Detection of Mangrove Forest Changes and Assessment of Carbon Stock and Economics Values in Samuth Songkram, Thailand Using Remote Sensing and GIS Techniques

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ABSTRACT

Thailand has introduced and implemented numerous policies to protect and restore the mangrove forests which provided mixed results. To maintain the trend of the increase of mangrove forest cover as well as to increase the possibilities of obtaining financial support under the REDD+ scheme or carbon offsetting scheme, assessment of the changes of forest cover and related carbon stocks becomes needed. This study estimated area changes of mangrove forest in Samuth Songkhram province using Remote Sensing and forest carbon stocks using forest inventory data. Five carbon pools were considered and respective allometric equations were used to derive carbon pools. Carbon emission reductions and removals were estimated 2030, based upon which economic potentials from carbon-based revenues were derived.

This study found that area of mangrove forests in Samuth Songkram had increased since 2001. In terms of carbon stocks, 2.9 million MgC were stored in the mangrove in 1973 but declined to 1.6 million MgC in 2001 and to 2.1 million MgC in 2016. For tree species in conservation zone was dominated by Avicennia alba (64.4%). In management zone, Rhizophora apiculata was dominated. Projection to the future suggested that conservation and management have resulted in carbon emission reductions and removals and therefore the carbon-based economic values were estimated at $4.4 million in 2021-2030 at the price $3.3 /tCO2. With the costs of conservation and management of $2.51/tCO2, the net economic values for this province were $1 million over the same period between 2021 and 2030. If the current management and conservation continue to succeed, there are huge carbon benefits. To benefit from the REDD+ scheme, project design document along with transparent monitoring, reporting and verification systems need to be developed.

***Keywords**: remote sensing, carbon stock, mangrove forest, GIS, biomass*

1. INTRODUCTION

Due to mismanagement, the global mangrove areas are less than half of their original cover in the last 50 years and mostly in the last two decades (Mangrove action project, 2016) [37]. The use of Global Forest Watch (GFW) found that 192,000 ha (1.38%) of mangrove forest were lost from 2001 to 2012 (Strong and Minnemeyer, 2015) [65]. The main causes of mangrove deforestation were the conversion of mangroves to different land uses or purposes such as aquaculture, charcoal, agriculture, urban expansion and selling wood. In Thailand, the early plans of economic development led to overexploitation of natural resources without any planning of their effects (Office the National Economic and Social Development Board, 2015) [44].

Mangrove areas had been sharply exploited due to the need for fast economic development and mismanagement. This overexploitation resulted in the loss of mangrove areas about 50.93% between 1961 and 1989 (Suwannakon, 1991) [67]. The goals of the 1st – 7th of Thai National Economic and Social Development (1961 – 1996) were to develop basic infrastructures and to support economic development but they did not concern about environment. Realizing the danger to its natural resources, this Thai National Economic and Social Development (1997-2001) was revised to include sustainable were managed of natural resources. This revising was included in the 8th – 11th plans.

Because of the reforms, mangrove forests were classified according to conservation and management. The former is the natural mangrove, while the latter is the restored mangrove whose management purposes are mainly for charcoal production (Jintanukun, 1997; Marine Knowledge Hub. 2010) [29] [39].

Although, forest areas of mangrove has increased in Samuth Songkhram Province, the increase is in the expense of natural mangrove forest because the province needs to conserve the mangrove forest, at the same time to manage other areas to support economic development. To understand the effects of conservation and management on mangrove forest, forest cover change needs to be understood. However, such information in currently is not available in sustainable management.

In addition, as REDD+ is permanent based payment, to obtain such payments at in required trend information on carbon stock emission reduction be made available. However, this information is also not available. As REDD+ scheme requires biodiversity be protected, information of carbon stock relative to species is also needed.

Therefore, to ensure long-term effective of conservation and organization mangrove forest in sustainable, assessment of the change in areas of mangrove and carbon stock need to be undertaken. Such large scale assessment is very expensive and time consuming. The use of remote sensing is the one of most efficiency technique in surveying and monitoring due to their highly accuracy, rapid and cost effective (Aschbacher, 1993)[6]. Therefore, appropriate conservation measures can not be achieved without identifying the area changes.

Once area changes are identified, total carbon stock can also be calculated by additionally using carbon stock per ha obtained from forest inventory. In addition, in knowing carbon stock changes and emission reductions, carbon-based revenues can also be estimated. Accordingly, these revenues can be used for conservation. Then the appropriate management in this area is discussed.

REDD+.

