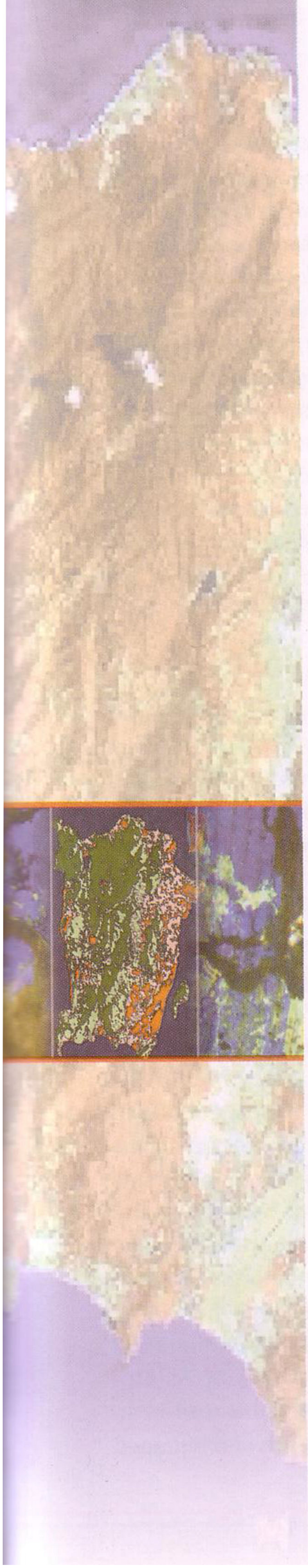

Chapter 8

GENERATION OF TASSELED CAP TRANSFORMATION COEFFICIENTS FOR THE USE OF TiungSAT-1 MULTI SPECTRAL EARTH IMAGING SYSTEM (MSEIS) DATA

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ABSTRACT

The so-called "Tasseled Cap" transformation developed by Kauth and Thomas in 1976 is a means for highlighting the most important (spectrally-observable) phenomena of crop development in a way that allows discrimination of specific crops. For Landsat Multispectral Scanner (MSS) data, the Tasseled cap transform performs an orthogonal transformation of the original data into new four-dimensional space consisting of the soil brightness index (SBI), the green vegetation index (GVI), the yellow stuff /

vegetation index (YVI) and a non-such index (NSI) associated with atmospheric effects. For LandSAT Thematic Mapper (TM) data, the Tasseled Cap vegetation index consists of three factors, "Brightness," "Greenness," and "Third." The Brightness and Greenness are equivalent to the MSS tasseled cap SBI and GVI, and the third component is related to soil features, including moisture status. In this project, an effort has been made to generate Tasseled Cap coefficients for TiungSAT-1 Multi Spectral Earth Imaging System (MSEIS) data which has no such coefficients yet. This is a recent effort since TiungSAT-1 is a Malaysian micro satellite which was recently launched in September 2000. These generated coefficients were then used to generate TC layers to derive vegetation and soil information from TiungSAT-1 data. Besides TiungSAT-1 data, LandSAT TM data were also used to compare the results obtained from TiungSAT-1. Both TiungSAT-1 and TM images were processed for TTC and supervised classification. The results show that the generated TTC coefficients are sufficient to separate vegetation information from TiungSAT-1 data.

INTRODUCTION

The "tasseled cap" Transformation is a linear transformation of satellite imageries/data that projects soil and vegetation information into a single plane in multispectral data space (Campbell, 1987). In a single plane, major spectral components of an agricultural scene are displayed in two dimensions. The transformation can be visualized as a rotation of a solid multi-dimensional figure (representing all spectral bands) in a manner that permits the analyst to view the major spectral components of an agricultural scene as a two-dimensional figure by producing a set of new variables. The rotation is sensor dependent. Once defined for a particular sensor (say LandSAT TM or TiungSAT-1) the same rotation will work for any scene taken by that sensor.

Three data structure (clustering of pixels) axes (new bands) are produced by TCT to define the vegetation information content, namely, brightness, greenness and wetness. Brightness is a weighted sum of all bands, defined in the direction of the principal variation in soil reflectance. Meanwhile, greenness is referred to the surface of the earth in biological terms; a qualitative estimate of green biomass. The index measures overall plant vigor, hydration, and chlorophyll content. It is orthogonal to brightness, a contrast between the near-infrared and visible bands, and it is strongly related to the amount of green vegetation in the scene. On the other hand, wetness is referred to as the surface wetness, including the water suspended in vegetation biomass, canopy and soil moisture. Wetness can be computed from LandSAT TM images by Kauth's Tasseled Cap operations. Wetness contrasts the sum of the visible and near-infrared channels against the sum of the longer wavelength bands and is named due to the sensitivity of the longer infrared channels to soil moisture (Crist and Cicone, 1984) (Figure 1).

The first tasseled cap Transformation was designed by Kauth and Thosmas (1976) for the use of LandSAT MSS data. This TTC is a technique which produces a transformation of the original data to a four-dimensional space. The transformation does this by identifying four new axes including SBI, GVI, YVI and a NSI associated with atmospheric effects. Generally, the first two indexes (SBI and GVI) contain more than 90% of the scene information. The second transformation was designed for LandSAT TM data by Crist and Cinone in 1984. The transformation for TM data is commonly called the brightness-greenness-wetness index because it identifies from the TM data four distinct components which identify the SBI, GVI, wetness index (WI), and the residual non-such attributed to atmospheric haze. However, the third Transformation was designed by Huang Cheng Quan (2001) to be used for LandSAT 7 images. The default coefficients used for MSS, TM and LandSAT 7 TM data are respectively shown in Appendices 1, 2 and 3.

A wide range of studies have been undertaken to create TTC images using satellite imageries. Among others, Patrick Yuen (2001) used TTC from IKONOS data to monitor crop development. Multitemporal data was used to detect celery blight. The result the study showed black lines in the transformed images, particularly on soil brightness index which showed dark soil that indicated to diseased crops. In the year 2000, Thurgate used TTC in fused images of SPOT and LandSAT data to derive ecological information. Jeremy and Comrie (1998) used TTC to produce plant cover map for a southwestern, semi-arid city in Arizona. TTC made them successful in classifying each species class, estimating the biomass and investigating the relationship between leave biomass and hydrocarbon production for the purpose of producing plant cover information. Another interesting study was successfully carried out by Emmanuel (1997) in Detroit using TTC to look at the changes in urban demographic pattern in relation to vegetation changes.

