CHAPTER IV
RESULTS

In this research, the geographic information system was applied to classify the suitable sugarcane plantation areas at Kanchanaburi Province based on the analysis of satellite imagery along with other indices and Potential Surface Analysis. The results of this research were presented below.

4.1 Classification of sugarcane cultivation areas in Kanchanaburi Province using Spectral Reflectance from field data

1) The spectral reflectance analysis of sugarcane in Kanchanaburi Province indicated that the spectral reflectance values of sugarcane cultivation areas range from 0.1920 to 0.2363. The spectral reflectance would be higher up to the sugarcane ages as shown in Table 4.2 and Figure 4.2

Table 4.1 Spectral reflectance of sugarcane in each age

Age (months)	Reflectance	Average
1	0.1468 - 0.2372	0.1920
2	0.1285 - 0.2824	0.2055
3	0.1273 - 0.2969	0.2121
4	0.1735 - 0.2781	0.2258
5	0.1625 - 0.2581	0.2103
6	0.2149 - 0.2494	0.2321
7	0.1916 - 0.2567	0.2241
8	0.1850 - 0.2877	0.2363

Source: Analysis

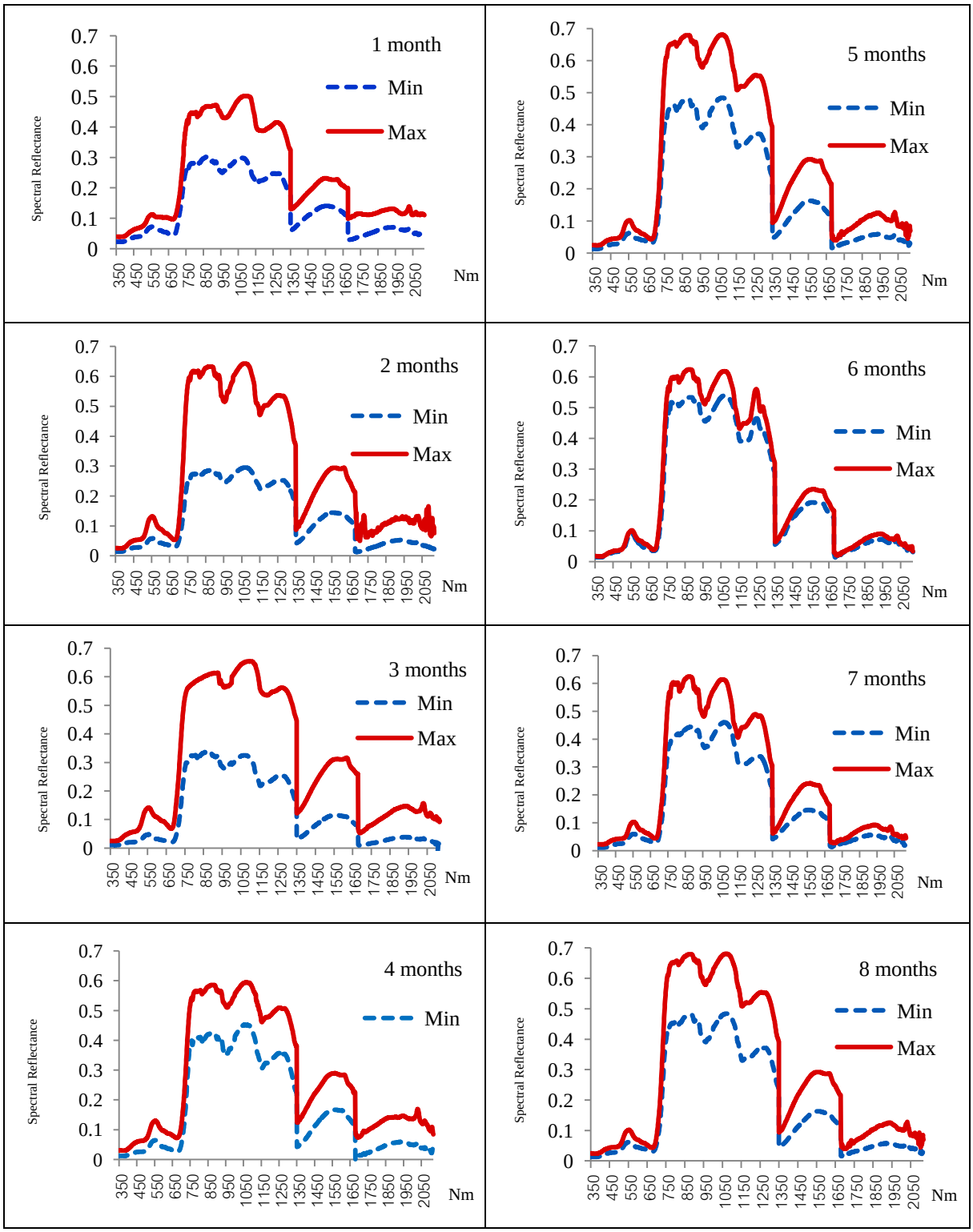


Figure 4.1 Min and max spectral reflectance based on ages of sugarcane

Source: Analysis

2) Spectral reflectance in each band

2.1) Spectral reflectance of sugarcane in visible band (0.45μm -0.90 μm) was in a range of 0.0170 - 0.5785 as shown in Figure 4.2

