CONIFER COVER TYPE DISCRIMINATION USING SATELLITE DATA

Dumitru Salajanu
School of Natural Res.& Environment
University of Michigan, Ann Arbor, MI.

Charles E. Olson Jr.
School of Natural Res.& Environment
University of Michigan Ann Arbor MI.

ABSTRACT

The primary objective of this study was to determine if decreasing pixel size increases overall accuracy so forest species can be separated when using satellite data, and the extent to which increasing the number of classes to be recognized results in a decrease in overall accuracy. Classification accuracy from SPOT-XS was compared with those from Landsat TM channels 2, 3 and 4, which have approximately the same spectral sensitivity as SPOT-XS. Reference maps prepared from enlarged prints of aerial photographs and field checks included nineteen cover types, nine of which were coniferous trees. A supervised classification with the maximum likelihood decision rule was used. Results with SPOT-XS alone yielded an overall accuracy of 70.1% and with Landsat TM 57.1% at species level. Since the same area and the same number of cover types were used in both cases, the difference in spatial resolution between SPOT-XS (20 m) and Landsat TM (30 m) is believed to be the main source of the differences in overall classification accuracy. It seems likely that spatial resolution has a greater effect on accuracy than spectral resolution when data from two sensors with different spatial resolution, but approximately the same range of spectral resolution, are used.

INTRODUCTION

Satellite data from sensors with different spatial and spectral resolution such as Landsat MSS, Landsat TM and SPOT-XS are often used in forest classification. Individual and overall classification accuracy vary widely depending on classification algorithm, pixel size, size of each

cover type, number of cover types used in classification, and study site location (East, Central, West of U.S). Most accuracy assessments have been based on statistical samples, but effects of some factors on accuracy assessment were analyzed in several studies with Landsat TM, MSS, SAR and SPOT-XS satellite data for totally enumerated reference data sets at the Sleeping Bear Dune test site in Leelanau County, Michigan (Ma 1985, Nugroho 1992, Dondurur 1994). Brightness value distributions, normality and lack of normality for each cover type and spectral band were addressed by Olson (1992).

BACKGROUND

Ma (1985) compared results of classified maps at Level I (Anderson et al., 1976) land cover/use classification from MSS and TM data with two different classifiers and achieved a 76% overall accuracy with TM Band-4 alone and the LIGMALS classifier. When all seven TM bands were used with the linear discriminant function classifier, the overall accuracy was 85%. His attempt to classify forest area to Level II resulted in a decrease in overall accuracy to 73% with TM and 71% when MSS data were used. The decrease in accuracy was attributed to greater TM spatial resolution, as well as overlap in brightness value ranges of different cover types.

Nugroho (1992) used SPOT-XS data to classify seven land cover types at Level II. He used several different classifiers and achieved an overall accuracy of 76% with a Linear Discriminant Function and 75% with a Parallelepiped classifier when a texture measure was included. He concluded that forest classification accuracy was greater when band ratio (3/2) and the texture measure were combined with the three original SPOT-XS data channels.

Dondurur (1995) used Landsat-TM, SPOT-XS and SAR satellite data to classify the same area, allowing a direct comparison of overall and individual classification accuracy between Level II classifications obtained from two sensors with different spatial and spectral resolution. He used a supervised classification and achieved an overall accuracy of 87% for TM and 85% for SPOT-XS. He concluded that even though significance test results indicated that TM data provided significantly better results than SPOT-XS, there was little practical difference in terms of overall accuracy. He attributed the higher overall accuracy of the TM classification to its higher spectral resolution compared to SPOT-XS. The interaction between number of spectral bands and pixel size is unclear, and more studies are needed.

OBJECTIVE

The main objective of this study was to determine the effect of spatial resolution (pixel size) and increasing number of cover types to be identified on overall and individual classification accuracy with which forest tree species can be determined from digital satellite data.

METHODS

Test Site

Stinchfield Woods and surrounding properties in northwestern Washtenaw County, Michigan were used as test site for this study. Stinchfield Woods consists of natural stands of broadleaved forest and a large variety of conifers planted between 1927 and 1967. Stinchfield Woods straddles a large kame, and terrain includes a mixture of relief forms that vary from flat areas with relatively low to moderate slope, to small areas of high slope. The surrounding area consists of a mixture of rangeland, pasture, agriculture, wetland, abandoned gravel pits and cropland/pasture, small ponds and residential features.

