USING SPOT 6 TO ESTIMATE BIOMASS AND CARBON STOCKS OF *PINUS MERKUSII* PLANTATION IN DINH HAI COMMUNE, THANH HOA PROVINCE

Nguyen Huu Nghia[1], Nguyen Hai Hoa[2], Le Thanh An[3],
Tran Thi Ngoc Lan[4], Amena Easmin[5], Nguyen Thi Minh Tu[6]

[1,2,3,4,6]*Vietnam National University of Forestry*
[5]*Stamford University of Bangladesh, Bangladesh*

SUMMARY

This study describes how the Inverse Distance Weighted Interpolation (IDW) in combination with the field-based survey and 2015 SPOT 6 data are applied to estimate biomass and carbon stocks of *Pinus merkusii* plantation in Dinh Hai commnue, Tinh Gia district, Thanh Hoa province. The construction of current map of *Pinus merkusii* shows that there is 87.0% of accuracy and accuracy asessment of interpolated maps of biomass and carbon stocks are over 83.0 %, showing this IWD interpolation is reliable and can be applicable in Dinh Hai commune. As a result, the total carbon stocks is estimated at about 1,959,622.4 tons, equivalent to 221,497,194,300 VND in Dinh Hai. Although having high values and potential for carbon stocks trading, the Payments for Forest Environmental Services (PFES) have not been implemented in Tinh Gia district yet. This study also has presented solutions for PFES implementation in Tinh Gia, thus enhancing local livelihoods.
Keywords: Biomass, carbon stocks, carbon trading, PFES, SPOT 6, Tinh Gia Protection Forest.

I. INTRODUCTION

Global warming has become increasingly serious and challenging to all nations in the Earth. Such high concentration of greenhouse gases (mostly CO_2) in the atmosphere is demonstrated as the main contributor to climate change (UNFCCC, 2007). With the aim to mitigate climate change, United Nation Framework Convention on Climate Change (UNFCCC) in 1992 and Kyoto Protocol in 1997 were ratified. This legal basis is significant to prove international community's commitment in reducing greenhouse effects. Carbon emission trading is considered as a promising option based on evaluating the values of forest carbon sink and stocks. Transaction of Clean Development Mechanism (CDM), especially initiative of Reducing Emissions from Deforestation and Forest Degradation (REDD and REDD+) on voluntary market are now playing a key important role on carbon trading in forestry.

There are various researches on biomass and carbon capacity of worldwide forests, both of them are necessary in the process of emissions and climate change reduction. There are 3 main accessing approaches to research on biomass and carbon capacity of forests, namely, experimental investigation, establishment of mathematical models for biomass and carbon capacity estimation, which are widespreadly utilised. In Vietnam, accumulative carbon investigation method is a very common application to calculate and predict dry biomass amount of forest.

Dinh Hai is one of 16 communes where is located in Tinh Gia district, has fairly large area of *Pinus merkusii* plantation. Up to date, there are few studies on constructing biomass and mathematical models to estimate biomass of forests in Tinh Gia district, Thanh Hoa province (Bao Huy, 2014). Therefore, the question of how much carbon stocks *Pinus merkusii* can store, remains unanswered. This paper intends to provide a scientific basic for estimating biomass and carbon stocks of *Pinus merkusii* plantation based on remotely sensed data. Findings will be used for the Payments

for Forest Environmental Services (PFES), which propose feasible policies on forest management and protection, thus improving living standard of local people in the study area.

II. RESEARCH METHODOLOGY

2.1. Study area

Dinh Hai commune is geographically located in Tinh Gia district, Thanh Hoa province, with latitude at 19.49483^0 and longitude at 105.74097^0 as shown in Fig. 01.