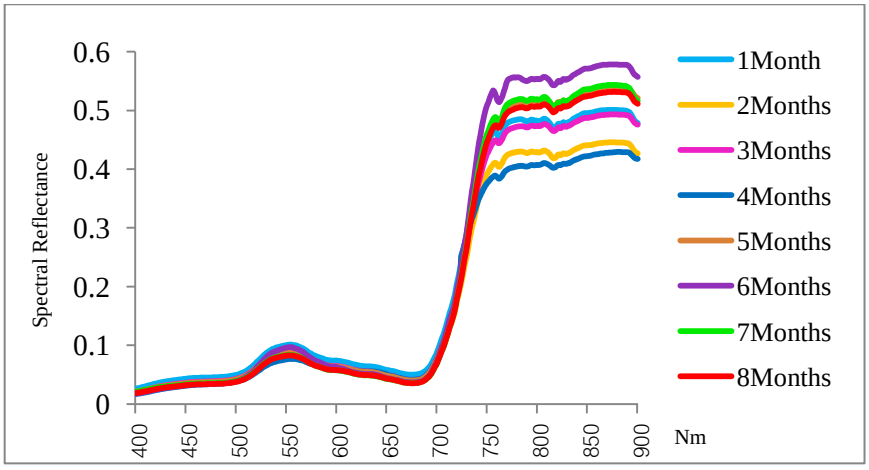


Figure 4.2 Spectral reflectance of sugarcane in visible band

Source: Analysis

2.2) Spectral reflectance of sugarcane in near infrared band (0.76 μm – 0.90 μm) was in a range of 0.3134 to 0.5785 as shown in Figure 4.3

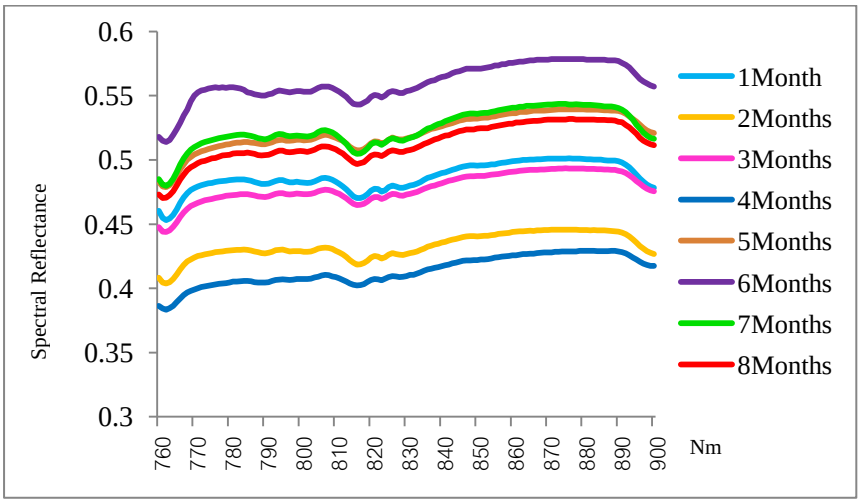


Figure 4.3 Spectral reflectance of sugarcane in near infrared band

Source: Analysis

2.3) Spectral reflectance of sugarcane in red band (0.63 μm - 0.69 μm) was in a range of 0.03542 to 0.6415 as shown in Figure 4.4

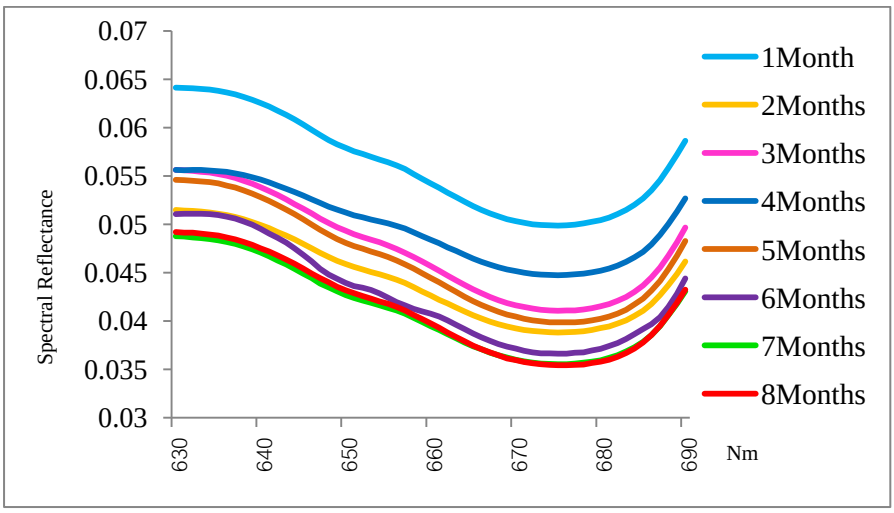


Figure 4.4 Spectral reflectance of sugarcane in red band

Source: Analysis

In brief, from the spectral reflectance of sugarcane in all 3 bands, the spectral reflectance of sugarcane in red band (0.63 μm - 0.69 μm) was able to identify the ages of sugarcane obviously.