Reference Data

Reference data sets used in accuracy assessment were derived from two enlarged prints prepared from April 1990 and 1995 black and white aerial photographs. Two reference data sets was compiled by total enumeration of land cover on 20, and 30 m grids that matched the SPOT-XS, and Landat-TM satellite data. The small number of pixels dominated by roads were considered part of adjacent cover types. Nineteen cover types were identified and used for accuracy assessment. The number of pixels in each cover type are given in Table 1.

Table 1. Cover type distribution within the reference maps.

Cover	Scientific	SPOT-XS		Landsat TM	
Type	Name	Pixels	%	Pixels	%
113 Residential		82	0.87	30	0.66
145 Telecommunic.		4	0.04	2	0.04
171 Gravel pit		25	0.26	19	0.42
211 Cropland		125	1.32	23	0.51
212 Pasture		9	0.10	27	0.59
300 Rangeland		1187	12.54	520	11.46
411 Broadleaf forest	*Quercus and Acer*	4859	51.34	2277	50.20
421 White pine	*Pinus strobus*	1011	10.68	503	11.09
422 Red pine	*Pinus resinosa*	538	5.69	256	5.64
423 Jack pine	*Pinus Banksiana*	50	0.53	24	0.53
424 Scotch pine	*Pinus sylvestris*	528	5.58	259	5.71
425 Aust/Cors pine	*Pinus nigra/ssp. laricie*	166	1.75	74	1.63
426 Norway spruce	*Picea abies*	195	2.06	98	2.16
427 Douglas fir	*Pseudotsuga menziesii*	82	0.87	39	0.86
428 Red Cedar	*Juniperus virginiana*	12	0.13	3	0.07
429 Mixed Conifer		237	2.50	121	2.67
431 Mixed Con/Brd		339	3.58	255	5.62
500 Water		5	0.05	3	0.07
600 Wetland		10	0.11	3	0.07
Total		9464	100.00	4536	100.00

Satellite Data

SPOT-XS data from May 1, 1988, and Landsat-TM data from May 22, 1994 data were used in this study. All data had been acquired in the 1B format, requiring no geometric correction. All data were collected in cloud free conditions.

Training sets

Training sets were identified in each of the satellite images based on field experience gained while preparing the reference data and by comparison with existing aerial photographs. The quality of the training sets was assessed in terms of the spectral separability using signature evaluation tools in ERDAS Imagine.

Digital Land Cover/Use Classification

SPOT-XS and Landsat-TM satellite data were used in a supervised classification with the Maximum Likelihood decision rule. A sample of the classified maps from SPOT-XS is presented in Figure 1. Each classification was quantitatively evaluated based on overall and individual cover type accuracy. These assessments were based on analyses of contingency tables prepared in ERDAS Imagine using methods similar to those described by Congalton (1983). The percentage of pixels correctly classified (PCC), Tau, and Cohen's Kappa indices were determined for each contingency table (Cohen, 1960).