These researches have proven that TTC is a useful technique to study vegetation. Therefore, effort has been taken in this study to:

1) generate coefficients of Tasseled Cap for the use of TiungSAT-1 with Fortran Compiler
2) produce TTC image using generated coefficients
3) assess the accuracy of generated coefficients by comparing the TTC products of TiungSAT-1 image with TTC product of TM (using coefficients of Crist & Cicone), by comparing the pixel distribution of TiungSAT-1 TTC image with pixel distribution pattern of TM's TTC and comparing classified TiungSAT-1 image with LandSAT TM image.

STUDY AREA

Penang Island (Figure 1) was selected as it explicitly represents various landuse types such as forest, urban, agricultural plots and bare soil. Furthermore, TiungSAT-1 data of this area is clear and free from cloud cover. The location (on north-western coast of Peninsular Malaysia) of the island is 5°15'U to 5°30'U and 100°10'T to 100°20'T. It comprises the Penang Island and a strip on the mainland named Seberang Perai which is linked by the Penang Bridge. The island measures a modest 285 sq. km. About 65% of Penang Island is still covered with vegetation while 35% is an urban (Cockatoo, 2002).

(1a)

Figure 1a. Penang Island on the Malaysian Map (Source: Penang Map and Interesting Locations, 2002)

(1b)

Figure 1b. Penang Island from Landsat-5 TM image acquired on 3 March 1998

DATA AND TECHNIQUES

Data

Two sets of satellite imageries were used in this study: TiungSAT-1 image (6 April 2001) and LandSAT image (3 March 1998). TM image was used as a base data to compare the results obtained from TiungSAT-1 image. Coefficients of TC were generated using Fortran Power station 4.0. With the generated coefficients, TTC was performed using the ERDAS MODELER. A brief description about TiungSAT-1 and TM images used in this study is given below:

Table 1. Specification of TiungSAT – 1 and LandSAT 5 TM Images Used in the Study

Satellite	TiungSAT-1	LandSAT 5
Sensor	KAI-1001 non- interlaced scientific sensor	*Thematic Mapper*
System	Passive	Passive
Altitude	670 km	705 km
Pixel size	80 m	30 m
Bands	1 – (0.50-0.59 µm)	1-(0.45-0.52 µm)
	2 – (0.61-0.69 µm)	2-(0.52-0.60 µm)
	3 – (0.81-0.89 µm)	3-(0.63-0.69 µm)
		4-(0.75-0.90 µm)
		5-(1.55-1.75 µm)
		7-(2.08-2.35 µm)

Techniques

The geometry correction of both TM and TiungSAT-1 data was carried out based on the topographic map of Penang with the scale of 1:87000. For LandSAT image, 12 sets of coordinates were determined from the map and geometric correction was done based on image to map technique. The RMSE of the correction is 0.3491. Subsequently, the TiungSAT-1 image was corrected using image to image method where corrected TM image acted as the master and TiungSAT-1 image as a slave image. A total of 8 sets of coordinates were used in each band of TiungSAT-1 image. This procedure yielded RMSE of 0.0633 for Band 1, 0.527 for Band 2 and 0.0462 for Band 3 (Appendices 4, 5, 6 and 7). After the Geometry Correction, nearest neighbors resampling technique was used to resample the image.

