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Original article

Indirect Use Value of Lat Krathing Forest Plantation, Thailand

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ABSTRACT

Indirect use value is a benefit of economic value of forest plantations that is important for decision-making in forest land use management and investment. This research classified the characteristics of the indirect use values in a 3,267.53 hectares Lat Krathing forest plantation (LKFP) as carbon di oxide (CO_2) sequestration and biodiversity value. Different methods were used to calculate each characteristic of the indirect use value: the market price method was used to calculate CO_2 sequestration and the contingent valuation method was used to calculate the biodiversity value. There were 6,147,852 Baht of CO_2 sequestration value and 2,760,548 Baht of biodiversity value. Therefore, the total indirect use value of the LKFP in 2017 was a total of 8,908,400 Baht. However, there are still other important economic values, such as the direct use value and the non-use value that requires further study.

Keywords: biodiversity value, carbon di oxide sequestration, contingent valuation method, economic value, market price method.

INTRODUCTION

Economic value, which includes use and non-use value, is a tool urgently needed for decision-making in operational land use planning and investment with regard to appropriate future activities, and to provide more reliable information on the environmental, social and economic value.

Forest plantations are increasingly providing both use and non-use benefits similar to the goods and services derived from natural forests, and the mosaic forests in agricultural land use are also increasing (Sloan and Sayer, 2015). In Thailand, the Forest Industry Organization (FIO), which is a state enterprise established in 1947, is involved in reforestation and has operated since 1967 that has planted teak (*Tectona grandis* Linn.f.) in the northern region and also planted other species such as rubber (*Hevea brasiliensis* Muell. Arg.), eucalyptus (*Eucalyptus* spp.), and acacia (*Acacia* spp.) in the other part of Thailand up until now. In 2016, the FIO was responsible for approximately 185,280.00 hectares of total plantation areas (FIO, 2016).

The Lat Krathing forest plantation (LKFP) of FIO is located at Chachoengsao province in the East region of Thailand. In 2017, LKFP had an area of 3,267.53 hectares that included 2,230.88 hectares of production forest area consisting of 1,317.06 hectares of stands of various species of commercial tree species and 913.82 hectares of agroforestry area. There were also 95.63 hectares of conservation forest area, and 941.02 hectares of other land uses, such as office, road, nursery, pool and space area.

Although, the LKFP has many important economic value characteristics in the production and conservation areas, but there was no economic valuation document in the past, especially the indirect use value. Therefore, the objective of this research was to

evaluate indirect use value of the LKFP in term of monetary unit and the research was employed appropriately different valuation method to find out the indirect use value.

MATERIALS AND METHODS

Study area

The LKFP is a rehabilitated site located in Lat Krathing sub-district, Sanam Chai Khet district, Chachoengsao province, Thailand. It is about 145 kilometers from the FIO office in Bangkok. Reforestation operations begun in 1968 in Kwae rabom-siyad national forest reserve with permission of the Royal Forest Department and under the supervision of Thai Plywood Company Limited. The LKFP area of 3,267.53 hectares consists of various land uses, including 2,230.88 hectares of production forest (mainly eucalyptus, teak, rubber, and acacia), 94.03 hectares of conservation forest and 941.02 hectares of other land uses, such as office, road, nursery, pool and space area (LKFP, 2016) (Figure 1).

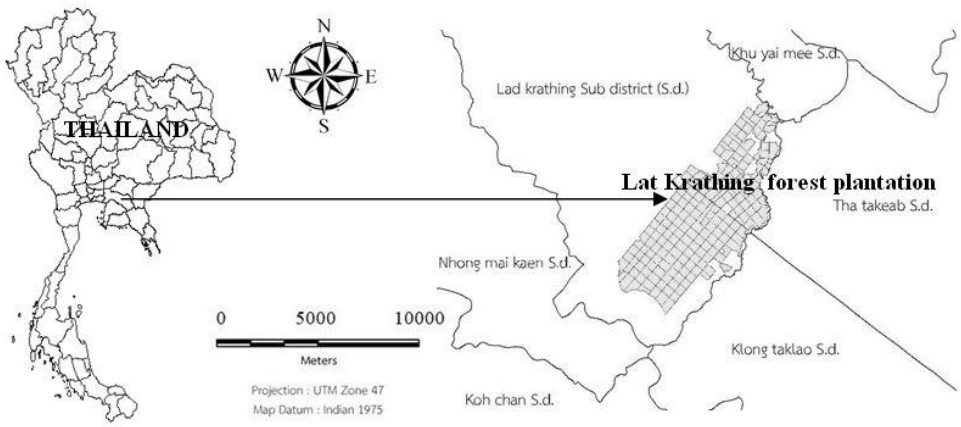

Figure 1 Location of Lat Krathing forest plantation (47P 775911E, 1498303N).

