the altitude belt of 500-1000 m (+515.83 ha), while the area of open forest is decreased sharply at the altitude belt of 200-500 m (-530.59 ha) and the area of bush is reduced at the altitude belt of 200-500 m (-225.40 ha), the altitude belt of 500-1000 m (-220.11 ha), and the area of agricultural/swidden land is decreased sharply at the altitude belt of 500-1000 m (-314.55 ha, the altitude belt of 200-500 m (-124.41 ha) (See Table 47).

Thus, for the whole period of 1988-2019, the first period of 1988-2009 witnesses a decrease in the area of close forests and converted into open forest and bush, and the second period of 2009-2019 is characterized by a rehabilitation process to convert open forest, bush and swidden land into close forest.

In summary, the characteristics of land use and land cover of Phia Oac – Phia Den National Park are the followings:

i). In general, the area of close forest accounts for a large proportion, ranging from 62% to 68% of the National Park's area, but this forest has low coverage during the period of 1998-2009; Open forest, in contrast to the trend of close forest, accounts for a certain percentage, around 7% in 1988, but tends to increase, up to about 13% in 2009 and 2019, mainly due to close forest degradation.

During the period 1988-1998, the area of close forest is decreased rapidly, and converted to open forest, while in the period 2009-2019, this area is increased, mainly due to the decrease of open forest and bushes.

ii). By commune, the area of close forest is distributed mainly in Phan Thanh and Thanh Cong communes, and for smaller portion, in Quang Thanh and Hung Dao communes. However, thee communes (Phan Thanh, Hung Dao and Hung Dao) witness large decrease in area of close forest due to the increase of open forest during period 1988-2009.

iii). By altitude, most of close forest are concentrated in the elevation zones ranging from 500m - 1500m, where large are of close forest is converted to open forest during period 1988-2009.

2.6.1.4. Landuse and landcover change in Nam Xuan Lac Reserve during 1988-2019

Nam Xuan Lac Reserve has a natural area of 4,150, 21 ha, of which strictly protected zone 2,547.04 ha; 1,586.12 ha ecological restoration zone; service - administrative zone 9.04 ha; the buffer zone in 8.01 ha. Nam Xuan Lac Reserve is located on the administrative territory of three communes Xuan Lac, Dong Lac and Ban Thi of Cho Don district, Bac Kan province. The area of the outer buffer zone is 16,371.53 ha..

The current status of land use types and forest types of Nam Xuan Lac Reserve by statistics are shown in the Table 59 below.

Table 59. *Area of land use types and forest types of Nam Xuan Lac Reserve*

Land use/Forest types	By administrative unit (ha)				Nature Reserve's buffer zone
	Total	Xuan Lac	Dong Lac	Ban Thi	
I. Forested land	**14,316**	**6,206**	**2,441**	**5,669**	**4,575**
1. Forest in terrestrial mountains	***6389***	***3463***	***1537***	***1389***	***1022***
Mixed wood forest + bamboo	1761	1028	206	527	994
Medium forest	600	600	-	-	-
Poor forest	96	91	-	5	26
Rehabilitated forest	3932	1744	1331	857	2
2. Forest on limestone	***7,219***	***2,303***	***850***	***4,066***	***3,335***
Rich forest on limestone	1,864	1864	-	-	-
Medium forest on limestone	264	113	-	151	-
Poor forest on limestone	4,903	326	848	3729	3335
Rehabilitated forest on limestone	188	-	2	186	-
3. Forested plantation	***708***	***440***	***54***	***214***	***218***
Young plantation	708	440	54	214	218
II. No-forest land	**2,552**	**1,788**	**224**	**540**	**117**
1. No-forest land in terr. mountains	***916***	***599***	***196***	***121***	***86***
Bareland with bushes (Ia, Ib)	756	550	191	15	84
Bareland with wood regrowth (Ic)	160	49	5	106	2
2. No-forest land on limestone	***60***	***1***	***59***	**-**	**-**
Bareland with bushes (Ia, Ib)	60	1	59	-	17
III. Other land	**1636**	**1189**	**28**	**419**	**31**
Other land	367	16	-	351	-
Agriculture	1269	1173	28	68	31
Total	**18,504**	**9,183**	**2,693**	**6,628**	**4,723**

The total number of people living in 3 communes of Nam Xuan Lac Reserve for year of 2019 is 8,386 people, with 1,881 households and divided into 28 villages, 4 -5 people per household (Table 60). The average population density of the region is 45 people/km^2, but its distribution is uneven. Dong Lac commune has the highest population density of 62 people/km^2, and Ban Thi commune has the lowest density of 26 people/km^2.

Table 60. *Polulation and labors of communes in the Nam Xuan Lac reserve in 2019*

No	Commune	No of villages	No of households	No of persons	Labors	Population density (pers/km^2)
1	Xuan Lac	14	845	4,140	2,399	45
2	Dong Lac	6	596	2,562	1,623	62
3	Ban Thi	8	440	1,684	1,138	26
	Total	**28**	**1,881**	**8,386**	**5,160**	**45**

Source: Statistical Yearbook of Cho Don district in 2019

There are 6 ethnic minorities, of which the Kinh about 53.49%, Tay - 33.02%, Nung - 4.39%, Dao - 4.35%, H'mong - 3.06%, other ethnic groups about 1.68%. Table 2 shows the composition of ethnic minorities by commune in Nam Xuan Lac Reserve. According to the ethnic traditions, the Tay and the Kinh often live in lowland areas, near roads, and cultivate wet rice; H'mong and Dao ethnic groups live mainly in the mountainous areas.

Table 61. *Minority ethnics of communes in 2019*

***Unit:* %**

No	Commune	Minority ethnic by composition					
		Kinh	**Tay**	**Nung**	**Dao**	**H'mong**	**Others**
1	Xuan Lac	17.93	32.68	5.42	0.23	2.19	0.00
2	Dong Lac	33.87	0.30	0.07	1.85	0.08	0.00
3	Ban Thi	5.08	0.13	7.69	6.82	2.37	1.68
Average		**53.49**	**33.02**	**4.39**	**4.35**	**3.06**	**1.68**

Nguồn: Statistical Yearbook of Cho Don district in 2019

(1). Landuse and landcover in the communes of Nam Xuan Lac Reserve during period 1989-2017

Table 62 shows a breakdown of the land-cover for the 3 communes covering Nam Xuan Lac Reserve.

Table 62. *Land use/land cover types for Nam Xuan Lac Reserve during 1989 – 2017*

Landuse/ landcover	**1989**		**1998**		**2007**		**2017**	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Close forest	13,913.6	72.2	15,188.4	78.8	14,629.5	75.9	13,491.2	70.0
Open forest	1,209.6	6.3	642.0	3.3	924.8	4.8	586.5	3.0
Bushes	1,731.4	9.0	360.8	1.9	1,680.2	8.7	1,423.6	7.4
Agricultural land	2,414.8	12.5	3,083.5	16.0	2,041.6	10.6	3,776.5	19.6
Mining/Bare land	7.3	0.0	2.0	0.0	0.5	0.0	0.6	0.0
Total	19,276.7	100.0	19,276.7	100.0	19,276.6	100.0	19,278.5	100.0

Source: Interpretation of remote sensing imagery, 2021

The landuse and landcover change for Bac Me Reserve during 1989 – 2019 is presented in the Table 63, Figure 26 and Figure 27.

Table 63. *Land use/land cover change for Nam Xuan Lac Reserve during 1989 – 2017 (%)*

Land use & Land cover	***1989-1998***	***1998-2007***	***2007-2017***	***1989-2017***
Close forest	+ 6.6	- 2.9	- 5.9	- 2.2
Open forest	- 2.9	+ 1.5	- 1.8	- 3.2
Bush	- 7.1	+ 6.8	- 1.3	- 1.6
Agricultural land/Paddy	+ 3.5	- 5.4	9.0	7.1
Water	- 0.0	- 0.0	+ 0.0	- 0.0

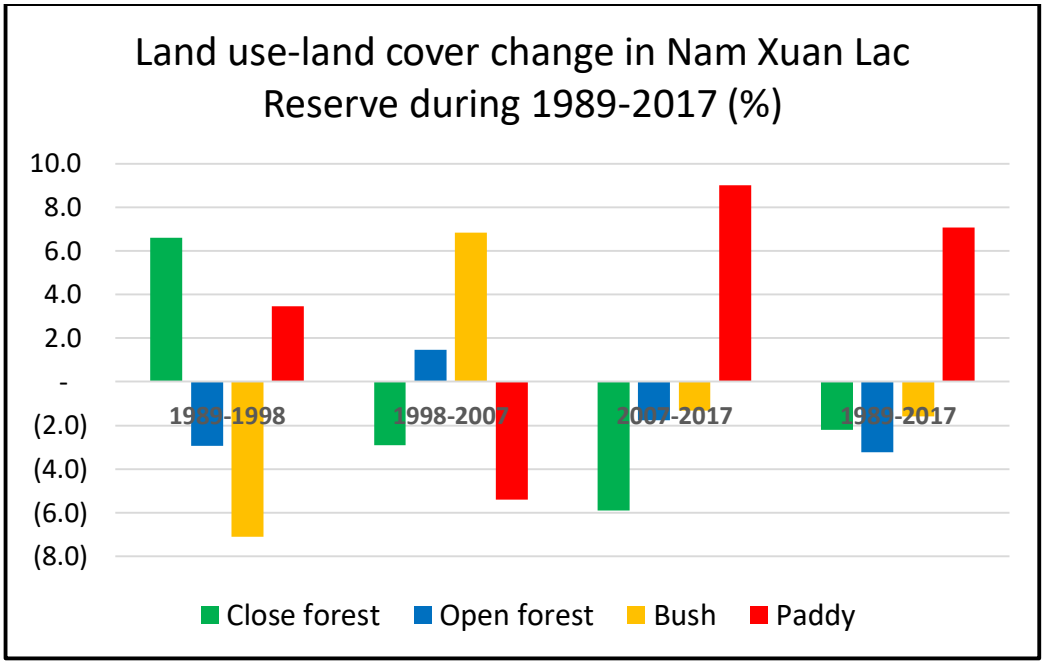


Figure 26. *Land use-land cover change in Nam Xuan Lac Reserve during 1989-2017 (%)*

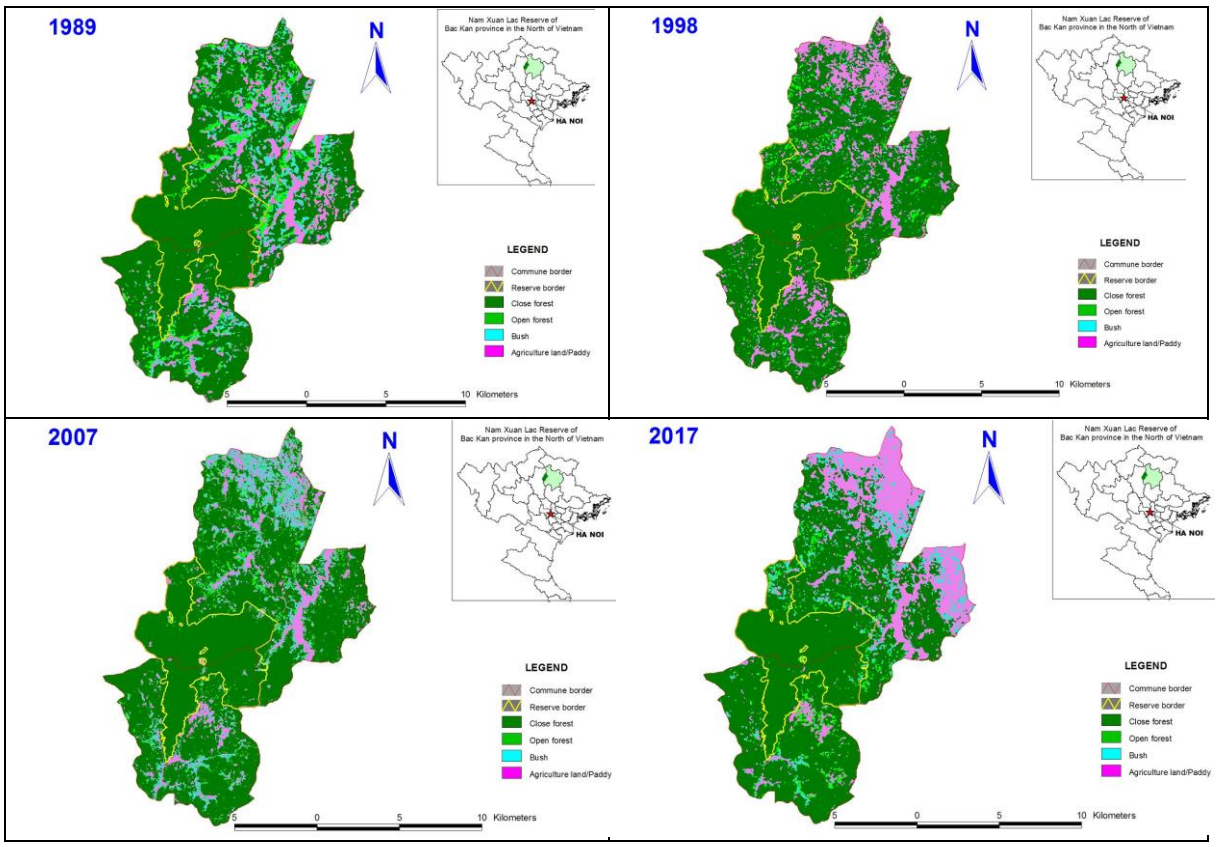


Figure 27. *Evolution of land use and land cover change for Nam Xuan Lac Reserve during 1989 – 2017*

(2). Land use and land cover by communes of Nam Xuan Lac Reserve during period 1989-2017

Tables 63, 64, 65 and 66 show the current landuse/landcover for 3 communes in Nam Xuan Lac Reserve for 1989, 1998, 2007 and 2017, extracted from analysis of satellite images.