2. OBJECTIVE

1. Assess the changes in mangrove areas between 1996 to 2016
2. Assess the carbon stock relative to trees in mangrove forest
3. Assess the carbon stock in mangrove forest between 2017 and 2030
4. Estimate the economic potential of carbon stock in mangroves for future under

3. METHODOLOGY

3.1 Study area

3.1.1 The criteria for selection of study area

Samuth Songkhram Province is one example mangrove areas that gaining less mangrove forest increasing (Marine Knowledge Hub, 2010) [39]. One popular reason of gaining less or stable mangrove forest is that the mangrove lands are in the private hands. Most land owners do not want to remain the mangrove forests because they provide less direct income comparing to other land use such as shrimp farming and residence areas. The last criteria of selecting this area is that the size of the area. According to employing remote sensing technique to extract the mangrove forest (Landsat satellite has 30*30 meters spatial resolution), the small areas are not appropriated.

3.1.2 Geography of selected area

The study area is located in the coastal of Samuth SongKhram Province, around the gulf of Thailand. The area of this province is 87,200.30 hectares. The south areas of Samuth Songkhram province is the coastal areas. The length of coastal area is around 41.80 kilometers.

3.2 Methodology

The overall approaches of this study to assess carbon stock and economic revenues using remote sensing and geographic information system techniques are divided to four parts (1) Data collection (2) Satellite image preparation (3) Image processing, and (4) Data analysis as shown in figure 1