Field survey and Data collection

This research identified two indirect use value characteristics, namely, CO_2 sequestration and biodiversity value. This research separated the field survey and data collection into two methods included sampling plots and interview by questionnaire for evaluate indirect use value. The materials were used for this research included a camera, chainsaw, computer, diameter tape, distance measuring tape, haglof vertex IV hypsometer, knife, pruning scissor, weighing scale, tally sheet for merchantable timber of forest plantation inventory, tally sheet for merchantable teak of forest plantation inventory, and questionnaires for local people.

Sampling plots

This research divided the plantation into production forest and conservation forest. The production forest area considered the forest inventory technique that depends on the specie types. First, *Acacia mangium* Willd., *Eucalyptus* spp., *Hevea brasiliensis* Muell. Arg and other species (except *Tectona grandis* Linn.f.). A systematic random sampling method based on the standing trees rows were used. In surveying, this study used systematic random sampling with 10 % sampling intensity, with a random starting row selected from the first 10 rows. The first sample was row number 5 from the production forest area boundary and the selection continued to rows 15, 25, 35, until the end of the other side of the forest. Second, *Tectona grandis* Linn.f. , the line plot system with 1.25 % sampling intensity was used. Circular sample plots of radius 12.62 m (or 500 m^2) were placed 200 m apart in a line from the baseline and cruise line. For all forestation collected consisted of survival rate, girth at breast height (GBH), and total height (Ht) of each tree in each sample row or sample plot (LKFP, 2016).

In the conservation forest area, a stratified random sampling method was used, with 6 temporary sample plots of size 40 × 40 m^2.

Each plot consisted of 10 x 10 m^2 sub-plots for tree (diameter at breast height (DBH) ≥ 4.5 cm) inventory, 4 x 4 m^2 sub-plots for sapling (DBH < 4.5 cm), and 1 x 1 m^2 sub-plots for seedling (H_t < 1.30 m), respectively. The GBH and H_t of trees in the sample plots were recorded (Thailand Greenhouse Gas Management Organization (Public Organization) [TGO], 2015).

Interview by questionnaire

Interview data divided this past of the local people considered 4,026 households from 11 villages around the LKFP and used the method of Yamane (1967). This research used a questionnaire to interview 390 of the household heads. First, general information about the local people. This included personal information, such as the respondent's name, and demographic and other background information, such as age, gender, education, status in the household, main career, revenue, expenditure, member in family, family settlements, future migration requirements, land holding status, participated in forest conservation activities, and training on forest resource conservation. Second, the information on the willingness to pay (WTP) for biodiversity in the LKFP. A biodiversity survey of plant and animal species found 69 species of plant resources, 22 species of mammals, 91 species of birds, 32 species of reptiles and 18 species of amphibians. Some species were nearly extinct and tended to be endangered species (Maelim *et al*., 2015). This study directly interviewed the local people about understanding the importance of biodiversity in the LKFP, WTP for the prevention, and treatment or restoration of biodiversity in the LKFP.

Data analysis

This section should divide into.

1. CO_2 sequestration.

This CO_2 sequestration value was calculated by using the allometric models to calculate above ground biomass (AGB) in each tree (Table 1).

The AGB of tree in the area was calculated using the AGB equations in Table 1. Then, the AGB estimates were converted to CO_2 sequestration units using the conversion equation that were created by TGO (n.d.) and the Intergovernmental Panel on Climate Change [IPCC] (2006), as follows (Equations 1 and 2).

$$C_{ABGi} = \left(\sum_{j=1}^{n} M_j \times CF \times \frac{44}{12} \right) \times \frac{A}{a} \quad (1)$$

$$C_{ABG} = \sum_{i=1}^{N} C_{ABGi} \quad (2)$$

Where

C_{ABG} = Total aboveground CO_2 sequestration (ton CO_2)

C_{ABGi} = Aboveground CO_2 sequestration at age class i (ton CO_2)

M_j = Total above ground biomass of tree *j* (ton/ha)

i, N = Age class (1,…,N), n = Tree species (1,…,n)

A = Total area (ha), a = Sample plot area (ha)

CF = The proportion of carbon in wood (0.4848, 0.4895, 0.466, 0.499 and 0.4848 of biomass in *Acacia mangium* Willd., *Eucalyptus* spp., *Tectona grandis* Linn.f., *Hevea brasiliensis* Muell. Arg. and other species, respectively (Tripattanasuwan, n.d.))

