COMPARISONS OF THREE REMOTELY SENSED DATA ON FOREST CROWN CLOSURE AND TREE VOLUME ESTIMATIONS

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ABSTRACT

The aim of this study is to examine the airborne multispectral scanning data, the SPOT HRV data, and the Landsat-TM data on forest crown closure and stand volume estimation. The airborne multispectral scanning data used in this study were MSS_1 to MSS_6 and MSS_8 to MSS_{11}. The SPOT data were XS_1、XS_2 and XS_3, and the Landsat-TM data were TM_1 to TM_5 and TM_7. All the digital data were collected from each sample plots which were respectively located on geometric corrected and radiomatic corrected airborne multispectral scanning, the SPOT and the Landsat-TM imageries. The stepwise regression approach was used to establish the regression equations in which the spectral bands, and their combinations were used as the independent variables and the forest crown closure and the stand volume were as the dependent variable. The spectral bands was the individual bands of the multispectral scanning data, the SPOT data and Landsat-TM data. The combinations were (1) band difference(2) normalization difference (3) tree ages and crown closure.The optimum equation was selected by their significant statistical F value and higher coefficient of determination(R^2). The findings of this paper were as follows：(1) The crown closure equations that were estabished by three remotely sensed data were eligible. Among the three equations, the equation which was developed by Landsat-TM data was the best, The airborne multispectral scanning data the second, the SPOT HRV data the third. (2) The stand volume equation that were estabished by three remotely sensed data were not eligible. Another parameters such as tree ages and crown closures were added. Especially the age factor was much more effectively. (3) On the crown closure and stand volume equation establishment, three independent variables were enough. No more variables were needed.

INTRODUCTION

Forest stand volume estimation is one of the main problems of forest mensuration. Foresters have examined the potentialities and limitations of estimations of tree volume and its related factors in the forests or on the aerial photograph for many years. Since the Landsat MSS data have been available in 1970's, the digital data and derived imagery have been used for monitoring vegetation change in extensive area but little utilized on forest stand estimation. The important reason for this was the relatively coarse resolution (80m) of the Landsat MSS data. However, this situation has altered in 1980's. Several new sensors such as Landsat-TM, SPOT HRV have been available. More spectral bands and fine resolution of these sensors made the detailed forest measurements possible . Some of the research interest were focus on forest canopy determination, and green biomass and tree volume estimation.

The aim of the work reported in this paper was to investigate the effects of different remotely sensed data on forest crown closure and tree volume estimation. These remotely sensed data were the airborne multispectral scanning data, the SPOT HRV data, and the Landsat-TM data. Some bands, of these three remotely sensed data were close related with vegetation condition. For example, in the visible and infrared regions, the forest crown closure is strongly correlated to the dry matter accumulation of trees. Green leaves of trees absorb red light and reflect the near-infrared radiation strongly. The red light is used in the photosynthesis as a catalyst for the conversion of water and carbon dioxide into sugars and hence all organic matter. So, the photosynthesis is direct related to tree biomass accumulation. In other words, the spectral reflectance in the visible and near-infrared regions can be used to estimate forest crown closure and stand volume.

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MATERIALS AND METHODS

1.The study site

This study was conducted in the Chi-tou district of the Experimental Forest of National Taiwan Universing in the central portion of Taiwan. The study area covers a 5,000 ha. section of national forest land with elevations ranging from 750m to 1,800m. The annual precipitation of this area is about 2,500mm and the humidity 85%. There are 1,500 ha. Man made plantations with ages from 1 to 80 years old. The others were covered by natural hardwoods and bamboos. In this long-time managed area, basic data of trees such as tree species, height, crown diameter, crown closure, growth situation and volume were available.

2.Data Utilized

These three remotely sensed data used in this study were adopted from the author's past study "A Study of Using Spectral Reflectance to Estimate Forest Crown Closure". In the above mentioned paper, the airborne multispectral scanning data were acquired by a DS-1260 airborne MSS system with 11 channels on April 10, 1987. A Computer Compatable Tape (CCT) containing airborne MSS data in band 1 to band 11 except band 7 were used in data processing. The SPOT data (band XS_1 、 XS_2 and XS_3)were acquired on December 10, 1986. It was raw level-1 images recorded in multispectral mode. The Landsat-TM data were acquired by Landsat-5 on January 17, 1987 with path/row annotation of 117/44. All six reflective TM bands were utillized in this study. The thermal infrared data which have 120m spatial resolution were not used (Table 1).

