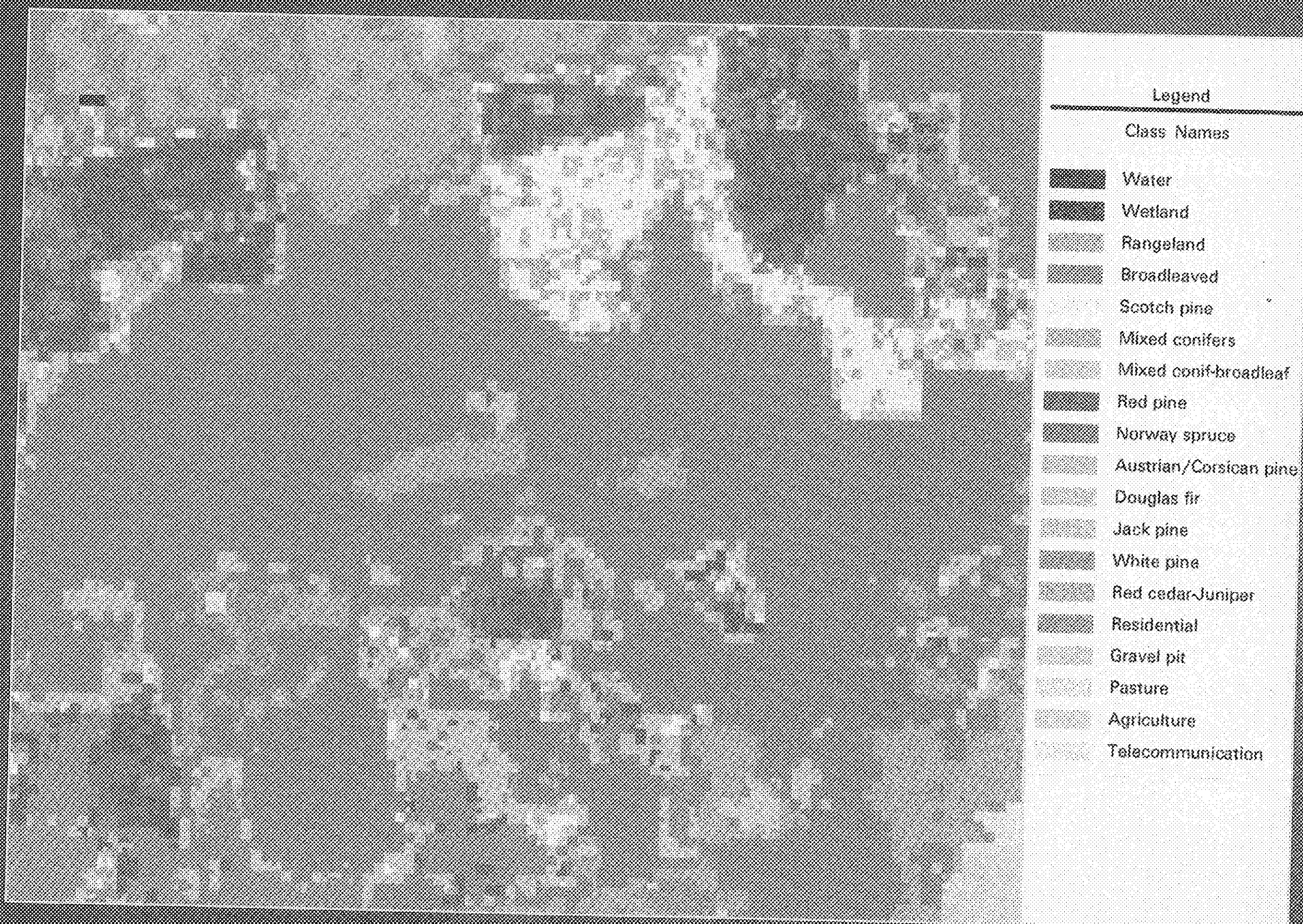

The Significance of Spatial Resolution

Identifying Forest Cover from Satellite Data

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ABSTRACT

The objective of this study was to determine if decreasing pixel size increases overall accuracy with which forest species can be separated using satellite data. Classification accuracy achieved with Landsat Thematic Mapper (TM) channels 2, 3, and 4 were compared with results from SPOT-XS. Reference data prepared from enlarged prints of aerial photographs and field checks included 19 cover types, nine of which were coniferous. Results with SPOT-XS alone yielded an overall accuracy of 70.1 percent, and with Landsat TM 57.1 percent at species level. Overall accuracy increased by 3 percent when either SPOT-XS or Landsat TM data were integrated with SPOT-PAN data.

Keywords: biometrics; land use; remote sensing

Twenty-five years ago, a National Academy of Sciences report identified species identification as a requirement if satellite data are to reach their full potential in forest inventory and monitoring; the report suggested that improving spatial resolution to 10 meters would probably be required (Committee on Remote Sensing Programs for Earth Resource Surveys [CORSPERS] 1976). Conversations with federal, state, and private forest managers confirm that this species identification requirement persists, and that an accuracy of 90 percent is required when separating broadleaved from conifer stands. This article describes a study to determine the effect of spatial resolution (pixel size) on the accuracy with which forest tree species can be identified from digital satellite data on a stand basis.