The below-ground CO_2 sequestration was calculated using a conversion equation. The sum of all of the below-ground CO_2 sequestration of a stand using the equations that was developed by TGO (n.d.) (Equation 3 and 4).

$$C_{BLGi} = C_{ABGi} \times R \quad (3)$$

$$C_{BLG} = \sum_{i=1}^{N} C_{BLGi} \quad (4)$$

Where

C_{BLG} = Total below-ground CO_2 sequestration (ton CO_2)

C_{BLGi} = Below-ground CO_2 sequestration at age class i (ton CO_2)

R = Dry weight ratio of root to tree (0.40, 0.44, 0.43, 0.33 and 0.40 of above ground biomass in *Acacia mangium* Willd., *Eucalyptus* spp., *Tectona grandis* Linn.f.,

Hevea brasiliensis Muell. Arg. and other species, respectively (Tripattanasuwan, n.d.)

Table 1 The allometric models for above ground biomass estimation in the LKFP.

Type of species	Equation	R^2
Productive forest area		
- *Acacia mangium* Willd.[1]	- $W_S = 0.017(DBH^2H_t)^{0.9973}$	0.99
	- $W_B = 0.00004(DBH^2H_t)^{1.4430}$	0.89
	- $W_L = 0.00004(DBH^2H_t)^{1.3462}$	0.98
	- $AGB = W_S + W_B + W_L$	
- *Eucalyptus camaldulensis* Dehnh.[1]	- $W_S = 0.0276(DBH^2H_t)^{0.9662}$	0.99
	- $W_B = 0.0002(DBH^2H_t)^{1.3684}$	0.92
	- $W_L = 0.0027(DBH^2H_t)^{0.8253}$	0.71
	- $AGB = W_S + W_B + W_L$	
- *Eucalyptus urophylla* S.T.Blake[2]	- $W_S = 0.0313(DBH^2)^{1.5067}$	0.99
	- $W_B = 0.0668(DBH^2)^{0.8346}$	0.94
	- $W_L = 0.0247(DBH^2)^{0.936}$	0.98
	- $AGB = W_S + W_B + W_L$	
- *Tectona grandis* Linn.f.[1]	- $W_S = 0.0265(DBH^2H_t)^{0.9468}$	0.99
	- $W_B = 0.0011(DBH^2H_t)^{1.1472}$	0.93
	- $W_L = 0.0197(DBH^2H_t)^{0.6867}$	0.81
	- $AGB = W_S + W_B + W_L$	
- *Hevea brasiliensis* Muell. Arg.[3]	- $W_S = 0.0804(DBH^2H_t)^{0.8341}$	0.97
	- $W_B = AGB - W_S - W_L$	
	- $W_L = 0.000008(DBH^2H_t)^{1.4986}$	0.91
	- $AGB = 0.0046\ (DBH^2H_t)^{1.2046}$	0.95
- Other species[1]	- $AGB = 0.0341\ (DBH^2H_t)^{0.9528}$	
Conservation forest area		
- Dry evergreen forest[4]	- $W_S = 0.0509(DBH^2H_t)^{0.919}$	
	- $W_B = 0.00893(DBH^2H_t)^{0.977}$	
	- $W_L = 0.0140(DBH^2H_t)^{0.669}$	
	- $AGB = W_S+W_B+W_L$	

Source: [1]Viriyabuncha *et al.* (2005), [2]Chansrikong (2017), [3]Tripattanasuwan *et al.* (n.d.), [4]Terakunpisut *et al.* (2007)

where W_S = Biomass of stem (kg), W_B = Biomass of branches (kg)
W_L = Biomass of leaves (kg), AGB = Above ground biomass (kg)
DBH = Diameter at breath height (cm), H_t = Total height (m)

The total CO_2 sequestration of the stand was calculated using Equation 5 (TGO, n.d.).

$$C_{TT} = C_{ABG} + C_{BLG} \quad (5)$$

where C_{TT} = Total CO_2 sequestration of stand (ton CO_2)

Finally, this research used the market price method to estimate the value of CO_2 sequestration in the LKFP from the increment of CO_2 sequestration of stand per year that was obtained from TGO (n.d.) (Equations 6 and 7).

$$I_{CS} = \frac{C_{TT}}{Y} \quad (6)$$

$$V_{CO_2} = I_{CS} \times P_C \quad (7)$$

Where

I_{CS} = Increment CO_2 sequestration of stand (ton CO_2/year)