Table 1 、 Remotely Sensed Data Used in This Study

Sensor	Recording Date	Band	Wavelength interval (um)
Airborne multispectral scanner	04/10/87	1	0.38-0.42
		2	0.42-0.45
		3	0.45-0.50
		4	0.50-0.55
		5	0.55-0.60
		6	0.60-0.65
		8	0.70-0.79
		9	0.80-0.89
		10	0.92-1.10
		11	8.50-13.0
SPOT-HRV	12/10/86	XS_1	0.50-0.59
		XS_2	0.61-0.68
		XS_3	0.79-0.89
Landsat-TM	01/17/87	1	0.45-0.52
		2	0.52-0.60
		3	0.63-0.69
		4	0.76-0.90
		5	1.55-1.75
		7	2.08-2.35

3.Data Processing

The image processing techniques of these remotely sensed data were implemented through the use of the Earth Resources Data Analysis System (ERDAS). In the geometric correction aspect, 22 、21 and 26 widely scattered ground control points were selected respectively from the airborne MSS, SPOT HRV and Landsat-TM images to compute the equations that transformed the images into the Transverse Mercator Coordinate System of the base map. The pixels of these remotely sensed data were resampled to a 10m×10m 、20m×20m and 30m×30m respectively by the nearest neighbor algorithm, The root-mean-squared error (RMSE) of the linear transformation model of these three images were 0.831 、0.711, and 0.489.

4.Independent Variables

On the sample plots selecting, forest maps of the study area were overlaid on the three remotely sensed images respectively by the assistance of GIS data. The total 78 sample plots were drawn systematically from each image. The digital data utilized in this study were collected from these sample plots. The independent variables of the equation in this study were the digital mumber of individual band, vegetation index, tree ages and crown closures. The digital number of individual band were collected from each sample plots. Six vegetation indices were computed from the equation as follows : IND_1 =NIR-R, IND_2=(NIR-R)/(NIR+R), $IND_3=(IND_2 +0.5)^{1/2}$, IND_4=NIR-G, IND_5=(NIR-G)/(NIR+G), and $IND_6= (IND_5+0.5)^{1/2}$, where, NIR is near-infrared band, R is red band , and G is green band. Tree ages were adopted from tree plantation's records. Forest crown closures were measured with a crown density scale under a stereoscope from the corresponding plots on the aerial photographs.

5.Regression equtation

Regression equations were derived from multiple regression analysis by using the digital number of spectral individual bands and vegetation indices. The individual band and vegetation index were the independent variables, and the forest crown closures and tree volumes were the dependent variables. The stepwise regression approach in the Statistical Analysis System (SAS) package was used to select the equations. Among the selected equations, one optimum equation was selected by significant F-value and higher coefficient of determination (R^2)value.

RESULTS AND DISCUSSIONS

1.Individual Band

As mentioned preeviously, the Statistical Analysis System (SAS) was used to perform the multiple regression analysis. In these regression equations, the individual band of remotely sensed data were used as the independent variable, and the forest crown closure which was measured in the corresponding plot on the aerial photographs was the dependent variable. Stepwise regression approach was used to selection the equation. Only the one with a significant F-value and higher R^2 value was adopted. Table 2 was the result of regression analysis of crown closure for the three indiviaual bands of the airborne multispectral scanning data. Selected individual bands were MSS_5(green) 、MSS_8(near-infrared) and MSS_9(near-infrared). Follow the same procedure, the results of regression analysis of stand volume for three individual bands of airborne multispectral data was obtained. The three selected individual bands of stand volume equation were MSS_5(green) 、MSS_6(red) and MSS_9 (near-infrored).

The SPOT data and Landsat-TM data were treated in the same way. All of the three SPOT XS bands were selected in the crown closure and stand volume estimation equation. In the Landsat data aspect, the TM_1 、TM_4 and TM_5 were selected in the crown closure equation; the TM_1 、TM_2 and TM_4 were selected in the stand volume estimation equation. The results were shown in Table 3.

Table 2 、Analysis of Variance of Crown Closare for Three Best Bands of Airborne Multispectral Scanning Data

R^2=0.53220190 C(p)=2.97888408

sources of variation	DF	sum of squares	mean square	F-value	prob>F
regression	3	986.09716302	328.69905434	25.79	0.0001
error	68	866.76574777	12.74655511		
total	71	1852.86291079			

variable	parameter estimate	S E	T for Ho Parameter=0	F-value	prob> | T |
intercept	57.06773936	39.39916581	26.74238352	2.10	0.1521
MSS_5	-0.21644522	0.06699600	133.24272339	10.44	0.0019
MSS_8	-0.46578177	0.12857460	167.28132398	13.12	0.0006
MSS_9	0.58403068	0.19274431	117.03102980	9.18	0.0035