4.2 Classification of sugarcane cultivation areas in Kanchanaburi Province using satellite imageries

4.2.1 Classification of sugarcane cultivation areas in Kanchanaburi Province using hybrid Interpretation

1) The classification of sugarcane cultivation areas in Kanchanaburi Province using hybrid interpretation showed that this province consisted of sugarcane cultivation areas for 843.887 square kilometers, forest areas for 10,447.257 square kilometers, water sources for 581.328 square kilometers, agricultural areas for 2,286.474 square kilometers, urban areas for 408.888 square kilometers and other areas for 421.306 square kilometers as shown in Figure 4.5

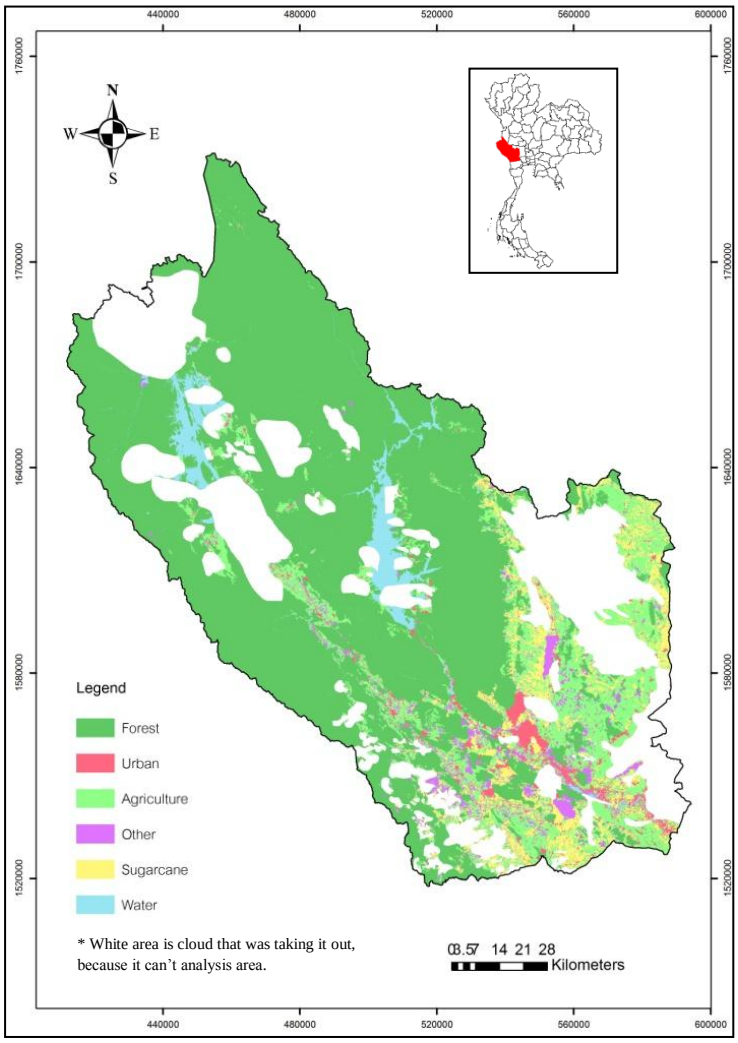


Figure 4.5 Sugarcane cultivation areas in Kanchanaburi Province based on hybrid interpretation

Source: Analysis

2) Accuracy classification for land utilization in Kanchanaburi Province

From 428 survey points in studied areas, it was found that classification of sugarcane cultivation areas in Kanchanaburi Province based on hybrid interpretation provided the overall accuracy at 68.22 % (Kappa index 0.60), as shown in Table 4.2.

Table 4.2 Accuracy assessment of error matrix

Hybrid Interpretation	Survey Points						
	Land Use	Forest	Agriculture	Urban	Sugarcane	Water	Other	Total
	Forest	84	4	7	3	2	7	107
	Agriculture	16	57	8	5	1	13	100
	Urban	6	3	25	4	2	6	46
	Sugarcane	5	19	5	84	4	3	115
	Water		2	1	-	14	3	20
	Other	3	5	1	3	-	28	40
	Total	114	90	47	99	23	60	428

Source: Analysis

4.2.2 Classification of sugarcane cultivation areas in Kanchanaburi Province using spectral reflectance from satellite imagery

1) The analysis of spectral reflectance from satellite imagery showed that the spectral reflectance of sugarcane ranged from 0.0000 to 0.5966 with mean at 0.2983 in near infrared band (0.76 μm – 0.90 μm) as shown in Figure 4.6.

