EXECUTIVE SUMMARY

ECOLOGICAL CORRIDOR STUDY FOR IMPORTANT FOREST COMPLEXES IN THAILAND

Department of National Parks, Wildlife and Plant Conservation

2012

FINAL REPORT

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For

Department of National Parks, Wildlife and Plant Conservation

By

Faculty of Forestry, Kasetsart University

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2012

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1: INTRODUCTION

1.1 Background

Protected areas play important roles in biodiversity conservation. Several research indicated that the larger protected areas can maintain and conserve biodiversity more effective than the smaller ones (Harris, 1984) because the larger area tends to have more wildlife species and numbers. Further more, some species can not survive in small and fragmented areas. At present, the distribution of protected areas in Thailand is covered about 20.6 % of the total country area. However, several of them are isolated, not connected to the large forest patches. To get effective biodiversity conservation protected areas must be managed in the larger and connected patches.

Department of National Parks, Wildlife and Plant Conservation manages protected areas of the country as 19 forest complexes according to basic criteria such as topography, forest types, watershed, plants and wildlife species distribution particularly large mammals. It is aimed to manage as ecosystem management approach to enclose larger area so that effective biodiversity conservation can be accomplished. However, fragmented areas still found in most terrestrial forest complexes. Thus, to solve this issue there is an urgent need to determine ecological corridors both wildlife and physical so that wildlife can move from forest patches with least obstacles and ecological integrity can be maintained. The study project on suitability assessment of ecological corridor was initiated to achieve this incident as well as to respond to the 2010 CBD program under the CBD Convention. According to the CBD agreement, it expects highly to accomplish the goal of reducing rate of biodiversity degradation in Thailand by year 2010 which certified in the Sustainable Development Summit at South Africa in 2002.

1.2 Framework

The project covered 17 terrestrial forest complexes in Thailand. Ecological status of these forest complexes was then evaluated by the landscape index. The suitability of wildlife and physical corridors was determined by the habitat suitability model and physical characteristics of forest area coverage. Types and locations of wildlife and physical corridors were identified with broad management guidelines. A 10-year (2013-2022) ecological management plan then proposed.

1.3 Objectives

1) Conduct rapid assessment on ecological status of terrestrial forest complexes of Thailand,

2) Identify appropriate types and locations of ecological corridors (wildlife and physical corridors),

3) Set up guidelines for corridor management, and

4) Propose a long term corridor management plan (10 year plan).

1.4 Outputs

1) Ecological status of 17 terrestrial forest complexes,

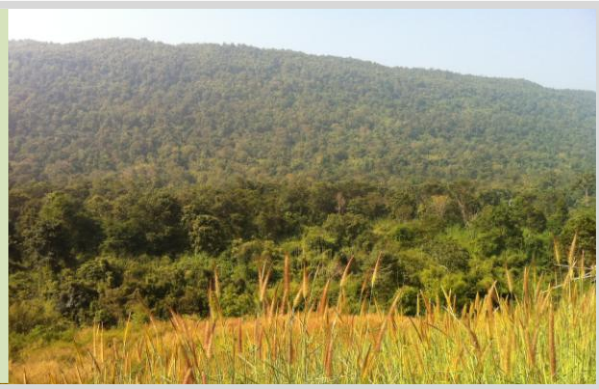
2) Maps and database for corridor management including number of corridors, corridor types, description, and location,

3) Guidelines for corridor management, and

4) Long term corridor management plan (10 year plan)

1.5 Impact

Management direction of ecological corridors and relevant protected areas at a country level for biodiversity conservation in Thailand



2: ECOLOGICAL STATUS OF THAILAND TERRESTRIAL FOREST COMPLEXES

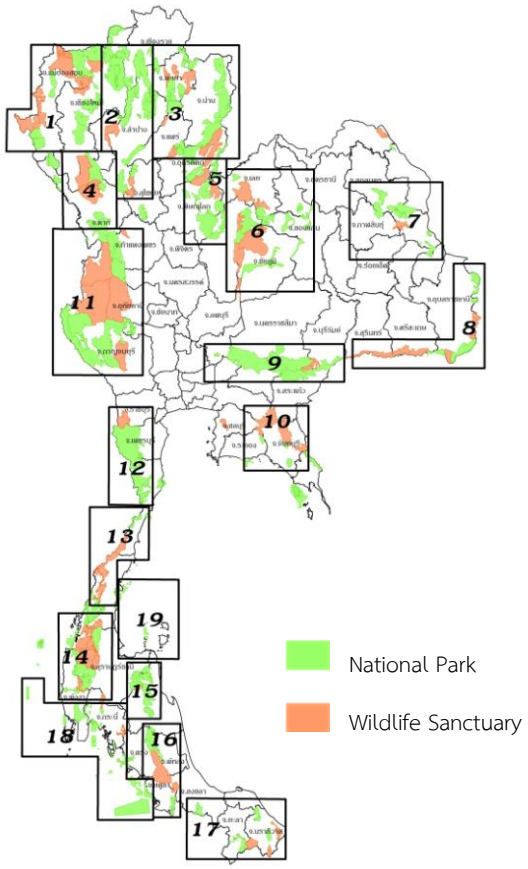
2.1 Background

Thailand divides protected areas into 19 forest complexes including 17 terrestrial and 2 marine forest complexes. For the terrestrial forest complexes, their bio-physical characteristics and intensity of threats to the survival of the forest complexes are varied which lead to incongruent ecosystem integrity and quality of environmental services provided. Ecological status of forest complexes is valuable information for biodiversity conservation and ecosystem based management regarding ecosystem integrity and significant ranking in landscape level for decision making on ecological corridor identification and management.

Ranking of the importances of the forest complexes in terms of ecological aspects on wildlife habitat and forest cover can be done by the landscape index. Landscape index are calculated from FragStats program Version 3.3 Build 5 (McGarigal *et. al*. 2002) with the value of each index between 0-100. The higher the value means the higher importance of the forest complex.

Map 1 Forest complexes of Thailand

1 Lum Num Pai-Salawin
2 Sri Lanna- Khun Tan
3 Doi Phuka-Mae Yom
4 Mae Ping-Om Koi
5 Phu Meang-Phu Thong
6 Phu Khiew-Nam Naew
7 Phu Parn
8 Phanom Dongrak-Pha Tam
9 Dong Phayayen-Khao Yai
10 Eastern
11 Western
12 Khaeng Krachan
13 Chumporn
14 Klong Saaeng-Khao Sok
15 Khao Luang
16 Khao Bantad
17 Hala-Bala
18 Mo Kho Similan-Peepee-Andaman
19 Mo Kho Ang-Thong-Ao Thai



2.2 Landscape index for ecological ranking of forest complexes

Landscape index explaining ecological status on forest cover and wildlife habitat aspect of 17 terrestrial forest complexes are shown in Table 1 to Table 3. All the landscape metrics were transformed to constraint the values ranging between zero and a hundred. The least suitable landscape configuration or composition is close to zero and vice versa.

Table 1 Landscape index for ecological ranking of forest complexes

Item	Landscape index for forest cover	Item	Landscape index for wildlife habitat
1	Forest cover percentage	1	Percentage of important wildlife species occurrence
2	Forest patch density	2	Habitat density of each wildlife species
3	Land cover diversity	3	Number of habitat patches for each wildlife species
4	Average weighted area of forest patch	4	Average weighted mean of habitat patch area for each wildlife species
5	Average weighted score of gyrazon	5	Average weighted score of gyrazon for each wildlife species
6	Average weighted score of forest patch shape	6	Average weighted score of wildlife habitat shape of each species
7	Average weighted score of forest patch proximity	7	Average weighted score of proximity of habitat patches of each wildlife species
8	Average weighted score of distance between forest patch	8	Average weighted score of distance between habitat patches of each species
9	Average weighted score of difference between forest patches		

The brief explanation of landscape index for plant cover is present in Table 2 and Table 3.