Table 63. *Land use / Land cover for communes of Nam Xuan Lac Reserve in 1989*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land/Paddy	Water
1	Dong Lac	3,644.6	2,063.5	244.4	507.4	823.1	6.2
2	Ban Thi	8,984.3	6,371.6	649.5	884.7	1,077.9	0.6
3	Xuan Lac	6,647.7	5,478.5	315.6	339.3	513.8	0.5
Total		**19,276.7**	13,913.6	1,209.6	1,731.4	2,414.8	7.3

Table 64. *Land use / Land cover for communes of Nam Xuan Lac Reserve in 1998*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land/Paddy	Water
1	Dong Lac	3,644.6	2,743.7	112.7	98.1	688.1	2.0
2	Ban Thi	8,984.3	6,752.1	355.4	205.7	1,671.2	0.0
3	Xuan Lac	6,647.7	5,692.6	173.9	57.1	724.1	0.0
Total		**19,276.7**	15,188.4	642.0	360.8	3,083.5	2.0

Table 65. *Land use / Land cover for communes of Nam Xuan Lac Reserve in 2007*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land/Paddy	Water
1	Dong Lac	3,650.7	2,671.5	165.0	286.1	527.9	0.3
2	Ban Thi	8,980.7	6,383.4	551.9	1,013.9	1,031.4	0.2
3	Xuan Lac	6,645.2	5,574.6	208.0	380.3	482.3	0.0
Total		**19,276.6**	14,629.5	924.8	1,680.2	2,041.6	0.5

Table 66. *Land use / Land cover for communes of Nam Xuan Lac Reserve in 2017*

No	Commune	Natural areas (ha)	Area interpreted from remote sensing imagery (ha)				
			Close forest	Open forest	Bushes	Agricultural land/Paddy	Water
1	Dong Lac	3,643.4	1,783.1	99.4	439.9	1,321.0	0.0
2	Ban Thi	8,979.5	5,846.0	213.3	845.0	2,075.1	0.1
3	Xuan Lac	6,655.6	5,862.2	273.9	138.7	380.3	0.5
Total		**19,278.5**	13,491.2	586.5	1,423.6	3,776.5	0.6

3). Landuse and landcover by altitude for Nam Xuan Lac Reserve during 1988-2019

The land use and land cover by altitude in Nam Xuan Lac Reserve for the years 1989, 1998, 2007, 2017 is presented in Tables 67, 68, 69 and 70. Topograpgy of Nam Xuan Lac Reserve is presented in Figure 28.

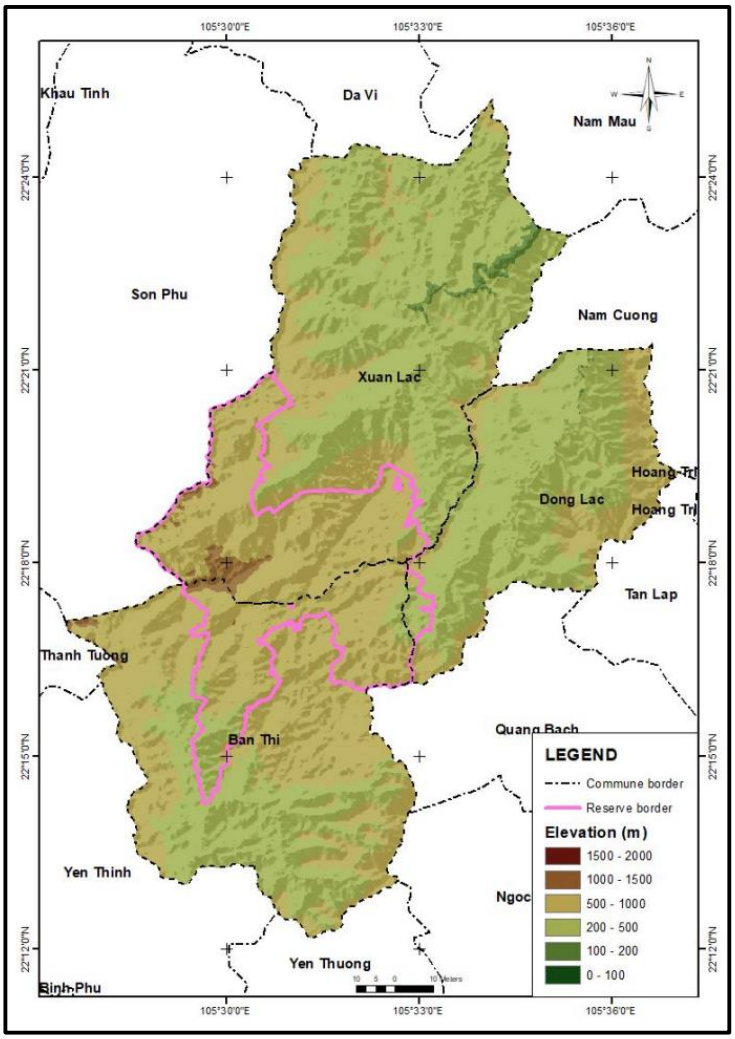


Figure 28. *Topographic map of Nam Xuan Lac Reserver*

Table 67. *Land use and Land cover by altitude for communes of Nam Xuan Lac Reserve in 1989*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	Total
100 - 200	29.1	24.7	39.3	53.9		147.0
200 - 500	5,687.9	987.5	1,289.6	1,602.3	16.2	9,583.6
500 - 1000	7,978.5	192.9	375.6	760.8	12.9	9,320.7
1000 - 1500	225.4					225.4
Total	13,920.9	1,205.1	1,704.5	2,417.0	29.0	19,276.7

Table 68. *Land use and Land cover by altitude for communes of Nam Xuan Lac Reserve in 1998*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	Total
100 - 200	42.4	7.5	10.9	84.5		145.2
200 - 500	6,842.6	316.7	250.5	2,158.7	24.5	9,592.9
500 - 1000	8,123.4	283.4	76.2	824.5		9,307.5
1000 - 1500	224.7	6.2				230.9
Total	15,233.1	613.9	337.6	3,067.6	24.5	19,276.7

Table 69. *Land use and Land cover by altitude for communes of Nam Xuan Lac Reserve in 2007*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	Total
100 - 200	16.9	14.1	35.6	75.0		141.6
200 - 500	6,046.7	592.1	1,421.3	1,505.3	23.2	9,588.6
500 - 1000	8,419.3	220.9	209.1	454.8		9,304.0
1000 - 1500	222.7	5.9	5.8	8.1		242.4
Total	14,705.6	832.9	1,671.8	2,043.1	23.2	19,276.7

Table 71. *Land use and Land cover by altitude for communes of Nam Xuan Lac Reserve in 2017*

Unit: ha

Altitude (m)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	Total
100 - 200	6.6		16.5	116.3	-	139.4
200 - 500	5,725.4	266.3	955.3	2,628.8	11.5	9,587.2
500 - 1000	7,562.9	305.9	423.9	1,020.6	11.6	9,324.8
1000 - 1500	225.2	-	-	-	-	225.2
Total	13,520.1	572.2	1,395.6	3,765.7	23.1	19,276.7

In summary, the characteristics of land use and land cover of Nam Xuan Lac Reserve are the followings:

i). In general, close forest has a large coverage, accounting for more than 70% in the Reserve (72.2% in 1989, 78.8% in 1998, 75.9% in 2007 and 70% in 2017). Open forest, accounts for a certain percentage, ranging from 3 % to 6.3%, but this forest decreases during period during 1989-2017.

During the period 1988-1998, the area of close forest is increased rapidly due to the decrease in open forest and bush. In the following periods, close forest has trend to decrease while open forest and bush increase (1998-2007) or agricultural land /shifting cultivation land increase (2007-2017).

ii). By commune, the area of close forest and open is distributed mainly in Ban Thi and Xuan Lac communes, where the large area of open forest and bush is concentrated in Ban Thi commune. During the period 1998-2017, there is a trend of conversion from close forest to bush or agricultural land/swidden land, especially in Ban Thi commune.

iii). By altitude, most of close forest and open forest are concentrated in the elevation zones ranging from 200m - 1000m; Bush and agricultural land/swidden land focus mostly in the elevaltion zone ranging from 200m – 500m, where large proportion of land use / land cover change is done.

2.6.2. Assessment of ecosystem services of the study sites

2.6.2.1. Cham Chu Reserve

(1). Assessment of ecosystem services for Cham Chu Reserve during the period 1986-2017

The method of value transfer (de Groot et al., 2012, Table 16, page 29) is used to calculate the Indexes of ecosystem services (provisioning, regulating, cultural and

supporting) for different types of land use (Close Forest, Open Forest, Bush, Agricultural land/Paddy, Fresh water) for Cham Chu Reserve. Some indexes/functions not defined by de Groot et al., (2012) were added from the methodology developed by Costanza et al., (1997: Table 2, p 256) for Function for Pollination (regulating ecosystem service) for the land use type is Agricultural land/Paddy. The index/function of the ecosystem service provided by the agricultural land/Paddy land use type is estimated from the statistics of production value (VND converted to USD) per 1 hectare of arable land, notable from the Statistical Yearbook of Ham Yen and Chiem Hoa districts, Tuyen Quang province in 2017 (See Table 12, p. 26).

Table 72 presents the total value of ecosystem services for each land use type of Cham Chu Reserve during 1986-2017 and Figure 29 shows the distribution map of ecosystem service value (USD/ha) in Cham Chu Reserve in 1986, 1998, 2007 and 2017.

Table 72. *Estimated total value of ecosystem services for each land use type of Cham Chu Nature Reserve*

Unit: Million USD

Landuse type	**1986**		**1998**		**2007**		**2017**	
	Million USD	%	Million USD	%	Million USD	%	Million USD	%
Close Forest	128.46	71.75	126.11	70.82	122.26	70.28	135.72	78.43
Open Forest	32.62	18.22	34.64	19.45	30.55	17.56	26.95	15.57
Bushes	10.96	6.12	10.35	5.81	12.48	7.17	4.06	2.35
Bare Land	0	0.00	0	0.00	0	0.00	0	0.00
Rice Paddy	6.32	3.53	6.15	3.45	8.19	4.71	5.84	3.37
Water surface	0.69	0.39	0.81	0.45	0.49	0.28	0.48	0.28
Total (Million USD)	179.05	100.00	178.06	100.00	173.97	100.00	173.05	100.00
Total (USD/ha)	***4.427***		***4.403***		***4.301***		***4.279***	

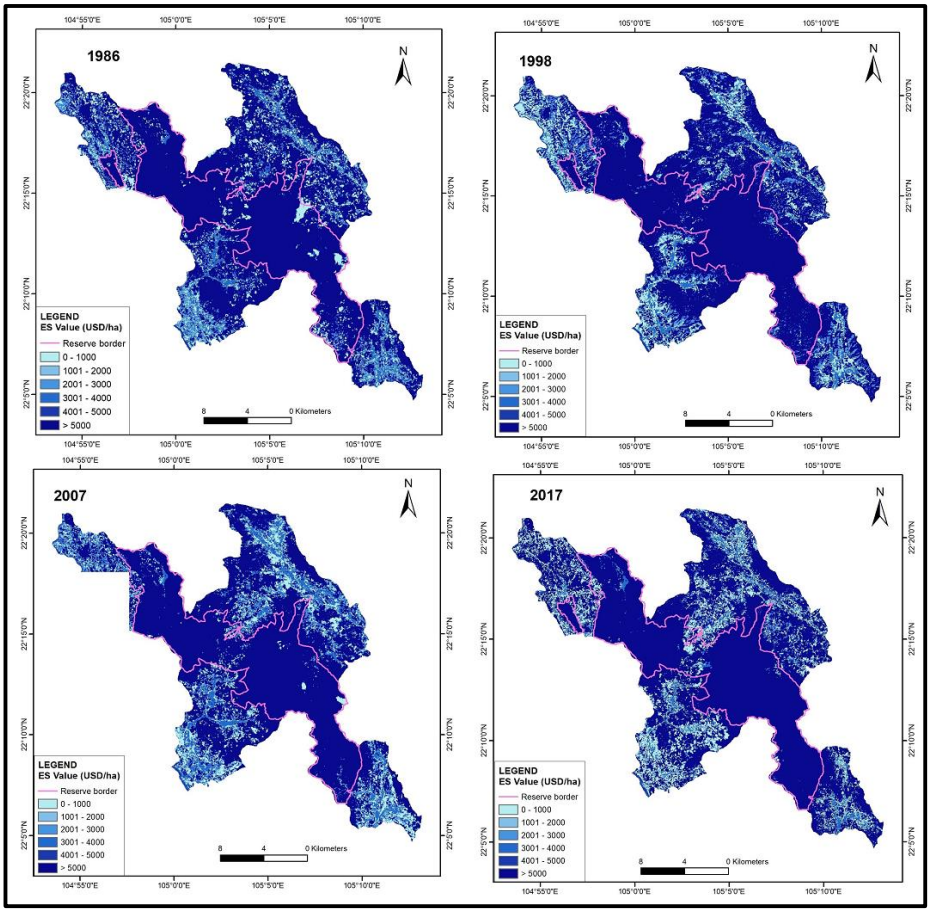


Figure 29. *Map of total value of ecosystem services (USD/ha) in Cham Chu Nature Reserve in 1986, 1998, 2007 and 2017.*

(2). Assessment of ecosystem services by commune for Cham Chu Reserve during the period 1986-2017

The value of ecosystem services for Cham Chu Reserve for years of 1986, 1998, 2007 and 2017 is shown in Tables 73, 74, 75 and 76.