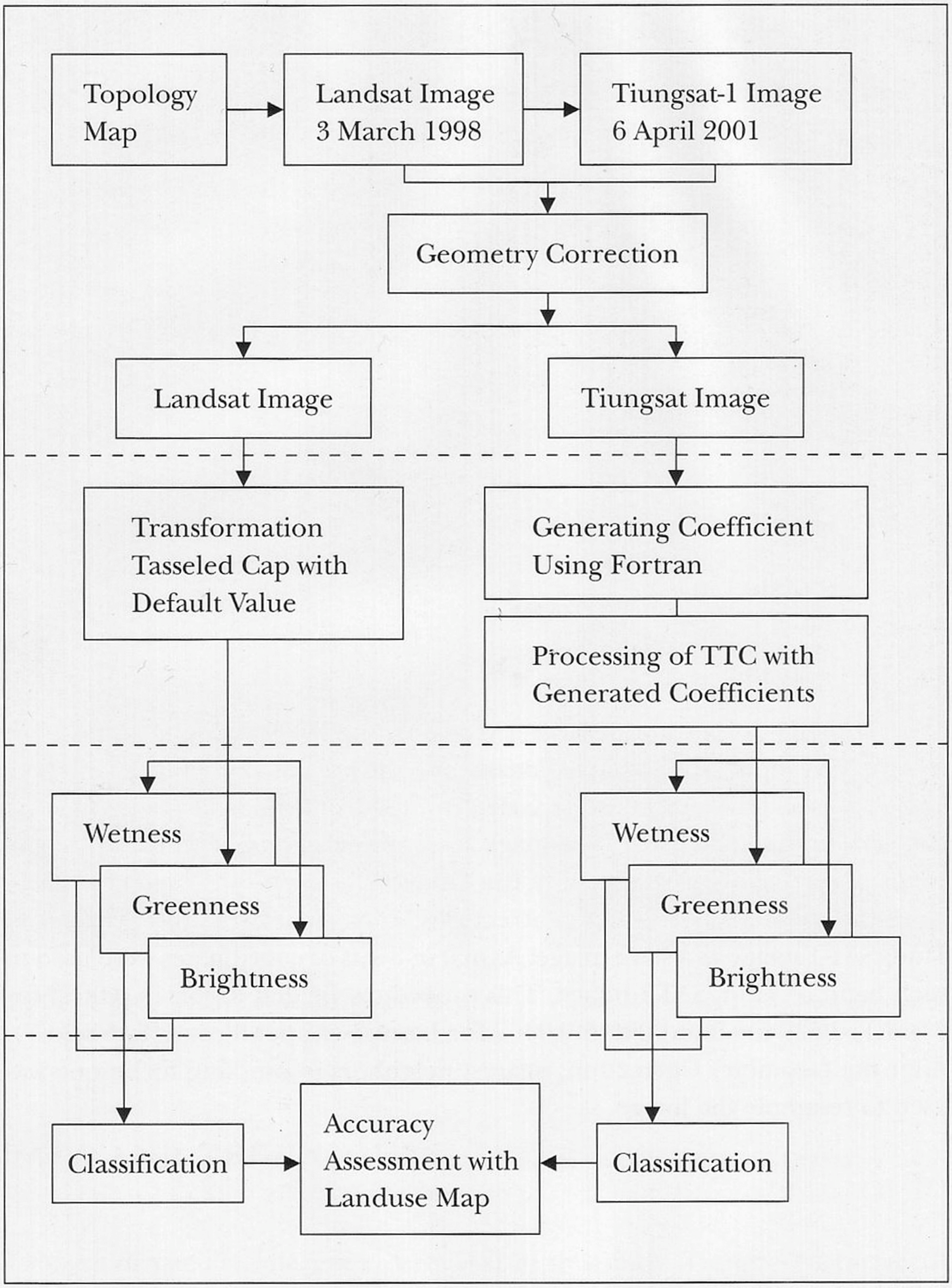


Figure 2. Methods Adopted in the Study

The next step was generating TTC Coefficients for TiungSAT-1 data with Fortran. The flowchart for generating the algorithm is shown in Figure 3.

Generating Brightness Coefficients

First step:
Bvalue = Sqrt (((Drysoil1 - Wetsoil1) **2) + ((Drysoil2 - Wetsoil2) **2) + ((Drysoil3 - Wetsoil3) **2))

Second step:
Brightco1 = (Drysoil1 - Wetsoil1) / Bvalue
Brightco2 = (Drysoil2 - Wetsoil2) / Bvalue
Brightco3 = (Drysoil3 - Wetsoil3) / Bvalue
Where,
Bvalue = Temporary value for second step
Drysoil 1,2,3 = Mean value dry soils for band 1,2,3
Wetsoil 1,2,3 = Mean value wet soils for band 1,2,3
Brightco 1,2,3 = Brigthness coefficients for band 1,2,3

Generating Greenness Coefficients

First step:
Gvalue = ((Grnveg1 - (Dryveg1 * Brightco1)) + (Grnveg2 - (Dryveg2 * Brightco2)) + (Grnveg3 - (Dryveg3 * Brightco3)))

Second step:
Grntemp1 = (Grnveg1 - Drysoil1) - (Gvalue * Brightco1)
Grntemp2 = (Grnveg2 - Drysoil2) - (Gvalue * Brightco2)
Grntemp3 = (Grnveg3 - Drysoil3) - (Gvalue * Brightco3)

Third step:
Divval = Sqrt ((Grntemp1 ** 2) + Grntemp2 ** 2 + (Grntemp3 ** 2))

Fourth step:
Greenco1 = Grntemp1/ Divval
Greenco2 = Grntemp2/ Divval
Greenco3 = Grntemp3/ Divval
Where, Grnveg 1,2,3 = Mean value green vegetable for band 1,2,3
Dryveg 1,2,3 = Mean value dry vegetable for band 1,2,3
Brightco 1,2,3 = Brightness coefficients TTC for band 1,2,3
Grntemp = Temporary greenness value
Divval = Temporary value for step four

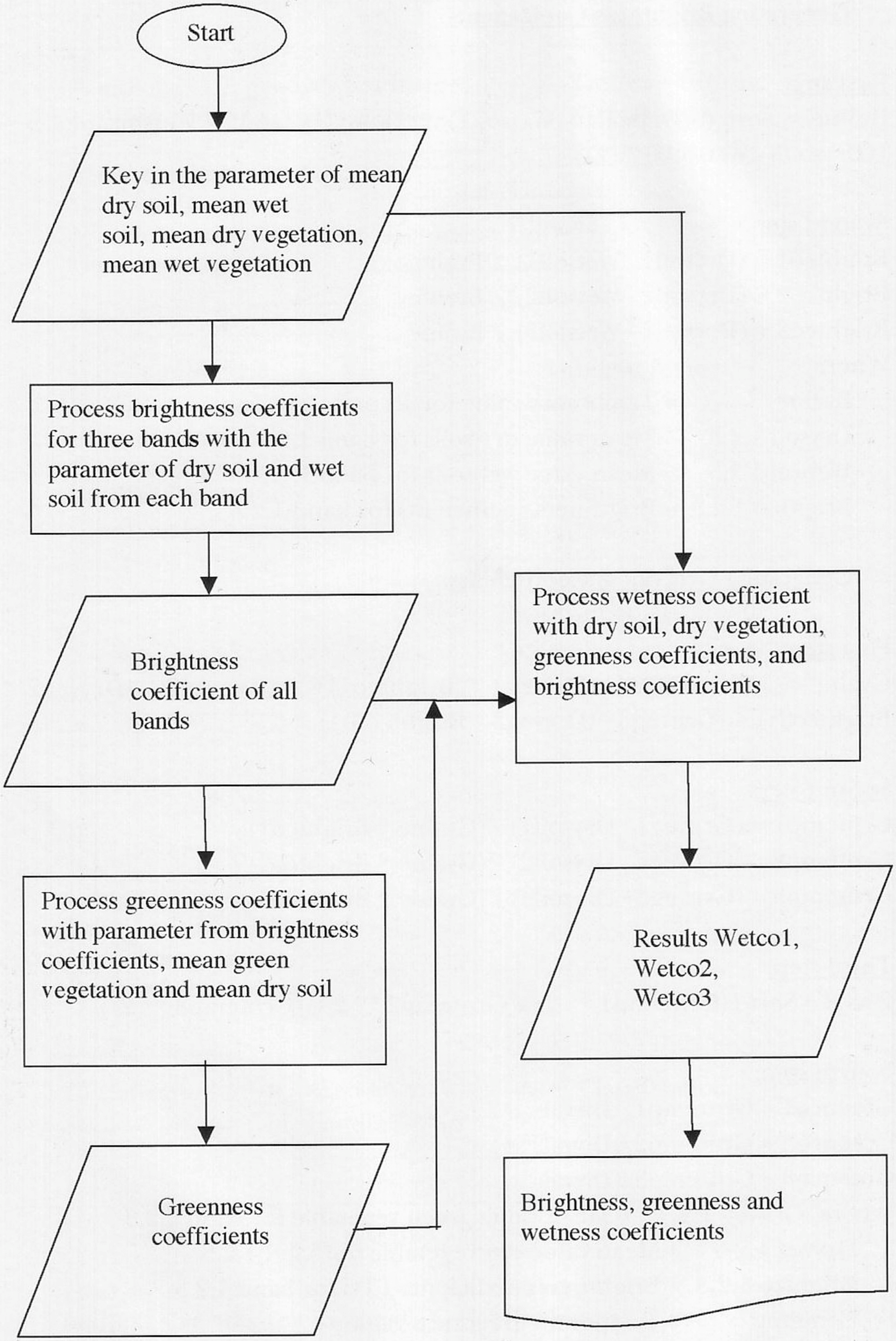


Figure 3. Steps for Generating TC Coefficients

Generating Wetness Coefficients

First step:

Wvalue1 = Dryveg1 - Drysoil1
Btemp = (Dryveg1 - Drysoil1) * Brightco1
Gtemp = (Dryveg1 - Drysoil1) * Brightco1
Wvalue 2 = Dryveg 2 - Drysoil 2
Btemp = (Dryveg2 - Drysoil2) * Brightco2
Gtemp = (Dryveg2 - Drysoil2) * Brightco2
W value 3 = Dryveg3 - D rysoil 3
Btemp = (Dryveg3 - D rysoil 3) * Brightco3
Gtemp = (Dryveg3 - D rysoil 3) * Brightco3

Second step:

Wvalue1 = Wvalue1 - ((Btemp* Brightco1) + (Gtemp* Greenco1))
Divval = Wvalue1 * Wvalue1
Wvalue2 = Wvalue2 - ((Btemp * Brightco2) + (Gtemp * Greenco2))
Divval = Wvalue2 * Wvalue2
Wvalue3 = Wvalue3 - ((Btemp * Brightco3) + (Gtemp * Greenco3))
Divval = Wvalue3 * Wvalue3

Third step:

Divval = Sqrt (Divval)

Fourth step:

Wetco1 = Wvalue1 / Divval
Wetco2 = Wvalue2 / Divval
Wetco3 = Wvalue3 / Divval

Where, Drysoil 1,2,3 = mean value dry soil for band 1,2,3
Wetsoil 1,2,3 = mean value wet soil for band 1,2,3
Grnveg 1,2,3 = mean value green vegetable for band 1,2,3
Dryveg 1,2,3 = mean value dry vegetable for band 1,2,3
Btemp = temporary brightness value at second step
Gtemp = temporary greenness value at second step

The values for parameters Drysoil (bands 1,2,3), Wetsoil (bands 1,2,3), Grnveg (bands 1,2,3) and Dryveg (bands 1,2,3) were acquired as follows:

The values are actually mean pixel values representing each land use types such as drysoil, wetsoil, green vegetation and dry vegetation on the image. Those values were obtained by selecting 20 sample points for each land types on the image based on landuse map and field visits. For drysoil, Georgetown and some industrial areas were selected, whereas for wetsoil, Pulau Jerejak and surrounding areas of the dam and sea lands were chosen. Meanwhile, Tanjung Bunga forest area and Pulau Rimba represent green vegetation and, finally, dry vegetation is represented by dry grassland.

The next step after generating TTC coefficients was using the coefficients to generate TCT layers for TiungSAT-1 image. This process was done by using the ERDAS MODELER. A new model was created by computing the algorithm as shown below.

Brightness = (Brightco1 * Piselvalue1) + (Brightco2 * Piselvalue2) + (Brightco3 * Piselvalue3)

Greenness = (Greenco1 * Piselvalue1) + (Greenco2 * Piselvalue2) + (Greenco3 * Piselvalue3)

Wetness = (Wetco1 * Piselvalue1) + (Wetco2 * Piselvalue2) + (Wetco3 * Piselvalue3)

Where Brightness = Output Brightness
Greenness = Output Greenness
Wetness = Output wetness
Brightco = Coefficients for each band
Greenco = Coefficients for each band
Wetco = Coefficients for each band

Subsequently, supervised classification (maximum-likelihood technique) was performed on both TiungSAT-1 and TM scenes. Five land cover types were classified in each scenes. The basic surface types, including water, forest, urban, and open land (non-forested areas such as clear-cuts and development area) were classified. Spectral signatures for the surface types were identified from the spatial distribution pattern shown in TCT layers to form training sets. Reference information including the landuse and topographic map and ground visiting were also used to set training areas.

The final task was to perform an accuracy assessment. Two sources of information were applied to perform the accuracy assessment: The classified image and the reference test information. The relationship of the two sets of information was summarized in an error matrix. Random sampling schemes were used to define the reference sets of test information.

RESULTS AND DISCUSSION

Coefficients

The generated coefficients using FORTRAN are shown in Table 2 below. These coefficients were used to produce TCT in the form of three planes of brightness, greenness and wetness in the ERDAS modeler.

Table 2. TTC Coefficients Generated using FORTRAN

	1	2	3
Brightness	0.4515697	0.7586371	0.4696325
Greenness	-0.6999524	-0.2350673	-0.6743960
Third (wetness)	-1.037826	-0.7900305	-1

The coefficients for wetness layer could not be accurately calculated due to the absence of longer infrared channel i.e. MIR in TiungSAT-1 data. Wetness layer is generated by dividing reflectance values from both visible and near infra red with reflectance values from mid infra red band. Formula for generating brightness, greenness and wetness values are given below:

Brightness = 0.4515697TS1+ 0.7586371 TS2 + 0.4696325 TS3
Greenness = 0.6999524 TS1 + -0.2350673 TS2 + -0.6743960 TS3
Wetness = -1.037826 TS1 + -0.7900305 TS2 + -1 TS3

TS 1, 2, 3 = Pixel values from TiungSAT-1 at Bands 1, 2 and 3.

Tasseled Cap Transformation

The generated coefficients were used to produce TCT on TiungSAT-1 image using ERDAS MODELER. Tasseled Cap Transformation was also performed for TM image in order to compare the accuracy of TiungSAT-1's TTC. Figure 4 shows TTC products from both TiungSAT-1 and TM images. With reference to Figure 4, the vegetated areas are revealed as a bright tone in greenness image whereas the same area is shown as a darker tone in brightness image. On the contrary, urban and concrete areas are revealed as a brighter tone in brightness image and a darker tone in greenness image. The brighter tone in wetness image is directly associated with the amount of water content in the soil. The absence of MIR channel in TiungSAT-1 image hinders the production of wetness layer. The comparison made between TC images of TM and TiungSAT-1 shows that greenness and brightness images are similar while wetness image is different.