Table 2 Description of landscape index for forest cover

Item	Landscape index	Symbol	Description	Range of Measurement	Interpretation
1	Forest cover percentage	CAP_Forested	Indicating a total number of forested areas existing in the landscape. The higher value indicates higher amount of forested areas existing.	0 ≤ FA≤ 100	The higher value, the better
2	Forest patch density	PD_100	Reflecting the landscape configuration of forest patches in terms of relative patch density comparing among all forest complexes. The lower value indicates less fragmented forest patches.	0≤PD_100≤100	The lower value, the better
3	Land cover diversity	SHDI	Representing a composition of ecosystems at the landscape level and showing how diverse a forest complex is. The higher value indicates higher diversity of plant communities.	0 ≤ SHDI	The higher value, the better
4	Average weighted area of forest patch	AREA_AM	Showing a landscape composition in terms of area-weighted mean of the size of a particular forest patches. The higher value indicates larger patches are found in the landscape.	0 < AREA_AM	The higher value, the better
5	Average weighted score of gyrazon	GYRATE_AM	A landscape configuration metric indicating how far forest patches expand in the landscape. The larger value indicates the larger extent of forest patches	0< GYRATE_AM	The higher value, the better

Table 2 (Continued)

Item	Landscape index	Symbol	Description	Range of Measurement	Interpretation
6	Average weighted score of forest patch shape	SHAPE_AM	A landscape configuration metric reflecting how complicate the shape of a forest patch is. The value is weighted by the size of forest patches.	0<SHAPE_AM	The smaller value, the better
7	Average weighted score of forest patch proximity	PROX_AM	A landscape configuration representing a degree of proximity among forest patches (i.e., a spatial arrangement) in the landscape by means of patch sizes and distances among patches. The higher value indicates landscape consists of larger patched sizes and closer distances among patches.	0< PROX_AM	The higher value, the better
8	Average weighted score of distance between forest patch	ENN_AM	Indicating landscape configuration in that the Euclidean distance between forest patches is weighted by their patch sizes. This metric aims to measure a degree of isolation among forest patches. The lower value means smaller degree of isolation.	0<ENN_AM	The lower value, the better
9	Average weighted score of difference between forest patches	ECON_AM	The metric is a measurement of contrastness between focal patches and surrounding patches in terms of different land cover types, e.g., agriculture, urban, forested area. The smaller value indicates less contrastness among patches.	0<ECON_AM≤ 100	The lower value, the better

Table 3 Description of landscape index for wildlife habitat

Item	Landscape index	Symbol	Description	Range of Measurement	Interpretation
1	Percentage of important wildlife species occurrence	existign_6spp	A value showing how many target mammal species exist in a Forest Complex, The higher value indicates higher number of large-mammal species found in a landscape.	0 ≤ existign_6spp ≤ 100	The higher value, the better
2	Habitat density of each wildlife species	hab_spp	A landscape configuration metric indicating a density of habitat patches of a given wildlife species. A lower value indicates lower degree of habitat fragmentation.	0≤ hab_spp ≤100	The lower value, the better
3	Number of habitat patches for each wildlife species	NP_spp	Indicating a total number of habitat patches for a given species. The smaller of a value, the lower degree of habitat fragmentation.	0 ≤ NP_spp	The lower value, the better
4	Average weighted mean of habitat patch area for each wildlife species	AREA_AM_spp	Showing a landscape composition in terms of area-weighted mean of the size of a particular habitat patches for a given species. The higher value indicates a landscape is comprised of large habitat patches.	0 < AREA_AM_spp	The higher value, the better
5	Average weighted score of gyrazon for each wildlife species	GYRATE_AM_spp	A landscape configuration metric indicating how far habitat patches expand in the landscape. The larger value indicates the larger extent of habitat patches of a given species found in that landscape.	0< GYRATE_AM_spp	The higher value, the better

Table 3 (Continued)

Item	Landscape index	Symbol	Description	Range of Measurement	Interpretation
6	Average weighted score of wildlife habitat shape of each species	SHAPE_AM_spp	A landscape configuration metric reflecting how complicate the shape of habitat patches for a given species is. The value is weighted by the size of habitat patches.	0<SHAPE_AM	The smaller value, the better
7	Average weighted score of proximity of habitat patches of each wildlife species	PROX_AM_spp	A landscape configuration representing a degree of proximity among habitat patches for a given species (i.e., a spatial arrangement) in the landscape by means of the patch sizes and the distances among habitat patches. The higher value indicates that landscape consists of larger patch sizes of the suitable habitat and closer distances among habitat patches.	0< PROX_AM	The higher value, the better
8	Average weighted score of distance between habitat patches of each species	ENN_AM_spp	Indicating landscape configuration in that the Euclidean distance between habitat patches for a particular species is weighted by their patch sizes. This metric aims to measure a degree of isolation among habitat patches. The lower value reveals smaller degree of habitat isolation.	0<ENN_AM	The lower value, the better

2.3 The result of ecological ranking of forest complexes by landscape index

The best forest complex regarding ecological status is the western forest complex with the score 74.8%. The second and the third are Dong Phayayen-Khao Yai and Phu Khiew-Nam Naew complexes with score 48.1 and 47.2, respectively**.** Table 4 and Figure 1 shows the ranking of ecological status of all terrestrial forest complexes.

Regarding to the results of ecological importance of forest complexes in Thailand, this study selected 8 forest complexes to be the target forest complexes on 10-year corridor management plan. They are Western, Khaeng Krachan, Mae Ping-Om Koi, Lum Num Pai-Salawin, Dong Phayayen-Khao Yai, Phanom Dongrak- Pha Tam, Phu Khiew- Nam Naew, and Eastern forest complexes.

Table 4 The result of ecological ranking of forest complexes by landscape index

Ranking No.	Forest complex	Ecological status by landscape index (%)		
		Forest cover	Wildlife habitat	Average
1	Western	89.45	84.84	74.83
2	Dong Phayayen-Khao Yai	58.50	57.56	48.10
3	Phu Khiew-Nam Naew	60.48	53.58	47.18
4	Khaeng Krachan	53.47	51.24	42.41
5	Mae Ping-Om Koi	59.66	46.18	41.92
6	Eastern	41.44	49.04	41.06
7	Phu Meang-Phu Thong	59.03	44.99	40.97
8	Klong Saaeng-Khao Sok	40.13	49.19	39.62
9	Lum Num Pai-Salawin	60.91	37.91	38.89
10	Phanom Dongrak-Pha Tam	39.75	48.61	38.74
11	Doi Phuka-Mae Yom	54.41	39.20	37.44
12	Sri Lanna- Khun Tan	56.12	31.74	35.82
13	Hala-Bala	33.35	41.38	34.56
14	Khao Luang	31.64	39.04	32.95
15	Chumporn	33.34	40.11	32.79
16	Khao Bantad	33.31	30.81	31.57
17	Phu Parn	40.23	23.21	29.96

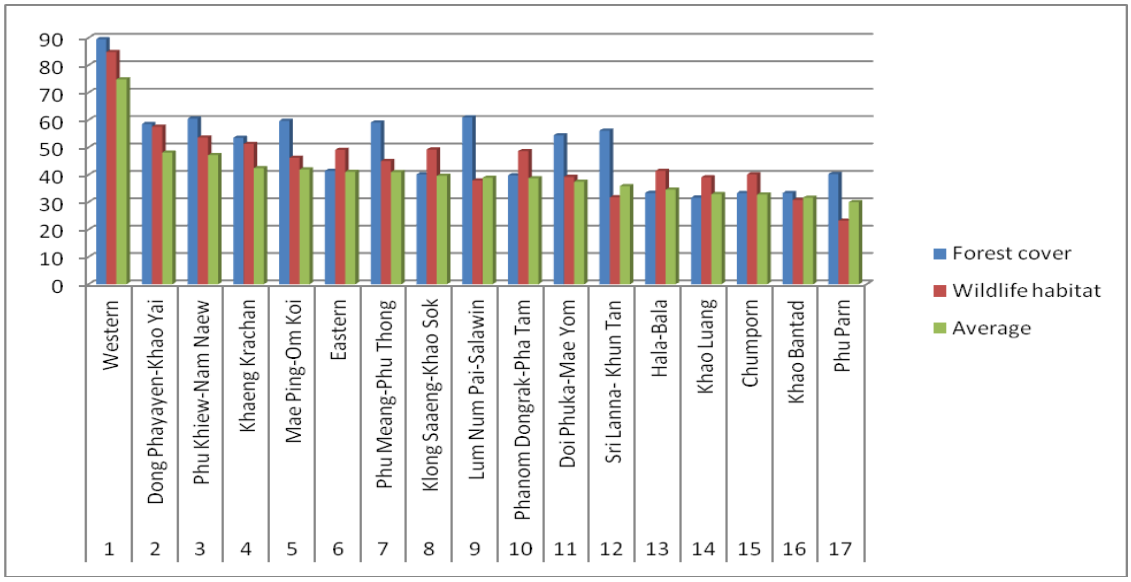


Figure 1 Ecological statuses of the forest complexes regarding forest cover, wildlife habitat and average value measured by landscape index