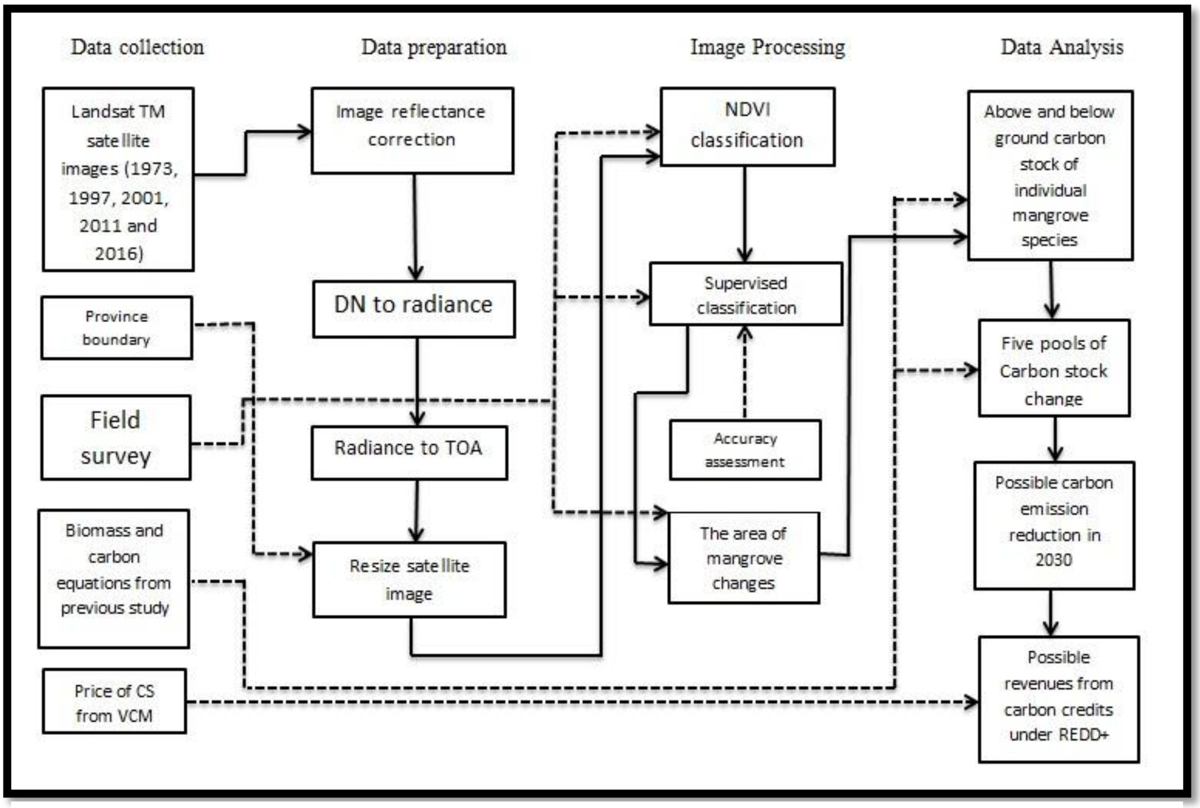

Figure 3.1 Methodology

3.2.1 Data collection

The Landsat satellite images were downloaded from United States Geological Survey. The above ground biomass values of specific mangrove species were collected from previous study which are located in Thailand and have similar climate conditions. The price of carbon credit is also based on the price of voluntary market in 2016.
The satellite images were mostly downloaded in the winter season because it is clear from cloud. The images were downloaded in the year 1973, 1997, 2001, 2011 and 2016. These periods were selected to monitor the mangrove area changes before the forest restoration policies (the eight plan of the Office of the National Economic and Social Development) had implemented in 1997. After the year 1997, the mangrove area changes were also classified to see the trend of changes. Moreover, the satellite image of year 2016 was classified to identify mangrove species related with ground survey because specific mangrove species content different amount carbon stock.
Field surveys were conducted three times. The first time was pre-survey assessment prior to plan for plot setting and tree measurement. Secondly, ten plots were designed according to purposive sampling to measure mangrove tree diameter and their species. These mangrove areas mostly are the mangrove plantations that have two main zones. These unique two zones have two main objectives; the first one is for mangrove conservation and the second purpose is for charcoal production. The plot size was 10*10 meters and ten plots were set up that the trees in conservation zone were measured at DBH ≥ 4.5 cm and all trees in second zone were measured. All tree species in both two zones were recorded. The last survey is for checking accuracy assessment that 99 ground points were identified systematically.

3.2.2. Satellite image preparation

NDVI is one of most effective formula to classify vegetation. Then it employed only Red band and NIR band. Moreover, supervised classification is one of the most popular applications that are often used to classify land use and land cover. Before each band was composited to enhance the objects, each band in Landsat satellite images was rescaled to Top of Atmospheric reflectance. This process has a two-step process. First the DNs must be converted to radiance values, and then these radiance values are needed to convert to reflectance values. For each scene, the sun, earth in astronomical units, the day of the year, the distance and solar zenith angle are provided in metadata.

3.2.3 Image processing

Satellite images were needed to resize or crop before they were composited because the large images consumed more time in analyzing process.
3.2.3.1 Remote sensing for mangrove forest classification
Remote-sensing images were used to classify mangrove forests in different years by analyzing NDVI and using supervised classification. Biomass could be estimated by regression equations among their band ratio indices using Normalized Difference Vegetation Index (NDVI).
NDVI formula

$$NDVI = (NIR-RED) / (NIR+RED) \quad (1)$$

In mangrove species identifying process, the mangrove forest was surveyed to identify their major mangrove specie distributions. The field surveys were conducted in 2016 to identify mangrove species related with satellite images using GPS. The mangrove field surveys were taken two times in different mangrove forest. It will survey mangrove species around the forest and following the nature trail. According to the nature of mangrove species, each species grow in their specific natural condition
3.2.3.1.2 Supervised classification

Then NDVI classified images were used as the base in supervised classification to identify the areas of interest using their values. Future more, the major mangrove specie distributions from field survey will be used to identify mangrove species in satellite images as giving examples of the area of interest in supervised classification process.

3.2.3.1.3 Post classification

In order to check the accuracy of image classification, 99 points of ground survey were checked systematically using Kappa analysis.

Kappa analysis: Khat Coefficient of Agreement

$$\widehat{K} = \frac{N\sum_{i=1}^{k} xii - \sum_{i=1}^{k}(xi+ + x+i)}{N - \sum_{i=1}^{k}(xi+ \times x+i)} \qquad (2)$$

Where $\widehat{K}$ is the number of rows (land-cover classes) in the matrix.

X_{ii} = the number of the observation in row i and column i

X_{i+} = the marginal totals for row i

X_{+i} = the marginal totals for column i

N = the total number of observations

$\widehat{K}$ values > 0.80 represent strong agreement or accuracy between the classification map and the ground reference information.

Finally, the mangrove areas were extracted and calculated from other land covers to assess the changes of mangrove areas and their species from 1973 to 2016 in the ArcGis application.

3.2.4 Data Analysis

3.2.4.1 The change of mangrove area from 1973 to 2016

The areas were calculated form satellite images in the year 1973, 1997, 2001, 2011 and 2016. From the year 1997 to 2016, the mangrove areas were divided to two main zones; the first zone has purpose for mangrove conservation and the second zone is for charcoal production. According to different spatial resolution of Landsat 1, the mangrove area in 1973 was not divided.