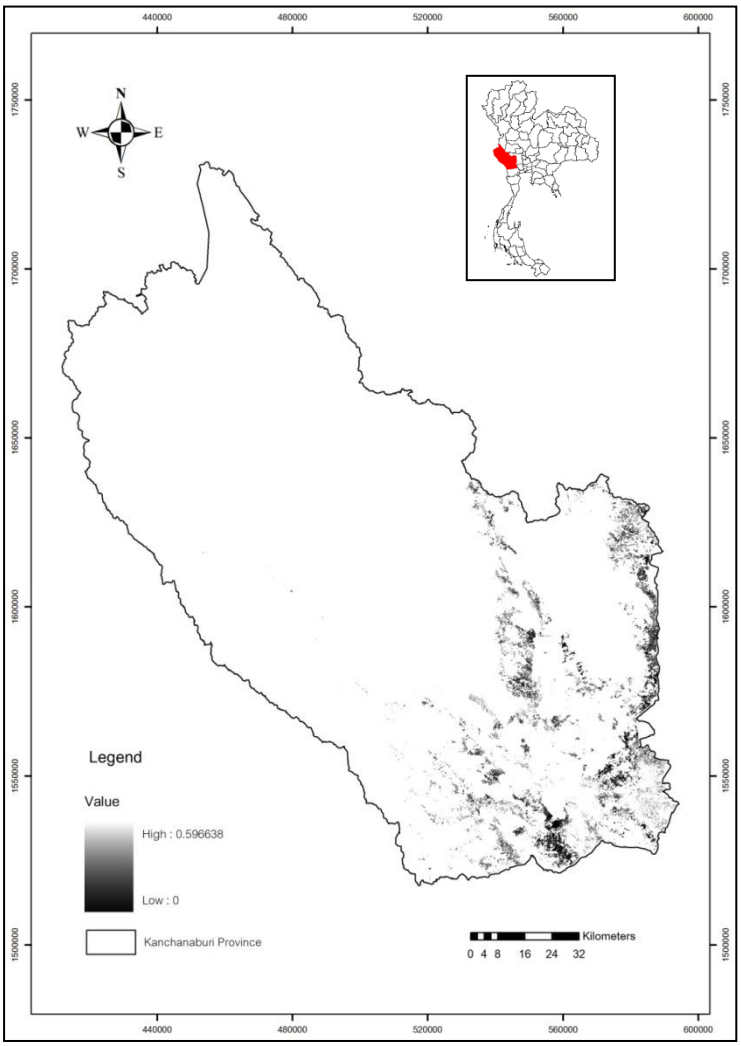


Figure 4.6 Spectral reflectance of sugarcane in Kanchanaburi Province based on satellite imagery

Source: Analysis

2) Analysis of spectral reflectance from satellite imagery and field data

From the analysis of correlation of both types of data, it was found that Band 4 showed the most correlation or the correlation was at 0.6783 (R^2 = 0.4602), thus the spectral reflectance from satellite imagery would be further analyzed by using other indices.

Table 4.3 Correlation and linear regression in each band

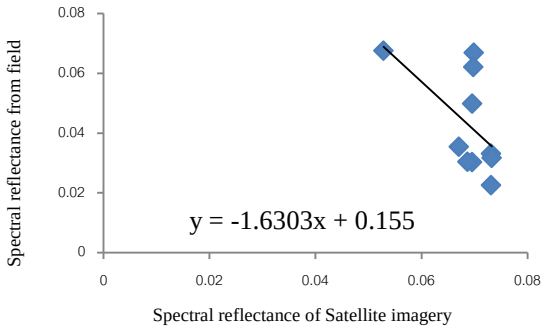
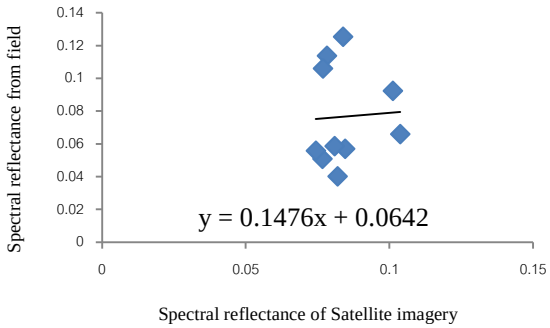
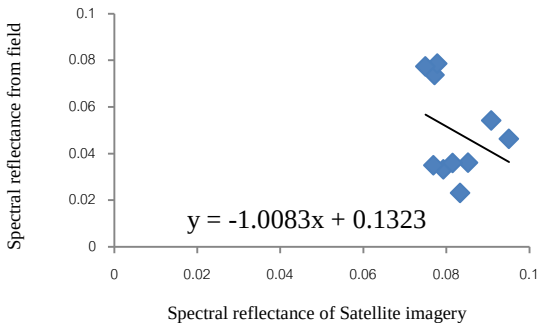
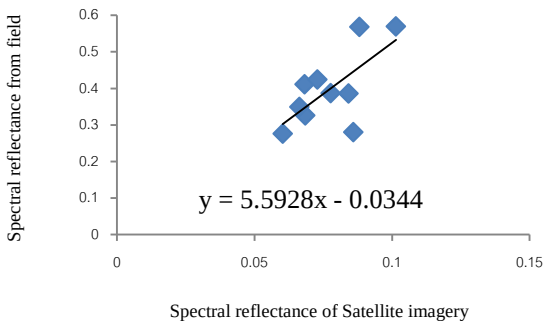
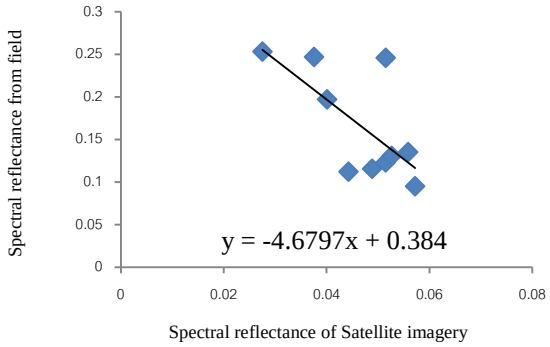
Band	Correlation	Linear Regression (R^2)	Scatter Plot
1	-0.5694	0.3242	
2	0.0499	0.0025	
3	-0.3218	0.1036	
4	0.6783	0.4602	