C_{TT} = Total CO_2 sequestration of stand (ton CO_2), Y= Age of stand (year)

P_C = Market price of CO_2 sequestration (166 Baht/ton CO_2)

V_{CO_2} = Value of CO_2 sequestration (Baht/year)

2. Biodiversity values.

The contingent valuation method (CVM) was used to calculate biodiversity values. The WTP for the preservation of all endangered species in the LKFP was used to calculate biodiversity values as was applied by Suksard (2009). This research created biodiversity value equation for the LKFP as follows (Equation 8).

$$V_B = \sum_{i=1}^{N} \frac{WTP_i \times N_P}{N_S} \qquad (8)$$

Where

V_B = Value of biodiversity (Baht)

WTP_i = Willingness to pay for biodiversity value in 2017 (Baht)

N_P = Number of population, N_S = Number of sample size (household)

i, N = Respondents (i = 1, 2, 3,..., 390)

3. Finally, the total indirect use value of the LKFP in 2017 was calculated as follows (Equation 9).

$$V_{IU} = V_{CO_2} + V_B \qquad (9)$$

where V_{IU} = Indirect use value (Baht)

RESULTS AND DISCUSSION

Carbon di oxide (CO_2) sequestration value.

The total AGB and Total C_{ABG} were 122,084.98 tons and 217,306.20 tons CO_2, respectively, in 2,150.44 hectares of the production forest area, In 95.63 hectares of the conservation forest area, the total AGB and Total C_{ABG} were 3,317.99 tons and 5,898.06 tons CO_2, respectively. Thus, in 2,246.07 hectares of the LKFP, this research calculated the total AGB and Total C_{ABG} as 125,402.97 tons and 223,204.26 tons CO_2, respectively. While, the total C_{BLG} in the production forest area and the conservation forest area were 89,779.50 ton CO_2 and 2,359.24 ton CO_2, respectively. Thus, the total C_{BLG} in the LKFP was 92,138.74 ton CO_2. Therefore, the total C_{TT} in the production forest area and the conservation forest area were 307,085.70 ton CO_2 and 8,257.30 ton CO_2, respectively. Thus, the total C_{TT} in the LKFP was 315,343.00 ton CO_2 (Table 2).

Table 2 The estimation of AGB, C_{ABG}, C_{BLG} and C_{TT}.

Type of species	Area (ha)	Total AGB (ton)	Total C_{ABG} (ton CO_2)	Total C_{BLG} (ton CO_2)	Total C_{TT} (ton CO_2)
Production forest area					
- *Acacia mangium* Willd.	752.15	73,077.89	129,903.27	51,961.31	181,864.58
- *Eucalyptus camaldulensis* Dehnh.	739.31	32,318.26	58,005.91	25,522.59	83,528.50
- *Eucalyptus urophylla* S.T.Blake	263.30	6,021.34	10,807.29	4,755.22	15,562.51
- *Tectona grandis* Linn.f.	239.27	6,868.53	11,736.02	5,046.49	16,782.51
- *Hevea brasiliensis* Mull.Arg.	73.57	1,933.25	3,537.21	1,167.28	4,704.49
- Other species	82.84	1,865.71	3,316.50	1,326.61	4,643.11
Total in production	**2,150.44**	**122,084.98**	**217,306.20**	**89,779.50**	**307,085.70**
Conservation forest area					
- Dry evergreen forest	95.63	3,317.99	5,898.06	2,359.24	8,257.30

Net total	**2,246.07**	**125,402.97**	**223,204.26**	**92,138.74**	**315,343.00**

The total CO_2 increment in the production forest area and the conservation forest area were 36,573.47 tons CO_2/year and 443.94 tons CO_2/year, respectively. Therefore, the total CO_2 increment in the LKFP was 37,017.41 tons CO_2/year. Therefore, The V_{CO_2} in the production forest area and the conservation forest area were 6,074,122 Baht/year and 73,730 Baht/year, respectively. Thus, the V_{CO_2} in the LKFP in 2017 was 6,147,852 Baht (Table 3).

Table 3 The estimation of the CO_2 sequestration increment and the value of CO_2 sequestration (V_{CO_2}).