The total area of Dinh Hai is estimated at about 2671.4 ha in which 378.2 ha is covered by *Pinus merkusii*. Besides, Dinh Hai is well-known as being a home for a variety of animals, it is also known as one of the most important income sources of local people, by providing pine resin, food and regulating water resources. Therefore, the study area is significantly important for local livelihoods and the environment.
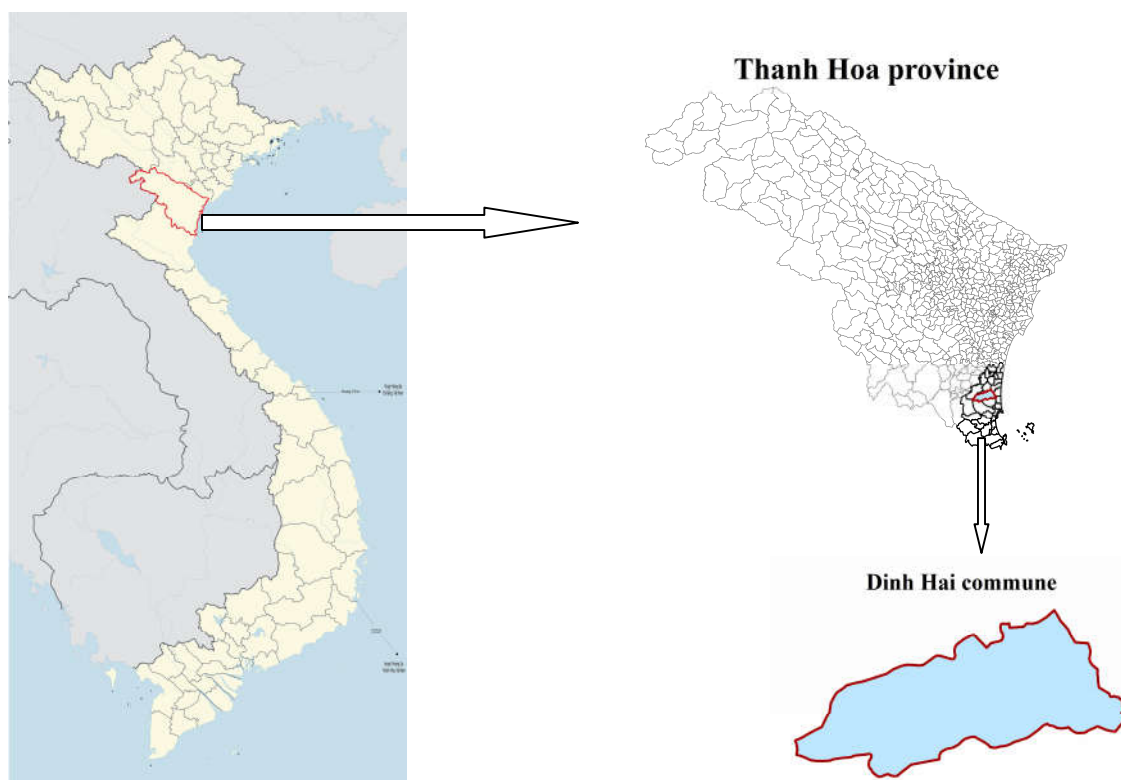

Figure 01. Study area in Tinh Gia district, Thanh Hoa province

2.2. Methods

At first, a face to face interview was carried out with managers and local people, then secondary data were collected from previous articles, reports and official documents to investigate the current status and management of *Pinus merkusii* up to 2015. Primary data in this study was mainly obtained from semi-structured interviews and open questions, which were used to identify the challenges and

opportunities for PFES implementation. Thirty households were randomly selected to collect information from diverse groups of local authorities, forest management agencies and local people in Dinh Hai.

In order to satisfy the study objectives, 76 plots with dimension of 20 m x 25 m (equivalent to 500 m^2) and the assistance of GPS Garmin 650 were set up and randomly selected by ArcGIS 10.2 in Dinh Hai. Within

each plot, DBH of each *Pinus merkusii* tree was measured at the breast height. In this study, 150 points collected by GPS Garmin 650 were used for the map classification and accuracy assessments. In particular, seventy percent of averaged DBH values from 76 plots is used for spatial interpolation, while 30% of total GPS points and averaged DBH values from plots are used for accuracy assessments

of classified map and interpolation method.

In addition, 2015 SPOT6 data was used to construct current status map of *Pinus merkusii* plantation by ArcGIS 10.2 with an Unsupervised Classification method. Classified map of *Pinus merkusii* was then used to estimate its biomass and carbon stocks based on the field-survey and Inverse Distance Weighted interpolation approach (IDW).