Table 4.3 (2) Correlation and linear regression in each band

Band	Correlation	Simple linear Regression (R^2)	Scatter Plot
5	-0.5694	0.4746	

Source: Analysis

4.2.3 Classification of sugarcane cultivation areas using several indices.

1) From classifying the sugarcane cultivation areas based on satellite imageries by analyzing many indices, it was found that NDVI, BI and WI ranged from 0.0825 to 0.4643, 40.8163 to 126.027 and 0.205 to 39 as shown in Table 4.4 and Figure 4.7.

Table 4.4 Normalized Difference Vegetation Index (NDVI), Bare Soil Index (BI) , Water Index (WI)

Index	**Min**	**Max**	**Average**
NDVI	0.138895	0.451107	0.295001
BI	73.27786	83.08269	78.18028
WI	0.659298	0.885568	0.772433

Source: Analysis

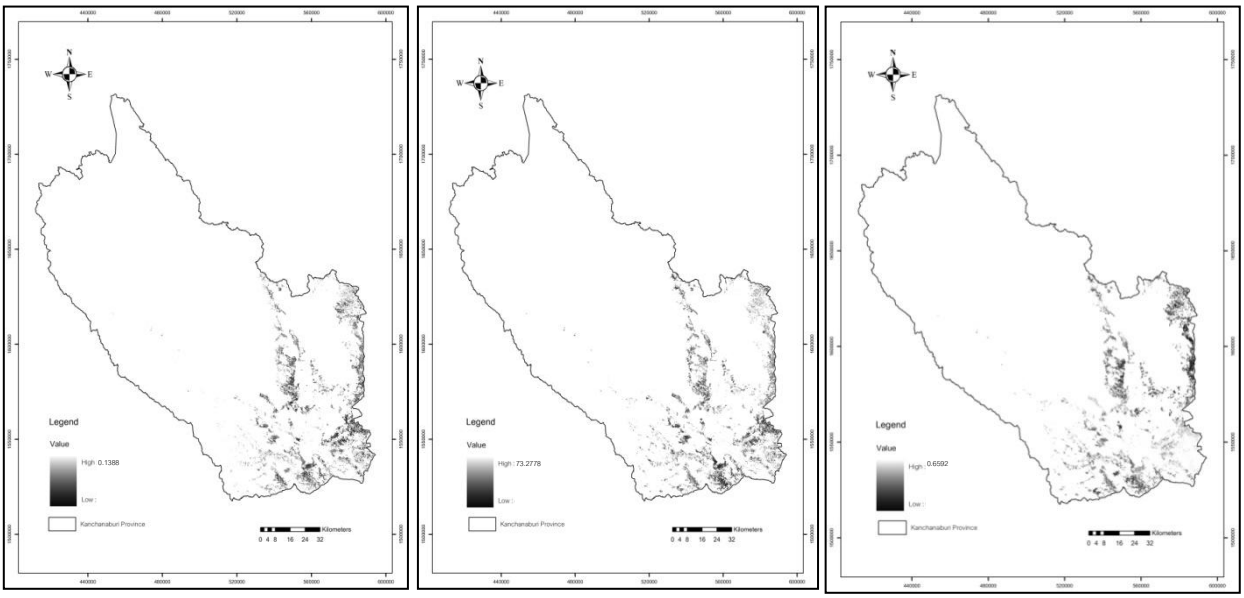


Figure 4.7 The Normalized Difference Vegetation Index, Bare Soil Index and Water Index

Source: Analysis

2) From the analysis of several indices subject to the ages of sugarcane, it was found that the Normalized Difference Vegetation Index reached the highest when the sugarcane was at age of 8 months (NDVI= 0.4511), because it contained the highest biomass quantity. The Bare Soil Index dropped to the lowest when the sugarcane was at age of 8 months (BI = 73.2778) because the top of sugarcane was most covered by soil, thus the little amount of soil was found. The Water Index reached the highest when the sugarcane was at the age of 8 months (WI = 0.8855) because it kept the most water, as shown in Table 4.5.

Table 4.5 Index of sugarcane in each age

Index / Age	NDVI			BI			WI		
	Min	Max	Average	Min	Max	Average	Min	Max	Average
1	0.1358	0.2340	0.1388	76.5589	82.6401	76.5271	0.7314	0.8171	0.6962
2	0.1528	0.2625	0.1989	78.6477	85.3126	81.1574	0.6202	0.7213	0.6720
3	0.2041	0.3502	0.2815	37.6888	81.9445	79.4223	0.6436	0.7648	0.6592
4	0.1417	0.2570	0.2933	79.1194	88.0878	83.0826	0.6233	0.7898	0.6789
5	0.1969	0.2810	0.2882	79.5802	81.5910	78.2439	0.6182	0.7306	0.7561
6	0.3171	0.3757	0.3470	75.2844	80.7947	77.9954	0.7217	0.7650	0.7412
7	0.2449	0.3159	0.2771	74.5864	78.8870	76.5955	0.7843	0.8536	0.8216
8	0.4199	0.4809	0.4511	71.2077	75.6067	73.2778	0.8379	0.9333	0.8855