Table 73. *Estimated total value of ecosystem services by commune for Cham Chu Reserve in 1986*

Unit: Million USD

No	Administrative unit	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	Total
I	**Ham Yen Distric**	**52.02**	**12.12**	**4.92**	**0**	**2.72**	**0.52**	**72,3**
1	Phu Luu commune	27.18	7.14	2.81	0	1.78	0.27	**39,18**
2	Yen Thuan commune	24.84	4.98	2.11	0	0.94	0.25	**33,12**
II	**Chiem Hoa district**	**76.46**	**20.5**	**6.02**	**0**	**3.6**	**0.14**	**106,72**

1	Trung Ha commune	34.47	8.66	2.05	0	1.46	0.08	**46,72**
2	Ha Lang commune	25.29	7.03	1.72	0	0.76	0.04	**34,84**
3	Hoa Phu commune	16.7	4.81	2.25	0	1.38	0.02	**25,16**
Total		**128.48**	**32.62**	**10.94**	**0**	**6.32**	**0.66**	**179.02**

Table 74. *Estimated total value of ecosystem services by commune for Cham Chu Reserve in 1998*

Unit: Million USD

No	**Administrative unit**	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	**Total**
I	**Ham Yen Distric**	**48.66**	**12.3**	**4.46**	**0**	**3.08**	**0.65**	**69,15**
1	Phu Luu commune	27.43	6.57	2.03	0	1.98	0.27	**38,28**
2	Yen Thuan commune	21.23	5.73	2.43	0	1.1	0.38	**30,87**
II	**Chiem Hoa district**	**77.45**	**22.32**	**5.89**	**0**	**3.05**	**0.16**	**108,87**
1	Trung Ha commune	34.15	8.85	2.36	0	1.21	0.07	**46,64**
2	Ha Lang commune	27.46	6.79	1.62	0	0.65	0.06	**36,58**
3	Hoa Phu commune	15.84	6.68	1.91	0	1.19	0.03	**25,65**
Total		**126,11**	**34.62**	**10.35**	**0**	**6.13**	**0.81**	**178.02**

Table 76. *Estimated total value of ecosystem services by commune for Cham Chu Reserve in 2007*

Unit: Million USD

No	**Administrative unit**	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	**Total**
I	**Ham Yen Distric**	**44.81**	**14.23**	**5.77**	**0**	**3.87**	**0.36**	**69,04**
1	Phu Luu commune	24.41	7.24	2.66	0	2.28	0.18	**36,77**
2	Yen Thuan commune	20.4	6.99	3.11	0	1.59	0.18	**32,27**
II	**Chiem Hoa district**	**77.44**	**16.32**	**6.73**	**0**	**4.34**	**0.13**	**104,96**
1	Trung Ha commune	32.28	7.05	3.08	0	2.09	0.06	**44,56**
2	Ha Lang commune	27.49	5.16	1.76	0	1.18	0.04	**35,63**
3	Hoa Phu commune	17.67	4.11	1.89	0	1.07	0.03	**24,77**
Total		**122.25**	**30.55**	**12.5**	**0**	**8.21**	**0.49**	**174**

Table 78. *Estimated total value of ecosystem services by commune for Cham Chu Reserve in 2017*

Unit: Million USD

No	Administrative unit	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	Total
I	**Ham Yen Distric**	**50.09**	**12.51**	**1.24**	**0**	**2.62**	**0.4**	**66,86**
1	Phu Luu commune	27.63	4.96	0.73	0	1.55	0.18	**35,05**
2	Yen Thuan commune	22.46	7.55	0.51	0	1.07	0.22	**31,81**
II	**Chiem Hoa district**	**85.62**	**14.46**	**2.84**	**0**	**3.28**	**0.08**	**106,28**
1	Trung Ha commune	32.67	7.16	1.72	0	1.51	0.03	**43,09**
2	Ha Lang commune	31.02	4.06	0.72	0	0.75	0.03	**36,58**
3	Hoa Phu commune	21.93	3.24	0.4	0	1.02	0.02	**26,61**
Total		**135.71**	**26.97**	**4.08**	**0**	**5.9**	**0.48**	**173.14**

(3). Assessment of ecosystem services by altitude for Cham Chu Nature Reserve during the period 1988-2019

Total value of ecosystem services by altitude for Cham Chu Reserve in 1986, 1998, 2007 and 2017 are presented in the Tables 77, 78, 79 and 80 below.

Table 79. *Estimated value of ecosystem services by altitude for Cham Chu Reserve in 1986*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	*Total*
0 - 100	4.66	4.24	4.20	3.48	0.56	**17.14**
100 - 200	18.96	14.35	4.22	1.68	0.11	**39.33**
200 - 500	43.33	12.41	2.18	0.69	0.04	**58.65**
500 - 1000	45.18	1.38	0.21	0.43	0.04	**47.24**
1000 - 1500	16.56	0.05	0.02	0.05	-	**16.69**
1500 - 2000	0.08	-	-	-	-	**0.08**
Total	**128.78**	**32.44**	**10.83**	**6.34**	**0.75**	**179.12**

Table 80. *Estimated value of ecosystem services by altitude for Cham Chu Reserve in 1998*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	*Total*
0 - 100	2.39	5.53	1.03	4.63	0.72	**14.30**
100 - 200	17.71	13.13	4.33	1.34	0.10	**36.60**
200 - 500	44.38	12.39	4.15	0.10	0.04	**61.07**
500 - 1000	45.58	2.70	0.57	0.10	0.04	**49.00**
1000 - 1500	16.49	0.21	0.06	0.03	-	**16.78**
1500 - 2000	0.08	-	-	-	-	**0.08**
Total	**126.63**	**33.96**	**10.15**	**6.20**	**0.90**	**177.83**

Table 81. *Estimated value of ecosystem services by altitude for Cham Chu Reserve in 2007*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	*Total*
0 - 100	1.66	4.90	3.45	5.30	0.41	**15.71**
100 - 200	12.97	13.08	5.53	2.38	0.10	**34.06**
200 - 500	44.48	10.41	3.19	0.34	0.04	**58.46**
500 - 1000	46.66	1.29	0.32	0.30	0.04	**48.61**
1000 - 1500	16.72	0.04	0.02	-	-	**16.79**
1500 - 2000	0.08	-	-	-	-	**0.08**
Total	**122.57**	**29.73**	**12.50**	**8.32**	**0.58**	**173.71**

Table 82. *Estimated value of ecosystem services by altitude for Cham Chu Reserve in 2017*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	*Total*
0 - 100	3.55	8.81	0.38	3.06	0.42	**16.23**
100 - 200	22.45	9.37	1.64	1.68	0.09	**35.23**
200 - 500	46.57	6.76	1.83	0.53	0.04	**55.73**

500 - 1000	46.66	1.25	0.17	0.53	0.04	**48.66**
1000 - 1500	16.72	0.06	0.02	0.03	-	**16.84**
1500 - 2000	0.08	-	-	-	-	**0.08**
Total	**136.04**	**26.26**	**4.05**	**5.83**	**0.60**	**172.77**

In summary, the characteristics of ecosystem service value for Cham Chu Reserve are as followings:

+ The value of ecosystem services for the whole Cham Chu Reserve is more than 179 million USD (in 1986) and more than 173 million USD (in 2017), and tends to decrease gradually. Similarly, the value of ecosystem services per hectare is decreased from USD 4,427 (in 1986) to USD 4,279 (in 2017).

+ Among types of land use, close forest has the highest value, varying from 70% to 78% of the total value of ecosystem services, of which the highest value was 128.46 million USD in 1986. Open forest has a smaller value, accounting for 15.57% - 19.45%. Other land uses have relatively low values.

+ Among the communes of the Reserve, Trung Ha commune (Chiem Hoa) has the highest value, followed by Phu Luu commune (Ham Yen district), then Ha Lang (Chiem Hoa), and 2 remaining communes (Yen Thuan and Hoa Phu) have a lower value. The proportion of ecosystem service value among communes also changes with the change of land use types over time.

+ By altitude, land use and land cover in the elevation zones ranging from 200m - 1000m contributes the largest value of ecosystem services (accounting for 60% of the value), then followed by the elevation zone ranging from 100m - 200m, the rest of the other zones (0 m – 100 m and >1000 m) have lower values.

2.6.2.2. Bac Me Nature Reserve

(1). Assessment of ecosystem services for Bac Me Nature Reserve during the period 1988-2019

The method of value transfer (de Groot et al., 2012, Table 1, page 55) is used to calculate the Indexes of ecosystem services (provisioning, regulating, cultural and supporting) for different types of land use (Close Forest, Open Forest, Bush, Agricultural land/Paddy, Fresh water) for Bac Me Nature Reserve. Some indexes/functions not defined by de Groot et al., (2012) were added from the methodology developed by Costanza et al., (1997: Table 2, p 256) for Function for Pollination (regulating

ecosystem service) for the land use type is Agricultural land/Paddy. The index/function of the ecosystem service provided by the agricultural land/Paddy land use type is estimated from the statistics of production value (VND converted to USD) per 1 hectare of arable land, notable from the Statistical Yearbook of Bac Me district, Ha Tuyen province in 2019 (See Table 17, p. 28).

Table 83 and Figure 20 present the total value of ecosystem services for each land use type of Bac Me Nature Reserve during 1988-2019 and Figure 21 shows the distribution map of ecosystem service value (USD/ha) in the Bac Me Nature Reserve in 1988, 1998, 2009 and 2019.

Table 83. *Estimated total value of ecosystem services by land use type for Bac Me Nature Reserve during 1988-2019*

Land use type	1988		1998		2009		2019	
	Million USD	%	Million USD	%	Million USD	%	Million USD	%
Close forest	68.79	74.25	53.90	60.22	58.60	64.65	51.82	58.14
Open forest	14.46	15.61	24.61	27.49	22.16	24.44	24.53	27.52
Bushes	8.16	8.80	9.67	10.80	7.69	8.48	9.26	10.39
Bare land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agricultural land/Paddy	0.79	0.85	1.13	1.26	0.45	0.50	1.92	2.13
Water	0.93	1.00	0.88	0.99	2.02	2.23	2.76	3.10
Total (Million USD)	***93.13***	***100.00***	***90.20***	***100.00***	***90.92***	***100.00***	***90.30***	***100.00***
Total (USD/ha)	***4416***		***4278***		***4312***		***4282***	

Thus, over the past 30 years, from 1988 to 2019, the total value of ecosystem services by land use types in the communes of Bac Me Nature Reserve has not changed much, fluctuating in the range of 90 - 93 million USD. However, the total value of ecosystem services only reached $ 90.30 million in 2019, a decrease of $ 2.84 million compared to 1988 (reaching $ 93.13 million). Close and open forests contribute the largest amount, about 85% to the total value of ecosystem services because of their particularly important roles through their inherent functions such as providing food, regulating water biochemical processes in the systems, reaching 4.452 USD/ha/year.

Among four types of ecosystem services, regulating services contribute the largest part to the total value of ecosystem services in Bac Me Natuer Reserve, reaching 37.47 million USD in 2019, accounting for 41.49% of total value, through the functions such

as air quality regulation, climate regulation, disturbance moderation, regulation of water flow, waste treatment, erosion prevention, nutrient cycling, pollination and biological control. Provisioning service has the second largest value, reaching 34.07 million USD, equivalent to 37.73% of the total value.

Table 85. *Estimated value of ecosystem services by types for Bac Me Nature Reserve in the period 1988 – 2019*

Ecosystem service types	1988		1998		2009		2019	
	Million **USD**	**%**	Million **USD**	**%**	Million **USD**	**%**	Million **USD**	**%**
Provisioning	34.01	36.52	33.40	37.04	33.08	36.38	34.07	37.73
Regulating	40.61	43.61	38.44	42.62	39.42	43.36	37.47	41.49
Supporting	4.25	4.56	4.88	5.41	4.02	4.42	4.69	5.19
Cultural	14.26	15.31	13.47	14.93	14.4	15.84	14.07	15.58
Total	***93.13***	***100.00***	***90.19***	***100.00***	***90.92***	***100.00***	***90.30***	***100.00***

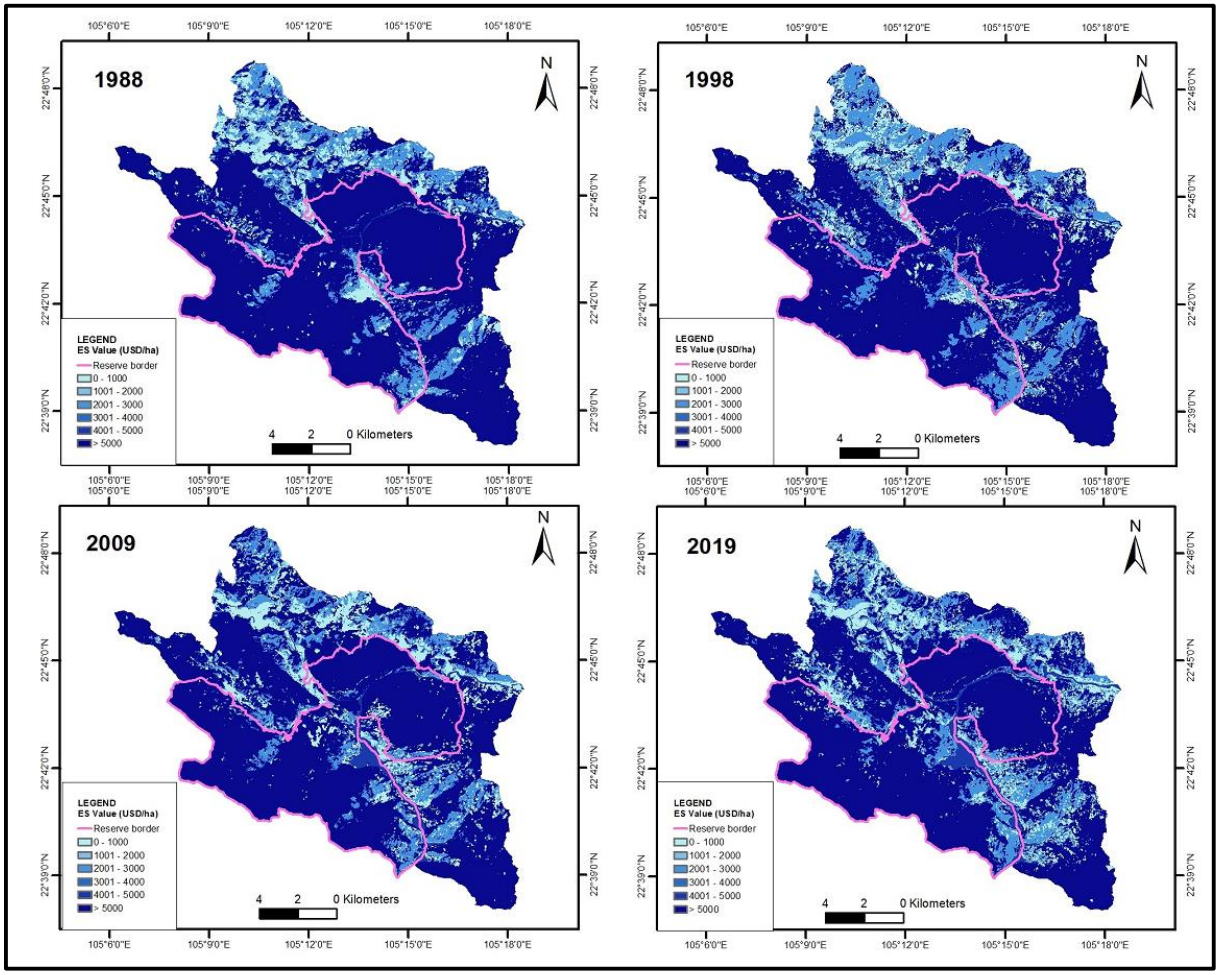


Figure 30. *Distribution map of total ecosystem services value (USD/ha) in Bac Me Nature Reserve in 1988, 1998, 2009 and 2019*

(2). Assessment of ecosystem services by commune for Bac Me Nature Reserve during the period 1988-2019

The value of ecosystem services for Bac Me Nature Reserve for years of 1988, 1998, 2009 and 2019 is shown in Tables 86, 87, 88, 89.