3.2.4.2 Assess the above and below ground of biomass and carbon stock according to their individual mangrove species

The above and below ground biomass and carbon of individual mangrove trees were assessed using the equations from previous studies. Formulas for assessment above and below ground biomass and carbon stock per hectares

$$AGB_{plot} = \frac{\sum AGB_i}{PlotSize} \qquad (3)$$

$$AGB_{average} = \frac{\sum AGB_{plot}}{TotalPlot} \qquad (4)$$

$$CAGB = AGB_{average} \times CT \qquad (5)$$

$$BGB_{plot} = \frac{\sum BGB_i}{PlotSize} \qquad (6)$$

$$BGB_{average} = \frac{\sum BGB_{plot}}{TotalPlot} \qquad (7)$$

$$CBGB = BGB_{average} \times CT \qquad (8)$$

3.2.4.3 Assess biomass and carbon stock of mangrove trees

As the above and below ground of biomass and carbon stock were already assessed, then litter, dead wood and soil organic carbon that also store large amount of carbon stock were estimated using equations. The areas of mangrove which were already classified in objective 1 were used to estimate carbon stock in the equations.

For litter and dead wood carbon stock were calculated using the average carbon stock values from previous studies. Litter and dead wood biomass are 13.24 MgC/ha or 14.1%, 16.34 MgC/ha or 17.4%, and 369 MgC/ha for the average soil carbon stock.

3.2.4.4 Making mangrove forest baseline and projectline for estimating mangrove forest in the future

To get the incentive support from REDD+, the baseline and projectline were needed to be developed. Therefore, two scenarios (baseline and projectline) are considered for 1973-2030 (Chheng et al., 2016) [12].

3.2.4.4.1 The baseline of mangrove forests without conservation and management

Formula:

$$FA_b(t) = FA_b(t_0) \times e^{-a_b \times t} \tag{9}$$

Data: 1973, 1997 and 2001

Where;

$FA_b(t)$	= Forest area cover under no conservation or baseline scenario
t	= Time step (year)
$FA_b\ t_0$	= Forest area at starting time (i.e. 1973, 1997 and 2001)
a_b	= Deforestation rate

3.2.4.4.2 The projectline of mangrove forests with conservation and management

Formula:

$$FA_p(t) = \frac{FA_{max} \times FA_p(t_0) \times e^{-a_p \times t}}{FA_{max} + FA_p(t_0) \times (e^{-a_p \times t} - 1)} \tag{10}$$

Data: 2001, 2011 and 2016

Where;

$FA_p(t)$	= Forest cover under conservation and management or projectline at time step
$FA_p(t_0)$	= Forest cover under conservation and management or projectline at staring time (i.e. 2001, 2011 and 2016
FA_{max}	= The maximum area of mangrove in the whole province
a_p	= Rate of increase

3.2.4.4.3 Weighted average of carbon stock

Formula:

$$CS_{WA} = \frac{(CS_{conservation} \times FA_{conservation}) + (CS_{management} \times FA_{management})}{FA_{total}} \tag{11}$$

Where;

CS_{WA}	= Weighted average of carbon stock of two zones
FA_{total}	= Total Forest area
$CS_{conservation}$	= Carbon stock in conservation zone
$CS_{management}$	= Carbon stock in management zone
$FA_{conservation}$	= Forest area in conservation zone
$FA_{management}$	= Forest area in management zone

3.2.4.4.4 Carbon stock changes and their credits (1973-2030)

$$CS_b(t) = FA_b(t_0) \times CS_{WA} \tag{12}$$

$$CS_p(t) = FA_p(t_0) \times CS_{WA} \tag{13}$$

$$CC = \left[\Delta CS_b(t) - \Delta CS_p(t)\right] \times \frac{44}{12} \tag{14}$$

Where;

CS_b = Baseline of carbon stock

CS_p = Projectline of carbon stock

CC = Carbon credit

ΔCS_b = The difference of carbon stock without conservation and management

ΔCS_p = The difference of carbon stock with conservation and management

3.2.4.5 Economic potential of carbon stock

To assess the potential economic from carbon emission reduction this study is based on the price of carbon in 2015 under voluntary carbon market of REDD+ scheme that it costs \$3.3/ tone of CO_2 emission reduction. In addition, \$10 and \$20 /tone of CO_2 emission reduction were compared for the possible future prices and the cost for conserving and managing mangrove forest were also calculated. The formula in assessment of potential revenues from carbon stock is following.

Formula for carbon revenues;

$$NCR = CC * (CP - RC) \quad (15)$$

Where;

NCR = Net carbon revenue

CC = Carbon credit

CP = Carbon price

RC = Reduction cost (*RC=US\$2.51/tCO2)

*RC refers to conservation and management costs for mangrove were estimated at \$2.51 by Ammar et. al. (2015)[3].

4. RESULTS

4.1 The mangrove areas in 1973 to 2016

The overall accuracy assessment of the mangrove images in 1973, 1997, 2001, 2011 and 2016 are 87%, 84%, 88%, 81% and 82%, and their kappa analysis are 82%, 79%, 84%, 76% and 75%.

