RICE YIELD ESTIMATION BY USING OBJECTIVE YIELD SURVEY AND REMOTE SENSING METHODS; CASE STUDY IN SINGBURI AND ANGTHONG PROVINCE

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Abstract. The research is using remote sensing and objective yield survey to perceive paddy field plantation area and yield production. Moreover this study also find correlation between reflectance derived from spectrometer in field survey and SMMS satellite image in CCD-4 bands. The result of study show reflectance value in 5 stages of rice including sowing/transplanting, tillering, panicle, flowering and harvesting when in term of satellite image. When knowing reflectance, it is useful for classify paddy field plantation area more quickly and accurately. Besides, this study create two rice forecasting models that one based on yield trend and other based on biomass and harvest index. The result model of rice in study area are fit with model that based on biomass and harvest index.

Keywords: Remote Sensing, Objective Yield Survey, Small Multi-Mission Satellite

1. Introduction

Office of Agricultural Economics (OAE) is one agency under Ministry of Agricultural and Cooperatives which are responsibility for agricultural statistic of Thailand. One of the agricultural survey methods is using Geo-Informatics to get information in agricultural plantation area. Nowadays this technology is so advance that can receive information in agricultural yield and production. Therefore this year OAE have pilot project to analysis paddy plantation area by using reflectance and estimate rice production by using Objective Yield Survey (OYS) and Remote Sensing (RS). The study area are Singburi and Angthong province which are the middle part province of Thailand. The satellite data use Small Multi-Mission Satellite (SMMS) in CCD format because it high frequency orbit and have several bands which can analysis both on agricultural plantation area and yield production.

The objective of this study is to find relationship between reflectance that derived from satellite data and spectrometer equipment including OYS data derive from field survey to make paddy field area database. Furthermore, studying which Vegetation Index (VI) suitable yield from OYS method to create rice forecasting model. The model determine 2 models base on trend yield and biomass.

2. RICE YIELD ESTIMATION BY USING OBJECTIVE YIELD SURVEY AND REMOTE SENSING METHODS; CASE STUDY IN SINGBURI AND ANGTHONG PROVINCE

2.1 Scope of work

In this study, we defined 10 sample areas to measure reflectance by using spectrometer , Remote Sensing (RS) and Objective Yield Survey (OYS) [1] in 5 stages during planting until harvesting normally rice duration 120 days but depend on rice species. The rice stage including sowing/transplanting, tilling, panicle initiation, flowering and harvesting [2]. After defined sample area, we determine sample plots for Remote Sensing and OYS technique. For Remote Sensing technique we set 5 sampling plots -at the corner 4 samples and the center 1 sample- to drawn rice stems approximately 2% from the total to find correlation and measure width and length of rice leaf to get leaf area index (LAI) and biomass. In part of Objective Yield Survey, we set 2 sample plots in diagonal line to monitor rice growth. Both technique sample plot size are 1 sq.m.

Initially, we measuring rice reflectance every stage by using spectrometer to make correlation with SMMS satellite image for 4 bands including Blue (B) Green (G) Red (R) and Near Infrared (NIR) bands. Then classify paddy field area by using reflectance of paddy field that derived from field survey and satellite data by cut another crop area except paddy field with NDVI profile duration 120 days. Subsequently, analyze Vegetation Index (VI) defined 2 vegetation index including NDVI (Normalized Difference Vegetation Index) and EVI (Enlarged Vegetation Index).

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[1] OYS is the technique that measure height, number of leafs, number of stem per bunch,length-width of leaf, awn length, number of rice grains and weight of rice.

[2] Duration rice stages as follow sowing/transplanting 0-25 days, tilling 26-60 days, panicle initiation 61-70 days, flowering 71-94 days and harvesting 95-120 days.

Normalized Difference Vegetation Index (NDVI) show crop cover by calculate ratio of difference of ground reflection between Near Infrared and Red band with sum total of 2 bands as equation:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Enhance Vegetation Index (EVI) is one of vegetation index that consider leaf area index (LAI) and crop canopy. It useful because it reduce environment effect such as atmosphere condition and soil characteristic.

$$EVI = G \times \frac{NIR - Red}{(NIR + C_1 \times Red - C_2 \times Blue + L)}$$

When parameter G = 2.5, C1 =6, C2 = 7.5 and L =1

This study create 2 forecasting models. The first is the model estimate with trend yield, Remote Sensing and use NDVI profile to find some stress that may cause rice production. The second is the model using biomass that rice can gather energy within stem which are derived from convert sun energy to rice mass. Then calculate Normalized Difference Vegetation Index (NDVI) and Simple Ratio Index (SR) of satellite image.