Source: Analysis

3) Relationship of Index

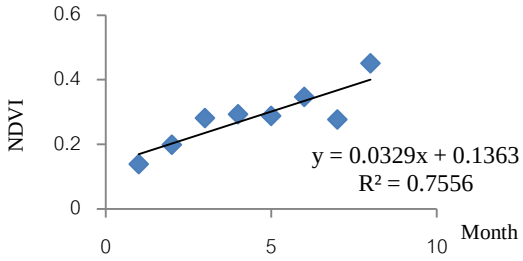
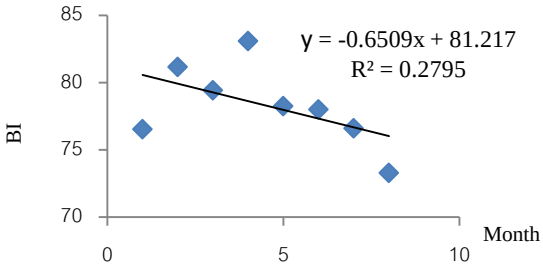
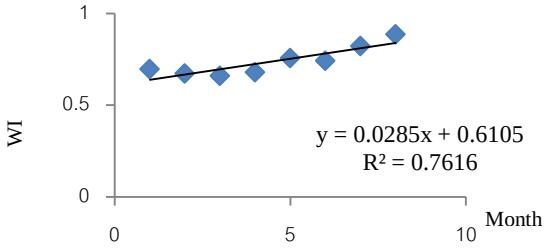
The Normalized Difference Vegetation Index, Bare Soil Index, and Water Index were analyzed by using regression analysis to determine the relationship of sugarcane areas in Kanchanaburi. The age of sugarcane was fixed at 1 month to 8 months (Y) as shown in Table 4.6 and 4.7

Table 4.6 Comparison of using indices in the construction of models by using the simple regression analysis

Index	**Model**	**R Square**
NDVI	Y = 22.9308 NDVI - 2.2445	0.7555
BI	Y = 38.1162 - 0.4293 BI	0.2794
WI	Y = 26.6979 WI - 15.2270	0.7615
NDVI +BI+ WI	Y = 10.9146 NDVI +0.2753 BI+26.4330 WI-39.6915	0.9344

Source: Analysis

Table 4.7 Scatter plot of sugarcane in each age

Index	Scatter Plot
NDVI	
BI	
WI	

Source: Analysis

This table indicated that the best model for the analysis of relationship in sugarcane was:

$$Y = 10.9146\ NDVI + 0.2753\ BI + 26.4330\ WI - 39.6915\ (R^2 = 0.9344)$$

4) From the classification of sugarcane areas using the model, the results showed that Kanchanaburi Province had total sugarcane areas for 821.91 square kilometers. Sugarcane cultivation areas at ages of 1 to 8 months in Kanchanaburi Province were 25.42, 56.75, 112.43, 179.69, 234.56, 79.07, 97.84 and 36.11 square kilometers as shown in Figure 4.8.

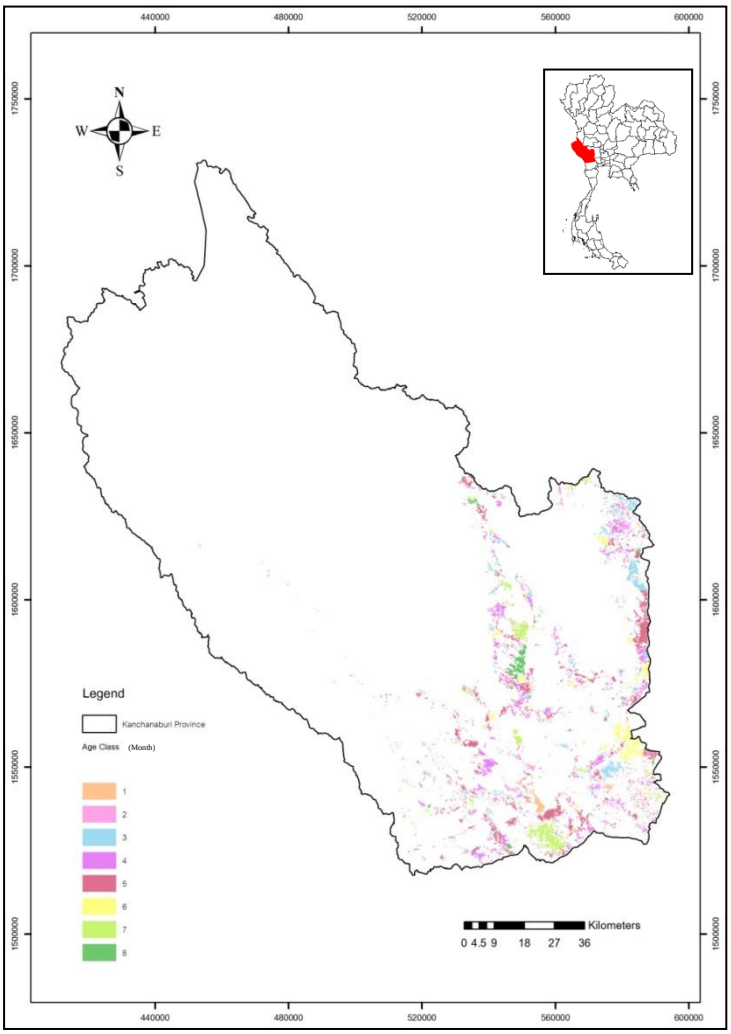


Figure 4.8 Sugarcane area using model of index

Source: Analysis

5) Accuracy assessment of classifying sugarcane cultivation areas in Kanchanaburi Province using the models

From 428 field survey points in studied area (classification accuracy) by comparing the Ground Truth Visit with the data from the classification of satellite imageries, it was found that the overall accuracy was about 82.71 % (Kappa index 0.67), as shown in Table 4.8.