Table 01. SPOT 6 data used this study

ID	Image ID	Date	Spatial resolution (m)
1	SPOT 6	18/05/2015	1.5 x 1.5
2	DEM	2011	30

IDW method was applied to estimate the biomass and the carbon stocks in this study. To estimate biomass, the following formula was used, which indicates the strong correlation between total tree biomass and $D_{1.3}$ (Vu Tan Phuong, 2011):

Tree biomass = $0.023 * D\,1.3^{2.9077}$ (kg/tree)

This equation indicates there is a strong correlation between tree biomass and $D_{1.3}$ with high value of R^2 ($R^2 = 0.9913$). Therefore, this formula was used to determine the biomass of *Pinus merkusii* plantation.

Biomass (ton/ha) is defined by:

Biomass (ton ha^{-1}) = (Tree biomass * Tree density)/10,000

Where: Tree density is equal to the total number of trees in 500 m^2.

Carbon stocks are then calculated according to the IPCC coefficients (IPCC, 2007):

$$C = 0.5 * Biomass\ (ton\ ha^{-1})$$

III. RESULTS AND DISCUSSIONS

3.1. Current status and the management scheme of *Pinus merkusii*

Management scheme of *Pinus merkusii* in Tinh Gia district:

Tinh Gia Protection Forest Management Board (PFMB) includes director and two vice

directors who are responsible for directly managing all activities according to the tasks and all policies assigned by provincial and state governments. Under Tinh Gia PFMB, there are six local Forest Protection and Management Stations (FPMS), which are placed at six locations, namely Hai Linh. Hai Nhan, Nguyen Binh, Truc Lam, Phu Lam and Truong Lam. Surprisingly, Dinh Hai commune has not had FPMS yet, but under the management of Hai Linh. Not only Dinh Hai but also other communes in Tinh Gia have not applied PFES yet. Therefore, the question of how the PFES is applied, has remained unanswered.

Status of *Pinus merkusii* plantation:

As a result of Unsupervised Classification approach of 2015 SPOT 6, the study has constructed the status map of land covers in which the spatial distribution and extents of *Pinus merkusii* are classified and calculated at 378.2 ha (Fig. 02). This finding confirms that Dinh Hai is the second largest area within 16 communes in Tinh Gia district, with 378.2 ha of *Pinus merkusii* that accounts for 17% of total Tinh Gia Protection Forest areas.
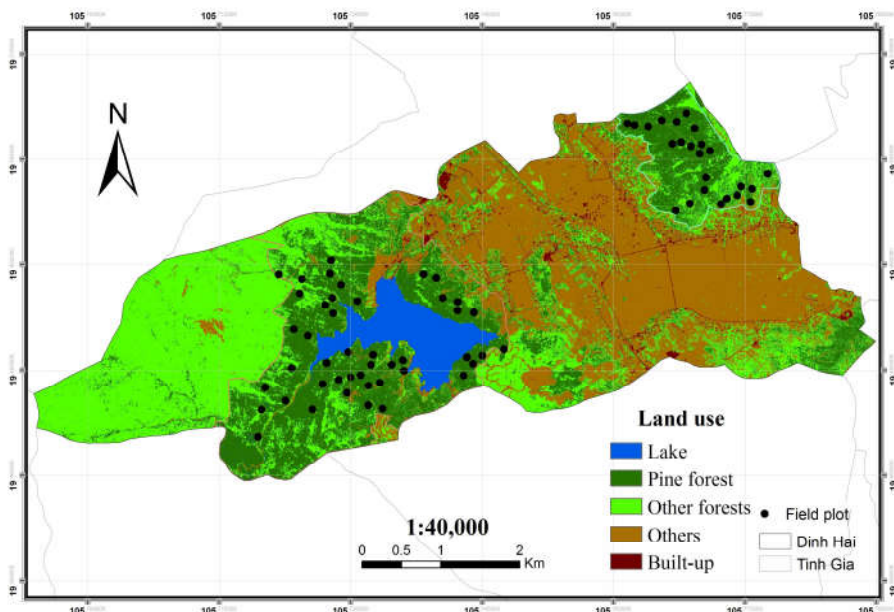
Figure 02. Status maps in Dinh Hai (87.0 % in accuracy, SPOT 6, 2015)