Classification

Five land cover classes were identified in both images. The purpose of the classification is to see, for example whether areas classified as forest and orchard show brighter tone in greenness layer and so on. Comparison between Figure 4 (TTC products) and Figure 5 (classified images) shows that left half of the island which represents forest and orchard are revealed as a brighter tone in greenness layer in both TiungSAT-1 and TM images, and a much more darker tone in brightness layer. Similarly, urban and bare soil (red and yellow color in Figure 5) are revealed as a brighter tone in brightness image but a darker tone in greenness layer. Wetness layer (Figure 4c) shows a much brighter tone for vegetation areas and the brightest tone for sea.

Accuracy assessment of classified images was done based on sample points taken from land use map of Penang. The overall accuracy achieved is 80.5% for TM and 77.6% for TiungSAT-1 (Table 3). Although both of the images use their own coefficients to generate TC, the difference is small. The slight difference in the overall accuracy between the two images could be due to the different date of data acquisition where TM is acquired in 1998 and TiungSAT-1 in 2000.

Table 3. The Overall Accuracy of Classified (Tasseled Cap) TiungSAT-1 and Images

Classification	Overall Accuracy	kappa
Image Tasseled cap LandSAT	80.5070 %	0.7485
Image Tasseled Cap TiungSAT-1	77.5610 %	0.7154

Analysis of Spatial Distribution

Pixel values derived from the TTC images were plotted to analyze the trend of each land cover types in the study area. Six categories of land cover used are urban and concrete, forest, clear water, turbid water, bare soil and vegetation. The brightness, greenness and wetness values obtained from TiungSAT-1 image were then compared with the original theory to see how accurate the TiungSAT-1 image was classified using the generated coefficients. This is shown in Figure 6. The three TTC layers were plotted against each other. For example, brightness values were plotted against greenness, wetness against greenness and brightness against wetness. The results of distribution in the three axes show that the pattern is not much different from the basic pattern of Tasseled Cap Transformation. The distribution of forest is at the upper left-most forming the tasseled cap. This pattern proves the truth that healthy, green vegetation has higher greenness