Table 86. *Estimated total value of ecosystem services by commune for Bac Me Nature Reserve in 1988*

No	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)						Total
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	
1	Lac Nong	4,632	14.89	2.75	1.99	0.00	0.17	0.31	***20.11***
2	Minh Ngoc	9,260	29.24	6.52	3.36	0.00	0.52	0.34	***39.97***
3	Thuong Tan	7,195	24.66	5.20	2.80	0.00	0.11	0.28	***33.06***
Total		***21,087***	***68.79***	***14.46***	***8.16***	***0.00***	***0.79***	***0.93***	***93.13***

Table 87. *Estimated total value of ecosystem services by commune for Bac Me Nature Reserve in 1998*

No	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)						Total
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	
1	Lac Nong	4,632	12.16	4.70	2.01	0.00	0.17	0.29	***19.33***
2	Minh Ngoc	9,260	22.67	10.27	4.34	0.00	0.79	0.30	***38.38***
3	Thuong Tan	7,195	19.07	9.64	3.32	0.00	0.17	0.29	***32.49***
Total		***21,087***	***53.90***	***24.61***	***9.67***	***0.00***	***1.13***	***0.88***	***90.20***

Table 88. *Estimated total value of ecosystem services by commune for Bac Me Nature Reserve in 2009*

No	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)						Total
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	
1	Lac Nong	4,632	12.98	4.48	1.54	0.00	0.11	0.26	***19.37***
2	Minh Ngoc	9,260	25.72	11.02	3.16	0.00	0.25	0.15	***40.30***
3	Thuong Tan	7,195	19.90	6.65	2.99	0.00	0.08	1.61	***31.24***
Total		***21,087***	***58.60***	***22.16***	***7.69***	***0.00***	***0.45***	***2.02***	***90.92***

Table 89. *Estimated total value of ecosystem services by commune for Bac Me Nature Reserve in 2019*

No	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)						Total
			Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	
1	Lac Nong	4,632	11.51	5.24	2.10	0.00	0.49	0.49	***19.83***
2	Minh Ngoc	9,260	23.48	10.77	3.61	0.00	1.01	0.46	***39.35***
3	Thuong Tan	7,195	16.83	8.52	3.55	0.00	0.42	1.80	***31.11***
Total		***21,087***	***51.82***	***24.53***	***9.26***	***0.00***	***1.92***	***2.76***	***90.30***

Table 90. *Estimation of several provisioning and regulating services by statistics for Bac Me district Ha Giang province in 2017*

No	*Ecosystem services*	*Value (Million VND)*	*Value (USD) (1 USD=22,980VND)*
1	***Provisioning services***	***780,149.50***	***33,949,064***
1.1	Agricultural production	692,342.19	30,128,033
1.2	Forestry production	78,834.80	3,430,583
1.3	Aquacultural production	8,972.51	390,449
2	***Regulating services***	***4,781.20***	***208,059***
2.1.	Payment for Forest Environmental Service	4,781.20	208,059
	Total	**784,930.70**	34,157,124

During the period of 1988-2019, the total value of ecosystem services are significantly different among communes in Bac Me Nature Reserve. Minh Ngoc commune has the largest value, varying in the range of 39.35 - 40.30 million USD, accounting for about 42.5% - 44.3% of the total value for the Reserve. Thuong Tan Commune, with the second largest value, varies between 31.11 - 33.06 million USD million, accounting for 34.4% - 36%. Lac Nong commune has the lowest value, ranging from 19.33 - 20.11 million USD, accounting for 21.3%-22.0% of the total value.

(3). Assessment of ecosystem services by altitude for Bac Me Nature Reserve during the period 1988-2019

Total value of ecosystem services by altitude for Bac Me Nature Reserve in 1988, 1998, 2009 and 2019 are presented in the Tables 91, 92, 93, 94 below.

Table 91. *Estimated value of ecosystem services by altitude for Bac Me Nature Reserve in 1988*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Total*
0 - 100	0.19	0.03	0.08	0.00	0.02	0.08	***0.40***
100 - 200	4.36	1.79	1.30	0.00	0.46	0.71	***8.61***
200 - 500	17.01	6.14	4.35	0.00	0.21	0.09	***27.80***
500 - 1000	31.64	4.58	2.47	0.00	0.08	0.02	***38.78***
1000 - 1500	16.10	0.14	0.01	0.00	0.01	0.00	***16.27***
1500 - 2000	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Total	***69.29***	***12.68***	***8.22***	***0.00***	***0.78***	***0.90***	***91.87***

Table 92. *Estimated value of ecosystem services by altitude for Bac Me Nature Reserve in 1998*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Total*
0 - 100	0.10	0.11	0.07	0.00	0.03	0.09	***0.40***
100 - 200	1.87	3.05	1.56	0.00	0.54	0.70	***7.71***
200 - 500	11.54	9.54	4.67	0.00	0.46	0.08	***26.29***
500 - 1000	25.04	8.94	3.31	0.00	0.09	0.01	***37.39***
1000 - 1500	15.53	0.62	0.09	0.00	0.00	0.00	***16.24***
1500 - 2000	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Tổng	***54.08***	***22.25***	***9.71***	***0.00***	***1.11***	***0.88***	***88.03***

Table 93. *Estimated value of ecosystem services by altitude for Bac Me Nature Reserve in 2009*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Total*
0 - 100	0.10	0.01	0.00	0.00	0.00	0.49	***0.59***
100 - 200	2.21	2.22	1.07	0.00	0.31	1.52	***7.33***

200 - 500	12.94	9.85	4.01	0.00	0.09	0.01	***26.90***
500 - 1000	27.76	7.49	2.57	0.00	0.02	0.00	***37.84***
1000 - 1500	15.74	0.26	0.11	0.00	0.00	0.00	***16.11***
1500 - 2000	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Tổng	***58.75***	***19.82***	***7.77***	***0.00***	***0.42***	***2.02***	***88.78***

Table 94. *Estimated value of ecosystem services by altitude for Bac Me Nature Reserve in 2019*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Bare land	Agricultural land/Paddy	Water	*Total*
0 - 100	0.08	0.00	0.00	0.00	0.00	0.51	***0.60***
100 - 200	1.11	2.12	1.60	0.00	0.94	2.20	***7.97***
200 - 500	11.06	8.72	5.33	0.00	0.69	0.05	***25.86***
500 - 1000	25.20	9.74	2.33	0.00	0.25	0.00	***37.53***
1000 - 1500	14.56	1.50	0.04	0.00	0.03	0.00	***16.13***
1500 - 2000	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Total	***52.01***	***22.10***	***9.31***	***0.00***	***1.91***	***2.77***	***88.10***

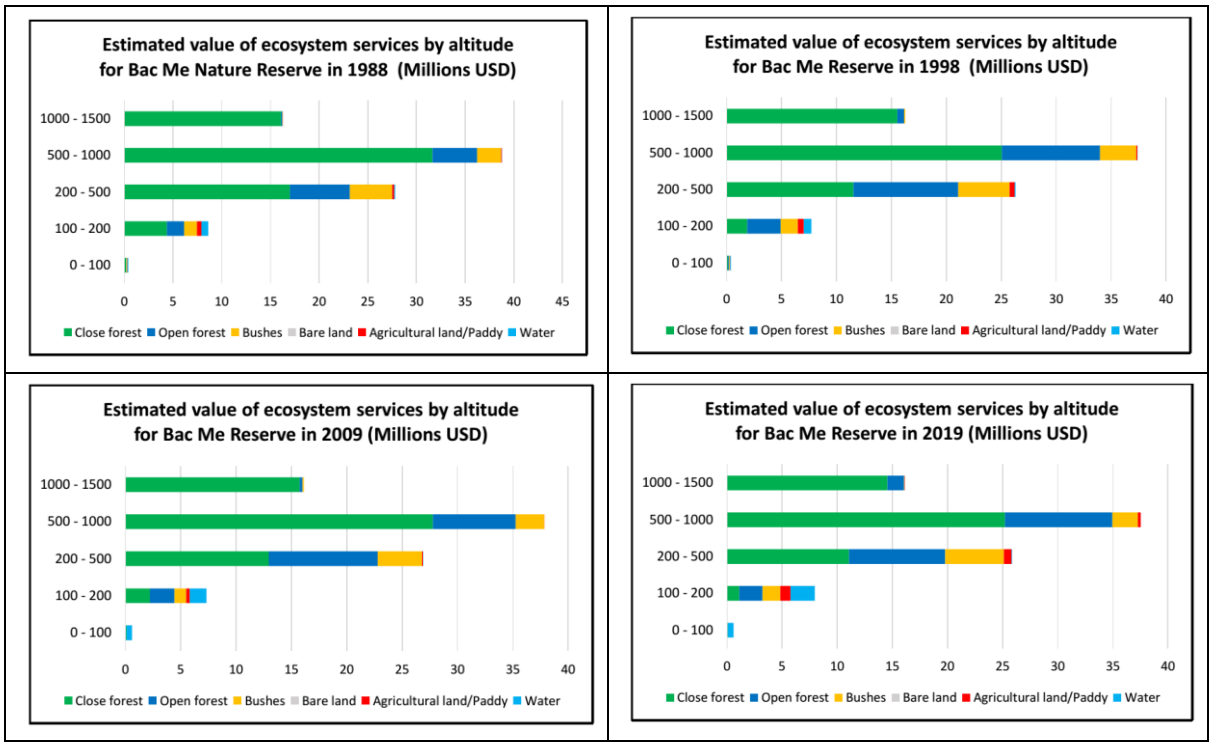


Figure 31. *Estimated value of ecosystem services by altitude for Bac Me Nature Reserve*

during 1988-2019

Thus, the value of ecosystem services at the altitude belt of 500 - 1,000 m contributes the largest amount, reaching 37 - 38 million USD/year, accounting for about 42% of the total value of ecosystem services of Bac Me Nature Reserve. The value at the altitude belt of 200 - 500 m contributes the second large amount, reaching about 27 million USD/year, accounting for about 30% of the total value. The land use and land cover types at other altitude belts, i.e. below 200 m and higher 1,000 m contribute less 30% of total value of ecosystem services.

In summary, the characteristics of ecosystem service value for Bac Me Reserve are as followings:

+ In general, the value of ecosystem services for the whole Bac Me Reserve is more than 93.13 million USD (in 1988) and more than 90.3 million USD (in 2019), and tends to decrease gradually. Similarly, the value of ecosystem services per hectare is decreased from USD 4,416 (in 1988) to USD 4,282 (in 2017).

+ Among types of land use, close forest has the highest value, decreasing from 74% (in 1988) to 58% (in 2019) of the total value of ecosystem services, of which the highest value is 68.79 million USD in 1988. Open forest has a smaller value, varying from 8% - 10% of total value, and other land uses have relatively low values.

+ Among the communes of the Reserve, Minh Ngoc commune has the highest value, followed by Thuong Tan commune and then Lac Nong commune. The proportion of ecosystem service value among communes also changes with the change of land use types over time.

+ By altitude, land use and land cover in the elevation zones ranging from 200m - 1000m contributes the largest value of ecosystem services (accounting for 70% of the value), then followed by the elevation zone ranging from 1000m - 1500m and those of 100m – 200m.

2.6.2.2. Phia Oac – Phia Den National Park

(1). Assessment of all ecosystem services for Phia Oac - Phia Den National Park during the period 1988-2019

The method of value transfer (de Groot et al., 2012, Table 1, page 55) is used to calculate the Indexes of ecosystem services (provisioning, regulating, cultural and supporting) for different types of land use (Close Forest, Open Forest, Bush, Agricultural land/Paddy, Fresh water) for Phia Oac – Phia Den National Park. Some indexes/functions not defined by de Groot et al., (2012) were added from the

methodology developed by Costanza et al., (1997: Table 2, p 256) for Function for Pollination (regulating ecosystem service) for the land use type is Agricultural land/Paddy. The index/function of the ecosystem service provided by the agricultural land/Paddy land use type is estimated from the statistics of production value (VND converted to USD) per 1 hectare of arable land, notable from the Statistical Yearbook of Cao Bang province in 2019 (See Table 18, p. 29).

Table 95 and Figure 20 present the total value of ecosystem services for each land use type of Bac Me Nature Reserve during 1988-2019 and Figure 21 shows the distribution map of ecosystem service value (USD/ha) in the Bac Me Nature Reserve in 1988, 1998, 2009 and 2019.