As a result, there were 76 plots selected and established randomly, then investigated in Dinh Hai commune (Fig. 03). To illustrate the topographical distribution of *Pinus merkusii,* DEM was used to classify the various elevation values as shown in Figure 03. Therefore, it can be easily seen *Pinus merkusii* has geographically distributed at 3 main ranges of altitude values, including 30 ÷ 63 m, 63 ÷ 140 m and 140 ÷ 231 m. In addition, pine density decreases gradually at the height above sea level from 231 ÷ 329 m (Fig. 03) and becomes unseen at the higher elevation. They mainly distribute in the East, the West, the South and the Southeast.
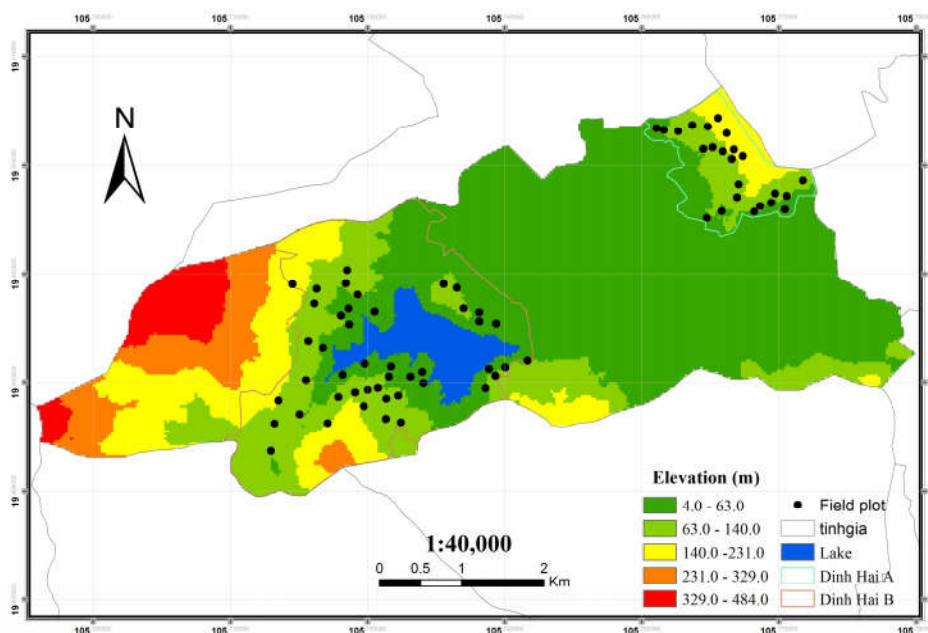

Figure 03. Spatial distribution of *Pinus merkusii* plots in different elevation values

The averaged DBH of each plot measured in the study site is summarised in Table 02.

Table 02. Averaged DBH of Pinus merkusii in Dinh Hai

Plot ID	DBH (cm)	Plot ID	DBH (cm)	Plot ID	DBH (cm)
1	18.73	27	27.82	53	26.31
2	18.81	28	29.0	54	25.74
3	15.73	29	26.95	55	24.54
4	22.06	30	22.48	56	25.30
5	21.67	31	20.67	57	25.53
6	21.58	32	21.53	58	21.15
7	19.26	33	21.61	59	22.61
8	22.38	34	23.02	60	22.00
9	17.01	35	25.03	61	22.24
10	20.19	36	24.18	62	21.48
11	21.33	37	22.4	63	21.08
12	23.64	38	21.68	64	22.17
13	24.44	39	23.19	65	24.76
14	24.05	40	21.42	66	24.83
15	24.76	41	21.09	67	21.27
16	25.70	42	23.87	68	19.95
17	25.65	43	23.62	69	20.24
18	23.43	44	24.96	70	22.62
19	23.46	45	25.88	71	22.95
20	24.59	46	26.88	72	22.93
21	24.68	47	27.89	73	22.62
22	24.66	48	26.60	74	21.97
23	29.00	49	25.08	75	22.49
24	23.07	50	26.89	76	23.17
25	23.07	51	26.57		
26	26.55	52	27.35		

As shown in Table 02, the diameter of *Pinus merkusii* is uneven. Findings have shown that there are relatively large differences in values of tree diameters due to additional plantation. Based on field survey in relation to $D_{1.3}$, the study has summarised the Descriptive Statistics of $D_{1.3}$ in the field. As a result, $D_{1.3}$ has ranged from $15.73 \div 29$ cm and averaged at 23.38 cm in the study area. The standard deviation is 2.60 cm, reflecting the variance of $D_{1.3}$, while standard errors is 0.77 cm, reflecting fluctuations in the average of $D_{1.3}$.