Table 3 、The Selected Three Independent Variables and Their Statistics of Individual Band Data

sensor	dependent variable	independent		variable				R^2	F-value	prob
multi-spectral scanner	crown closure	MSS_5		MSS_8		MSS_9				
		10.44	0.0019	13.12	0.0006	9.18	0.0035	0.532	25.79	0.0001
	volume	MSS_5		MSS_6		MSS_9				
		2.17	0.1454	4.47	0.0383	4.66	0.0344	0.119	3.07	0.0336
SPOT HRV	crown closure	XS_1		XS_2		XS_3				
		17.6	0.0001	12.54	0.0007	3.28	0.0739	0.83	72.73	0.0001
	volume	XS_1		XS_2		XS_3				
		0.99	0.3236	1.55	0.217	0.80	0.3737	0.013	2.66	0.0537
Landsat-TM	crown closure	TM_1		TM_4		TM_5				
		19.49	0.0001	445.34	0.0001	164.26	0.0001	0.903	232.49	0.0001
	volume	TM_1		TM_2		TM_4				
		1.61	0.2081	2	0.1618	2.82	0.0971	0.054	1.42	0.2423

Table 3 summarized the selected independent variables and their statistics of three remotely sensed images from individual band data. Taking the airborne multispectral scanning data as an example, in the crown closure estimation equation, the selected individual were MSS_5 、MSS_8 、 and MSS_9. Their R^2 and F-value were 0.532 and 25.79 respectively. The probability was 0.0001. The values under the independent variable in tables were their F-value and probability. For instance, the F-value of of MSS_5 was 10.44, probability was 0.0019. Studying Table 3 briefly, a primary conclusion was that the crown closure estimation equations were effectively but the volume equations were not.

Table 4 、 The Selected Five Independent Variables and Their Statisties of Individual Band Data

sensor	dependent variable	independent variable										R^2	F-value	prob
multi-spectral scanner	crown closure	MSS_5		MSS_6		MSS_8		MSS_9		MSS_{10}				
		2.76	0.0101	0.18	0.6706	3.98	0.0501	1.56	0.0166	0.43	0.5143	0.539	15.44	0.0001
	volume	MSS_5		MSS_6		MSS_8		MSS_9		MSS_{10}				
		5.95	0.0407	3.11	0.0824	3.78	0.0562	1.77	0.1889	4.36	0.0403	0.198	1.58	0.1771
Landsat-TM	crown closure	TM_1		TM_2		TM_3		TM_4		TM_5				
		22.62	0.0001	1.09	0..3005	6.84	0.0108	6.41	0.0135	5.01	0.0283	0.910	148.84	0.0001
	volume	TM_1		TM_2		TM_3		TM_4		TM_7				
		2.60	0.1112	1.73	0.1920	3.62	0.0612	6.16	0.1054	2.08	0.1536	0.099	1.61	0.1689

General speaking, the more independent variables in a equation give more information about the dependent variable. What happened if more than three independent varialales contained in a multiple regression equation ? Table 4 was the results of five independent variables selected from the individual band of the airborne multispectral scanning data and the Landsat-TM data. By their R^2 and F-value. A conclusion were made that the five independent variable equations in Table 4 were not more effectively on crown elosure and stand volume estimation than the equations with three independent variables in Table 3. In another words, three independent variables were enough in the crown closure and stand volume equation establishment, no more variables were needed.

2.Vegetation Index

As mentioned previously, the vegetation indices used in this study were IND_1=NIR-R, IND_2=(NIR-R)/(NIR+R), $IND_3=(IND2+0.5)^{1/2}$, IND_4=NIR-G, IND_5=(NIR-G)/(NIR+G) and $IND_6=(IND5+0.5)^{1/2}$. These vegetation indices computed by the digital number of three remotely sensed data respectively were used as the independent variables in the regression equations and the crown closure and stand volume as the dependent variables The results were shown in Table 5.

Table 5 、 The Selected Independent Variables and Their Statistics of Vegetation Index Data

sensor	dependent variable	independent variable				R^2	F-value	prob
multi-spectral scanner	crown closure	IND_1		IND_2				
		16.11	0.0001	6.72	0.0116	0.43	26.08	0.0001
	volume	IND_2		IND_4				
		6.7	0.0117	5.4	0.0321	0.093	3.55	0.0341
SPOT HRV	crown closure	IND_1		IND_6				
		97.23	0.0001	4.39	0.0393	0.797	153.16	0.0001
	volume	IND_1		IND_2				
		1.66	0.2017	1.09	0.2988	0.048	1.98	0.1448
Landsat-TM	crown closure	IND_2		IND_5				
		294.02	0.0001	20.36	0.0001	0.821	174.3	0.0001
	volume	IND_1		IND_2				
		1.79	0.185	0.76	0.3852	0.045	1.78	0.1754