Table 96. *Estimated total value of ecosystem services for each land use type of Phia Oac – Phia Den National Park*

Land use type	1988		1998		2009		2019	
	Million USD	%	Million USD	%	Million USD	%	Million USD	%
Close forest	104.35	82.67	96.53	77.12	95.77	76.20	103.06	79.66
Open forest	11.11	8.80	17.60	14.06	20.91	16.64	19.26	14.88
Bushes	9.69	7.68	9.91	7.92	7.79	6.19	5.96	4.61
Agricultural land	1.08	0.85	1.13	0.90	1.22	0.97	1.09	0.84
Mine/Bare land	-	-	-	-	-	-	-	-
Total (Million USD)	**126.22**	**100.00**	**125.17**	**100.00**	**125.69**	**100.00**	**129.37**	**100.00**
Total (USD/ha)	**6,292**		**6,240**		**6,266**		**6,449**	

Thus, over the past 30 years, from 1988 to 2019, the total value of ecosystem services by land use type in the communes of Phia Oac - Phia Den National Park has not changed much, ranging between 125 - 129 million USD. In particular, the total value of ecosystem services in 2019 reached USD 129.37 million, an increase of USD 3.68 million compared to 2009 (reaching USD 125.69 million) due to the sharp increase in the area of close forest. Close and open forests contribute the largest amount, about 95% of the total value of ecosystem services because of their particularly important roles through inherent functions such as providing food, food, regulating biochemical cycles on Earth, reaching 5,263 USD/ha/year.

Among the four types of ecosystem services, regulating services contribute the largest value to the total value of ecosystem services in Phia Oac - Phia Den National Park, reaching $59.31 million in 2019 (45.85%).

Table 59 presents the value of ecosystems services for each land use type for Phia Oac – Phia Den National Park and Figure 16 shows the distribution map of ecosystem service value (USD/ha) in Phia Oac NP – Phia Den in 1988, 1998, 2009 and 2019.

Table 97. *Value of ecosystem services by types for Phia Oac - Phia Den National Park in the period 1988 – 2019*

Ecosystem service types	1988		1998		2010		2019	
	Million **USD**	**%**	Million **USD**	**%**	Million **USD**	**%**	Million **USD**	**%**
Provisioning	45.68	36.19	45.37	36.25	45.32	36.06	46.29	35.78
Regulating	56.26	44.58	55.65	44.46	56.75	45.15	59.31	45.85
Supporting	5.17	4.09	5.26	4.20	4.33	3.44	3.56	2.75
Cultural	19.11	15.14	18.90	15.10	19.30	15.35	20.21	15.62
Total (Million USD)	***126.22***	100.00	***125.17***	100.00	***125.69***	100.00	***129.37***	100.00

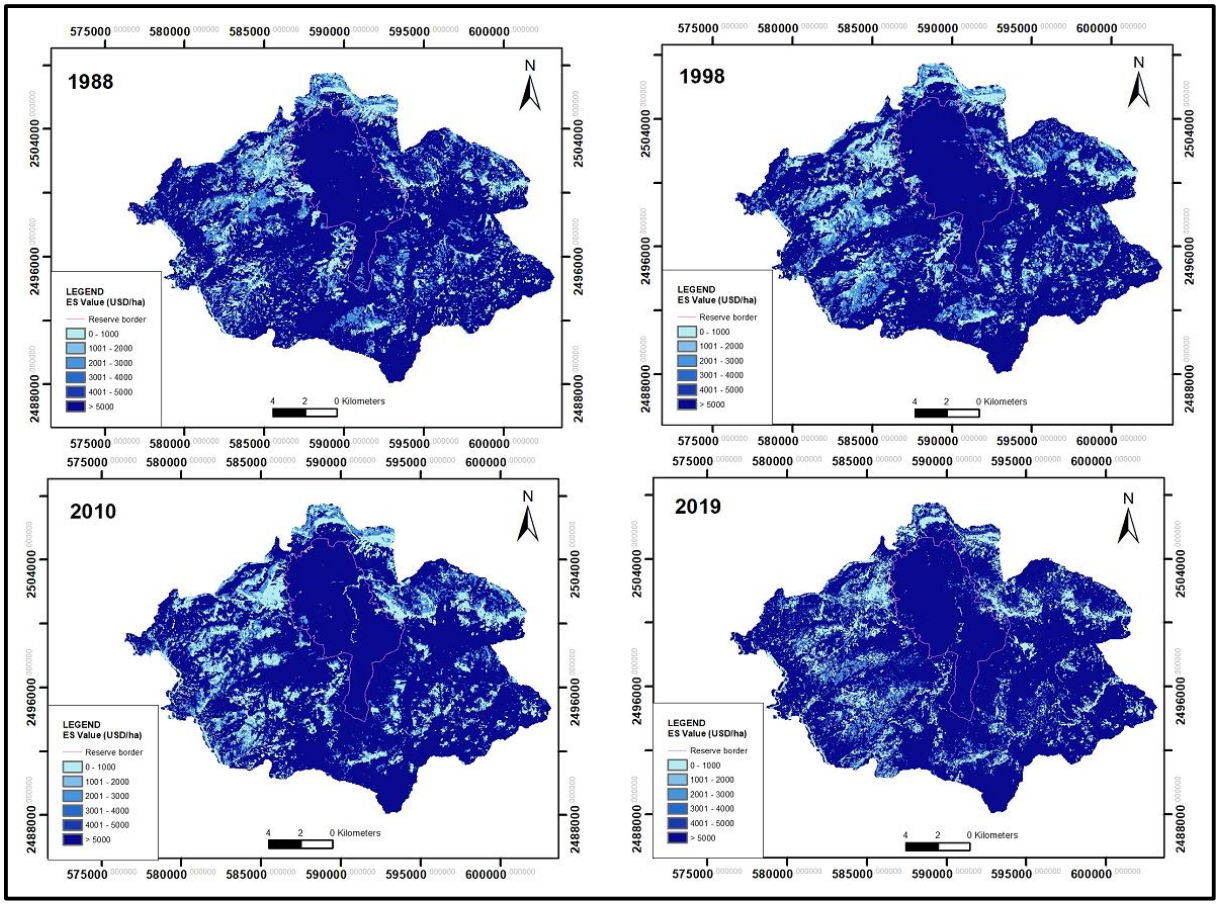


Figure 32. *Distribution map of total ecosystem services value (USD/ha) in Phia Oac - Phia Den National Park in 1988, 1998, 2009 and 2019*

(2). Evaluation of total ecosystem services by communes of Phia Oac – Phia Den National Park for period 1988-2019

The value of total ecosystem services by commune for Phia Oac - Phia Den National Park for the years 1988, 1998, 2009 and 2017 are presented in Tables 98, 99, 100 respectively. In general, these values for Phia Oac - Phia Den National Park in the period 1988 - 2019 did not change much.

Table 98. *Estimated value of total ecosystem services by commune for Phia Oac - Phia Den National Park in 1988.*

No	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.29	30.54	4.21	2.22	0.23	-
2	Quang Thanh	5,977.59	23.39	1.83	1.67	0.18	-
3	Phan Thanh	8,368.66	25.82	3.50	3.71	0.44	-
4	Hung Đao	4,408.13	17.60	1.25	1.12	0.13	-
5	Tinh Tuc town	2,155.63	6.99	0.32	0.97	0.11	-
Total		**29,060.29**	**104.35**	**11.11**	**9.69**	**1.08**	-

The value of total service ecosystems is significantly different between the communes of Phia Oac - Phia Den National Park. In 1988, the total value of ecosystems services in the National Park reached 126.22 million USD, of which, close forest had the highest value of ecosystem services, reaching 104.35 million USD, contributing 82.67% total value of ecosystem services. Among the 5 communes of the National Park, Thanh Cong commune has the largest value, followed by Phan Thanh commune, Quang Thanh commune, Hung Dao commune and the lowest is Tinh Tuc town, respectively 37.20 million USD, 33 million USD. 47 million USD, 27.07 million USD, 20.09 million USD, 8.39 million USD, (29.47%, 26.52%, 21.45%, 15.92%, 6.65%).

Table 99. *Estimated value of total ecosystem services by commune for Phia Oac - Phia Den National Park in 1998*

STT	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.29	27.75	5.52	2.73	0.26	-
2	Quang Thanh	5,977.59	21.17	3.70	1.74	0.19	-

3	Phan Thanh	8,368.66	25.56	4.15	3.32	0.46	-
4	Hung Đao	4,408.13	15.03	3.63	1.34	0.12	-
5	Tinh Tuc town	2,155.63	7.02	0.61	0.79	0.10	-
Total		**29,060.29**	**96.53**	**17.60**	**9.91**	**1.13**	-

Table 100. *Estimated value of total ecosystem services by commune for Phia Oac - Phia Den National Park in 2009*

No	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.29	29.76	5.55	1.60	0.26	-
2	Quang Thanh	5,977.59	21.13	3.14	1.62	0.24	-
3	Phan Thanh	8,368.66	22.20	7.72	2.98	0.49	-
4	Hung Đao	4,408.13	15.29	4.01	0.87	0.13	-
5	Tinh Tuc town	2,155.63	7.39	0.49	0.72	0.10	-
Total		**29,060.29**	**95.77**	**20.91**	**7.79**	**1.22**	-

Table 101. *Estimated value of total ecosystem services by commune for Phia Oac - Phia Den National Park in 2019*

No	Commune	Natural areas (ha)	Value of ecosystem services by land use types (Million USD)				
			Close forest	Open forest	Bushes	Agricultural land	Mine/Bare land
1	Thanh Cong	8,150.29	30.12	5.01	1.82	0.25	-
2	Quang Thanh	5,977.59	22.21	3.84	0.88	0.22	-
3	Phan Thanh	8,368.66	26.11	6.50	2.32	0.40	-
4	Hung Đao	4,408.13	17.98	2.11	0.48	0.13	-
5	Tinh Tuc town	2,155.63	6.65	1.79	0.46	0.09	-
Total		**29,060.29**	**103.06**	**19.26**	**5.96**	**1.09**	-

Thus, the value of total ecosystem services for the National Park in 2019 reached 129.37 million USD, of which, ecosystem services of close forest have the highest

value, reaching 95.77 million USD, contributing 79.66 % of total ecosystem services value.

(3). Assessment of ecosystem services by altitude for Phia Oac - Phia Den National Park during the period 1988-2019

The largest area of the national park is distributed mainly at the altitude of 500 - 1,000m, about 17,000 ha, of which the area of close forest fluctuates about 10,000 ha, accounting for 58-59%. Next, the second largest area of the national park is distributed at the altitude belt of 1,000 - 1,500m, mainly close forest.

Among the land use and land cover types of Phia Oac - Phia Den National Park, close forest occupies the largest area, 18,000 - 19,000 ha, accounting for 62 - 68%. In which, the area of close forest is distributed mainly at the altitude belt of 500-1,500m, accounting for about 85-90% of the total area of close forest of the National Park.

The value of ecosystem services at the altitude of 500 - 1,000m contributes the largest part, reaching USD 69 - 72 million/year, accounting for about 55% of the total value of ecosystem services of the Park, followed by in altitude belt of 1,000 - 1,500m has the second largest contribution value, 36 - 38 million USD/year, accounting for 28 - 30%. In which, close forests contribute about 96-104 million USD/year.

Table 102. *Estimated value of ecosystem services of Phia Oac - Phia Den National Park classified by altitude in 1988*

Unit: Million dollars

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land	Mining/Bare land	Total
0 - 100	0.22	0.00	0.00	0.00	0.00	***0.22***
100 - 200	0.08	0.01	0.02	0.01	0.00	***0.12***
200 - 500	10.04	2.11	0.92	0.15	0.00	***13.22***
500 - 1000	57.21	7.70	6.45	0.69	0.00	***72.05***
1000 - 1500	32.36	1.29	2.29	0.22	0.00	***36.16***
1500 - 2000	4.43	0.01	0.01	0.00	0.00	***4.45***
Total	***104.35***	***11.11***	***9.69***	***1.08***	***0.00***	***126.22***

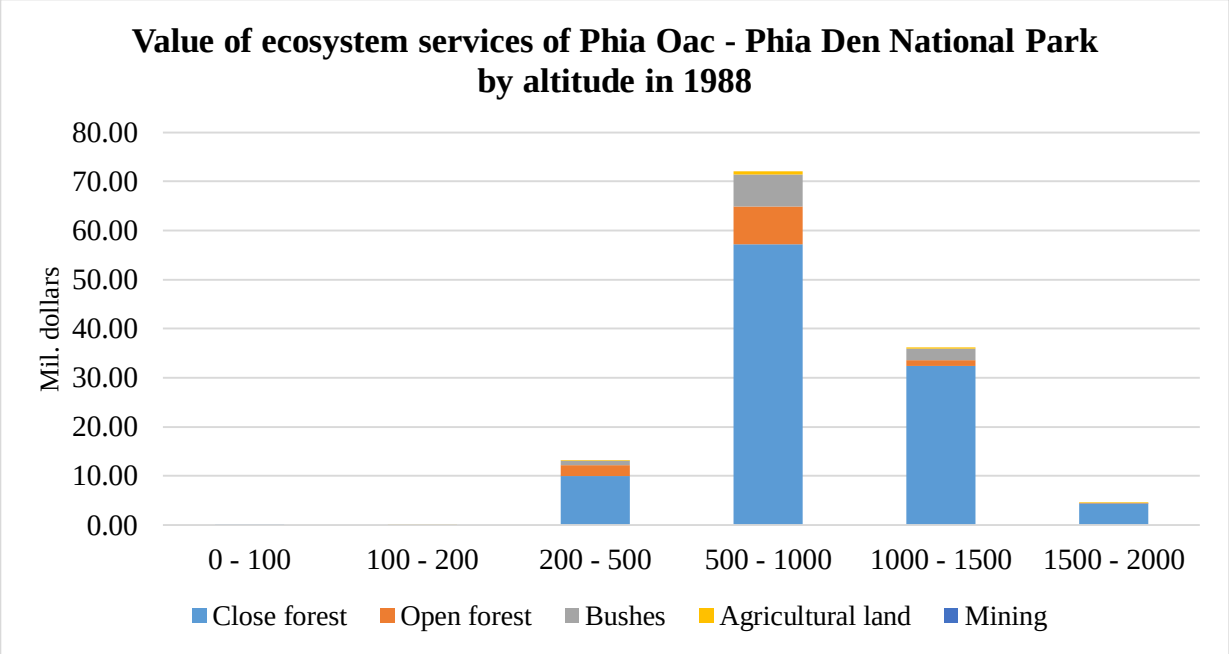


Figure 33. *Value of ecosystem services of Phia Oac - Phia Den National Park by altitude in 1988*