Type of species	Age (year)	Average CO_2 increment		Market price[1] (Baht/ tonCO_2)	V_{CO_2} (Baht/ year)
		(ton CO_2/ ha/year)	(ton CO_2/ year)		
Production forest area					
- *Acacia mangium* Willd.	1-32	0.67	19,618.34	166.08	3,258,214
- *Eucalyptus camaldulensis* Dehnh.	2-32	0.35	10,169.22	166.08	1,688,904
- *Eucalyptus urophylla* S.T.Blake	1-29	0.30	3,111.97	166.08	516,836
- *Tectona grandis* Linn.f.	1-24	0.24	2,242.13	166.08	372,373
- *Hevea brasiliensis* Mull.Arg.	3-5	0.44	1,251.21	166.08	207,801
- Other species	3-46	0.06	180.60	166.08	29,994
Total in production		**0.44**	**36,573.47**	**166.08**	**6,074,122**
Conservation forest area					
- Dry evergreen forest	7-48	0.12	443.94	166.08	73,730
Net total		**0.42**	**37,017.41**	**166.08**	**6,147,852**

Source: [1]Hamrick and Gallant (2017) and Exchange-Rates.org (2017)

According to the result, this research found that;

1. Most of the total AGB and C_{ABG} in the LKFP were in the production forest area (97.35 %). This was because most of the trees (95.74 %) were in the production forest area. The average AGB in the production forest area was more than in the conservation forest area, and there was the highest volume in the *Acacia mangium* Willd. followed by *Eucalyptus camaldulensis* Dehnh., Dry evergreen forest, *Tectona grandis* Linn.f., *Hevea brasiliensis* Mull.Arg. and *Eucalyptus urophylla* S.T.Blake. The remaining species had lower AGB than the average AGB. This probably means that the *Acacia mangium* Willd. is the fastest growing species, and also most of the sample plots were located in older stands. While, the average C_{TT} in the production forest area was more than in the conservation forest area. The *Acacia mangium* Willd. was the highest and others species were lower than the average C_{TT} or followed the average AGB trend. And when considering the average CO_2 increment per rais per year, this research found that the *Acacia mangium* Willd. was highest followed by *Hevea brasiliensis* Mull.Arg., *Eucalyptus camaldulensis* Dehnh., *Eucalyptus urophylla* S.T.Blake, *Tectona grandis* Linn.f. and Dry evergreen forest, and others species were lower than the average CO_2 increment per rais per year. That means *Acacia mangium* Willd. is the fastest growing species in the LKFP while, other species are slower growing species and also lowest in the value of CO_2 sequestration than the average.

Biodiversity values.

The total WTP in donation and the total WTP in wages were 51,614 Baht/year and 2,708,934 Baht/year, respectively. Therefore, the total value of biodiversity in 2017 was 2,760,548 Baht (Table 4).

According to the result, this research found that the most of the local people had WTP for biodiversity of 1-10 days per year in wage (17.44 % of all) followed by 11-20 days per year, 21-30 days per year and more than 30 days per year. Very few local people (0.77 %) had WTP in donation because of their low income.

Indirect use value.

According to the CO_2 sequestration value and the biodiversity value, this research can calculate the indirect use value of the LKFP in 2017 as 8,908,400 Baht.

Table 4 The estimation of the value of biodiversity (V_B) in 2017.

WTP	Quantity (households)	Proportion (%)	V_B Average (Baht/household)	V_B Total (Baht/year)
Donation				
- None	387	99.23	-	-
- 1,000 Baht/year	1	0.26	2.56	10,307
- 2,000 Baht/year	2	0.51	10.26	41,307
Total donation	**390**	**100.00**	**12.82**	**51,614**
Wage[1]				
- None	290	74.36	-	-
- 1-10 days/year	68	17.44	214.81	864,825
- 11-20 days/year	20	5.13	206.91	833,020
- 21-30 days/year	10	2.56	194.28	782,171
- > 30 days/year	2	0.51	56.86	228,918
Total wage	**390**	**100.00**	**672.86**	**2,708,934**
Total			**685.68**	**2,760,548**

Remark : [1]Local dairy wage equal 308 Baht per day.

CONCLUSIONS

This research calculated the indirect use value of the LKFP in 2017 was 8,908,400 Baht including.

1. In 2,150.44 hectares of the production forest area, the increment CO_2 sequestration and V_{CO_2} were 36,573.47 tons CO_2 per year and 6,074,122 Baht per year, respectively. In 95.63 hectares of the conservation forest area, the increment CO_2 sequestration and V_{CO_2} were 443.94 tons CO_2 per year and 73,730 Baht per year, respectively. Therefore, the increment CO_2 sequestration and V_{CO_2} in 2017 were 37,017.41 tons CO_2 and 6,147,852 Baht, respectively.

2. The biodiversity value in LKFP 2017 was 2,760,548 Baht

However, there are still other important economic values, such as the direct use value and the non-use value that requires further study.

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