3: ECOLOGICAL CORRIDORS

Ecological corridor was determined at 3 different scales: forest complex level, regional, and international level. At the forest complex level, the distances of the two or more forest patches intended for corridor connection are generally less than 12 kilometers. The regional level, the distance are more than 12 kilometers. For the international level, it was the attempt of forest connection between neighboring countries so called Transboundary corridors. Ecological corridor at the forest complexes level composes of wildlife corridors and physical corridors. Wildlife corridor aimed at connecting forest patches in terrestrial forest complexes and surroundings for the livelihoods of the 2 target species; both are the landscape species of the country: wild elephant (*Elephas maximus*) and tiger *(Panthera tigris).* Physical corridor aims to connect forest patches without wildlife consideration. Physical corridors generally focus on the benefit of environmental services the larger forest patches could provide such as watershed protection. Types of corridors were also identified as linear corridor, landscape corridor, and stepping stones corridors.

3.1 Wildlife corridors

Types and locations of wildlife corridors were determined by statistical modeling and GIS application based on the data base from the Department of National Parks, Wildlife and Plant Conservation.

3.1.1 Habitat Distribution Modeling for Important Mammals at Countrywide Level

The modeling aimed at finding the area suitable for wildlife distribution of such important species as wild elephant (*Elephas maximus*) Guar (*Bos gaurus*), banteng (*Bos javanicus*) samba deer (*Rusa unicolor*), barking deer (*Muntiacus muntjak*), and tiger (*Panthera tigris*). Wildlife occurrence data was derived from the Karnjanasakha *el al* (2010) report. Spatial information was used with the application of GIS and principles of maximum entropy (maxent) were employed (Shannon, 1948; Jaynes, 1957) by MaxEnt program (Phillips *et. al*., 2006).

3.1.2 Analysis of appropriate wildlife corridors

The analysis of appropriate wildlife corridor applied an approach from Beier *et. al.* (2005) comprising of 2 steps: (1) score rating of wildlife corridor suitability by 3 factors: wildlife presence, habitat suitability, distance between the patches (see Table below), and (2) searching for the potential paths of prioritized wildlife corridors by Corridor Designer Program Version 0.2 (Beier *et. al.* 2005) with application of the least-cost modeling technique (Adriaensen *et. al*. 2003).

Table 5 Score rating of wildlife corridor suitability

Wildlife presence 1/		Wildlife habitat suitability 1/		Score of the combination of wildlife presence and habitat suitability 2/	Distance between A and B 3/	Wildlife corridor suitability score 4/
Patch A	Patch B	Patch A	Patch B			
x	x	x	x	0	0,1,2	0
x	x	0	x	1	0,1	0
x	x	x	0		2	1
x	x	0	0	2	0	0
					1	2
					2	4
x	0	-	-	3	0	1
					1	3
0	x	-	-		2	5b
0	0	-	-	4	0	1
					1	5a
					2	6

Remark:

1/ x = No wildlife occurrence/Not suitable for wildlife habitat, 0 = Wildlife occurrence/Suitable for wildlife habitat

2/ 0 = Not suitable for wildlife corridor, 1 = Suitable, for expanding wildlife habitat,
2 = Possible, if wildlife restoration apples in the area (s), 3 = Wildlife corridor enables,
4 = Most suitable;

3/ 0 = The distance is more than twice a distance of daily wildlife movement, 1 = The distance is between the distance of daily wildlife movement and the twice distances,
2 = The distance is within a distance of daily wildlife movement,

4/ 0 = Not suitable to be wildlife corridor, 1 = Least suitable,
2 = Rather moderately suitable, if wildlife restoration applies, 3 = Moderately suitable,
4 = Rather highly suitable, if wildlife restoration applies, 5 = Highly suitable,
6 = Very Highly suitable

3.1.3 Wildlife corridors proposition in terrestrial forest complexes

The study identified 174 wildlife corridors within the 17 forest complexes (Figure 2). Wildlife corridors are also classified into linear, landscape and stepping stone as shown in Figure 4 which landscape wildlife corridors are mostly found. Only 76 corridors are in high priority (rank 1 and 2). Eight forest complexes: Western, Khang krachan, Mae Ping-Om Koi, Lum Num Pai-Salawin, Dong Phrayayen-Khao Yai, Phanom Dongrak-Pha Tam, Phu Khiew- Nam Naew, and Eastern, are identified as high importance in terms of ecological status measured by the landscape index. As a result, 32 high priority corridors in these complexes are proposed for implementation in the 10 year corridor management plan.