Table 103. *Estimated value of ecosystem services of Phia Oac - Phia Den National Park by altitude in 1998*

Unit: Million dollars

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land	Mining/Bare land	Total
0 - 100	0.20	0.00	0.00	0.00	0.00	***0.20***
100 - 200	0.09	0.04	0.02	0.01	0.00	***0.15***
200 - 500	9.35	2.57	1.30	0.12	0.00	***13.34***
500 - 1000	49.63	12.38	6.93	0.80	0.00	***69.74***
1000 - 1500	32.81	2.60	1.67	0.19	0.00	***37.27***
1500 - 2000	4.45	0.01	0.01	0.00	0.00	***4.46***
Total	***96.53***	***17.60***	***9.91***	***1.13***	***0.00***	***125.17***

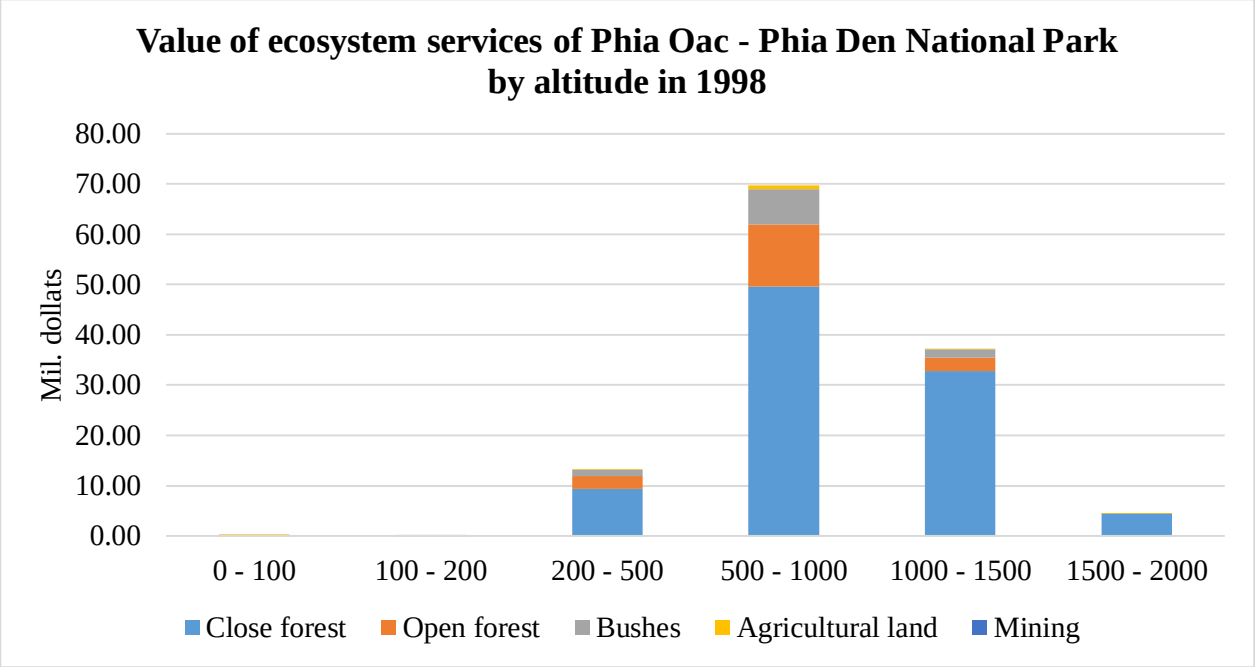


Figure 34. *Value of ecosystem services of Phia Oac - Phia Den National Park by altitude in 1998*

Table 104. Estimated value of ecosystem services of Phia Oac - Phia Den National Park by altitude in 2009

Unit: Million dollars

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land	Mining/Bare land	Total
0 - 100	0.18	0.00	0.00	0.00	0.00	***0.18***
100 - 200	0.00	0.07	0.02	0.01	0.00	***0.10***
200 - 500	5.40	5.61	1.20	0.19	0.00	***12.40***
500 - 1000	50.22	13.59	5.30	0.88	0.00	***70.00***
1000 - 1500	35.52	1.63	1.25	0.13	0.00	***38.54***
1500 - 2000	4.45	0.00	0.01	0.00	0.00	***4.46***
Total	***95.77***	***20.91***	***7.79***	***1.22***	***0.00***	***125.69***

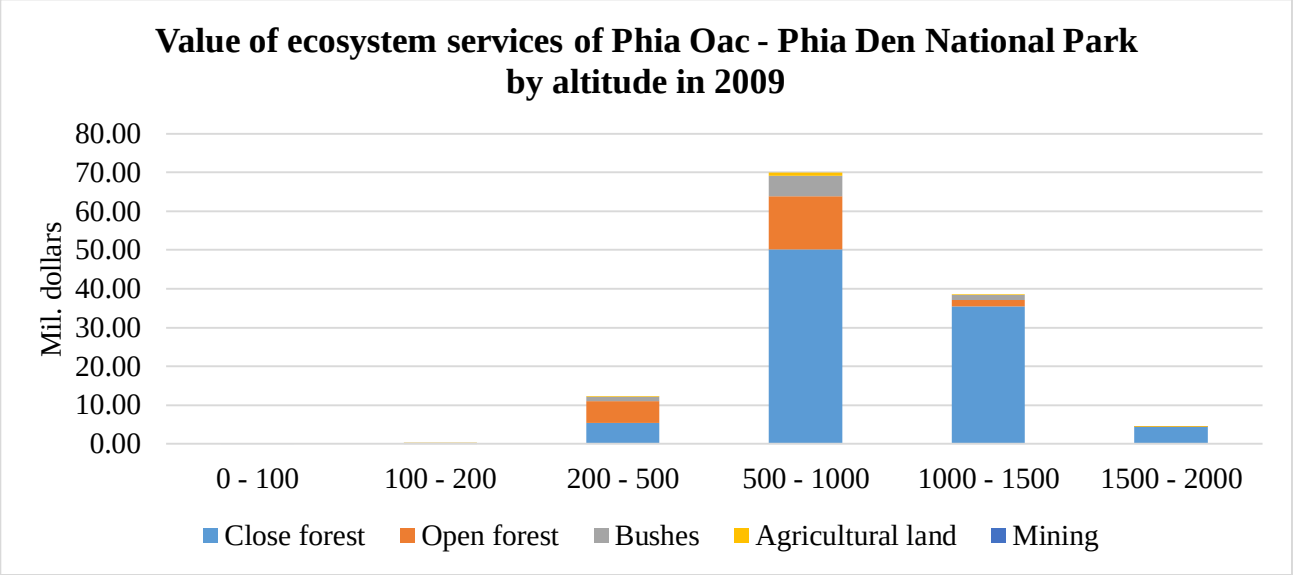


Figure 35. *Value of ecosystem services of Phia Oac - Phia Den National Park by altitude in 2010*

Table 105. *Estimated value of ecosystem services of Phia Oac - Phia Den National Park by altitude in 2019*

Unit: Million dollars

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land	Mining	Total
0 - 100	0.20	0.00	0.00	0.00	0.00	***0.20***
100 - 200	0.06	0.04	0.01	0.01	0.00	***0.12***
200 - 500	9.98	2.82	0.59	0.15	0.00	***13.54***
500 - 1000	52.93	13.68	4.70	0.79	0.00	***72.10***
1000 - 1500	35.41	2.71	0.67	0.14	0.00	***38.93***
1500 - 2000	4.47	0.00	0.00	0.00	0.00	***4.48***
Total	***103.06***	***19.26***	***5.96***	***1.09***	***0.00***	***129.37***

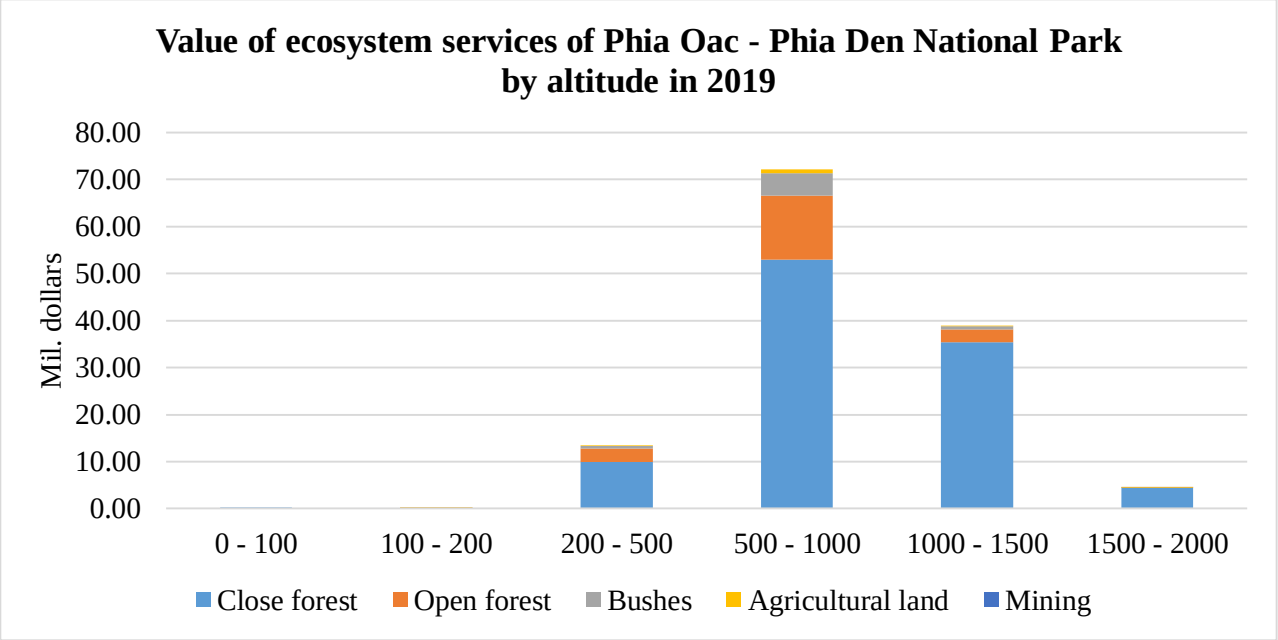


Figure 36. Value of ecosystem services of Phia Oac - Phia Den National Park by altitude in 2019

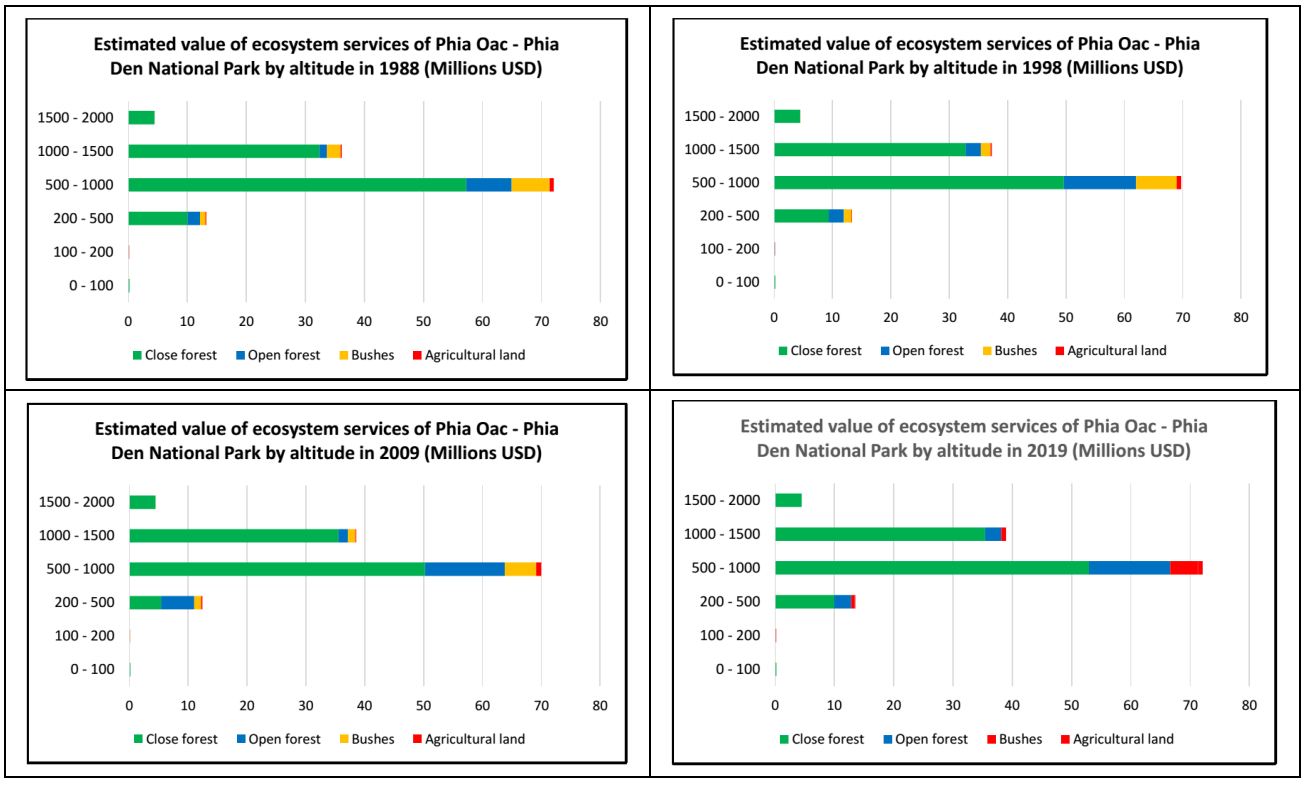


Figure 37. *Estimated value of ecosystem services by altitude for Phia Oac – Phia Den National Park during 1988-2019*

In summary, the characteristics of ecosystem service value for Phia Oac – Phia Den National Park are as followings:

+ In general, the value of ecosystem services for the whole Phia Oac – Phia Den National Park is more than 126.22 million USD (in 1988) and more than 129.37 million USD (in 2019), and tends to increase gradually. Similarly, the value of ecosystem services per hectare is increased from USD 6,292 (in 1988) to USD 6,419 (in 2019).