3.2. Estimation of biomass and carbon stocks in *Pinus merkusii*

3.2.1. Estimation of biomass-based field survey

Biomass estimation-based field survey:

As values of DBH measured are taken as an average for the whole study area, the biomass and carbon stocks are then calculated as shown in Table 03.

Table 03. Summary of averaged DBH, biomass and carbon stocks in study sites

Study site	DBH (cm)	Biomass (ton)	Carbon stocks (ton)
Dinh Hai	23.38 ± 2.6	136.4 ± 47.2	68.2 ± 23.6

3.2.2. Estimation of biomass and carbon stocks-based IDW interpolation

Biomass estimation-based Inverse Distance Weighted Interpolation in Dinh Hai

To construct the spatial maps of biomass and carbon stocks, 70 percent of plot-based survey was used to interpolate for the whole study area (Fig. 04), while 30% of total data was used to assess the accuracy of interpolated maps. In this study, Dinh Hai has two separate sites, so interpolation and accuracy assessment were conducted seperately as Dinh Hai A and Dinh Hai B as shown in Figure 04 and Figure 05.
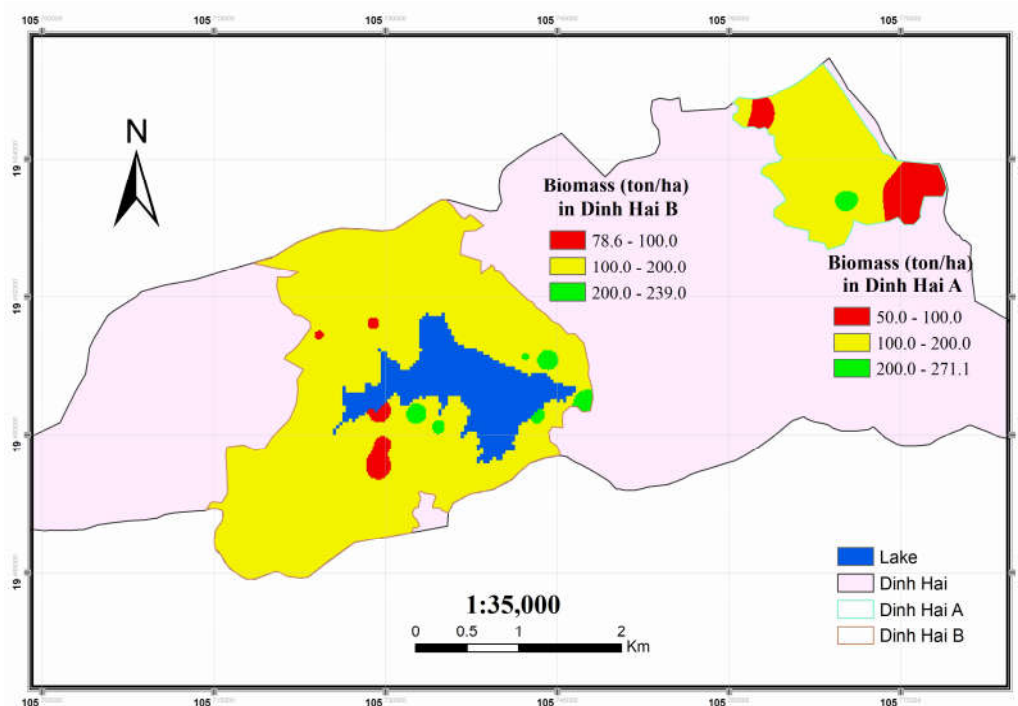

Figure 04. Biomass values of *Pinus merkusii* in Dinh Hai commune

As a result, the interpolated biomass shown that biomass of *Pinus merkusii* mostly range from 100 ÷ 200 ton ha^{-1} both in Dinh Hai A and Dinh Hai B, while the areas with biomass less than 100.0 ton ha^{-1} and greater than 200.0 ton ha^{-1} are very small. As accuracy assessments indicated that there are 87.0% and 83.0% of map accuracies for Dinh Hai A and Dinh Hai B defined, respectively. These findings confirm that the interpolation method is reliable and applicable for the biomass estimation in Dinh Hai commune.