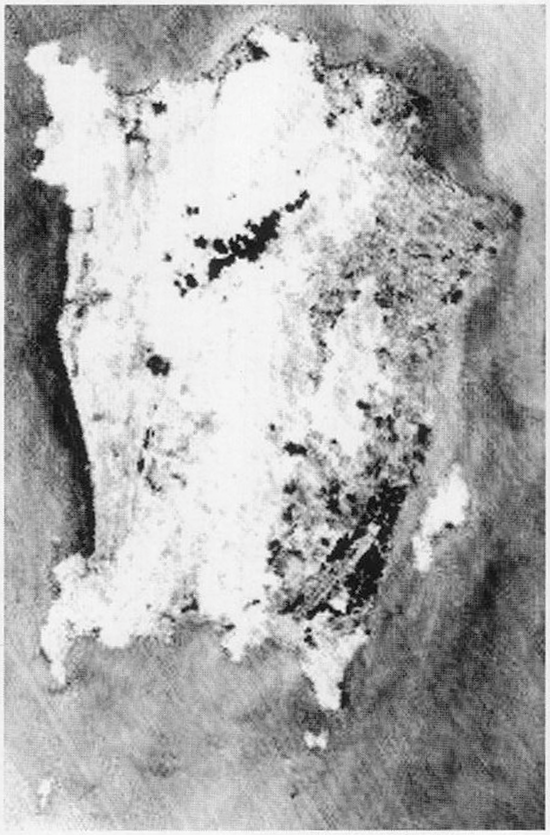


Figure 4a (i). Greenness image from TiungSAT-1

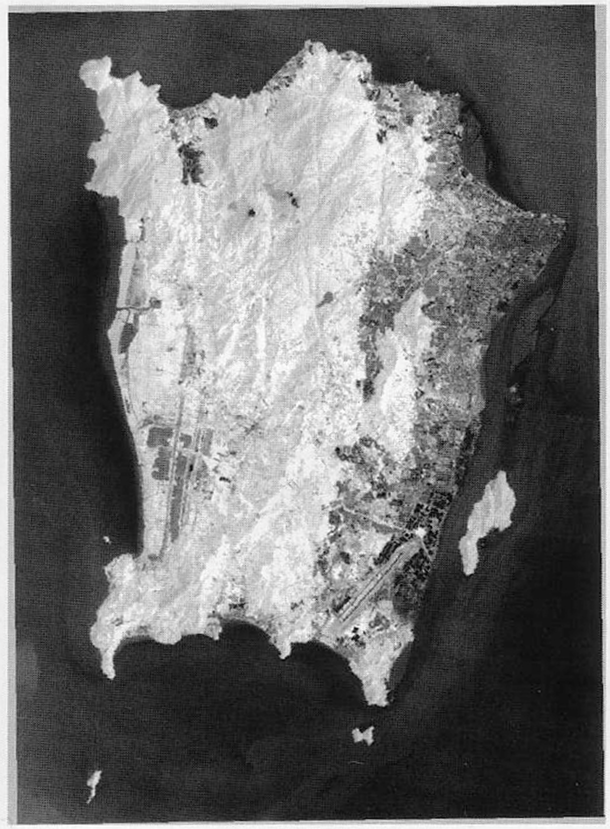


Figure 4a (ii). Greenness image from LandSAT

Figure 4b (i). Brightness image from TiungSAT-1

Figure 4b (ii). Brightness image from LandSAT

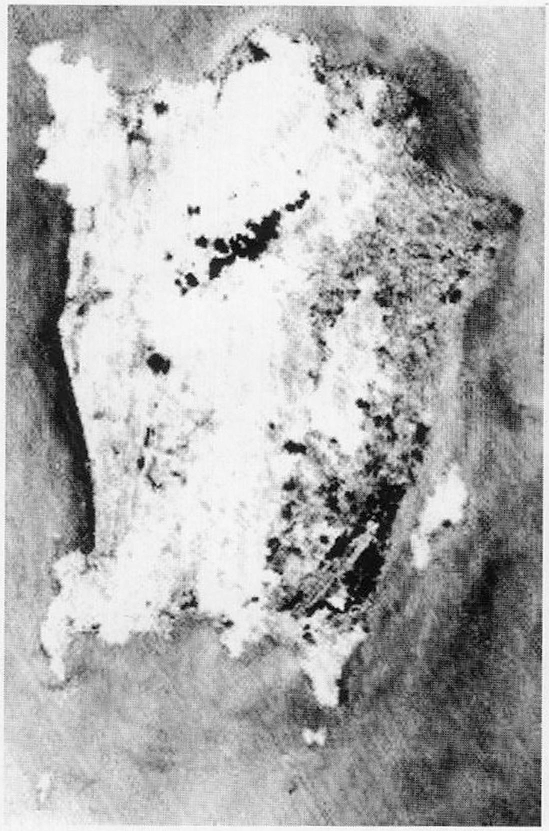


Figure 4c (i). Wetness image from TiungSAT-1

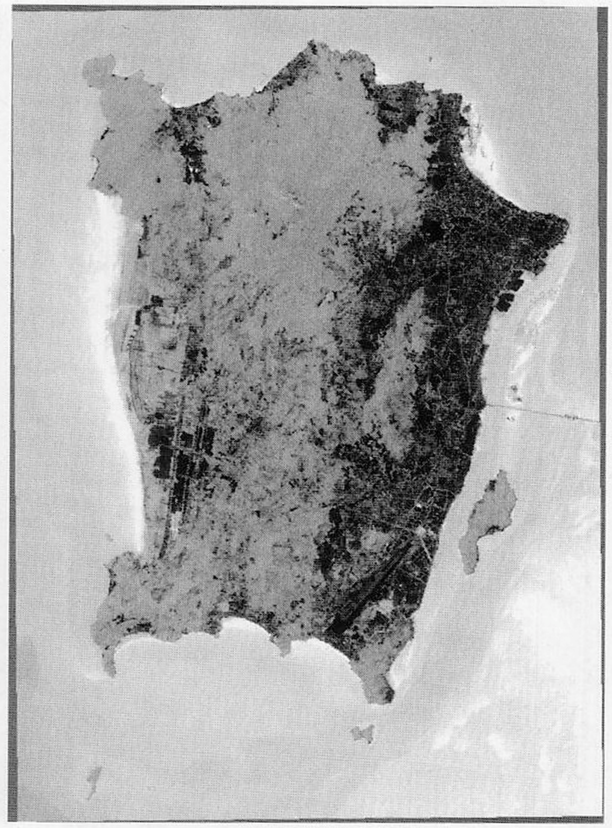


Figure 4c (ii). Wetness image from LandSAT

values but lower brightness values. On the contrary, distribution of urban and concrete and bare soil are at the lower right-most in the graph. This indicates that land with less/without any vegetation reveal low values in greenness but high values in brightness (representing soil information). Green vegetation also has high moisture content and this is shown by their values in wetness layer.

CONCLUSION

The generated coefficients for TiungSAT-1 image produce good results. This is done by comparing the TTC products produced using the generated coefficients in TiungSAT-1 image with TTC products of TM image. Furthermore, classification results also show similarity with TTC products. In addition, the spatial distribution of pixels from TTC products of TiungSAT-1 image coincides with the original theory. Therefore, it can be summarized that the generated coefficients are good and reliable in extracting vegetation information from TiungSAT-1 imagery. However, the absence of MIR channel in TiungSAT-1 image

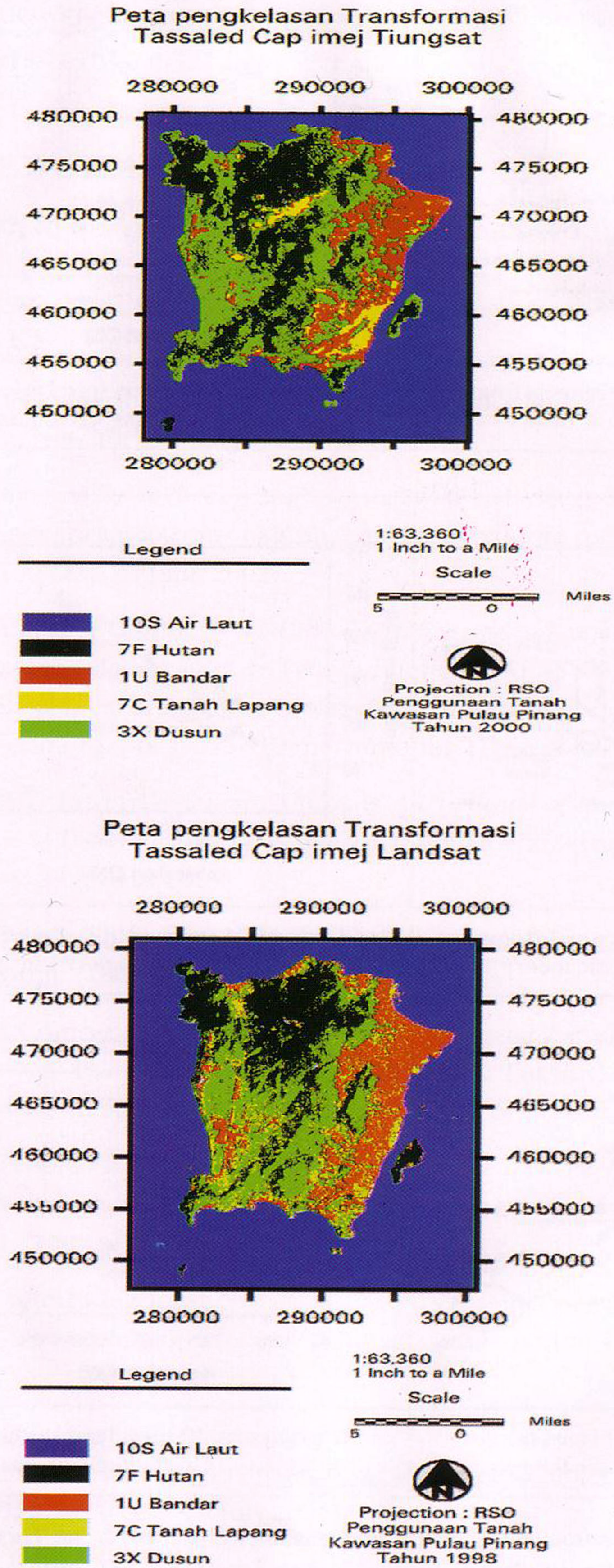
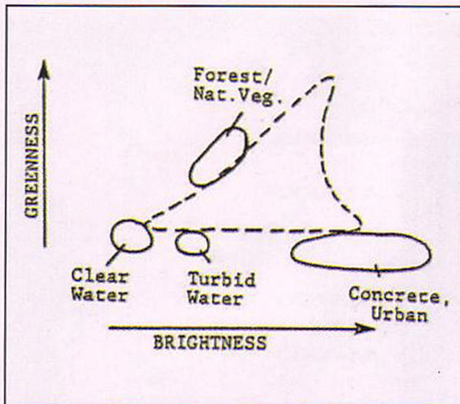
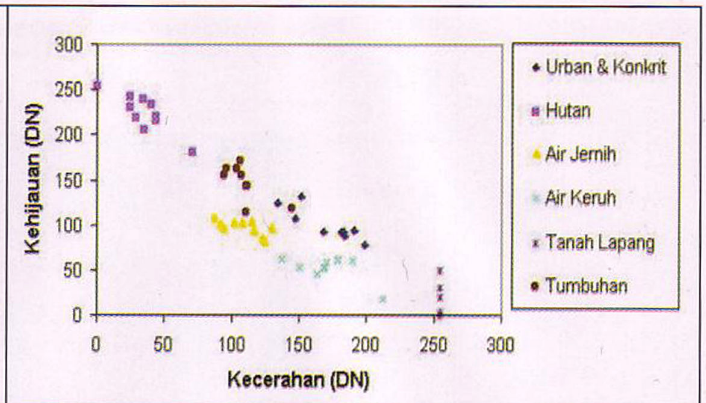