+ Among the services, regulating service has the highest value, accounting for about 45% of the total value of the national park, followed by provisioning service, accounting for about 35%-36% of the total value and cultural service accounts for about 3%-4%.

+ Among types of land use, close forest has the highest value, decreasing from 83% (in 1988) to 76% (in 2019) of the total value of ecosystem services, of which the highest value is 104.35 million USD in 1988. Open forest has a smaller value, accounting for 9% (in 1988) and for about 15% (in 2019).

Bush accounts for 5% - 7% of total value, and other land uses have relatively low values.

+ Among the communes of the Reserve, Thanh Cong commune has the highest value, followed by Phan Thanh commune and then Quang Thanh commune.

+ By altitude, land use and land cover in the elevation zones ranging from 500m - 1500m contributes the largest value of ecosystem services (accounting for about 85% of the value), then followed by the elevation zone ranging from 200m - 500m and other elevation zones have a small value.

2.6.2.4. Nam Xuan Lac Reserve

(1). Assessment of ecosystem services for Nam Xuan Lac Reserve during the period 1988-2019

Table 106 presents the value of ecosystems services for each land use type for Nam Xuan Lac Reserve and Figure 32 shows the distribution map of ecosystem service value (USD/ha) in Nam Xuan Lac Reserve in 1989, 1998, 2007 and 2017.

Table 106. *Estimated total value of ecosystem services for each land use type of Nam Xuan Lac Reserve*

Land use type	1989		1998		2007		2017	
	Million USD	%	Million USD	%	Million USD	%	Million USD	%

Close forest	73.227	81.32	79.937	87.29	76.995	84.37	71.004	81.72
Open forest	6.366	7.07	3.379	3.69	4.867	5.33	3.087	3.55
Bushes	4.725	5.25	0.985	1.08	4.585	5.02	3.885	4.47
Agricultural land	5.695	6.32	7.271	7.94	4.814	5.28	8.906	10.25
Water	0.031	0.03	0.008	0.01	0.002	0.00	0.003	0.00
Total (Million USD)	**90.044**	**100.00**	**91.580**	**100.00**	**91.264**	**100.00**	**86.884**	**100.00**
Total (USD/ha)	**3,099**		**3,151**		**3,141**		**2,990**	

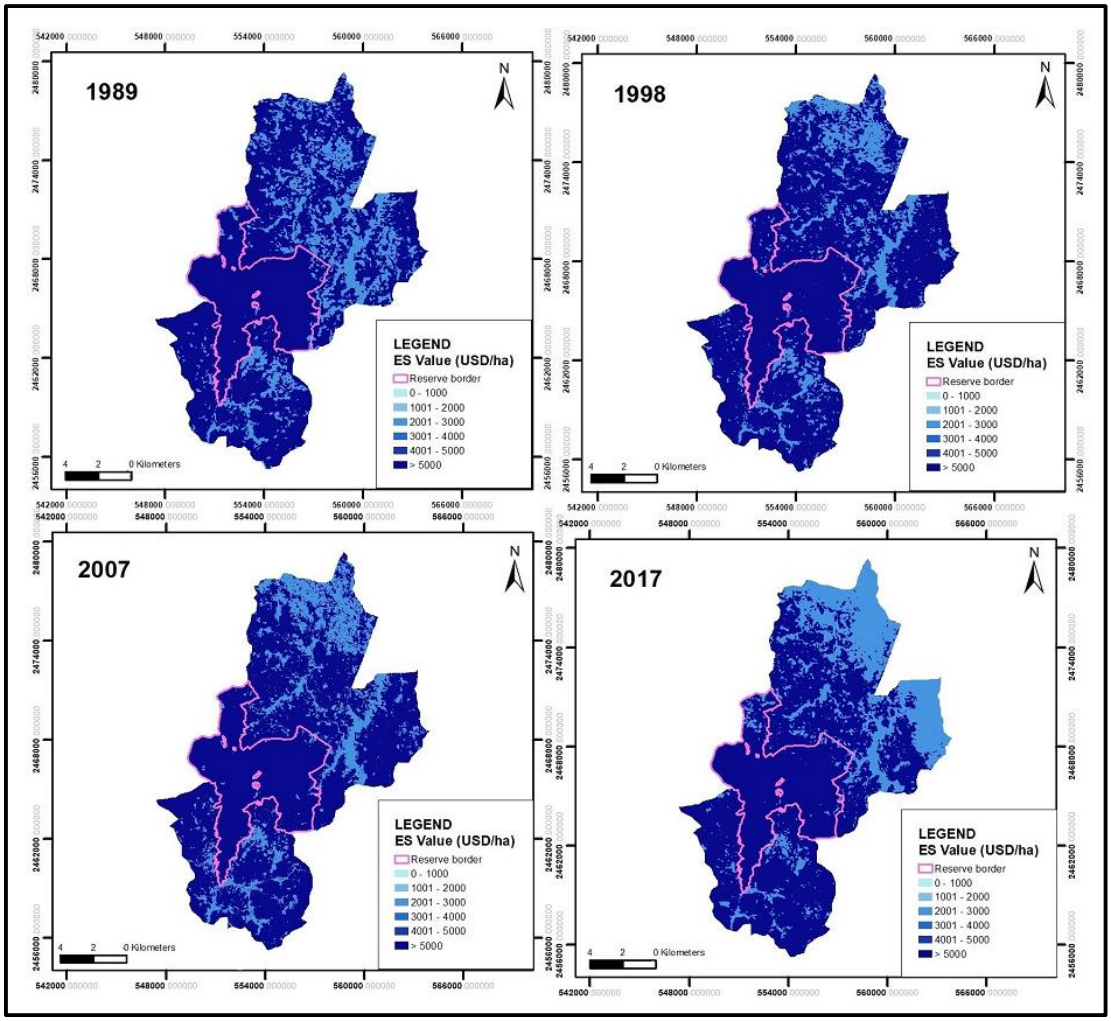


Figure 38. *Distribution map of total ecosystem services value (USD/ha) in Nam Xuan Lac Reserve in 1989, 1998, 2007 and 2017*

(2). Assessment of ecosystem services by commune for Nam Xuan Lac Reserve during the period 1988-2019

The value of ecosystem services for Nam Xuan Lac Reserve for years of 1989, 1998, 2007 and 2017 is shown in Tables 107, 108, 109 and 110.

Table 107. *Estimated total value of ecosystem services by commune for Nam Xuan Lac Reserve in 1989*

No	Commune	Value of ecosystem services by land use types (Million USD)					Total
		Close forest	Open forest	Bushes	Agricultural land/ Paddy	Water	
1	Dong Lac	10.86	1.29	1.38	1.94	0.03	**15.50**
2	Ban Thi	33.53	3.42	2.41	2.54	0.00	**41.91**
3	Xuan Lac	28.83	1.66	0.93	1.21	0.00	**32.63**
Total		**73.23**	**6.37**	**4.73**	**5.69**	**0.03**	**90.04**

Table 108. *Estimated total value of ecosystem services by commune for Nam Xuan Lac Reserve in 1998*

No	Commune	Value of ecosystem services by land use types (Million USD)					Total
		Close forest	Open forest	Bushes	Agricultural land/ Paddy	Water	
1	Dong Lac	14.44	0.59	0.27	1.62	0.01	**16.93**
2	Ban Thi	35.54	1.87	0.56	3.94	-	**41.91**
3	Xuan Lac	29.96	0.92	0.16	1.71	-	**32.74**
Total		**79.94**	**3.38**	**0.98**	**7.27**	**0.01**	**91.58**

Table 109. *Estimated total value of ecosystem services by commune for Nam Xuan Lac Reserve in 2007*

No	Commune	Value of ecosystem services by land use types (Million USD)					Total
		Close forest	Open forest	Bushes	Agricultural land/ Paddy	Water	
1	Dong Lac	14.06	0.87	0.78	1.24	0.00	**16.95**
2	Ban Thi	33.60	2.90	2.77	2.43	0.00	**41.70**
3	Xuan Lac	29.34	1.09	1.04	1.14	-	**32.61**
Total		**77.00**	**4.87**	**4.59**	**4.81**	**0.00**	**91.26**

Table 110. *Estimated total value of ecosystem services by commune for Nam Xuan Lac Reserve in 2017*

No	Commune	Value of ecosystem services by land use types (Million USD)					Total (Million USD)
		Close forest	Open forest	Bushes	Agricultural land/ Paddy	Water	
1	Dong Lac	9.38	0.52	1.20	3.12	-	**14.22**
2	Ban Thi	30.77	1.12	2.31	4.89	0.00	**39.09**
3	Xuan Lac	30.85	1.44	0.38	0.90	0.00	**33.57**
Total		**71.00**	**3.09**	**3.89**	**8.91**	**0.00**	**86.88**

(3). Assessment of ecosystem services by altitude for Nam Xuan Lac Nature Reserve during the period 1988-2019

Total value of ecosystem services by altitude for Nam Xuan Lac Reserve in 1989, 1998, 2007 and 2017 are presented in the Tables 111, 112, 113, and 114 below.

Table 111. *Estimated value of ecosystem services by altitude for Nam Xuan Lac Reserve in 1989*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	*Total*
100 - 200	0.15	0.13	0.11	0.13	0	**0.52**
200 - 500	29.94	5.2	3.52	3.78	0.07	**42.5**
500 - 1000	41.99	1.02	1.02	1.79	0.05	**45.88**
1000 - 1500	1.19	0	0	0	0	**1.19**
Total	**73.27**	**6.34**	**4.65**	**5.7**	**0.12**	**90.08**

Table 112. *Estimated value of ecosystem services by altitude for Nam Xuan Lac Reserve in 1998*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	Total
100 - 200	0.22	0.04	0.03	0.2	0	**0.49**
200 - 500	36.01	1.67	0.68	5.09	0.1	**43.56**
500 - 1000	42.75	1.49	0.21	1.94	0	**46.4**
1000 - 1500	1.18	0.03	0	0	0	**1.22**
Total	**80.17**	**3.23**	**0.92**	**7.23**	**0.1**	**91.66**

Table 113. *Estimated value of ecosystem services by altitude for Nam Xuan Lac Reserve in 2007*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	Total
100 - 200	0.09	0.07	0.1	0.18	0	**0.44**
200 - 500	31.82	3.12	3.88	3.55	0.1	**42.47**
500 - 1000	44.31	1.16	0.57	1.07	0	**47.12**
1000 - 1500	1.17	0.03	0.02	0.02	0	**1.24**
Total	**77.4**	**4.38**	**4.56**	**4.82**	**0.1**	**91.26**

Table 114. *Estimated value of ecosystem services by altitude for Nam Xuan Lac Reserve in 2017*

Unit: Million USD

Altitude (meters)	Close forest	Open forest	Bushes	Agricultural land/Paddy	Water	Total
100 - 200	0.03	0	0.04	0.27	0	**0.35**
200 - 500	30.13	1.4	2.61	6.2	0.05	**40.39**
500 - 1000	39.8	1.61	1.16	2.41	0.05	**45.03**
1000 - 1500	1.19	0	0	0	0	**1.19**
Total	**71.16**	**3.01**	**3.81**	**8.88**	**0.1**	**86.95**

In summary, the characteristics of ecosystem service value for Nam Xuan Lac reserve are as followings:

+ In general, the value of ecosystem services for the whole Reserve fluctuates between 90 - 91 million USD in the period 1989 - 2007, then decreased to nearly 87 million USD in 2017. Similarly, the value of ecosystem services per 1 hectare is decreased from 3,151 USD (in 1998) to 2,990 USD (in 2017).

+ Among the types of land use, close forest has the highest value, changing from 81% of total value of the Reserve (in 1989) then increasing to more than 87% (in 1998) and decreasing to about 84% (in 2007) and about 81% (in 2017). Similarly, the value of ecosystem services per hectare is decreased from 3,099 USD (in 1989) to 2,990 USD (in 2017).

+ Among the communes of the Reserve, Ban Thi commune has the highest value, followed by Xuan Lac commune and Dong Lac commune. The proportion of ecosystem service value among communes also changes with the change of land use types over time.

+ By altitude, land use and land cover in the elevation zones ranging from 200m - 100m contributes the largest value of ecosystem services, accounting for about 97% - 98% of the value.

2.7. Discusssion and recommendation for conservation

2.7.1. Discusssion

2.7.1.1. Land use and land cover change in study sites during period of 1988 – 2019

Regarding close forests, this forest accounts for a large proportion at the study sites, mainly concentrated in the altitude belt from 200-1500m. During the period of 1988-2009, Close forest (tropical forest) tends to reduce and convert to open forest, bushes as different form of degraded tropical forest, concentrated mainly at the altitude belt of 200-1000m. During the period of 2009-2019, Close forest tends to increase in area, mainly due to efforts to protect forests and natural process of forest vegetation rehabilitation and reforestation. However, Bac Me NR still faces serious deforestation.

Regarding to Open forest, this forest has lower proportion in comparison with Close forest among the landuse/landcover in the areas and is concentrated mainly at the altitude belt of 200-1000 meters. During the period of 1988-2009, Open forest tends to increase rapidly in expense of loss of Close forest due to the process of forest degradation. In the period of 2009-2019, Open forest has a tendency to decrease because part of this area converted to close forest by the process of natural regenetion. Regarding to Bush, the area of this type has similar trend of open forest, that is, it increased rapidly during the period of 1988-2009 and decreased during the period 2009-2019.

The trend of landuse/landcover change in Bac Me Nature Reserve and Phia Oac-Phia Den National Park during the period of 1988-2019 is presented in Table 117.