Table 4.8 Accuracy assessment of error matrix

Hybrid Interpretation	Survey Points			
	Land Use	Sugarcane area	Other	Total Points
	Sugarcane area	188	25	213
	Other	31	166	203
	Total	219	191	428

Source: Analysis

4.3 Assessment of potential suitability of sugarcane cultivation areas and land misutilization in Kanchanaburi Province

4.3.1 Identification of suitable sugarcane cultivation areas using Potential Surface Analysis (PSA)

In the identification of suitable sugarcane plantation areas by using Potential Surface, GIS, Overlay Analysis, Weighting Factors, and Rating Factors were applied depending on the levels of following factors: annual rainfall, soil drainage, soil depth, soil texture, temperature, slope, pH, distance from irrigation, distance from water sources, and land utilization. Weighting and rating score has been employed based on experts in those fields. The results are as follows:

1) High suitability for sugarcane cultivation areas included 2,284.93 square kilometres or 12.04 % of total areas in the province. High suitability was found in Sai Yok District, Thong Phaphum District and Si Sawat District respectively.

2) Moderate suitability for sugarcane cultivation areas included 12,315.03 square kilometres or 64.87% of total areas in the province. Moderate suitability was found in Thong Pha Phum District, Sangkhlaburi District and Si Sawat District respectively.

3) Low suitability for sugarcane cultivation areas included 3,871.98 square kilometres or 20.39% of total areas in the province. Low suitability was found in Thong Pha Phum District, Sangkhlaburi District and Sai Yok District respectively.

4) Areas not suitable for sugarcane cultivation areas included 512.69 square kilometres or 2.70% of total areas in the province. Such areas were found in Bo Ploi District, Muang District and Panom Taun District respectively, as shown in Table 4.9 and Figure 4.9.

Table 4.9 Suitable sugarcane plantation areas in Kanchanaburi Province as calculated by Potential Surface Analysis

Level / District	High (km^2)	Moderate (km^2)	Low (km^2)	Non-Suitable (km^2)
1. Dan Makham Tia	42.38	502.71	21.92	28.30
2. Tong Phaphum	481.23	2,101.94	1,372.94	3.74
3. Ta Muang	43.49	517.42	30.31	28.82
4. Ta Maka	105.24	289.62	16.55	25.52
5. Sai Yok	570.18	1,637.84	514.11	5.54
6. Bo Phoi	117.59	846.68	169.78	107.86
7. Phanom Thuan	124.70	327.78	52.56	64.88
8. Muang Kanchanaburi	240.71	1,031.88	143.43	99.18
9. Lao Kwan	38.15	709.63	87.15	71.74
10. Si Sawat	290.30	1,806.03	271.03	1.01
11. Sung Kha Buri	140.63	1,981.29	1,083.47	3.04
12. Nong Pi	68.03	220.33	33.57	9.27
13. Huai Krajao	22.24	341.84	75.08	63.76
Total	2,284.93	12,315.03	3,871.98	512.69