2.2 Results

2.2.1 Rice Reflectance for analysis paddy field area

Using spectrometer to measure rice reflectance in sample area, we found average of rice in each stage. The frequency of reflectance from spectrometer are stored every 2 nanometer wavelength (420-800 nanometer) so there are 191 bands total and then create spectrum library for classify paddy field plantation area by convert to multi-spectrum 4 bands of SMMS satellite image. The SMMS sensor have width approximately 80 nanometer (430-950 nanometer). The result are the data seem of sensor as equation

$$Reflectance = \sum_{i=1}^{n} Rj \times Sj / N$$

When Rj are reflectance from spectrometer

Sj are response of spectrum for sensor of SMMS satellite image

j have value 400-1,000 nanometer

i = 1-4 (band 1-4)

N = the amount of Rj that have value more than 0.5

Rice Stage	R	G	B	NIR
Reflectance from spectrometer				
Sowing/transplating	0.045875	0.082556	0.083891	0.186758
Tillering	0.022795	0.066726	0.033807	0.275926
Panicle	0.014093	0.045755	0.020110	0.369169
Flowering	0.014528	0.049428	0.025696	0.371637
Harvesting	0.025490	0.083472	0.066146	0.352464
Transform reflectance to Multi-spectrum				
Sowing/transplating	0.043169	0.070878	0.070262	0.137627
Tillering	0.033037	0.053373	0.039011	0.19038
Panicle	0.01548	0.03195	0.02082	0.269608
Flowering	0.022337	0.033438	0.021783	0.269289
Harvesting	0.028623	0.066614	0.060442	0.249958

Table 1. Convert reflectance from spectrometer to Multi-spectrum

Then analysis by using spectrum mapper, NDVI and EVI with the field survey in sample area and production statistic . It found that NDVI is high accuracy than other. So the paddy field area by using NDVI in Singburi classified by stage of rice.

Date	Sowing	Tillering	Panicle	Flowering	Harvesting	Total (Rai)	% Error
15/5/2012	101,273.15	116,768.83	28,904.67	432,000	15,667.51	263,045.56	16.31
16/6/2012	13,829.93	96,175.98	65,406.45	96,125.96	27,815.22	299,333.55	4.76
11/7/2012	13,221.41	28,838.06	74,153.29	110,884.51	51,911.47	279,008.75	11.23
22/7/2012	7,871.98	21,135.58	37,288.55	17,149.37	65,839.91	249,285.41	20.69

Table 2. Paddy field plantation area classified by NDVI in Singburi

Date	Sowing	Tillering	Panicle	Flowering	Harvesting	Total (Rai)	% Error
15/5/2012	65,858.04	55,592.46	20,968.40	872.43	83,284.82	226,576.17	30.88
16/6/2012	37,614.12	122,039.49	42,116.62	42,326.16	40,489.11	284,585.52	13.18
11/7/2012	21,337.31	65,449.27	94,395.04	63,114.94	28,956.30	273,252.88	16.64
22/7/2012	10,457.92	34,164.12	86,664.89	102,424.28	29,019.56	262,730.78	19.85

Table 3. Paddy field plantation area classified by NDVI in Angthong

2.2.2 Yield Estimation from satellite image

Model 1 estimate yield production by using OAE trend yield during B.C. 1981-2012 and remote sensing. The result of model is Singburi reveal that $Y_{trend} = 9.6032x + 417.64$ when $r^2 = 0.619$ and x is year order. For year 2012 (n=32) have $Y_{trend} = 724.94$ Kg/Rai while Angthong average production of major rice is $Y_{trend} = 12.132x + 296.471$ at $r^2 = 0.779$ and for year 2012 have Y_{trend} 684.7 Kg/Rai.