The areas of mangrove are divided to two zones in different years. According to the limitation of satellite Landsat 1, their bands are limited and resolutions are rougher than Landsat 5-8. Then the mangrove area image in 1973 which was recorded by Landsat 1 was classified to only mix species of mangrove. Therefore, in 1973, the mangrove areas were 5,479.14 ha.

This study found that most mangroves in Samuth Songkhram province are secondary mangroves or mangrove plantation but they could be classified to two main categories; the first zone is for mangrove conservation purpose and the second mangrove plantation is for charcoal production.

Table 4.1 Change in mangrove area

Year	Species	Area(ha)	Total(ha)
1973	Mixed mangroves	5,479.14	5,479.14
1997	*A. alba, X. granatum, S. caselaris* *Rhizophora apiculata*	540.73 3,264.99	3,805.71
2001	*A. alba, X. granatum, S. caselaris* *Rhizophora apiculata*	654.91 2,723.43	3,378.34

2011	*A. alba, X. granatum, S. caselaris* *Rhizophora apiculata*	655.36 3,056.08	3,711.45
2016	*A. alba, X. granatum, S. caselaris* *Rhizophora apiculata* *Sonnerata caselaris*	642.74 3,815.89 16.77	4,475.41

4.2 Assess the carbon stock relative to trees in mangrove forest

In order to reduce the variance of their carbon content and their specie richness, two zones are identified.

As shown in table 4.2, this study found that in conservation zone, *A. alba* is the most found in this zone (64.4%), followed by *S. caselaris*, *R. apiculata*, *X. granatum* (20.3%, 13.6% and 1.7%), and their average carbon stock of above ground and below ground is 236.82 MgC/ha. In management zone, Most specie is *R. apiculata* that their average carbon stock is 102.8 MgC/ha for above and below ground carbon stock.

Table 4.2 The above and below ground carbon stock of individual mangrove species

Zone	Species	Kg/m	Mg/ha	MgC/ha
Conservation	*Avicennia alba*	2,444.76	244.48	114.90
	Rhizophora apiculata	285.23	28.52	13.41
	Xylocarpus grnatum	3.08	0.31	0.14
	Sonneratia caselaris	2,305.56	230.56	108.36
Sum		**5,038.63**	**503.86**	**236.82**
Management	*Rhizophora apiculata*	**2,187.18**	**218.72**	**102.80**

For conservation zone, the average aboveground and below ground carbon stock is 138.1 $\pm$ 67.1 MgC/ha and 102.8 $\pm$7.9 MgC/ha in management zone. The weighted average of carbon stock in five pools of two zone is 505.0 MgC/ha. Where other previous studies found that the amount of above ground and below ground carbon stock in mangrove plantation for charcoal in Yeesan, Samuth Songkhram Province, Thailand is 141.56 MgC/ha (Kridiborworn et. al., 2012) [32].

4.3 The carbon balance in mangrove forest

Mangrove biomass was calculated using previous allometric equations relative with individual mangrove species (all sample plots). Firstly, above ground biomass and below ground biomass were calculated from diameters that were measured from the plots. Then they were converted to carbon stock.

The confidence interval of carbon stock in the conservation zone is 293.79 $\pm$*142.72* or 48.58%. The average above ground and below ground biomass of the conservation zone is 293.79 $\pm$142.72 Mg/ha. Then the upper above ground and below ground biomass is 436.52 Mg/ha and the below above ground and below ground biomass is 151.07 Mg/ha (table 4.3).

Table 4.3 Biomass calculation from sampling plots in conservation zone

Plot no.	DBH (cm)	ABG (Kg/ha)	BGB (Kg/ha)	AB+BG biomass (Kg/ha)	AB+BG biomass (Kg/ha)	AB+BG biomass (Mg/ha)
1	16.21	4,018.87	1,364.03	5,382.90	538,290.79	538.292
2	16.06	4,139.75	1,567.83	5,707.58	570,758.85	570.75

3	21.02	3,312.56	1,242.94	4,555.50	455,550.06	455.55
4	12.53	1,966.96	822.74	2,789.71	278,971.28	278.97
5	14.32	608.94	253.56	862.51	86,251.16	86.25
6	6.35	156.00	24.53	180.53	18053.67	18.05
7	10.34	788.81	298.27	1,087.08	108,708.88	108.70
SUM	**96.86**	**14,991.92**	**5,573.92**	**20,565.84**	**2,056,584.72**	**2,056.58**
AVERAGE	**13.83**	**2,141.70**	**796.27**	**2,937.97**	**293,797.81**	**293.79±*142.72***

The confidence interval, of carbon stock in management zone is 218.72 ±*16.92* or 17.74%. The average above ground and below ground biomass of this zone is 218.72 ±16.92 Mg/ha. Then the upper above ground and below ground biomass is 235.64 Mg/ha and the below above ground and below ground biomass is 201.80 Mg/ha (table 4.4).