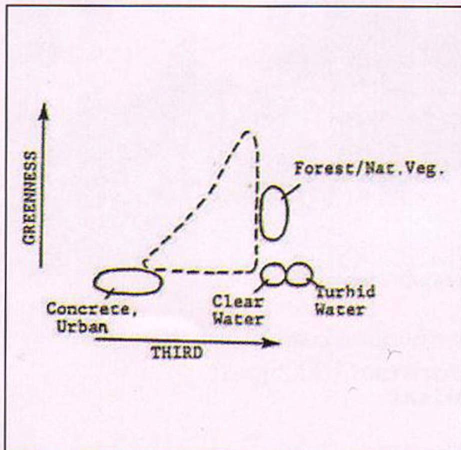
Figure 5. Classified (Tasseled Cap) images of TiungSAT-1 and TM.



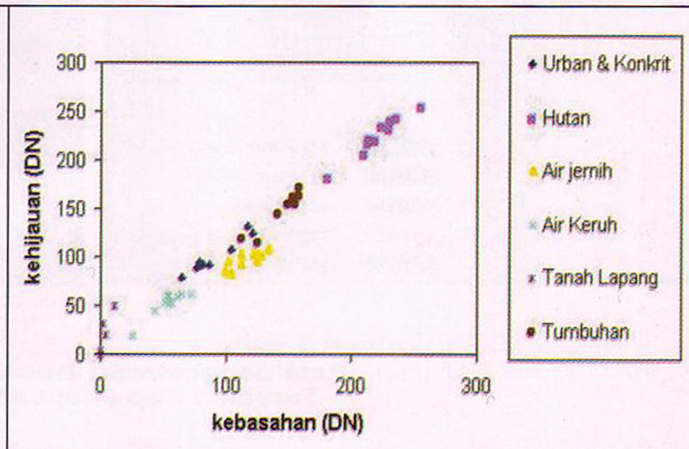
Brightness vs. Greenness from LandSAT/basic theory



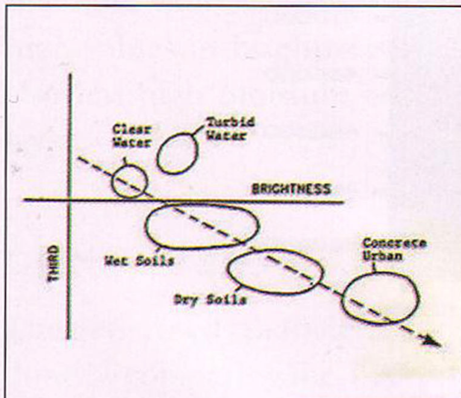
Brightness vs. Greenness (pixel values from Tasseled Cap TiungSAT-1 image



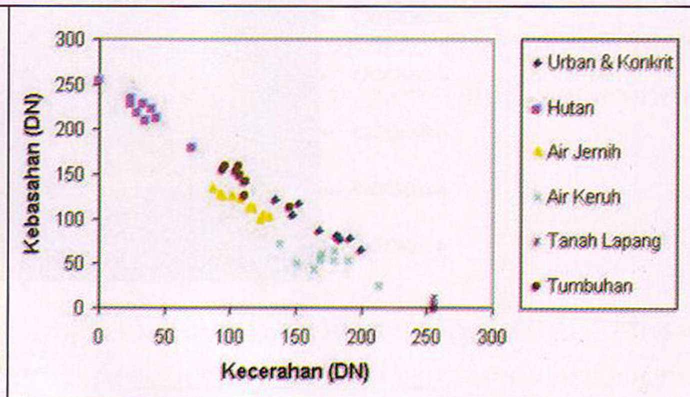
Third vs. Greenness from LandSAT/basic theory



Wetness vs. Greenness (pixel values from Tasseled Cap TiungSAT-1 image



Brightness vs. Third from LandSAT/basic theory



Brightness vs. Wetness (pixel values from Tasseled Cap TiungSAT-1 image

Figure 6. Comparison of TCT values (using generated coefficients) for TiungSAT-1 with the original pattern of distribution from LandSAT's TTC basic theory.

affects the production of a more accurate wetness layer. This problem is expected to be resolved in the future.