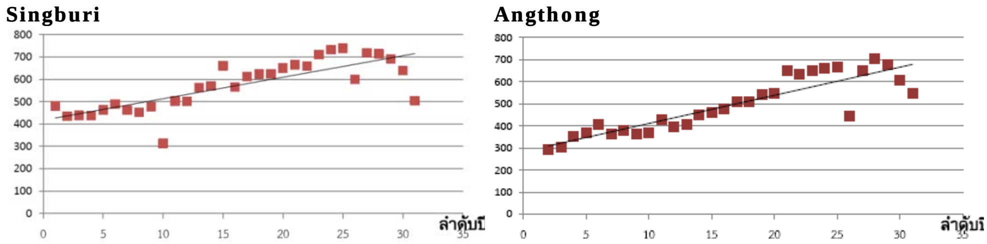


Figure 1. Relation between major rice and year of Singburi and Angthong

Then calculation stress that may be effect yield which is result from real condition. It occur to rice characteristic and can percept with remote sensing as equation

$$Y_{ndvi} = RiceYield - Y_{trend} = a + bx + cX^2$$

Here x is specific characteristic of rice that indicate nourish and health in term of vegetation index 3 formats including

1) $NDVI_{max}$ is the maximum NDVI value during rice growing or during 120 days.
2) $NDVI_{slope}$ is the change of NDVI value that start when know this area have grow rice until day which have maximum NDVI value.
3) $NDVI_{sum}$ is total of NDVI start rice plant day until harvested day.

When a, b, c are the parameters.

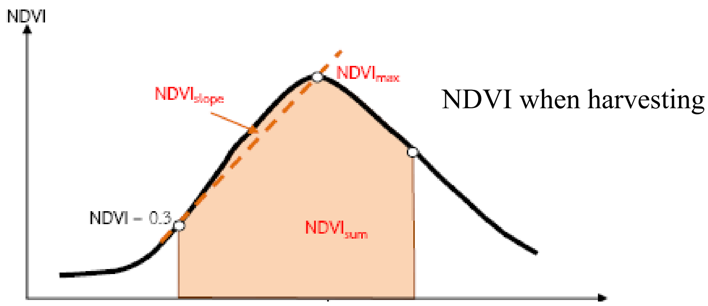


Figure 2. Specific Characteristic of Vegetation Index-NDVI

Combine with yield derived from OYS method that have cutting rice in harvesting stage to get final yield at 15 percentage humidity. Then use deviation from yield trend and specific characteristic of vegetation index to adjust in linear regression. Yield Production in Singburi compare with satellite image $NDVI_{max}$, $NDVI_{slope}$ and $NDVI_{sum}$

Sample Plot	Rice Yield	RiceYield-Ytrend	$NDVI_{max}$	$NDVI_{slope}$	$NDVI_{sum}$
1	909.04	184.10	0.65227	0.00579	58.77083
2	907.35	182.41	0.58765	0.00614	44.35613
3	833.41	108.47	0.64832	0.00746	51.31737
9	573.53	-151.41	0.66843	0.00521	56.00648
10	882.35	157.41	0.68173	0.00718	49.79393

Table 4. Comparation between yield and NDVI factor in Singburi

For x is $NDVI_{max}$

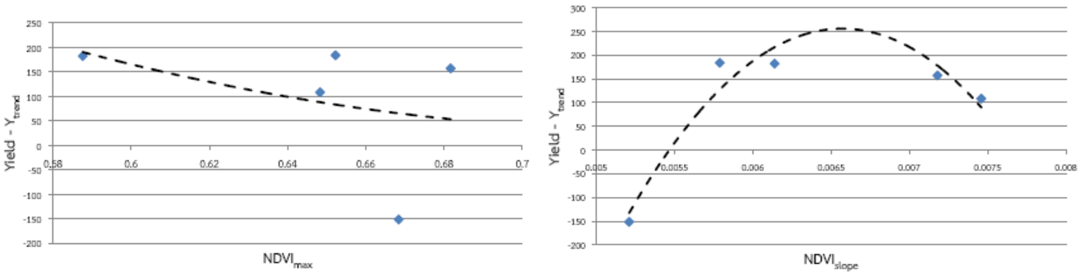
$$Y_{NDVI} = 3,785.7 - 10,114.5\ x + 6,801.5\ X^2$$