Table 4.4 Biomass calculation from sampling plots in management zone

Plot no.	DBH (cm)	AGB (Kg/ha)	BGB (Kg/ha)	AB+BG Biomass (Kg/ha)	AB+BG Biomass (Kg/ha)	AB+BG Biomass (Mg/ha)
8	5.18	1,774.34	321.65	2,095.99	209,599.25	209.60
9	3.24	2,026.62	365.85	2,392.47	239,246.72	239.25
10	3.02	1,758.95	314.11	2,073.07	207,306.72	207.31
SUM	**11.45**	**5,559.91**	**1,001.62**	**6,561.53**	**656,152.70**	**656.15**
AVERAGE	**3.82**	**1,853.30**	**333.87**	**2,187.18**	**218,717.57**	**218.72±*16.92***

The following table 4.5 showed the carbon stocks in different years based in respective zones. The carbon stocks in conservation zone have slowly increased since 1997. For the management zone, carbon stocks had lost about 272,677 MgC from 1997 to 2001. However, the carbon stocks in have increased again in 2011 and continuously to 2016.

Table 4.5 All carbon stocks divided by two zones

Year	**Conservation zone (MgC)**	**Management zone (MgC)**	**Total (MgC)**
1973	2,952,076.85		2,952,076.85
1997	291,338.78	1,643,938.22	1,935,277.00
2001	352,863.16	1,371,260.56	1,724,123.73
2011	353,105.84	1,538,753.02	1,891,858.85
2016	354,525.72	1,921,32 2.73	2,275,848.45

4.4 The economic potential of carbon stock in mangrove for the future

In estimate economic potential for mangrove forest conservation and management, baseline and projectline were estimated (figure 4.1).

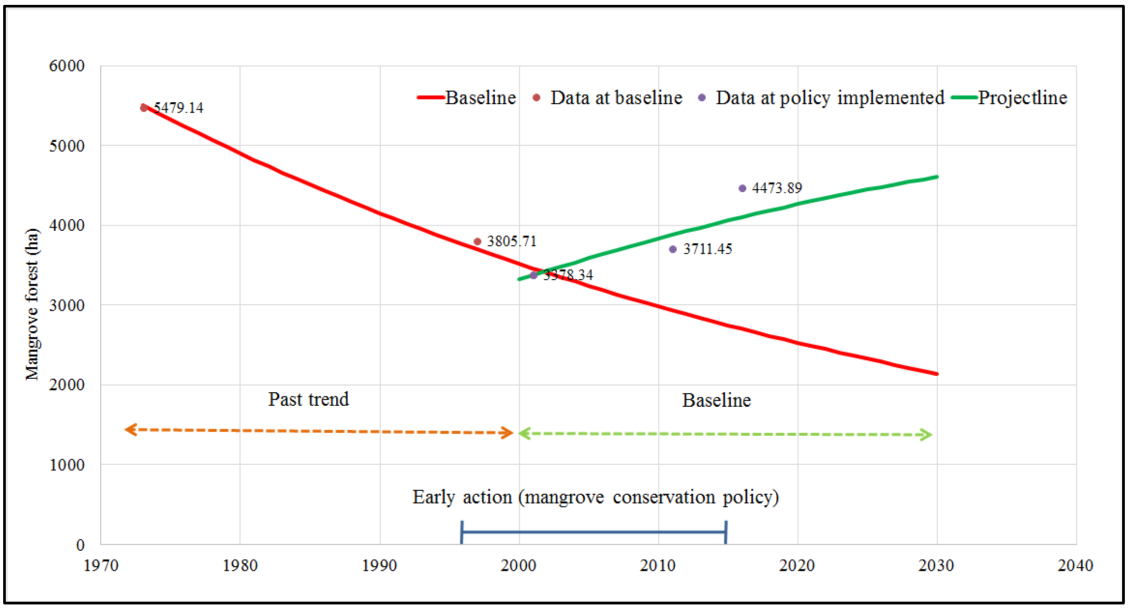

Figure 4.1 Baseline and projectline of mangrove forest changes

As showing in figure 4.1, without early action policies, deforestation rate is 45.49 ha/year^{-1} under baseline from 1973 to 2001 but forest areas increase about 42.42 ha/year^{-1} under projectline from 2001 to 2030. The mangrove areas, cabon stock, and carbon credit change with and without conservation from 2001 to 2030 are shown in the table 4.9. The mangrove forests had decreased to 3,378 ha in 2001 and have divertly increased since mangrove forest conservation policies have implemented in 1997 and 2000. From the projectline trend in 2001 to 2030, the situation of mangrove forests have been increasing because some policies have implemented in this period such as mangrove conservation policy of the eight plan of the Office the National Economic and Social Development in 1997 and the mangrove conservation policy of cabinet resolution in 2000. This increasing period of mangrove forest has been resulted from early action (some policies implemented)(Table 4.7). If there has not implemented any policy, the mangrove areas in Samuth Songkhram would have around 2,001 ha in 2030 (based on past trend baseline).