Table 6 、 The Selected Independent Variables and Their Statistics of Individual Band and Vegetation Index Data

sensor	dependent variable	independent variable						R^2	F-value	prob
multi-spectral scanner	crown closure	MSS_5		MSS_8		MSS_9				
		10.44	0.0019	13.12	0.0006	9.18	0.0035	0.532	25.79	0.0001
	volume	IND_1		IND_4		IND_6				
		0.85	0.3608	5.26	0.0246	9.49	0.0029	0.148	4.85	0.0035
SPOT HRV	crown closure	XS_3		IND_3		IND_6				
		383.31	0.0001	5.65	0.0199	3.99	0.0493	0.84	137.83	0.0001
	volume	IND_1		IND_4		IND_5				
		9.82	0.0025	12.24	0.0900	2.95	0.0903	0.062	4.29	0.0076
Landsat-TM	crown closure	TM_1		TM_4		TM_5				
		19.49	0.0001	445.34	0.0001	164.26	0.0001	0.903	232.49	0.0001
	volume	TM_1		IND_5		IND_6				
		0.72	0.398	2.48	0.0196	2.12	0.0468	0.058	1.54	0.0212

By Table 5,the same conclusion could be made that the crown closure estimation equations were eligible, the volume equations were not.

3. Individual Band and Vegetation Index

Using the individual band and vegetation index of the three remotely sensed data together in the multiple regression analysis, the results were shown in Table 6. Take the SPOT HRV as an example, three independent variables XS_3 、 IND_3 and IND_6, were selected in the crown closure estimation equation. Their R^2 was 0.840, F-value 137.83., probablity 0.0001.

By Table 6, A similar conclusion was that the crown closure equations were also qualified to estimate forest crown closure. but the volume equations were not.

Follow the same procedure of section 1, five independent variables were selected from the individual band and vegetation index data. The results were shown in Table 7. By Table 7, the equation with 5 independent variables did not indicate more effective also than that with 3 independent variables on crown closure and stand volume estimation. A same conclusion can be made that three independent variable were enough on regression equation establishment.

Table 7 、 The Selected Five Independent Variables and Their Statistics of Individual Band and Vegetation Index Data

sensor	dependent variable	independent					variable					R^2	F-value	prob
multi-spectral scanner	crown closure	MSS_5		MSS_6		MSS_8		MSS_9		MSS_{10}				
		8.88	0.004	8.21	0.0056	15.05	0.0002	2.24	0.1026	11.55	0.0012	0.539	15.44	0.0001
	volume	MSS_9		IND_2		IND_3		IND_5		IND_6				
		12.09	0.0009	2.88	0.0943	6.43	0.0136	10.48	0.0019	5.2	0.0258	0.245	4.35	0.0018
Landsat-TM	crown closure	TM_1		TM_2		TM_3		TM_5		IND_5				
		27.7	0.0001	6.44	0.012	6.06	0.0162	1.15	0.2864	4.84	0.031	0.910	148.84	0.0001
	volume	TM_1		TM_3		TM_4		TM_7		IND_6				
		0.19	0.6607	0.17	0.6777	1.57	0.2143	0.28	0.5995	1.51	0.2228	0.109	0.86	0.5136

4.Tree Factor

The results of Table3 、 5 and 6 indicated that volume equations developed from the airborne multispectral scanning data, SPOT XS data and Landsat-TM data were not done well on stand volume estimation. Another parameters might be needed to add to the equations.

Table 8 showed the independent variables of volume equation and their statistics from the individual bands, tree ages and crown closures ($\sqrt{\ }$cc). These volume equations that were established from the remotely sensed data and ground measured data were much more effectively. Among the independent variables, the tree ages seems to be a key factor for volume estimation.

Table 8、The Selected Independent Variable and Their Seatistics of Volume Equation

sensor	independent	variable					R^2	F-value	prob
multispectral	MSS_8		MSS_{10}		age				
scanner	1.86	0.0474	13.12	0.0006	87.27	0.0001	0.614	36.08	0.0001
SPOT HRV	XS_1		XS_3		age				
	1.74	0.0404	2.16	0.0453	97.25	0.0001	0.577	33.12	0.0001
Landsat-	TM_5		age		$(cc)^{1/2}$				
TM	4.90	0.0277	66.69	0.0001	9.21	0.0033	0.621	41.00	0.0001

CONCLUSION

The findings of this paper were as follows：(1) The crown closure equations that were established by three remotely sensed data were eligible. Among the three equations, the equation which was developed by Landsat-TM data was the best, The airborne multispectral scanning data the second, the SPOT HRV data the third. (2) The volume equations that were established by three remotely sensed data were not eligible. Another parameters such as tree ages and crown closures should be added. Especially the age factor was much more effectively. (3) On the crown closure and stand volume equation establishment, three independent variables were enough, no more variables were needed.

REFRENCE

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