For X is $NDVI_{slope}$

$$Y_{NDVI} = -8,959.3 + 2,804,672.5X - 213,360,213.5\ X^2$$

For X is $NDVI_{sum}$

$$Y_{NDVI} = 5,302.4 - 193.5X + 1.78\ X^2$$



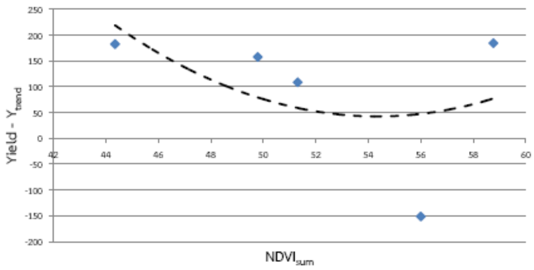


Figure 3. Relation with deviation of yield trend and $NDVI_{max}$, $NDVI_{slope}$ and $NDVI_{sum}$ of Singburi

Yield Production in Angthong compare with satellite image $NDVI_{max}$, $NDVI_{slope}$ and $NDVI_{sum}$

Sample Plot	Rice Yield	RiceYield-Y_{trend}	$NDVI_{max}$	$NDVI_{slope}$	$NDVI_{sum}$
1	882.35	191.53	0.65125	0.00681	55.07716
2	870.59	179.77	0.64078	0.01024	43.37908
3	758.82	68	0.63983	0.00828	41.76792
9	823.53	132.71	0.72432	0.00675	63.42285
10	887.17	196.35	0.67470	0.00708	49.51674

Table 5. Comparation between yield and NDVI factor in Angthong

For x is $NDVI_{max}$

$$Y_{NDVI} = -21{,}570 + 63{,}840.5\ X - 46{,}775.2\ X^2$$

For X is $NDVI_{slope}$

$$Y_{NDVI} = 2{,}357.2 - 533{,}753.3\ X + 31{,}330{,}338.2\ X^2$$

For X is $NDVI_{sum}$

$$Y_{NDVI} = -1{,}970.1 + 81.8\ X - 0.77\ X^2$$

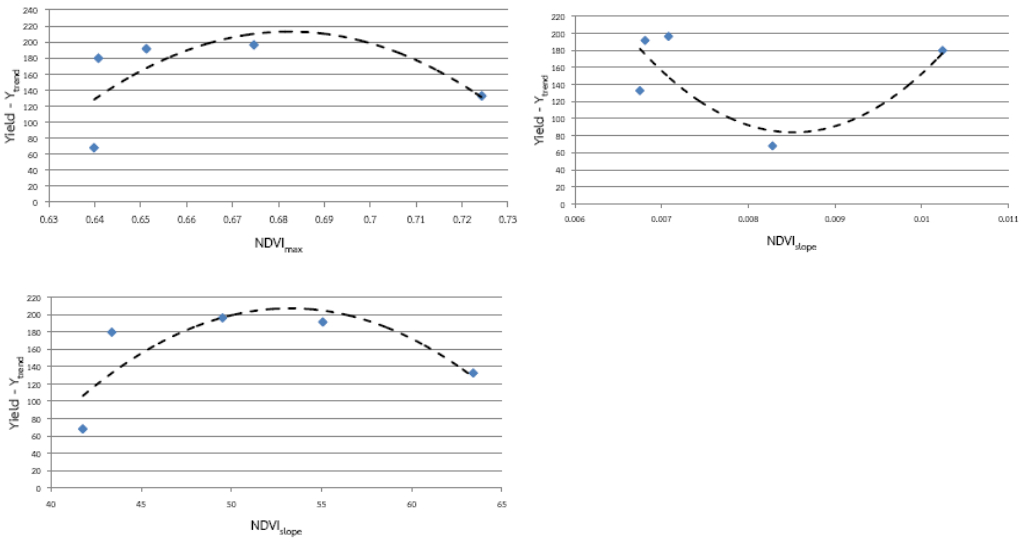


Figure 4. Relation with deviation of yield trend and $NDVI_{max}$, $NDVI_{slope}$ and $NDVI_{sum}$ of Angthong

Calculate yield production and remote sensing technique can calculate as equation

$$\text{Rice Yield} = Y_{trend} + Y_{NDVI}$$

The results of remote sensing technique with satellite image are as distribution curve. It is shown that there are some outlier data at corner both on left and right side.