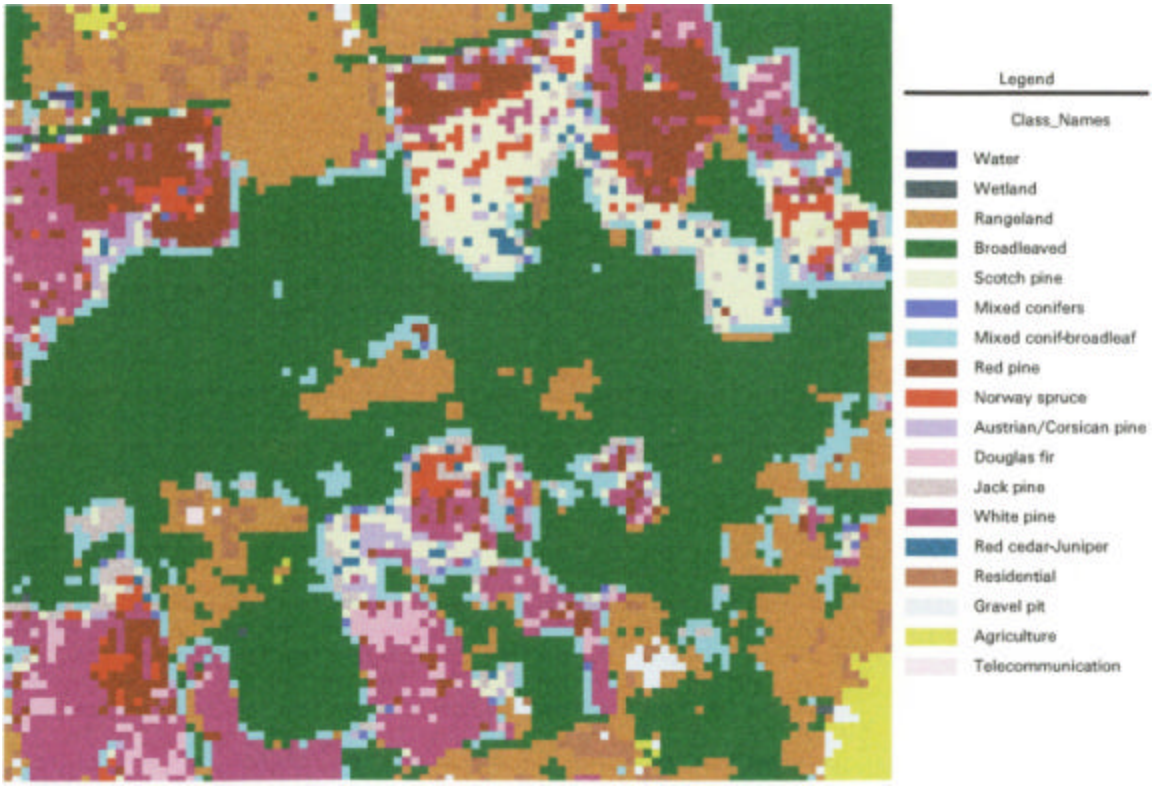

Figure 1. Classified map from SPOT-XS satellite data, channels 1, 2, and 3

RESULTS AND DISCUSSION

Overall classification accuracy for the six Level I classes was 91.5%, while at Level II (for 10 classes) accuracy declined to 84.7% with SPOT-XS data. When all nineteen Level III classes were included, accuracy dropped to 70.1% for SPOT-XS data. At all three levels of classification overall accuracy with SPOT-XS data was greater than with TM Channel 2, 3, 4 data. Since the bandwidths of the SPOT-XS channels are similar to those of Landsat-TM channels 2, 3 and 4, it seems likely that the difference in ground resolution between SPOT-XS (20 m) and Landsat TM (30 m) is the main source of the differences in overall classification accuracy.

Contingency tables used in the accuracy assessments for Level III classifications are presented in Tables 2, and 3. Good individual classification accuracy was obtained in more homogeneous and high crown density cover types that occupy large area such as broadleaved forest, rangeland and some red and white pine areas. Each sensor proved to be better at discriminating some cover types than the others.

Table 2. Contingency Table for Classified Maps from Landsat-TM Ch. 2, 3, 4.

		REFERENCE																				
	Code	Cover Type	113	145	171	211	212	300	411	421	422	423	424	425	426	427	428	429	431	500	600	Total
C	113	Residential	10		1	4	3	78	52										3		1	154
	145	Telecommunic																				0
L	171	Gravel Pit			14			11	5		2								1			33
	211	Cropland	2			18	1	3	1													25
A	212	Pasture	4			1	21	30	25	2									1			84
	300	Rangeland	13	1	2		2	339	263	7			1		1				24	1		654
S	411	Broadleaved		1	1			38	1558	10	1	2	7	6		2			43			166
		Forest																				9
	421	White Pine						3	81	171	35	2	23	16	18	8		10	32			399
S	422	Red Pine							5	90	162		19	17	11	2		29	12			347
	423	Jack Pine							14	11		9	16	1	1	2		13	11		1	79
I	424	Scotch Pine	1					6	43	39	6	3	151	7	3	3		21	42			325
	425	Aust.-Corsic.								4	6			6				2	1			19
		Pine																				
F	426	Norway Spruce						1	5	95	36	3	5	15	57	2		21	11			251
	427	Douglas Fir							7	53	1	2	17	3	6	18		13	15			135
I	428	Red Cedar-Juniper								1	1	1	2	1			1	2				9
	429	Mixed Conifer							21	4	3	1	7				1	3	8			49
E	431	Mixed						10	197	15	3	1	9	2	1	2	1	7	49			297
		Con/Brdlvd																				
	500	Water																		2		2
D	600	Wetland						1		1									2		1	5
		Total	30	2	19	23	27	520	2277	503	256	24	259	74	98	39	3	121	255	3	3	4536
		PCC %	33.3	0.0	73.7	78.3	77.8	65.2	68.4	34.0	63.3	37.5	58.3	8.1	58.2	46.1	33.3	2.5	19.2	66.7	33.3	57.1