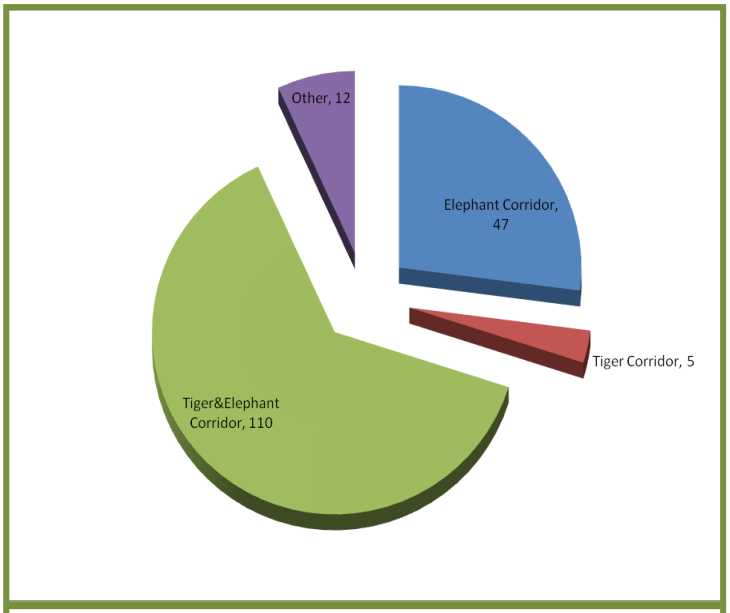


Figure 2

Number of Wildlife corridors within 17 forest complexes

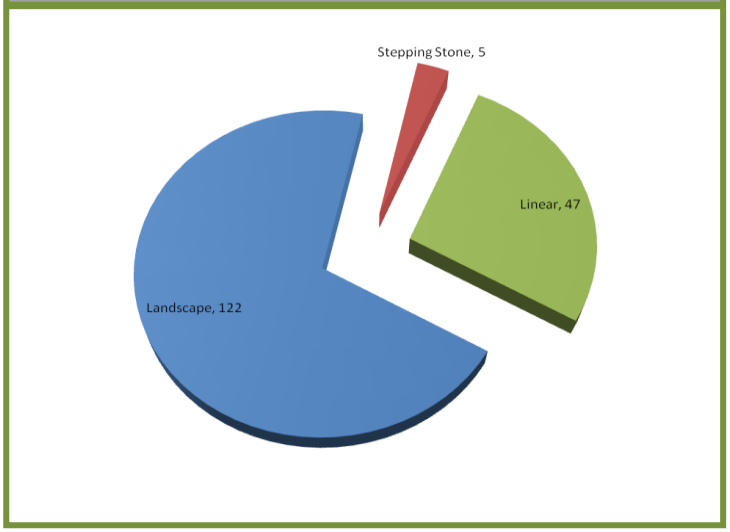


Figure 3

Types of wildlife corridors within 17 forest complexes

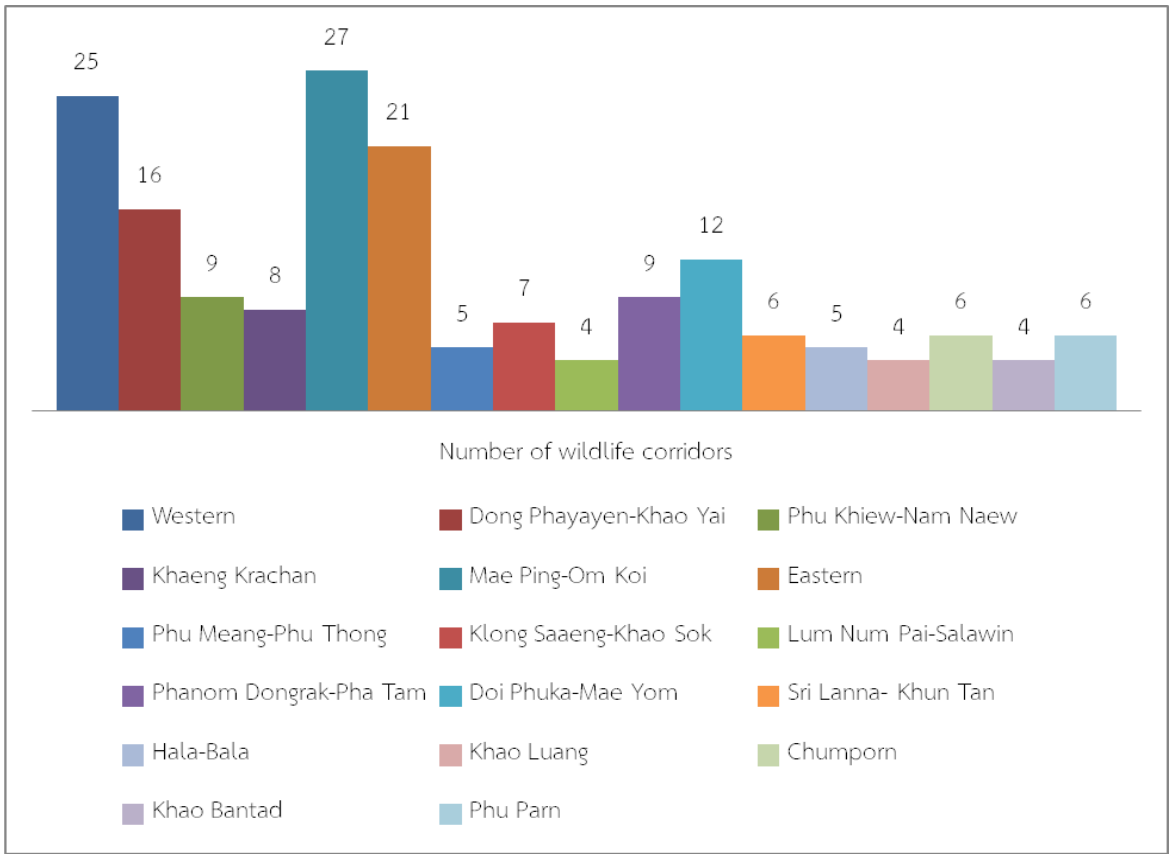


Figure 4 Number of wildlife corridors classified by the terrestrial forest complexes

3.2 Physical corridors

3.2.1 Data analysis

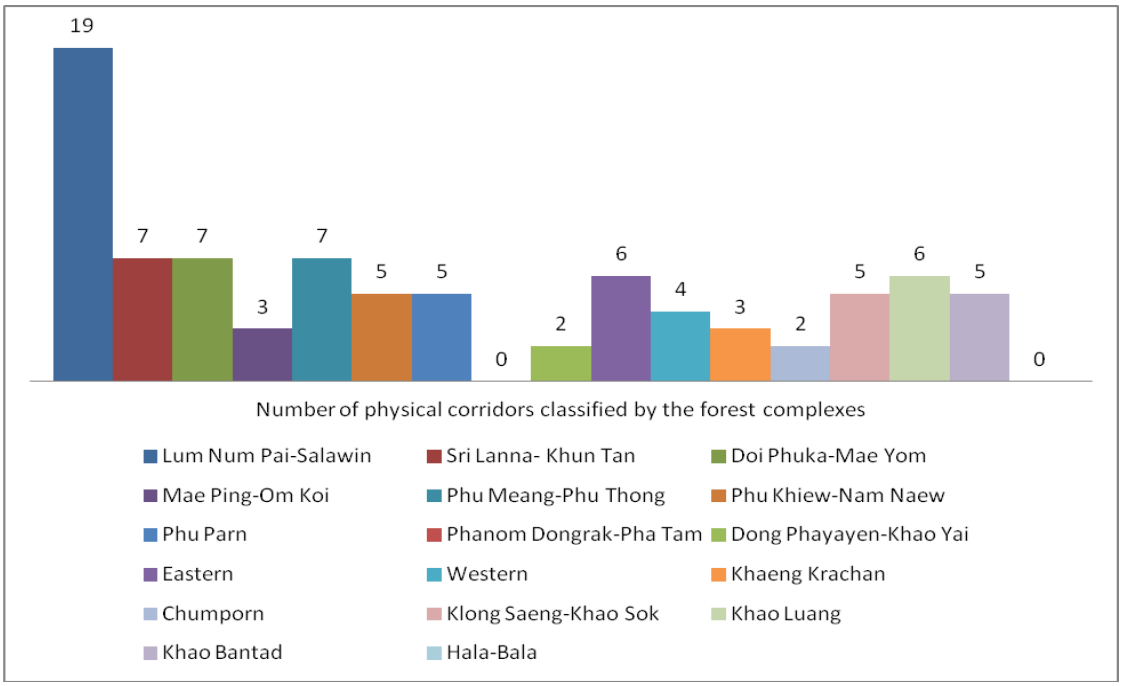
The first step of physical corridor estimation was to identify forest patches outside the protected areas by the get near feature technique in GIS. The physical corridor classified as connected forest patch corridor, linear corridor, disconnected forest patch corridor, and stepping forest patch corridors. Then, the second step was to classify the physical corridor suitability levels by the weighting score method. The suitability of physical corridors was classified into 5 levels: Highly suitable (HS), Suitable (S), Moderate suitable (MS), Less suitable (LS), and Not suitable (NS).

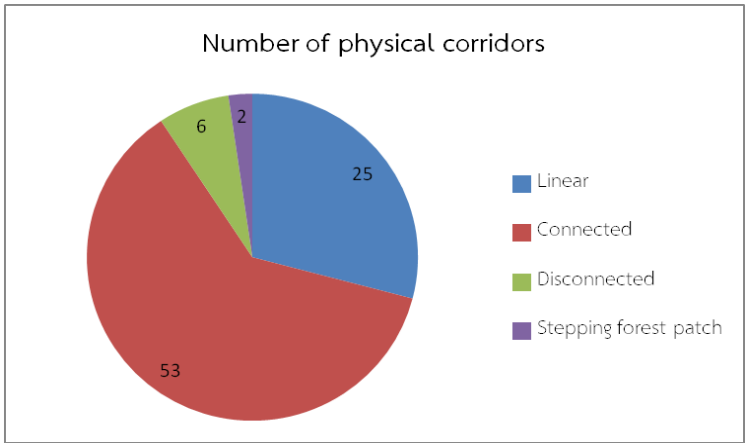
3.2.2 Physical corridor proposition

The study identified 86 physical corridors ranking HS and S for the 17 forest complexes (Table 6). For the 10 year corridor management plan, the 31 corridors in 8 high ecologically important forest complexes will be the target. In addition, there are 19 physical corridors that overlap with the wildlife corridors rank 1 and 2, and one is overlapped with the regional corridor. Ten of them are in the eight forest complexes making these corridors also first priority of taking action.