Singburi **Angthong**

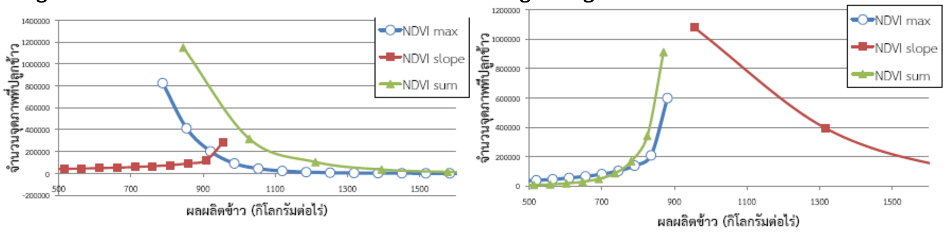


Figure 5. NDVI Distribution curve of yield production in Singburi and Angthong

If use this model to forecast yield production in study area, it seem to fit only year 2012. It can not use for normal case. Thus it essential to continue collect data at least 5 years to create rice database and validate the results. Furthermore, it should be set suitable value of $NDVI_{max}$, $NDVI_{slope}$ and $NDVI_{sum}$ to restrict some of the outlier data.

Model 2 calculate yield production by biomass and harvest index. First step is calculate PAR (Photo-synthetically Active Radiation). The assumption base on crop can absorb some energy from the sun for photosynthesis (only between wavelength 400-700 nanometer). This wavelength have ratio less than 50 percent of total radiation energy of sun to the earth but normally use ratio at 48 percent. Generally, measuring PAR have 2 methods for example measuring by PAR equipment or calculate by sun model. This study use calculate energy that send to earth because the earth surface are a have different angle with radiation. Then we analysis PAR per day by calculate accumulate energy on ground surface from sunlight on daytime in term of sun energy intensity and adjust PAR/day by consider sunshine time average on study area.

Following we calculate fraction of absorbed PAR (fAPAR). According to sunlight send energy to ground surface and crop can not absorb all energy except energy in PAR. Another factor is ratio that crop can absorb PAR for primary productivity or “fAPAR”. The fAPAR can be measure indirect way by measure reflected-radiation. Many researches show that there are related between fAPAR and vegetation index for example NDVI and Simple Ratio (SR). While NDVI have range between -1 untio 1 but SR have not limit on positive value that mean SR have value between 0 - ∞. Estimation fAPAR by using NDVI as equation

$$f\text{ APAR} = \frac{\text{NDVI} - \text{NDVI}_{min}}{\text{NDVI}_{max} - \text{NDVI}_{min}}$$

For estimate fAPAR by use SR as equation

$$fAPAR = \frac{SR - SRmin}{SRmax - SRmin}$$

When SR have related with NDVI is

$$\text{SR} = \frac{1 + \text{NDVI}}{1 - \text{NDVI}}$$

Determine NDVI distribution curve on satellite image about paddy field area pixel. The result show that on percentile 5 have NDVI_{min} = 0.0897 and percentile 95 NDVI_{max} = 0.6592. Then cut samples that have abnormal value in each side (5% per side) so within curve the area is 90%. Moreover transform to f APAR by use equation as the above.

Million pixels –Paddy field area **Absorbed PAR**

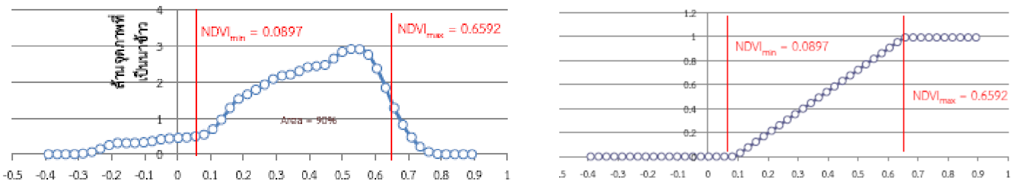


Figure6. Distribution of vegetation index on pixel that found it be paddy field area and fAPAR from equation

Calculation total above ground biomass derived from accumulate biomass per day and convert energy to rice structure as equation

$$\text{Biomass}_{agb} = \sum_{i=1}^{n} \varepsilon_i \,.\, \text{FAPAR}_i \,.\, \text{PAR}_i$$

$$= \varepsilon \,.\, \sum_{i=1}^{n} \text{FAPAR}_i \,.\, \text{PAR}_i = \varepsilon \,.\, \sum_{i=1}^{n} \text{APAR}_i$$