Carbon stocks estimation-based spatial interpolation of Pinus merkusii:
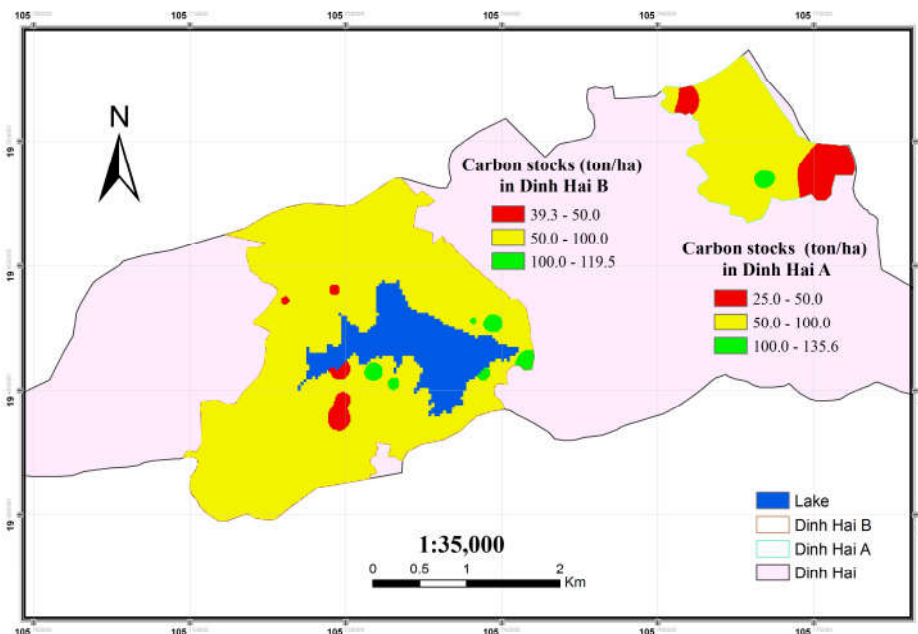
Figure 05. Carbon stocks of *Pinus merkusii* in Dinh Hai commune (A) and (B)

Figure 05 shown that carbon stocks in Dinh Hai A and Dinh Hai B are calculated at from $50.0 \div 100.0$ ton ha^{-1}, respectively. Similar to the biomass, interpolation of carbon stocks shown that the carbon stocks with range of from $50 \div 100.0$ ton ha^{-1} is dominant in both Dinh Hai A and Dinh Hai B.

3.3. Challenges and opportunities for PFES implementation in Tinh Gia district

Conducting the interviews with 30 of total 38 households in Dinh Hai has found that there are a great potential for PFES implementation in Dinh Hai commune in particular and Tinh Gia in general. However, study area still has numerous challenges in pursuing PFES implementation as summarized in Table 04.

Table 04. SWOT analysis for PFES application in Tinh Gia district

<u>Strengths</u>	<u>Weaknesses</u>
• Dinh Hai's plantation covered almost 17.5%, equivalent to 378.18 ha in the Tinh Gia Protection Forest. • Both district and local authorities as well as local people are highly aware of values of forest protection and understand importance of forest policies in relation to forest management and protection. • There is a strong cooperation and connection between authorities and local people; forest owners are allowed to exploit pine resin and are responsible for managing their allocated forest area.	• The thick litter and shrub may lead to increasing frequencies of forest fire and outbreak of diseases. • There is a current lack of evaluation indicators, such as monitoring systems, policy guidelines, economic instrument related to biodiversity, watershed and carbon sequestration, may lead to weaken forest management in study site. • Payments for managing allocated one ha of forest, about 70,000 VND is quite lower than other provinces[1], may lead to discouragement of local participation.

Opportunities	**Threats**
• Based on the data collected, total estimation of CO_2 for the whole study area is about 1,959,622.37 tons, which are a great opportunity to participate on international carbon market, such as REDD+, PFES, so Dinh Hai may get additional fundings for carrying out forest management and protection activities. • Effective implementation of PFES may improve the quantity and quality of forests, thus contributing to better manage forest resources in Tinh Gia district. • Financial assistance from PFES is more likely to increase local livelihoods in Dinh Hai.	• Difficult to quantify the value of forest environmental services. • Unable to manage all of PFES users. • Lack of commitment and compliance between forest owner and PFES user as the boundary is still unclearly and legally defined. • The PFES implementation procedures are time-consuming that may prevent the authorities' determination from pursuing PFES.