Table 117. *Trend of landuse/landcover change in the study sites during the period of 1986/1988 – 2017/2019*

Study sites	Close forest	Open forest	Bushes	Bare land	Agricultural land/ Paddy	Water	*Note*
Cham Chu Reserve	--	++	+	+-	+	+-	Close forest decreased sharply and converted to Open forest and

							Bush; Bare land slightly increased
Bac Me NR	--	++	+	+-	+-	+	Close forest decreased sharply and converted to Open forest and Bush; Bare land slightly increased
Phia Oac – Phia Den NP	-	++	--	+-	+-	+-	Close forest decreased sharply and converted to Open forest; A part of Bush converted to Open forest; During 2009-2019, Close forest increased significant, while Open forest deacreased
Nam Xuan Lac Reserve	-+	--	-+	-+	++	NA	Close forest slightly decreased; Open forest decreased sharply while agricultural land or swiden land increased accordingly

Note:
++ : Strong increase; + : Moderate increase; +- : Minor increase
-+: Minor decrease; - : Moderate decrease; -- : Strong decrease;
+/-: both increase and decrease

According to the report of the Management Board of Bac Me Conservation Area and Phia Oac - Phia Den National Park and the Department of Agriculture and Rural Development, the threats of biodiversity loss and deforestation include: 1). Hunting, shooting, trapping and catching animals; 2). Excessive exploitation of non-timber forest products; 3). Illegal logging and firewood exploitation; 4). Encroachment on land for agricultural and forestry production; 5). Forest fires caused by human activities.

In fact, these threats have been intensified by the impact of macro socio-economic development policies, such as the reform policy (known as DOI MOI) in 1986 and WTO accession in 2007, which have contributed to making Vietnam a low-middle income country (2010), reaching $2,389 yearly income/per capita in 2017 (GSO, 2017). Vietnam's forestry policy has undergone significant changes, shifting from the economic sector of forest exploitation before 1986, to the policy of protection and limited exploitation of natural forests or “closure of the forest gates” from 1994-1995, and subsequent forest conservation and development policies since 2004 (MARD, 2004). In the period since Doi Moi (1986) to 2012, land use changes in the Northern

mountainous region were characterized by the conversion of swidden land into arable land and afforestation land (Shivakoti et al., 2016). Nguyen et al. (2020) showed that forest governance regimes have a significant effect not only on forest land use/landcover change but also on the quantity and values of forest ecosystem service derived from forests. Thus, the evolution of forestry policy has affected land use/landcover change and ultimately affects the value of biodiversity and ecosystem services. In addition, DARD (2014) found that illegal logging, woodland clearing for agriculture, forest fires, and hunting are the most severe threats to biodiversity in the protected areas and other mountainous areas in Viet Nam (Wood et al., 2013). The expansion of cropland changes the landscape pattern, as agricultural production is one of the underlying reasons for deforestation and forest degradation, causing a gradual increase in ecological deprivation (Khuc et al., 2018).

2.7.1.2. Assessment of ecosystem services in study sites during period of 1986/1988 – 2017/2019

Regarding ecosystem services, according to preliminary assessment, the total value of ecosystem services (provisioning, regulating, cultural and supporting) ranges from 90-93 million USD, equivalent to 4,282 USD/ha/year for Bac Me NR and from 125-129 million USD, equivalent to USD 4,452/ha/year for Phia Oac-Phia Den National Park. However, this value has a trend to deacrease during the period 1988-2019 due to the degradation of forest ecosystems.

Despite the fact that there are few studies in Vietnam on measuring total ecosystem service value, Table 10 showed a comparison of ecosystem services for forest ecosystems in protected areas in Vietnam in terms of total ecosystem service value per hectare. For comparison, a mangrove forest ecosystem in Thai Thuy Nature Reserve has a total ESV of $1758/ha (including provisioning, regulating, supporting, and cultural services) (ISPONRE, 2018), while forest ecosystems in Cat Tien Natural Park have a value of $726/ha (including provisioning, regulating and cultural services) (GECD, 2014). Meanwhile, Ca Mau mangrove forest ecosystem provisioning and regulating services are valued at up to $3,316/ha (Vo et al., 2015). Although there are certain differences in the results of these studies because of different methods, the findings of this study using the value transfer method combined with the remote sensing gives a relative benefit that fits the particular context of Vietnam.

Table 118. *Comparison of total ecosystem service value for forest ecosystems in protected areas in Vietnam.*

Study sites /Area (Year of publication)	Total ESV ($/ha)	Provisioning service ($/ha)	Regulating service ($/ha)	Supporting service ($/ha)	Cultural service ($/ha)	Main methods used and reference
Cham Chu Reserve / 40,445.19 ha (2017)	4,279					Value transfer and GIS/RS
Bac Me Reserve / 21,087 ha (2019)	4,282	1,616	1,777	222	667	Value transfer and GIS/RS
Phia Oac-Phia Den NP / 29,060ha (2019)	4,452	1,593	2,041	123	695	Value transfer and GIS/RS
Nam Xuan Lac Reserve / 19,276.7 ha (2017)	2,990					Value transfer and GIS/RS
Cat Tien National Park / 71,000ha (2014)	726	39	668	-	11	Market price, cost-based, benefit transfer (GECD, 2014)
Ca Mau mangrove forest / 187,533ha (2015)	3,316	2,344	973	-	-	Market price, remote sensing (Vo et al., 2015)
Thai Thuy mangrove forest / 13,100ha (2016)	1,758	1,172	463	20	103	Market price, direct interview, value transfer (ISPONRE, 2018)

The overall assessment methodology in this study can be applied to the rapid assessment of ecosystem services for specific protected areas and regions, and be considered as the basis of land use planning and biodiversity conservation. While the value of global ecosystem services is estimated to be around USD125-145 trillion for 2011 (in 2007 USD) (Costanza et al., 2014), the value of the ecosystems services in Vietnam is estimated at about $28.87 billion (WWF, 2013), equivalent to 16.8% of GDP in 2013. In fact, ecosystem services

have not been appropriately considered in Vietnam in policymaking processes, while globally sustainable development policy is making more use of ecosystem services valuation (Brondizio et al., 2019). Ecosystem services values are increasingly integrated into strategic environmental assessments and development policy for national and global conservation and resource management (Mukherjee et al., 2014).

2.7.2. Recommendation for conservation

In the past 20 years, Vietnam's Government has issued many policies on biodiversity conservation associated with sustainable development. The Law on Biodiversity (2008) emphasizes the management, use and conservation of biodiversity, while the Forestry Law (2017) focuses on guiding the biodiversity conservation in protected areas, and the Law on Environmental protection (2020) considers the use and conservation of some natural ecosystem services. In addition, the National Strategy on Biodiversity (2013) also clearly identifies biodiversity as the foundation of the green economy; Conservation associated with sustainable use of biodiversity contributes to poverty reduction and improvement of people's quality of life. Policies of the provinces, such as Tuyen Quang, Ha Giang, Cao Bang and Bac Kan all have provincial biodiversity conservation planning to localise national policies into their specific local conditions. The conservation and sustainable development planning for Cham Chu, Bac Me, Nam Xuan Lac Reserves and Phia Oac - Phia Den National Park - all assess the value of biodiversity, consider difficulties, challenges, advantages and opportunities to propose development plan. The studies on land use / land cover change and assessment of ecosystem service value of the GIS-Remote Sensing group and those on species biodiversity provide important results in updating scientific data in implementing conservation planning.

Therefore, some recommendations for conservation work for the four study sites are as followings:

- Continue to synthetize the latest knowledge about protected areas, especially in terms of taxonomy, population and socio-economic pressures on ecosystems and species, in order to have a basis for proposing policies for conservation and sustainable use of biodiversity;

- It is necessary to strengthen the conservation and restoration of natural forests, especially in sloping land with an altitude of 200-1000 meters, where human impact on forest vegetation is greatest.

- It is necessary to raise people's awareness, in combination with livelihood development for local communities, associated with conservation of biodiversity values.

- There should be in-depth studies on the value of biodiversity and ecosystem services, in order to have a basis for proposing policies on payment for ecosystem services for the study area.

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Other reports and documents, made by Tuyen Quang, Ha Giang, Cao Bang and Bac Kan People's Committees and their department.

3. PUBLICATIONS AND PRODUCTS

List all scientific publications and other products/works of the group members, including those accepted for publication, and presentations in scientific or public meetings. Please upload electronic reprints or copies of all items to the folder when available.

1. Hoang Van Thang and Vo Thanh Son, 2020. Ecosystem service Trade-offs in the Northern mountainous region of Vietnam. Vietnam Environment Administration Magazine (VEM). No. 12 (2020) 44-46.

2. Vo Thanh Son, Luu The Anh, Dao Minh Truong, Trong Dai Ly, and Jing Sun, 2021. Evaluation of Ecosystem Service Changes due to Land Use and Land Cover Dynamics in Cham Chu Nature Reserve. Environment and Natural Resources Journal. Paper accepted by 15/10/2021 and published online (…..)

4. EMPOWERMENT OF YOUNG SCIENTISTS

4.1. Guiding principles for education and training

Brief description of regulations or guideline of the research group for young research assistants.

Research assistants are eligible to participate in group research activities ranging from planning, document searching and review, conducting fieldwork, data collection, data analysis and write a report. Through these specific works, research assistants can gain practical knowledge and skills in their research work. Researchers provide asssistants with guidance on specific techniques such as determining coordinates, building maps, and editing reports produced by research assistants.

Thus, the GIS/RS research group of the project has also contributed to support knowledge and skills for 2 PhD students (Mr. Hoang Tuan Anh and Du Vu Viet Quan) and 1 graduate student (Ms. Nguyen Thi Lan Phuong) to implement their works and study.

4.2. Achievement of each young scientist

Listing all products and results realized by research assistants and/or young scientist during the time of project implementation and assessment of their progress.

5. APPENDIX: Photo of main landuse and landcover in the four study sites

Figure 1. *Forest cover in Thanh Cong commune, Phia Oac – Phia Den National Park (6/5/2021)*

Figure 2. *Forest cover in Hung Dao commune, Phia Oac – Phia Den National Park (8/5/2021).*

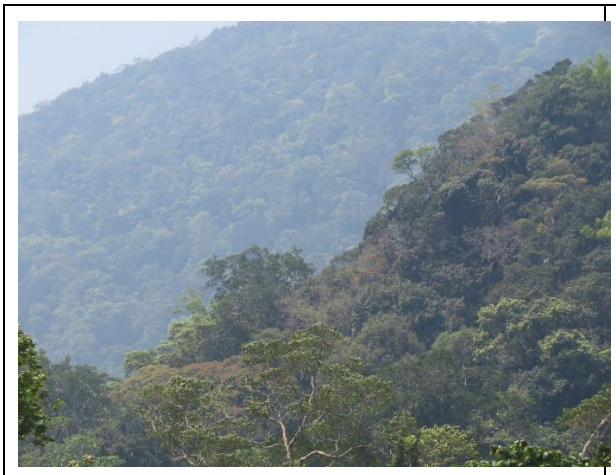

Figure 3. *Forest cover in Yen Thuan commune, Cham Chu Reserve*

Figure 4. *Forest trees in the top of Phia Oac mountain, Phia Oac – Phia Den National Park (8/5/2021).*

Figure 5. *Forest cover in Phan Thanh commune, Phia Oac – Phia Den National Park (8/5/2021)*

Figure 6. *Forest cover in Lac Nong commune, Bac Me Reserve*

Figure 7. *Forest Plantation (Acacia) in Lac Nong commune, Bac Me Reserve*

Figure 8. *Forest plantation (Pine) in the Phan Thanh commune, Phia Oac – Phia Den National Park (6/5/2021).*

Figure 9. *Rice paddies Minh Ngoc commune, Bac Me Reserve*

Figure 10. *Rice paddies in Trung Ha commune, Cham Chu Reserve*

Figure 11. *Rice paddies in Yen Thuan commune, Cham Chu Reserve*

Figure 12. *Rice paddies in Lac Nong commune, Bac Me Reserve*

Figure 13. *Rice paddies in Xuan Lac commune, Nam Xuan Lac Reserve*

Figure 14. *Maize field in valley of Yen Thuan commune, Cham Chu Reserve*

Figure 15. *Maize field in valley of Yen Thuan commune, Cham Chu Reserve*

Figure 16. *Maize field in Minh Ngoc commune, Bac Me Reserve*

Figure 17. *Fruit crop (orange tree) in sloping land of Phu Luu commune, Cham Chu Reserve*

Figure 18.*Close-up of orange trees in sloping land of Phu Luu commune, Cham Chu Reserve*

	
Figure 19. *Landscape of Phia Oac – Phia Den National Park*	**Figure 20**. *Landscape of Cham Chu Reserve*

	
Figure 21. *Landscape of Bac Me Reserve*	**Figure 22**. *Landscape of Nam Xuan Lac Reserve*

Figure 23. *Bushes and bareland in Thuong Tan commune, Bac Me Reserve*

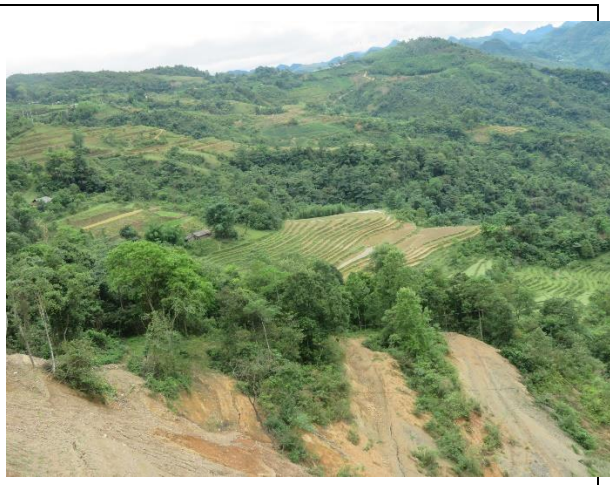

Figure 24. *Bushes and bareland in Tinh Tuc town, Phia Oac – Phia Den National Park*

Figure 25. *Logging forest trees for plywood in Ha Lang commune, Cham Chu Reserve*

Figure 26. *Utilisation of forest plantation for plywood in Ha Lang commune, Cham Chu Reserve*

	
Figure 27. *Discussion with local people about forest changes and local livelihood development in Ban Thi commune, Nam Xuan Lac Reserve*	**Figure 28**. *Discussion with local people about landuse change and local livelihood development in Lac Nong commune, Bac Me Reserve*