By sum up the total of above ground biomass using NDVI that have value more than 0.3 until date that collect data from field survey in each stage. Another factors that essential to convert is radiation use efficiency. It is efficiency that rice can store energy in fAPAR to rice biomass. Consider average biomass or dry weighted and fAPAR in stage panicle, flowering and harvesting and determine $NDVI_{max}$-SR_{max} and $NDVI_{min}$-SR_{min} from Percentile at 95 and 5 to calculate accumulate APAR and adjust this parameters until receive highest r^2 as follow

The first process, we use parameter when $NDVI_{max} = 0.6592$ and $NDVI_{min} = 0.0897$. The result $R^2 = 0.7125$.

The second process, we use parameter when $SR_{max} = 4.8691$ and $SR_{min} = 1.1970$. The result $R^2 = 0.6733$.

Then we increase or decrease same parameters until R^2 value is highest.

The third process, we use parameter when $NDVI_{max} = 0.51$ and $NDVI_{min} = 0.28$. The result $R^2 = 0.7583$.

The fourth process, we use parameter when $SR_{max} = 3.0816$ and $SR_{min} = 1.7778$. The result $R^2 = 0.7623$.

Sample Plot	Stage 3		Stage 4		Stage 5	
	Avg.Bio	fAPAR	Avg.Bio	fAPAR	Avg.Bio	fAPAR
1	521.80	380.40	821.03	547.73	1465.37	657.67
2	869.76	355.79	630.29	513.15	1530.63	618.42
3	322.77	245.57	567.94	412.89	1289.99	553.91
4	502.70	324.15	613.22	490.90	1524.70	642.91
5	637.53	352.01	998.10	518.76	1235.69	667.48
6	480.03	405.43	745.25	559.27	1498.70	591.20
7	885.66	381.23	965.13	547.86	1548.15	666.79
8	197.54	189.71	540.01	356.33	1506.37	564.37
9	251.14	266.53	351.66	433.27	1075.23	577.58
10	216.56	213.85	519.95	380.69	No data	-

Table 6 . Relation between average biomass and *f*APAR when $SR_{max} = 3.0816$ and $SR_{min} = 1.7778$.

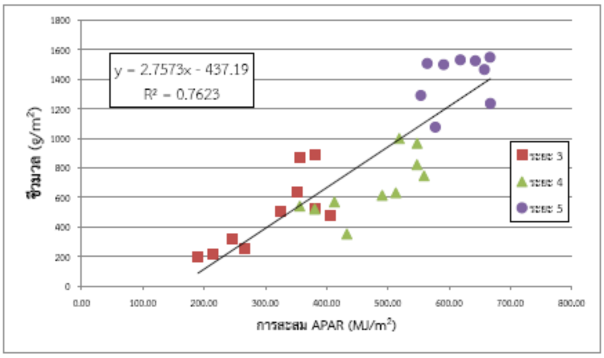


Figure7. Relationship between accumulate APAR and rice biomass when SRmax = 3.0816 and SRmin = 1.7778

By assumption NDVI in grain filling stage have related with accumulate protein in grain after rice are flowering stage and still have more NDVI. It indicates that still collect more biomass so harvest index is as equation

$$HI = HI_{max} - HI_{range}\left(1 - \frac{NDVI_{post}}{NDVI_{pre}}\right)$$

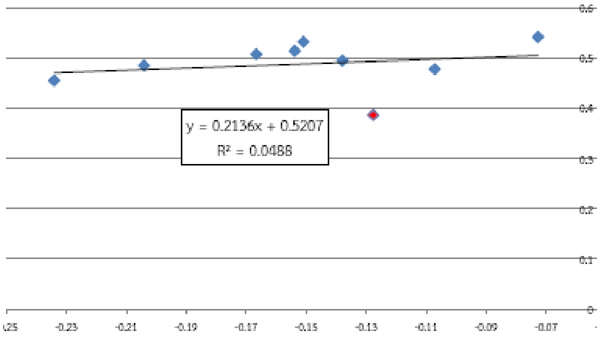
$$= HI_{max} - HI_{range}\left(\frac{NDVI_{pre} - NDVI_{post}}{NDVI_{pre}}\right)$$

For this project use HI_{max} = 0.5 and HI_{range} =0.2. Besides, $NDVI_{pre}$ is NDVI average before rice are panicle to flowering and $NDVI_{post}$ is NDVI average before rice flowering until harvesting. It is seem that rice flowering is highest NDVI. Harvest index is to seek relation between harvest index and average NDVI before and after flowering.