ACKNOWLEDGEMENTS

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APPENDICES

Appendix 1. Tasseled Cap Coefficients for LandSAT MSS				
	Band 4	**Band 5**	**Band 6**	**Band 7**
Brightness	0.433	0.632	0.586	0.264
Greenness	-0.290	-0.562	0.600	0.491
Yellowness	-0.829	0.522	-0.039	0.194
Non-such	0.223	0.012	-0.543	0.810

Appendix 2. Tasseled Cap Coefficients for LandSAT TM						
Band 1	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 7**	
Brightness	0.3037	0.2793	0.4743	0.5585	0.5082	0.1863
Greenness	-0.2848	-0.2435	-0.5436	-0.7243	-0.0840	-0.1800
Third (wetness)	0.1509	0.1973	0.3279	0.3406	-0.7112	-0.4572
Fourth	-0.8242	0.0849	0.4392	-0.0580	0.2012	-0.2768
Fifth	-0.3280	0.0549	0.1075	0.1855	-0.4357	0.8085
Sixth	0.1084	-0.9022	0.4120	0.0573	-0.0251	0.0238

Appendix 3. Tasseled Cap Coefficient for LandSAT 7						
	Band 1	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 7**
Brightness	0.3037	0.2793	0.4743	0.5585	0.5082	0.1863
Greenness	-0.2848	-0.2435	-0.5436	-0.7243	-0.0840	-0.1800
Third (wetness)	0.1509	0.1973	0.3279	0.3406	-0.7112	-0.4572
Fourth	-0.8832	-0.0819	-0.4580	-0.0032	-0.0563	0.0130
Fifth	0.0573	-0.0260	0.0335	-0.1943	0.4766	-0.8545
Sixth	0.1238	-0.9038	0.4041	0.0573	-0.0261	0.0240

Appendix 4. GCPs for Correcting LandSAT TM Image

	Cell X	**Cell Y**	**Easting (m)**	**Northing (m)**	**X Residual**	**Y Residual**	**RMS**
GCP #1	2773.0504	-4586.2681	279700	478500	0.168	0.011	0.168
GCP #2	3056.6684	-4559.3554	288800	479500	-0.056	-0.004	0.056
GCP #3	3380.6553	-4783.9726	299300	472200	-0.373	-0.025	0.037
GCP #4	3300.5640	-5094.6919	296900	461900	1.032	0.069	1.034
GCP #5	3177.9298	-5301.8476	293000	455000	-0.332	-0.022	0.333
GCP #6	2991.1835	-5299.6518	287000	455000	-0.180	-0.012	0.181
GCP #7	2781.1983	-5167.1179	280200	459300	0.022	0.001	0.022
GCP #8	8731.1434	-10681.6501	279300	473600	0.056	0.004	0.056
GCP #9	2812.8015	-4886.1868	281100	468600	0.063	0.004	0.038
GCP #10	2846.1733	-5198.1296	282300	458300	-0.038	-0.003	0.064
GCP #11	3172.0759	-4860.7082	292631	469500	-0.222	-0.015	0.223
GCP #12	3061.1976	-4887.2625	289080	468800	-0.138	-0.009	0.139

Titik kawalan selisih X = 0.3483, Y= 0.0232 RMS = **0.3491**

Appendix 5. GCPs for correcting band 1 of TiungSAT-1 image

	Input X	Input Y	Petunjuk X	Petunjuk Y	**X Residual**	**Y Residual**	**RMS**
GCP #1	436.559	1197.338	280306.656	479114.719	0.049	0.064	0.080
GCP #2	525.080	1277.275	299421.906	472159.969	-0.012	-0.011	0.016
GCP #3	868.153	1010.901	296700.565	461914.196	0.043	0.028	0.051
GCP #4	765.542	631.552	291261.651	450282.387	-0.050	0.013	0.052
GCP #5	548.919	278.115	280459.843	453318.000	0.014	-0.075	0.076
GCP #6	135.366	325.793	280087.000	458915.884	0.045	0.064	0.078
GCP #7	161.278	501.993	279238.121	473772.118	-0.088	-0.034	0.094
GCP #8	154.023	886.525	288652.876	479879.337	-0.001	-0.049	0.049

RMSE X =0.0458, Y= 0.0480 RMS = **0.0633**

Appendix 6. GCPs for correcting band 2 of TiungSAT-1 image							
	Input X	**Input Y**	**Petunjuk X**	**Petunjuk Y**	**X Residual**	**Y Residual**	**RMS**
GCP #1	433.509	-95.114	280147.744	479081.365	-0.014	-0.044	0.046
GCP #2	584.821	-290.375	299129.442	472390.168	-0.013	-0.005	0.014
GCP #3	491.821	-376.625	296677.692	461947.529	0.026	-0.058	0.063
GCP #4	372.321	-436.375	291229.539	452140.530	-0.053	0.059	0.080
GCP #5	267.821	-352.875	280423.498	453139.392	0.060	-0.023	0.064
GCP #6	390.321	-144.625	279424.637	473570.640	-0.027	0.038	0.047
GCP #7	296.445	-307.490	280332.693	457679.669	-0.015	-0.009	0.018
GCP #8	541.071	-163.625	290502.915	479291.390	0.036	0.040	0.054
RMSE X = 0.0349, Y= 0.0396 RMS = **0.0527**							

Appendix 7. GCPs for correcting band 3 of TiungSAT-1 image							
	Input X	**Input Y**	**Petunjuk X**	**Petunjuk Y**	**X Residual**	**Y Residual**	**RMS**
GCP #1	483.759	-37.800	280147.744	479081.365	0.071	0.051	0.087
GCP #2	637.080	-233.902	299129.442	472390.168	0.048	0.060	0.076
GCP #3	543.492	-318.895	296643.750	461929.750	0.012	-0.090	0.091
GCP #4	426.321	-380.875	291543.750	452010.250	-0.024	0.033	0.041
GCP #5	317.162	-295.021	280422.874	452960.940	0.057	0.036	0.067
GCP #6	440.354	-83.971	279090.208	473743.914	-0.019	-0.065	0.068
GCP #7	343.902	-249.182	280170.750	457467.250	-0.060	-0.016	0.062
GCP #8	591.241	-104.980	290323.819	479369.851	-0.085	-0.008	0.085
RMSE X = 0.0405, Y= 0.0223 RMS = **0.0462**							