Table 6 Number of physical corridors classified by corridor types

No.	Forest Complex	Corridor types				Total
		Connected	Linear	Disconnected	Stepping patch	
1	Lum Num Pai-Salawin	14	5	0	0	19
2	Sri Lanna- Khun Tan	3	4	0	0	**7**
3	Doi Phuka-Mae Yom	6	0	1	0	**7**
4	Mae Ping-Om Koi	0	3	0	0	**3**
5	Phu Meang-Phu Thong	5	2	0	0	**7**
6	Phu Khiew-Nam Naew	2	2	1	0	**5**
7	Phu Parn	4	1	0	0	**5**
8	Phanom Dongrak-Pha Tam	0	0	0	0	**0**
9	Dong Phayayen-Khao Yai	0	1	0	1	**2**
10	Eastern	3	1	2	0	**6**
11	Western	4	0	0	0	**4**
12	Khaeng Krachan	2	0	1	0	**3**
13	Chumporn	1	0	1	0	**2**
14	Klong Saaeng-Khao Sok	3	2	0	0	**5**
15	Khao Luang	3	2	0	1	**6**
16	Khao Bantad	3	2	0	0	**5**
17	Hala-Bala	0	0	0	0	**0**
	Total	**53**	**25**	**6**	**2**	**86**





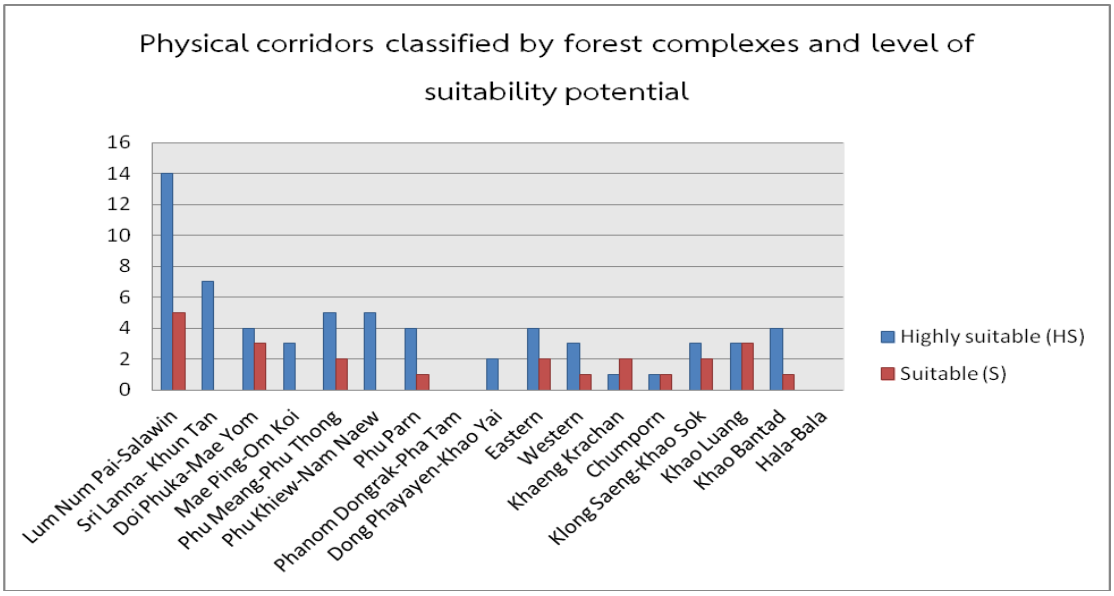


Figure 5 Summary of physical corridor distribution of the terrestrial forest complexes

3.3 Regional and Transboundary corridors

There are 33 regional corridors (distance more than 12 kilometers) connecting between forest complexes country-wide. The corridors in focus are those connecting on North-South direction from Lum Num Pai-Salawin to Khaeng Krachan forest complexes. Additionally, there are 13 Transboundary corridors with the neighboring countries: the Laos People's Democratic Republic, Kingdom of Cambodia, the Republic of the Union of Myanmar, and Malaysia.

Table 7 Transboundary corridors

Forest Complexes Number	Forest Complexes	Transboundary corridor				Total
		Myanmar	Laos, PDR	Cambodia	Malaysia	
8	Phanom Dongrak-Pha Tam		1	3		4
10	Eastern			1		1
12	Khaeng Krachan	1				1
17	Hala-Bala				2	2
	Total at forest complex level (1)	1	1	4	2	8
	Total at regional level (2)	3		1	1	5
	Grand total (1) + (2)	4	1	5	3	13

Location of wildlife and physical corridors are shown in Map 1 placed in a pocket on the back of the back cover.

4: MANAGEMENT GUIDELINES

Design of ecological corridors to connect forest patches is a substantial strategy for biodiversity conservation of the country. The goal for ecological corridor proposition is forest connection and restoration of biodiversity and ecosystem services of terrestrial forest complexes. The ecological corridor was done by determining the conservation targets, identifying threats, assessing ecological status of forest complexes, and identifying appropriate paths and/or areas for forest connection. Then, management guidelines and national management plan for corridor management was set up, finally (Figure 6).

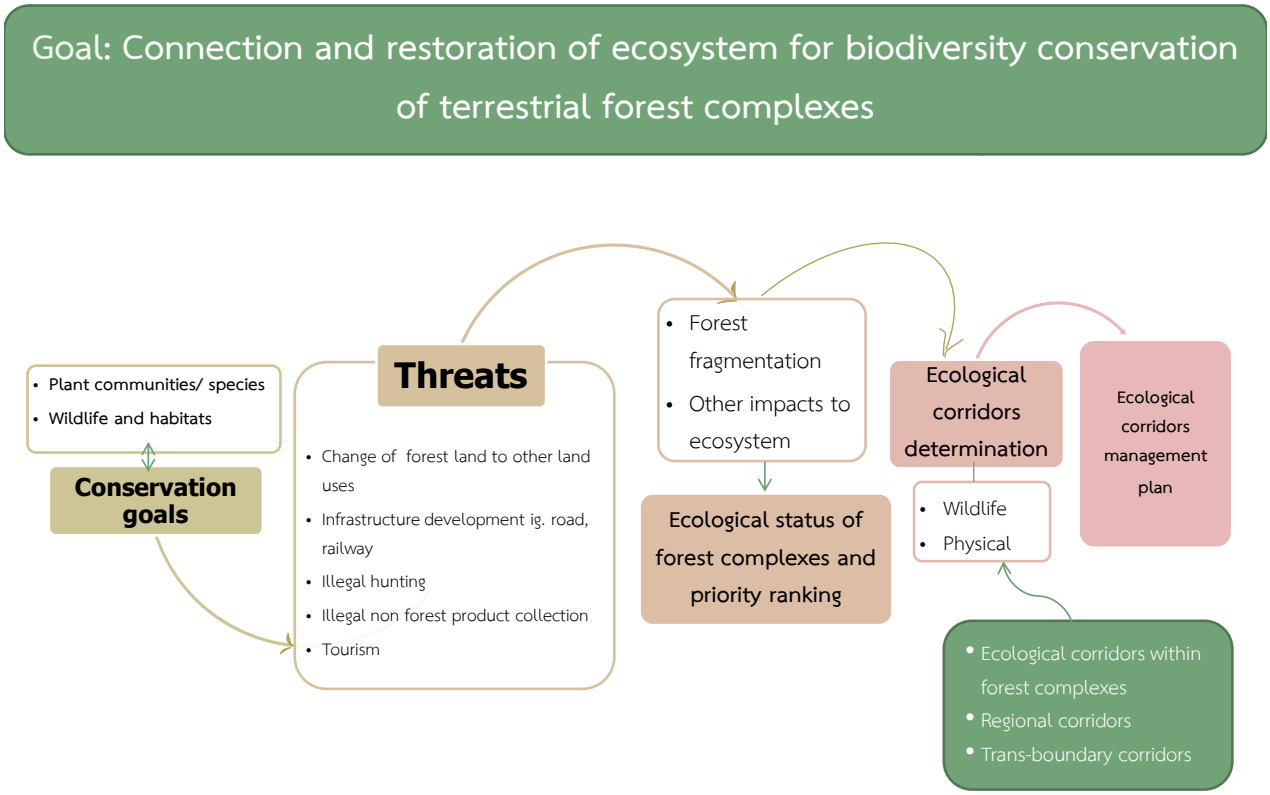


Figure 6 Diagram representing a conceptual framework of ecological corridor establishment for biodiversity conservation of Thailand

4.1 Conservation Target

The study set conservation target on biodiversity conservation at wildlife species and plant community level. The two wildlife species: wild elephant (*Elephas maximus*) and tiger *(Panthera tigris)* were selected. Justification of species selection is that wild elephant and tiger are flagship species which is well known for their conservation value. Wild elephant is known as an umbrella species, requires large habitat area and has substantial influence to other herbivore species. Issue of wild elephant-human conflict is clearly eminent in many areas. Tiger is a keystone species, the largest predator in Thailand but under severe threat to extinction. However, it is worth taking note here that the corridor study should not end at only these two species. The future study should expand the conservation target to cover other important species.