K hat = 44.6%, Tau = 39.7%

Table 3. Contingency Table for Classified Maps from SPOT-XS Ch. 1, 2, 3.

		REFERENCE																			
	Code	Cover Type	113	145	171	211	212	300	411	421	422	423	424	425	426	427	428	429	431	500	600	Total
C	113	Residential	50		3	1	3	147	10										2			216
	145	Telecommunic		4																		4
L	171	Gravel Pit			15	10		22	4													51
	211	Cropland				109	3	22	5													139
A	212	Pasture					0															0
	300	Rangeland	29		5	5	3	885	474	11	1		9					2	47		1	1472
S	411	Broadleaved Forest	2		2			87	3899	7	1	1	6	2		1			46		7	4061
	421	White Pine						5	37	706	87	1	33	26	32	28		50	32			1037
S	422	Red Pine								80	360		3	8	59	7		21	6			544
	423	Jack Pine						1	47	4	4	23	44	12	16		3	19	42	1		216
I	424	Scotch Pine						4	16	29	27	7	296	44	5	3	3	66	21			521
	425	Aust.-Corsic. Pine							5	17	12	1	19	44	3			13	7			121
F	426	Norway Spruce							2	16	36	11	47	4	58	1		34				209
	427	Douglas Fir							1	104	2			2	5	39		3	1			157
I	428	Red Cedar-Juniper							2	3		1	31	7	3		5	4	1			57
	429	Mixed Conifer						1	12	4	1	2	6	2	5	1		9	2			45
E	431	Mixed Con/Brdlvd	1					12	337	30	7	3	34	15	9	2	1	16	130	1		598
	500	Water																		3		3
D	600	Wetland						1	8										2		2	13
		Total	82	4	25	125	9	1187	4859	1011	538	50	528	166	195	82	12	237	339	5	10	9464
		PCC %	61.0	100	60.0	87.2	0.0	74.6	80.2	69.8	66.9	46.0	56.1	26.5	29.7	47.6	41.7	3.8	38.4	60.0	20.0	70.1

K hat = 59.6%, Tau = 57.4%

Errors

Both SPOT and Landsat-TM satellite data provided low individual classification accuracy (less than 50%) for Austrian /Corsican pine, jack pine, mixed conifer, mixed conifer/broadleaf and wetland cover type. Low crown density, planting in narrow strips and the presence of broadleaved vines (poison ivy, Virginia creeper, river bank grape) on the trunk and in the crown affected classification accuracy. Lower crown density due to thinning and/or tree windthrow created a favorable climate (condition) for shrubs and vine species invasion. Austrian and jack pine were present in several narrow strips less than 20 m wide making recognition difficult and resulting in low classification accuracy. Many residential pixels comprised houses surrounded by different species of trees and/or large lawns. Such pixels were often classified as forest, rangeland, or even pasture and were considered incorrectly classified when compared to the reference map.

CONCLUSION

- ?? Overall accuracy of land cover/use classification does increase when pixel size is reduced. Accuracies obtained with SPOT-XS (20 m pixel) data were better at all three levels of classification than those obtained with Landsat-TM (30 m pixel) using only TM Channels 2, 3 and 4 data.
- ?? Accuracy decreased as the number of cover types to be identified increased.
- ?? Classification results were affected by both size and variability within the cover types. Those cover types which were more uniform and occupied large areas were better classified than those that were heterogeneous and small (narrow strips less than 20 m).

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