Table 4.6 These mangrove forests increasing significantly are the result of early action policies.

Year	Species	Area(ha)	Total(ha)
1973	Mixed mangroves	5,479.14	5,479.14
1997	*A. alba, X. granatum, S. caselaris* *Rhizophora apiculata*	540.73 3,264.99	3,805.71
2001	*A. alba, X. granatum, S. caselaris* *Rhizophora apiculata*	654.91 2,723.43	3,378.34
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2016	*A. alba, X. granatum, S. caselaris* *Rhizophora apiculata* *Sonnerata caselaris*	642.74 3,815.89 16.77	4,475.41

Furthermore, from this mangrove area projectline estimates that in 2030 with the current policies and management (Table 4.7), Mangrove forest in Samuth Songkhram Province would be 4,608 ha. This etmated that mangrove forests could be reasonable to ask for incentives under REDD+ for carbon emission reduction.
These early policy introduced in Thailand could be considered as early action under the REDD+ scheme, and therefore the carbon emission reduction or removals resulting from increasing forest cover could be eligible for funding.

Table 4.7 These mangrove forests increasing significantly are the result of early action policies

Year	**Policies**	**Eligibility**
1973	Business as usual	Baseline
1991	Mangrove conservation and restoration led by local leader in Khlong Khon district	Baseline
1997	Mangrove forest conservation plans of the Thai National Economic and Social Development	Early action
2000	Mangrove conservation policy of cabinet resolution	Early action

However, emission reduction vary depends on the chosen baseline scenario. For example, if baseline based on past trend is compared, the emission reduction is 2.1 million ton between 2016 and 2030. If the baseline based on linear projection is compared, the emission reduction is only 1 million ton.
Then the carbon revenues were estimated using the priced \$3.3 /tCO2 (price in 2015) (Carbon Marketplace, 2016), under past linear baseline about \$4.7 million could be get in 2001 – 2016 from REDD+ due to successful conservation and restoration mangrove forest (early action policies). Based on this price, between 2017 and 2020, \$0.9 million can be the compensation for conservation mangrove forest, and \$2.1 million is the compensation of the period 2021-2030. If the price is based on past trend baseline, between 2021 and 2030, \$4.4 million could be get from selling carbon credits. The compared prices of carbon credits and their carbon credits in different periods are shown in the table 4.8.

Table 4.8 Comparing with different price of carbon credit and the baseline

Carbon credit	**Based on linear baseline ($ million)**			**Based on past trend baseline ($ million)**		
	3.3	**$10**	**$20**	**$3.3**	**$10**	**$20**
2001-2016	4.7	14.3	28.7	9.7	29.5	59
2017-2010	0.9	3	6	2	6.2	12.4
2021-2030	2.1	6.3	12.7	4.4	13.5	27

Furthermore, if the cost of conservation and management mangroves is \$2.51/ton (Conservation and management costs for mangrove were estimated at \$2.51 by Ammar et. al., 2015) [3], their revenues based on linear baseline between 2021 and 2030 would be \$1 million from REDD+ supporting. If it is based on past trend baseline, the revenues would be \$0.5 million from 2021 to 2030

During the Paris agreement period, average reductions and removals are 60 MgCO2 /ha/year and therefore net revenues is $47-1042/ha depending on carbon prices.

5. CONCLUSION AND DISCUSSION

Using RS and GIS techniques, mangrove area changes were estimated between 1973 and 2016. This study found that the mangrove forests in Samuth Songkhram province had decreased from 5,479 ha to 3,378 ha between 1973 and 2001, but according to the main mangrove conservation and restoration policies from local leader and government found that the mangrove had increased to 4,473 ha in 2016. This study divided the mangrove areas in this to two zones due to their management and species which the first is for mangrove conservation and the second is for mangrove management. This dividing also reduces the variance of biomass and carbon stock calculation in mangrove trees. In comparing the mangrove areas changes found that mangrove areas in conservation zone have increased toward the sea, while the mangrove in management zone mostly found in the same places because their cycling cutting is 12 years. These continuously increasing of mangrove forest in conservation zone is the of mangrove conservation policy that has led by local people. As the mangrove is their sources of income, they help to look after mangrove forests including the mangrove conservation law from government. For example, when local people see the cutting or disturbing of mangrove forests they will inform officers to catch the invaders. As a result of effective laws, no one in the local community cut or invades the mangrove forests. Furthermore, in this conservation zone, there are ecotourism and mangrove plantation programs so mangroves in this area have increased continuously.