Physical corridor intention is to make the connection of forest patches for sustainable environment and ecosystem services such as providing good water, clean air, preventing flood and drought, and alleviating climate change impact.

4.2 Study Areas

The scope of the corridor study aimed at national level that wildlife and physical corridors must be identified in 17 terrestrial forest complexes. However, only corridors in 8 forest complexes, some regional and Transboundary corridors were selected for implementation in the 10 year national corridor management plan.

Table 8 List of selected forest complexes and justification of selection for implementation in the 10 - year national corridor management plan

List of Forest Complexes	Reasons for selection
1. Western Forest Complex	- Highest rank in terms of ecological value among the 17 terrestrial forest complexes, - High importance as a key area for connection to other forest complexes at national level in north-south direction; north to Mae Ping-Om Koi and south to Khaeng Krachan forest complex which can further connect to other forest complexes in the mentioned direction. Thus, support more wildlife movement and stability of the ecosystem, - Importance at international level; Two protected area units are inscribed as Thung yai Naresuan-Huay Kha Keang natural world heritage site.

Table 8 (Continued)

List of Forest Complexes	Reasons for selection
2. Mae Ping-Om Koi Forest Complex	- Ecological status in terms of forest ground cover is 59.66%, ranking the third among 17 terrestrial forest complexes, - High importance as a key area for connection to other forest complexes at national level.
3. Lum Num Pai-Salawin Forest Complex	- Ecological status in terms of forest ground cover is 60.91%, ranking the second to the western forest complex, - High importance as a key area for connection to other forest complexes at national level (Connect to Mae Ping-Om Koi),
4. Khaeng Krachan Forest Complex	- Ecological status in terms of forest ground cover and wildlife habitat is 42.41%, the forth of the 17 forest complexes, - High importance as a key area for connection to other forest complexes at national level, - High importance as a key area for Transboundary corridor connecting Thaninthayi National Park in Myanmar enable the whole area protected to 7,292.25 square kilometer from both countries, - Designated as ASEAN Heritage Park and under the process of nomination to a world heritage site, - Clear evidence of wildlife (wild elephant)-human conflict.
5. Dong Phayayen-Khao Yai Forest Complex	- Ecological status in terms of forest ground cover and wildlife habitat is 48.1%, ranking the second, - High importance as a key area for connection to other forest complexes at national level in east-west direction (to Phranom dongrak- Pha Tam forest complex), - High importance as a key area for Transboundary corridor connecting Banteay Chhmar National Protected Landscape, Preach Vihear National Protected Forest in Cambodia, - Importance at international level; Being Inscribed as the Dong Phayayen-Khao Yai world heritage site.
6. Phranom dongrak - Pha Tam Forest Complex	- High importance as a key area for connection at national and international level in east-west direction, - High importance as a key area for Transboundary corridor connecting Preach Vihear National Protected Forest in Cambodia and Phou Xiengthong National Biodiversity Conservation Area in Laos, PDR.

Table 8 (Continued)

List of Forest Complexes	Reasons for selection
7. Phu Khiew – Nam naew Forest Complex	- Ecological status in terms of forest ground cover and wildlife habitat is 47.18%, ranking the third, - Contain relative large collection of rare and endemic plant species, cover two bio-geo regions (Indochina and Indo-Burmese or Himalayan), - High importance as a key area for connection to other forest complexes at national level to Dong Phayayen-Khao Yai forest complex, - Clear evidence of wildlife (wild elephant)-human conflict.
8. Eastern Forest Complex	- Ecological status in terms of forest ground cover and wildlife habitat is 41.06%, ranking the sixth, - High importance as a key area for Transboundary corridor connecting Central Cardamom Protected Forest, Phnom Sankos Wildlife Sanctuary, and Samlaut Multiple Use Management Area in Cambodia enable the whole area protected to 8,413.83 square kilometer from both countries, - Clear evidence of wildlife (wild elephant)-human conflict.

4.3 Threats

The study revealed that most important threat to biodiversity conservation in corridors is forest reserves encroachment. Changing forest land into agricultural land and settlement areas were most found. The following Table summarized threats found within and outside protected areas in case study sites of Eastern forest complex and Phu Khiew-Nam Naew.

Rubber plantation in proposed wildlife corridors

One year old rubber tree plantation in forest reserves

Encroached forest reserves

Illegal logging

Table 9 Threats of biodiversity conservation in ecological corridors

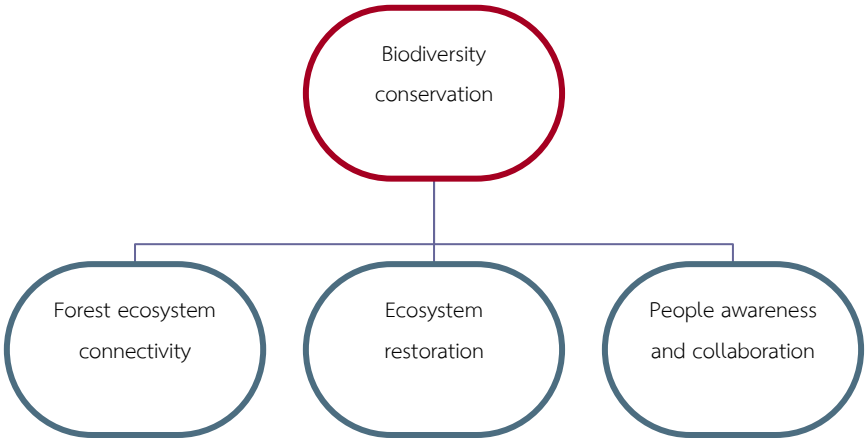
THREATS
Forest loss/Encroachment – forest area in forest reserves changing to agricultural and settlement areas
Illegal wildlife poaching and trade of wildlife
Non timber - forest products collection inside and outside PAs (NTFPs)
Domestics animal raising
Infrastructure development (highways, road, dam, etc)
Damage of agricultural products by wild elephant
Insufficient collaboration from local people
Insufficient knowledge and conservation awareness of local people and general public
Unrested land and land use national policy
Laws and regulation may restrict some innovative approach to corridor success

4.4 Approaches

Ecosystem management is a core approach. Other corresponding mechanism or approaches applied herewith are: people participation, law enforcement, economics tool and mechanism for biodiversity conservation such as Payment for Environmental services (PES).

4.5 Management guidelines

4.5.1 Goals



4.5.2 Management guidelines

The guideline divides into 3 phases: preparation, implementation, monitoring & evaluation. The management is divided into 3 levels: at forest complex (local level), regional, and international levels.

Table 10 Corridor management guidelines

Level of management action	Guidelines of management action
I. PREPARATION PHASE	
At forest complex and regional level	
Target corridors in 8 important forest complexes: - Western - Khaeng Krachan - Mae Ping-Om Koi - Lum Num Pai-Salawin - Dong Phayayen-Khao Yai - Phanom dongrak- Pha Tam - Phu Khiew- Namnaew - Eastern Wildlife corridors rank 1 & 2 = 32 corridors Physical corridors rank HS & S = 31 corridors Overlapped of wildlife and physical corridors = 10 corridors Regional corridors = 15 corridors	Announce national policy for ecological corridor Resources and land use survey in target corridors Public relation to all stakeholders Prepare the relevant stakeholders: information dissimilation, training, meeting, workshop, demonstration, awareness and knowledge transfer. Planning and working with local stakeholders
At international level	
10 corridors at Laos PDR, Cambodia, Myanmar connections	Preparation for working together at Transboundary corridors : data collection and planning Public relation
II. IMPLEMENTATION PHASE	
At forest complex and regional level	
All target corridors and country-wide	Public relation
Corridors on existing agricultural/settlement land which have legal land titles	Economics instrument/mechanism: - Compensation - Amelioration - Economic incentives for farmer collaboration on wildlife passing on their property, forest plantation, agroforestry - Revenue sharing

Table 10 (Continued)