Sample Plot	Avg. HI	$NDVI_{pre}$	$NDVI_{post}$	$(NDVI_{pre}-NDVI_{post})/NDVI_{pre}$
1	0.530000	0.53	0.61	-0.1509434
2	0.5078975	0.48	0.56	-0.166666
3	0.5142993	0.52	0.6	-0.1538462
4	0.5421003	0.55	0.59	-0,0727273
5	0.4852917	0.497	0.59	-0.2040816
6	0.4780271	0.56	0.62	-0.1071429
7	0.4950583	0.58	0.66	-0.137931
8	0.386648	0.47	0.53	-0.1276596
9	0.455244	0.47	0.58	-0.2340426
10	n.a.	0.51	0.56	-0.0980392

Table 7 . Calculate Harvest Index and $NDVI_{pre-post}$

Average Harvest Index



$(NDVI_{pre}$-$NDVI_{post})/NDVI_{pre}$

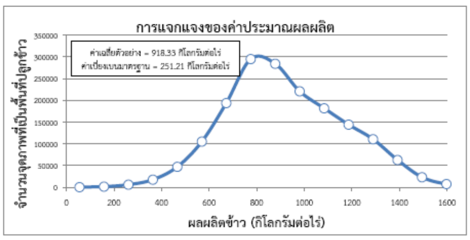
Figure 8. Ratio between $(NDVI_{pre}$-$NDVI_{post})/NDVI_{pre}$ and harvest index

Although this model found that there are some error so it necessary to collect more data to develop model. Thus this study define harvest index by using constant that derived from paddy field total 8 plots because plot number 8 have harvest index different from another plot and number 10 no data. Rice Yield Estimation is as equation

$$\text{Rice Yield} = \text{HI x Biomass}_{agb}$$

The result of calculate with satellite image and parameter NDVImax SRmax and $NDVI_{min}$ SR_{min} at percentile 95 and 5.The fAPAR by NDVI have average of rice production 922.61 Kg./Rai and standard deviation 230.99 Kg./Rai and fAPAR have rice yield production 834.16 Kg./Rai and standard deviation 224.91 Kg./Rai. There are $NDVI_{max}$ = 0.6592 and $NDVI_{min}$ = 0.0897 and SR_{max} = 4.8691 and SR_{min} = 1.1970. Then we adjust parameters to get highest R^2 so calculate fAPAR by NDVI have yield average 918.33 Kg./Rai and standard deviation 251.21 Kg./Rai and calculate fAPAR by SR get rice yield 892.02 Kg./Rai and standard deviation 250.34 Kg./Rai.

Singburi



Angthong

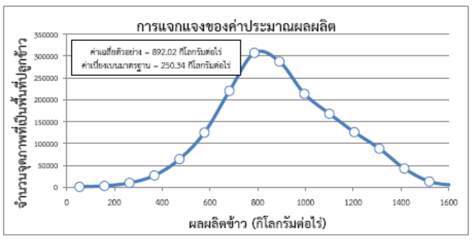


Figure 9. Yield Production Distribution in Singburi and Angthong

However the result indicae that standard deviation are very high (approximately 250 Kg./Rai). The problem effect from some pixel at the edge of paddy field and some pixel effect by noise of cloud because during study are rainy season.

3. Conclusion

This study found that reflectance value is easier to analysis paddy field plantation area. Moreover on the process developing rice forecasting model it still have some inconsistent among data from field survey both on using trend yield and biomass.

So OAE have planed to continue study to create rice database and validate the data at least 5 years . Moreover the study will expand to another area in other region that a good representative of rice growing of Thailand and also various kind of rice planting in variety of terrain such as floodplain, hill, etc. to make rice yield producation more accurate and precise. Finally this study have plan to expand to various pattern on rice growing such as transplant rice or seeding, parashooting or paddy-sown field. Beyond with different rice species. Comprise with consideration rice yield forecasting models that have factor suitable for rice pattern of Thailand.

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