[1]*PFES report in Vietnam from 2011-2014.*

3.4. Recommendations for PFES implementation in Tinh Gia and Thanh Hoa province

Based on the findings, it can be said that there is an enormous importance of *Pinus merkusii* for implementing PFES policy. Therefore, solutions for how PFES implementation is significant in Dinh Hai, Tinh Gia district in particular. Firstly, local authorities and local households should be encouraged to participate in all REDD+ and PFES activities to receive additional financial support for better forest protection and development. Besides, another important role of pine forest as a function of water regulation should be included when estimating *Pinus merkusii* values in Thanh Hoa in general and Tinh Gia in particular.

Secondly, the Payments mechanism for forest environmental services as good samples

from Lam Dong and Lai Chau shoud be learnt for Dinh Hai commune. This is because maximum benefits from PFES will lead to significantly improve the livelihoods of local people, thus contributing to better forest protection and management. Consequently, local people are more likely to be active in guarding their assigned forest and more responsible for their allocated forest areas. Thirdly, the management and administration schemes should be set up in a way of encouraging local people to protect and monitor forest resources by clear guidance of social policies and techniques to develop forest resources.

Based on the field measurements, the study has estimated the amount of carbon stocks and calculated the commercial value of *Pinus merkusii* in Dinh Hai commune as shown in Table 05**.**

Table 05. Proposed estimation of carbon stocks and commercial values of *Pinus merkusii*

Items	Values
Pinus merkusii	378.2 ha
Total absorbed CO_2	1,959,622.37 (ton)
Price	$5/ton
Conversion (Up to 10/07/2017 at 12:30pm by Vietcombank)	1USD = 22,449 VND
Total estimated	219,957,812,920.65 (VND)

Source: Adapted from Vu Tan Phuong (2006).

PFES mechanism also should be applied in line with what the forest offers. Carbon stocks of *Pinus merkusii* should be paid as the selling price of carbon credits on the market, which is now from 5 ÷ 10 USD ton^{-1} in consultation with payments rate implemented in some provinces. For example, Lai Chau has paid an average price of 342,734 VND ha^{-1} year^{-1}, an average of Lam Dong province is 342,500 VND ha^{-1} year^{-1}. In Binh Dinh province, the averaged price paid was 303,259 VND ha^{-1} year^{-1} (PFES Report in Vietnam from 2011 to 2014).

IV. CONCLUSIONS

SPOT 6 offers a great opportunity for constructing forest covers, estimating biomass and carbon stocks through Inverse Distance Weighted Interpolation approach known as IDW. By using 2015 SPOT 6, study has successfully constructed the status map of *Pinus merkusii* plantation in Dinh Hai commune. As a result of accuracy assessment shown that there are relatively high accuracy of *Pinus merkusii* cover, about 87.0% in 368.2 ha in study area. Similarly, there are around 87.0% and 83.0 % of interpolated biomass map, indicating this method is reliable and should be applied to estimate biomass and carbon stocks in Dinh Hai.

The high values of biomass and carbon stocks offer a great potential on carbon trading values. The higher carbon stocks values and the larger commercial value that *Pinus merkusii* will provide forest owners more incomes, which significantly improve forest management and protection if PFES implemented in this area.

Acknowledgement

REFERENCES

1. Bao Huy (2014). Develop a method for measuring and monitoring forest carbon with community participation in Vietnam. *Journal of Forest and Environment*, 44:34-45 (Vietnamese languague).

2. Bao Huy (2016). Using SPOT 5 and GIS to estimate and monitor evergreen broad-leaf forest biomass and carbon stocks in Tay Nguyen. *Journal of Vietnam Science and Technology* 9(676):52-59 (Vietnamese languague).

3. Decision No 380/QĐ-TTg of Prime Minister dated 10 April 2008 on the Payments on Forest Environmental Services policy (Vietnamese languague).

4. Tran Quang Bao, Le Thai Sơn. (2013). Using highly spatial resolution data to determine the forest distribution and its storage of carbon stocks., *Journal of Agriculture and Rural Development*, 63-72 (Vietnamese languague).

5. Vu Tan Phuong (2010). Develop a model to estimate single biomass of *Pinus kesiya* forest in Su Phi district, Ha Giang province. *Journal of Forest Science* (Vietnamese languague).

6. Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., Lescure, J. P (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145(1), 87-99.

7. Goetz, S., Dubayah, R. (2011). Advances in remote sensing technology and implications for measuring and monitoring forest carbon stocks and change. *Carbon Management*, 2(3), 231-244.

8. Kiyono, Y., Furuya, N., Sum, T., Umemiya, C., Itoh, E., Araki, M., Matsumoto, M. (2010). Carbon stock estimation by forest measurement contributing to sustainable forest management in Cambodia. *Japan Agricultural Research Quarterly: JARQ, 44*(1), 81-92.

9. Myeong, S., Nowak, D. J., & Duggin, M. J. (2006). A temporal analysis of urban forest carbon storage using remote sensing. *Remote Sensing of Environment*, 101(2), 277-282.

10. Roy, P. S., & Ravan, S. A. (1996). Biomass estimation using satellite remote sensing data—an investigation on possible approaches for natural forest. *Journal of biosciences*, 21(4), 535-561.

11. Saatchi, S. S., Harris, N. L., Brown, S., Lefsky, M., Mitchard, E. T., Salas, W., Petrova, S (2011). Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the National Academy of Sciences*, *108*(24), 9899-9904.

12. Smith, J., & Scherr, S. J. (2002). *Forest carbon and local livelihoods: assessment of opportunities and policy recommendations* (No. CIFOR Occasional Paper no. 37, p. 45p).

SỬ DỤNG ẢNH SPOT 6 ƯỚC TÍNH SINH KHỐI VÀ TRỮ LƯỢNG CACBON RỪNG THÔNG TRỒNG THUẦN LOÀI TẠI XÃ ĐỊNH HẢI, HUYỆN TĨNH GIA, TỈNH THANH HÓA

Nguyễn Hữu Nghĩa[1], Nguyễn Hải Hòa[2], Lê Thành An[3], Trần Thị Ngọc Lan[4], Amena Easmin[5], Nguyễn Thị Minh Tú[6]

[1,2,3,4,6]*Trường Đại học Lâm nghiệp*
[5]*Đại học Stamford, Bangladesh*

TÓM TẮT

Nghiên cứu này cho thấy tiềm năng ứng dụng của ảnh vệ tinh độ phân giải cao SPOT 6 trong ước tính sinh khối và trữ lượng cácbon cho rừng trồng Thông nhựa (*Pinus merkusii*) tại huyện Tĩnh Gia, tỉnh Thanh Hóa. Từ thực trạng tại khu vực nghiên cứu đã chỉ ra rằng bản đồ sinh khối và trữ lượng cácbon được xây dựng với độ chính xác khá cao (trên 83%) để ước tính CO_2 và đề xuất phương án hợp lý cho việc áp dụng PFES tại địa phương. Kết quả nghiên cứu khẳng định phương pháp nội suy nghịch đảo khoảng cách có trọng số có độ tin cậy và có thể áp dụng cho Định Hải. Bằng điều tra thực địa tại 76 ô tiêu chuẩn trong khu vực nghiên cứu kết hợp cùng phương pháp nghịch đảo khoảng cách có trọng số (IDW) đã chỉ ra rằng trữ lượng cácbon tại khu vực nghiên cứu là rất lớn so với những điều tra tại các tỉnh khác, khoảng 1,959,622.37 tấn tương ứng với số tiền 219,957,812,920.65 VND, kết quả này cho thấy tiềm năng phát triển kinh tế cũng như nâng cao đời sống người dân địa phương của rừng khi Tĩnh Gia tham gia vào thị trường cácbon. Bên cạnh những tiềm năng tham gia thị trường cácbon, hiện tại PFES chưa được áp dụng tại huyện Tĩnh Gia. Do vậy, việc nghiên cứu nhằm cung cấp cơ sở tính toán, đánh giá cụ thể về những tiềm năng trên của cơ chế PFES cho các nhà hoạch định chính sách là rất cần thiết để có thể sớm áp dụng PFES tại huyện Tĩnh Gia nói riêng và tỉnh Thanh Hóa nói chung.

Từ khóa: PFES, rừng phòng hộ Tĩnh Gia, sinh khối, SPOT 6, thị trường Carbon, trữ lượng Carbon.