Level of management action	Guidelines of management action
Corridors on existing agricultural/settlement land which legal land titles are unknown	Prove of land titles
	Economics instrument/mechanism: - Compensation - Amelioration - Economic incentives for farmer collaboration on wildlife passing on their property, forest plantation, agroforestry - Revenue sharing
Corridors on existing illegal agricultural/settlement land	
- If it is Zone C of Forest Reserves (Conservation Zone)	Law enforcement
	Government must restore the forest ecosystem and/or seek Corporate Social Responsibility (CSR)
	Designate the area to be Wildlife hunting area, forest park or adjunct it to nearby protected areas
- If it is Zone A or E of Forest Reserves, Permanent forest, Public property	Law enforcement
	Declare as community forest and allowing wildlife passing through, planting wildlife forage species, create salt licks, CSR
	Set up Local forest cooperatives (LFC) - Forest plantation in corridors and surrounding areas by the local forest cooperatives - Selection of tree species determined by the government agency and LFC - Pay the forest reserve land rental with discount rate - Sustainable forest management for timber and forest products

Table 10 (Continued)

Level of management action	Guidelines of management action
Corridors on existing forest cover	
- Forest reserves or Permanent forest	Designate as wildlife hunting area
	Annex to nearby protected areas
	Community forest establishment and manage for wildlife usage
	In case of degraded forest, restore forest/ecosystem
- Forest Plantation of Forest Industry Organization (FIO) or private forest plantation	Management for wildlife corridor under Forest Stewardship Council: FSC
- Public land	Community forest
- Land Reform for Agriculture (Sor Por Kor)	Return right of land to forest land
	Designate as wildlife hunting area, forest park, annex to nearby protected areas, or community forest
Corridors on existing road dissected	
- Road with light traffic; road width is not wide (2 ways)	Regulate “the road closed period”
	Public relation, give information to road users in advance
	Signage forewarning wildlife crossing and controlling car speed
	Rubber speed bump
- Road with high traffic	Cooperation with responsible agencies
	Public relation
	Design of engineering structure (wildlife over pass/under pass /tunnel) and construct the physical structure
	Prevent wildlife moving outside the protected areas and designated corridors with appropriate techniques
	Prevent threats to wildlife ig. patrolling, collaboration and partnership at local level

Table 10 (Continued)

Level of management action	Guidelines of management action
At international level	
10 corridors at Laos PDR, Cambodia, Myanmar connections	Implementation phase : biodiversity conservation
	Public relation
III. EVALUATION AND MONITORING	
Local and country-wide	
Target corridors in 8 important forest complexes total of 73 corridors Regional corridors = 15 corridors	Monitor wildlife usage in corridors - Wildlife species - Wildlife abundance - Number of wildlife using the corridors - Survey of threats - Monitor all indicators every year continuously for 10 years - Summary of monitoring results
	Public relation
At international level	
10 corridors at Laos PDR, Cambodia, Myanmar connections	Monitoring the progress of Transboundary corridors establishment
Forest complex, regional, international level	
All target corridors	State of the corridor report: Summary of corridor management at all levels

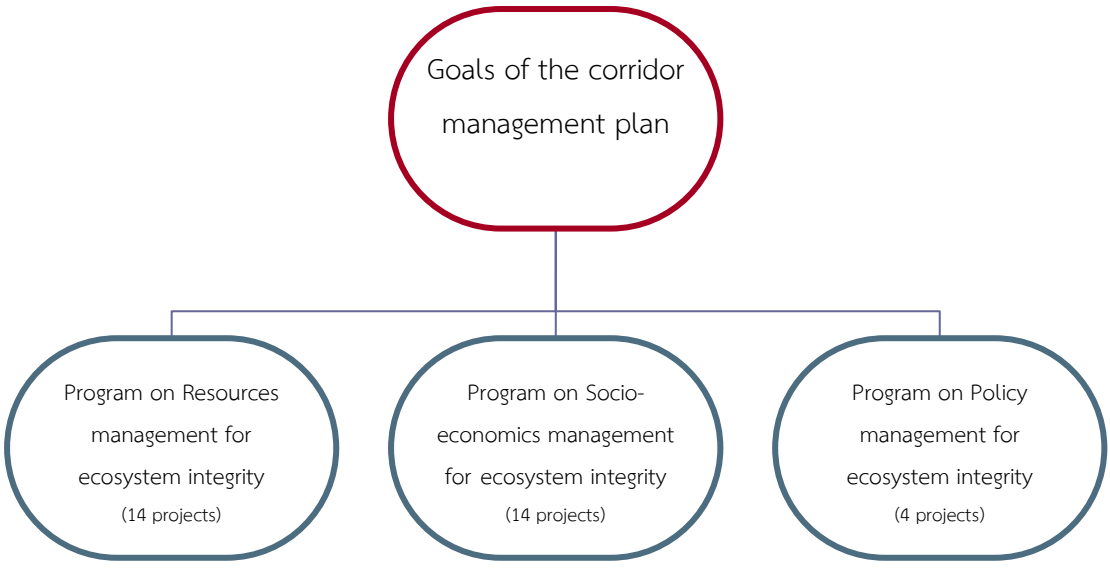
5: CORRIDOR MANAGEMENT PLAN

5.1 Goals of the plan

1) Guidelines for corridor implementation on ecosystem connectivity, restoration and biodiversity conservation of 8 terrestrial forest complexes: Western, Khang krachan, Mae Ping-Om Koi, Lum Num Pai-Salawin, Dong Phayayen-Khao Yai, Phanom Dongrak-Pha Tam, Phu Khiew - Nam Naew, and Eastern.
2) Forest patches in protected areas are connected through 88 ecological corridors:
   - 32 wildlife corridors having the distance less than 12 kilometers,
   - 31 physical corridors
   - 10 overlapped wildlife and physical corridors
   - 15 wildlife corridors having the distance more than 12 kilometers
3) Guidelines for 10 Transboundary corridors between Thailand and the Republic of the Union of Myanmar, Kingdom of Cambodia, and the Lao People's Democratic Republic,
4) Local people and general public have clear understanding and more awareness of forest connectivity and ecological corridor approaches for biodiversity conservation.

5.2 Programs and Projects

Three planning programs with 32 projects are proposed:



I. Program on resources management for ecosystem integrity

1. Management for ecosystem connection

1.1 Management of wildlife corridors for wild elephant and tiger in forest complex

1.2 Management of wildlife corridors for wild elephant and tiger between forest complex

1.3 Management of physical corridors

1.4 Survey and design of wildlife corridor for highway 317 intersection between Khlong Khruo Wai Chalerm Pra Kiet wildlife sanctuary and Khao Soi Dao Wildlife Sanctuary (wildlife corridor code 10-02-3-06-04)

1.5 Survey and design of wildlife corridor for highway 12 intersection between Nam Naew National Park patch 1 and patch 2 (wildlife corridor code 06-19-3-06-06)

1.6 Survey and design of wildlife corridor for highway 12 intersection between Phu Pha Man National Park and Pha Phung Wildlife Sanctuary (wildlife corridor code 06-05-1-06-00)

1.7 Establishment of wildlife hunting areas, forest parks, and/or annexing corridors into nearby protected areas

1.8 Management of Transboundary corridors

2. Management of wildlife population and habitat

2.1 Management of wildlife habitat, food and water resources

2.2 Reintroduction of wildlife species

3. Research Plan

3.1 Suitability assessment of important wildlife corridor Project

3.2 Study of abundance and distribution of keystone species and umbrella species

3.3 Study of biodiversity and database establishment

3.4 Monitoring of corridor management success

II. Program on socio-economics management for ecosystem integrity

4. Human resources capacity building in corridor management and public relation

4.1 Outreach program and information / knowledge dissemination in local areas

4.2 Public relation of ecological corridor

4.3 Youth nature education program

4.4 Protected area personnel efficiency and effectiveness enhancement in area patrolling

4.5 Local involvement in forest reserve area patrolling

5. Stake holders participation

5.1 Participatory wildlife - human conflict management

5.2 Establishment of community participation network in protected areas management

5.3 Promotion of wildlife tourism in ecological corridors

6. Management of land tenure and sustainable use of resources

6.1 Resolving unclear land tenure issues

6.2 Management of sustainable forest resource uses

7. Promoting economic mechanisms for ecological corridors management

7.1 Encouragement of appropriate occupations for better livelihood of local communities around protected areas

7.2 Study of appropriate compensation approach for corridors

7.3 Sufficient economy encouragement for sustainable community development

7.4 Action research on Payment for Ecosystem Services (PES) for ecological corridor management

III. Program on Policy and Institution development for biodiversity conservation

8. **Policy and Institution Development**

8.1 Collaboration among government agencies in corridor management

8.2 Law and policy instrument for corridor management study

8.3 Review and reclassification of forest complexes for ecosystem management

8.4 Appropriate institution structure for forest complex administration study

Table 11 Summary of programs, plans, and activities of the 10 - year corridor management plan of important forest complexes in Thailand

Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
		1	2	3	4	5	6	7	8	9	10			
I. Program on resources management for ecosystem integrity														
1. Management for ecosystem connection														
1.1 Management of wildlife corridors for wild elephant and tiger in forest complex project	1		✖	✖	✖	✖	✖					3,311.10	NPD, RFD	51 Wildlife corridors in 8 forest complexes
1.2 Management of wildlife corridors for wild elephant and tiger between forest complex project	1			✖	✖	✖	✖					32.65	NPD, RFD	6 Regional corridors in 8 forest complexes
1.3 Management of Physical corridors project	1		✖	✖	✖	✖	✖					47.65	NPD, RFD	31 physical corridors in 8 forest complexes
1.4 Survey and design of wildlife corridor for highway 317 intersection between Khlong Khruo Wai Chalerm Pra Kiet wildlife sanctuary and Khao Soi Dao Wildlife Sanctuary (wildlife corridor code 10-02-3-06-04)	1		✖									9.66	DOH	Physical/ engineering plan for HWY 317 at wildlife corridor code 10-02-3-06-04
1.5 Survey and design of wildlife corridor for highway 12 intersection between Nam Naew National Park patch 1 and patch 2 (wildlife corridor code 06-19-3-06-06)	1			✖								33.8	DOH	Physical/ engineering plan for HWY 12 at wildlife corridor code 06-19-3-06-06
1.6 Survey and design of wildlife corridor for highway 12 intersection between Phu Pha Man National Park and Pha Phung Wildlife Sanctuary (wildlife corridor code 06-05-1-06-00)	2					✖						4.83	DOH	Physical/ engineering plan for HWY 12 at wildlife corridor code 06-05-1-06-00

Table 11 (Continued)

	Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
			1	2	3	4	5	6	7	8	9	10			
1.7	Establishment of wildlife hunting areas, forest parks, and/or annexing corridors into nearby protected areas	1	×	×									-	NPD	50 sites of wildlife hunting areas, forest parks, and/or protected area annexing are designated.
1.8	Management of Transboundary corridors project	1		×	×	×	×	×					16.4	NPD	3 sites: (1) Eastern forest complex and PA in Cambodia (2) Khaeng Krachan Forest Complex and PA in Myanmar (3) Chumporn forest complex and PA in Myanmar
															Total budget 3,456.09 million baht
	2. Management of wildlife population and habitat														
2.1	Management of wildlife habitat, food and water resources Project	2			×	×	×	×	×				3,527.30	NPD	In corridors and 8 forest complexes
2.2	Reintroduction of wildlife species Project	3					×	×	×	×	×		10	NPD	Phu Khiew- Namnaew
															Total budget 3,537.30 million baht

Table 11 (Continued)

	Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
			1	2	3	4	5	6	7	8	9	10			
3. Research Plan															
3.1	Suitability assessment of important wildlife corridor	1	✖	✖	✖	✖	✖						37.85	NPD	51 wildlife corridors in 8 forest complexes
3.2	Study of abundance and distribution of keystone species and umbrella species	1	✖	✖	✖	✖	✖						20	NPD	8 forest complexes
3.3	Study of biodiversity and database establishment	1	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	212.85	NPD	8 forest complexes
3.4	Monitoring of corridor management success	2		✖	✖	✖	✖	✖	✖	✖	✖	✖	7.2	NPD	Progress report of corridor management
															Total budget 277.9 million baht

Table 11 (Continued)

	Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
			1	2	3	4	5	6	7	8	9	10			
II. Program on socio-economics management for ecosystem integrity															
4. Human resources capacity building in corridor management and public relation															
4.1	Outreach program and information / knowledge dissemination in local areas	1	✖	✖	✖	✖	✖						0.96	NPD	Local communities have knowledge & understanding on corridor management
4.2	Public relation of ecological corridor	1	✖	✖	✖	✖	✖						2.5	NPD	Continuous & effective communication between the corridor management project and the public
4.3	Youth nature education program	1	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	3.0	NPD Local Academic Institution	Local youth has good knowledge and awareness of forest resources values and ecological corridors
4.4	Protected area personnel efficiency and effectiveness enhancement in area patrolling	1	✖		✖		✖		✖		✖		2.7	NPD	More effectiveness in patrolling
4.5	Local involvement in forest reserve area patrolling	1	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	20.91	RFD DAO	Local involvement in forest reserve patrolling and protection at proposed corridors
															Total budget 30.07 million baht

Table 11 (Continued)

	Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
			1	2	3	4	5	6	7	8	9	10			
5. Stake holders participation															
5.1	Participatory wildlife - human conflict management	1	✖	✖	✖								80.0	NPD RFD LA	Reduce conflict between human and wild elephant at corridors and nearby agricultural land
5.2	Establishment of community participation network in protected areas management	1	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	5	NPD	Participatory citizen network is set up and operated continuously
5.3	Promotion of wildlife tourism in ecological corridors	2			✖	✖	✖	✖	✖	✖	✖	✖	5	NPD RFD LA University/ Academic Institution	A Community based tourism activity at corridor site
															Total budget 90 million baht

Table 11 (Continued)

	Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
			1	2	3	4	5	6	7	8	9	10			
6.	**Management of land tenure and sustainable use of resources**														
6.1	Resolving unclear land tenure issues	1		×	×	×							5.2	NPD RFD LA DOL	Appropriate and feasible guidelines approach to resolve the land use conflict/ overlapping of land tenure
6.2	Management of sustainable forest resource uses	1	×	×	×	×	×	×	×	×	×	×	0.96	NPD RFD LA	Natural resource dependency is reduced at the target corridors
															Total budget 6.16 Million baht
7.	**Promoting economic mechanisms for ecological corridors management**														
7.1	Encouragement of appropriate occupations for better livelihood of local communities around protected areas	2	×	×	×	×	×						5	CDD LA	better livehood of local communities
7.2	Study of appropriate compensation approach for corridors	1	×	×	×								0.5	NPD LA DCD Private Organization (CSR)	Appropriate and acceptable compensation model

Table 11 (Continued)

	Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
			1	2	3	4	5	6	7	8	9	10			
7.3	Sufficient economy encouragement for sustainable community development project	2	✖	✖	✖	✖	✖						3.0	CDD	Sufficient economy network for local communities established
7.4	Action research on Payment for Ecosystem Services (PES) for ecological corridor management	1	✖	✖	✖								1.5	NPD	Appropriate PES model for corridor management
															Total budget 10 million baht
	III. Program on Policy and Institution development for biodiversity conservation														
	8. Policy and Institution Development														
8.1	Collaboration among government agencies in corridor management	1	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	1.0	NPD	Cooperation activities among government agencies
8.2	Study on law and policy instrument for corridor management	1	✖										0.4	NPD	Appropriate laws and policy supporting corridor management
8.3	Review and reclassification of forest complexes for ecosystem management	1	✖	✖									2.0	NPD	New classification of forest complexes

Table 11 (Continued)

	Activities	Priority	Year of implementation										Budget (mil. baht)	Responsible agency	Goals
			1	2	3	4	5	6	7	8	9	10			
8.4	Study on appropriate institution structure for forest complex administration	1	✘										-	NPD	Improved forest complex administration ; increase unified administration and reduced administrative problems in forest complexes
															Total budget 3.4 Million baht
													Grand total budget		**7,410.92 Million baht**

Remark:

LA = Local Administration

NPD = National Park, Wildlife and Plant Conservation Department

DOH = Department of Highways

DAO = District Administrative Organization

RFD = Royal Forest Department

DOL = Department of Lands

CDD = Community Development Department

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