In order to maintain the successful conservation and expand the areas of mangrove forests, the following activities should continuously implemented

1. Local participation in the conservation of the mangrove forests
2. Good local leadership that have attracted support from the local community, Royal Department of Forestry (at initial), and government
3. Creation of local conservation-based employment to generate more incomes
4. Community partolling
5. Voluntary restoration of mangrove species
6. Environmental education to raise the awareness of the importances of mangrove forest ecosystems for local livelihood

According to the two mangrove forest divided and using forest inventory, carbon stock by species were estimated. In this step, only above ground and below ground carbon stock were calculated. This study found that the most specie that is found in mangrove conservation zone is *Avicennia alba* which has carbon stock content 114 MgC/ha, following by *Sonneratia caselaris* (108.36 MgC/ha), *Rhizophora appiculata* (13.41 MgC/ha) and *Xylcarus granatum* (0.14 MgC/ha). The average above ground and below carbon in this zone is 138 MgC/ha. In the management zone, mostly found *Rhizophora appiculata* which this species are planted for charcoal production. It contents carbon stock about 102.80 MgC/ha. This information is important for biodiversity safeguarding under the REDD+ scheme. As the mangrove species are not only content large amount of carbon stock, but also provide the large ecosystem services and biodiversity which directly impact on local livelihood and their resources. For example, local fisheries in this areas have an income from collecting cockle or fishing fish around the mangrove forest as nearby mangrove forest provide more fish than far away areas (Mumby et al., 2004) [41]. Moreover, in comparison of mangrove carbon stocks in this study with other studies such as in Yeesan district, Samuth Songkhram province, Thailand and in

Vietnam found that the carbon stocks on this area is less than the other studies due to less density and some dead mangrove trees in conservation zone. In order to increase carbon stock in conservation zone, the density of mangrove trees should be considered.

In term of carbon stock changes, Samuth Songkhram province had lost about 37,071 tonC/year between 1973 and 2000 but gained about 41,423 tonC/year between 2001 and 2016. Based on linear baseline between 2017 and 2030, this province will get about 1 million tons CO2 emission reduction. If the carbon emission is based on projectline with the current policy implementation, between 2017 and 2030, this province can get more 0.9 million ton CO2 removal. Therefore, from 2017 to 2030 with the current policy implementation and practices, this mangrove forest can reduce CO2 emission about 1.9 million ton from the atmosphere.

For economic potential, based on the current policies, their practices and the price of carbon credit as $3.3/ton (Voluntary carbon market price in 2015), $2 million will be got between 2017 and 2020. About $4.4 million will be got between 2021 and 2030. If the management cost is $2.51 /tCO2, they could get about $0.8 million between 2017 and 2030 based on linear trend and about $1.8 million based on past trend. Moreover, this province also can ask for the incentive support for successful mangrove conservation and restoration between 2001 and 2016 from REDD+. These successful in increasing mangrove forests and their carbon stock from early action can be asked for compensation in conservation and management under REDD+. However, the amount of carbon credits is depends on which baselines are chose to estimate the future carbon emission.

This study found that mangrove forest both in conservation and management are likely to increase carbon stock in the forests. Therefore, mangrove conservation and management activities can provide huge benefits in terms of carbon-based financial supports

6. RECOMMENDATION

6.1 Policy recommendations

To obtain financial support for conservation and management, project design document (conservation plan) is needed. In order to design the effective policies to conserve mangrove forest, the areas which mangroves are able to grow should be identified for planning suitable areas for mangrove conservation. Moreover, the understanding of mangroves density is also important in designing mangrove restoration and conservation measures to enhance carbon stock and estimate the future carbon stocks and for preparing report to get financial support under REDD+.

Current successful conservation policies need to be maintained in order to increase area of mangrove as well as carbon stocks. As a result of effective policies in conserving mangrove, the early action policies should be continuously implemented.

The comparison of carbon stock in mangrove forest in conservation zone is less than carbon stock in mangrove in other areas. Then the restoration such as enrichment planting can result in even more carbon stock increase because current stocks are still low

This assessment study may be used to develop a mechanism for obtaining economic values under the REDD+ scheme.

6.2 Recommendations for future research

Future research on local perception on their current conservation and management would provide insights for effective conservation and management planning.

Direct measurement of other carbon pools would give better results for overall carbon assessment.

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