Source: Analysis

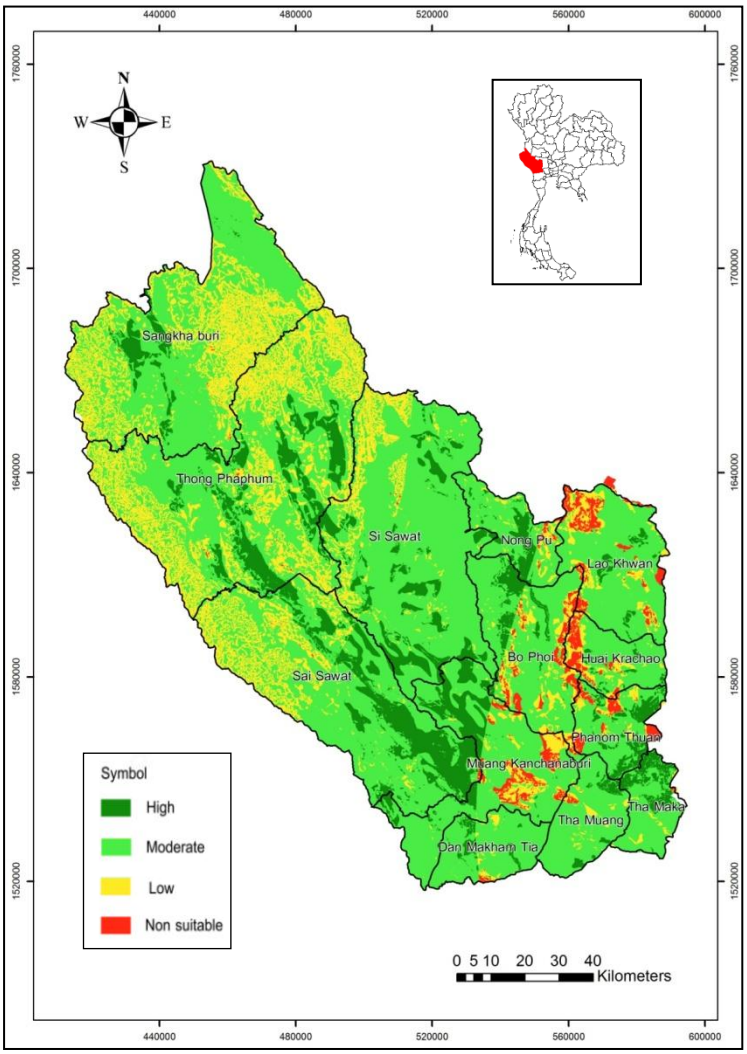


Figure 4.9 Suitable sugarcane plantation areas in Kanchanaburi Province by Potential Surface Analysis

Source: Analysis

4.3.2 Comparison of suitable sugarcane cultivation areas based on spatial potential

From the analysis of suitable sugarcane cultivation areas based on satellite imageries and sugarcane cultivation areas got from the analysis of spatial potential, it was found that the amount of sugarcane cultivation areas was less than other agriculture areas. This meant that the land was wrongly utilized because the areas suitable for sugarcane cultivation were used for growing other plants. The suitable plantation areas for sugarcane exclude urban areas, forests and water sources due to

limitations of law and other environmental factors. For example, water sources cannot be used to grow plants, or the forests cannot be intruded as prescribed by law as shown in Table 4.10

Table 4.10 Land misutilization in areas suitable for sugarcane cultivation in Kanchanaburi province

			misutilization	
Area / Level	**Suitability sugarcane area (km^2)**	**Sugarcane area (km^2)**	**Agriculture area (km^2)**	**Other area (km^2)**
High	629.48	121.99	415.52	91.97
Moderate	2,476.78	648.63	1,559.12	269.03
Low	306.85	49.40	222.72	34.73
Non Suitable	135.171	23.84	86.03	25.301
Total	3,548.32	843.88	2,283.41	421.03

Source: Analysis

4.4 Evaluation of suitability of sugarcane cultivation in Kanchanaburi Province in terms of food and energy

4.4.1 Analysis of sugarcane productivity in term of food

The analysis of sugarcane productivity in term of food was sugar. Sugarcane about 11 cc. BS would yield about 9.5 tons per Rai, and 1 ton of fresh sugar could produce sugar about 102.5 kg. Accordingly, the sugarcane cultivation areas in Kanchanaburi Province included 821.91 square kilometers or 513,693.75 Rai, which could produce sugar about 500,209.28 tons.

4.4.2 Analysis of sugarcane productivity in term of energy

The analysis of sugarcane productivity in term of energy was ethanol. One ton of fresh sugarcane could produce 70 liters of ethanol. The production of sugarcane in Kanchanaburi Province amounted to 4,880,090.62 tons, which could produce 341,606,343.4 liters of ethanol.

4.4.3 Comparison of sugar consumption in Kanchanaburi Province

From the analysis of sugar consumption in Kanchanaburi Province, the consumption amount was 32,577.01 tons by comparing the average sugar consumption of the Department of Health in 2011 (average sugar consumption of 39 kilograms per person per year). Form the analysis of sugar consumption derived from satellite data analysis 500,209.28 tons of sugar was produced at Kanchanaburi. This meant that the amount of sugar after consumption there was 467,632.27 tons. The excessive amount was sold outside the province or used in the production of ethanol for 358,623.41 liters.

4.4.4 Comparison of sugarcane productivity in sugarcane cultivation areas based on the spatial potential

From the analysis of sugarcane productivity based on suitable sugarcane cultivation areas, excluding forests, water sources and urban areas, the analysis of sugarcane productivity of sugarcane cultivation areas had the following results:

1) Areas of high suitability for sugarcane cultivation could produce sugar about 383,097.59 tons, and about 261,627,625 liters of ethanol.

2) Areas of moderate suitability for sugarcane cultivation could produce sugar about 1,494,018.53 tons, and about 1,020,305,344 liters of ethanol.

3) Areas of low suitability for sugarcane cultivation could produce sugar about 186,746.99 tons, and about 127,534,531.3 liters of ethanol, as shown in Table 4.11.

Table 4.11 Production from sugarcane plantation areas using Potential Surface Analysis

Area / Level	sugarcane area (km^2)	sugarcane area (Rai)	Produced sugarcane (Ton)	Sugar (Ton)	Ethanol (Liter)
High	629.48	393,425.00	3,737,537.50	383,097.59	261,627,625
Moderate	2,454.87	1,534,293.75	14,575,790.63	1,494,018.53	1,020,305,344
Low	306.85	191,781.25	1,821,921.87	186,746.99	127,534,531.3
Total	3,391.20	2,119,500.00	20,135,250.00	2,063,863.12	1,409,467,500

Source: Analysis