Background

Satellite data from sensors with different spatial and spectral resolution have been used for land cover classification. The most common classification schemes are derivatives of the hierarchical system defined by Anderson et al. (1976). Level I classes are the most general (e.g., urban, agriculture, rangeland, forest). Each level I class may be subdivided into more specific level II classes, and these further divided into even more specific level III classes. Separation of broadleaved from conifer forest occurs at level II and further separation to species at level III.

Overall and individual classification accuracies vary widely depending on satellite data source, classification algorithm, pixel size, size of each cover type, number of cover types used in classification, and study site location. Most accuracy assessments have been based on statistical samples, but effects of some factors on accuracy assessment were analyzed in several studies with Landsat Thematic Mapper (TM), Landsat multispectral scanner (MSS), synthetic aperture radar (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). Total enumeration of the reference data set resulted in the observation that brightness value distributions were neither normal nor symmetrically distributed about their means for any cover type or spectral band (Olson and Ma, 1989; Olson 1992).

Ma (1985) compared results from Landsat MSS data with those obtained from Landsat TM data for land cover–use classification to level I. He achieved 76 percent overall accuracy with TM band-4 alone in a parallelepiped classifier. When all seven TM bands were used with a linear discriminant function classifier, overall accuracy was 85 percent. His attempt to classify forest area to level II resulted in a decrease in overall accuracy to 73 percent with TM and 71 percent when MSS data were used. Overlap in the brightness value ranges of many cover types was a factor in the decreasing accuracy with both sensors (Ma and Olson 1989). The higher accuracy using TM was attributed to its greater spatial resolution.

Nugroho (1992) used SPOT-XS data with a texture measure as an extra data channel to classify seven land cover types at level II. He used several different classifiers and achieved an overall accuracy of 76 percent with a linear discriminant function and 75 percent with a parallelepiped classifier. 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 (1994) used Landsat TM, SPOT-XS, and airborne SAR data to classify 3,950 acres. He used a supervised classification and achieved an overall accuracy of 87 percent with TM, 85 percent with SPOT-XS, and 85 percent with SAR C-band when results were compared with the totally enumerated reference data set. Even though significance tests indicated that TM data provided significantly better results than SPOT-XS, he concluded there was little practical difference in terms of overall accuracy, but attributed the higher overall accuracy of the TM classification to its higher spectral resolution compared to SPOT-XS.

Similar work was also being done elsewhere. Lillesand et al. (1985) evaluated both manual and computer-assisted image interpretation techniques to level II, where textural and tonal contrast aided in the separation of hardwoods and conifers. Differentiation between conifer species was observed in some instances, but accuracy of identification of Norway spruce was only 45 percent. The authors reported difficulties in differentiating small agricultural areas from recently logged areas. They also reported some problems distinguishing nonforest features, such as roads, plowed fields, and highly reflective wetlands. After these were eliminated, more accurate classifications were obtained. The authors reported an overall and class average accuracy, based on assessment of homogeneous test areas, of 93 and 85 percent, respectively.

Borry et al. (1990) compared the performance of conventional digital classification techniques with visual interpretation of digitally enhanced monotemporal SPOT images for the identification of tree species in Belgium. A panchromatic scene was used to determine the contribution of 10 × 10 meter spatial resolution to visual interpretation. To assess the value of the information gained at different stages in the phonological cycle, four SPOT (XS) multispectral images were selected to correspond with distinct stages of the phenological process. They used five enhancement procedures to prepare SPOT images for visual interpretation and a supervised, per-point classification. Interpretation results were compared to cover-type maps obtained from color infrared photographs and classification accuracy was determined statistically. They reported an increase in interpretation accuracy for the September images when the panchromatic and multi-

***Opposite:* Classified map of Stinchfield Woods area in Michigan, from SPOT-XS integrated data.**

Table 1. Cover type distribution within the reference maps.

Cover type	Scientific name	SPOT-XS		Landsat TM	
		Pixels	Percent	Pixels	Percent
113 Residential		82	0.87	30	0.66
145 Telecommunications		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		1,187	12.54	520	11.46
411 Broadleaf forest	*Quercus/Acer spp.*	4,859	51.34	2,277	50.20
421 White pine	*Pinus strobus*	1,011	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 Austrian-Corsican 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 conifer and broadleaf		339	3.58	255	5.62
500 Water		5	0.05	3	0.07
600 Wetland		10	0.11	3	0.07
Total		9,464		4,536	

spectral channels were combined; but, for both visual interpretation and digital classification, images obtained during the spring yielded better results. They also reported no increase in classification accuracy of tree species discrimination when band ratio (3/2) was combined with the three original SPOT-XS data channels. For images collected in June, overall classification accuracy (nine cover types) varied from 62 percent (producer accuracy) to 65 percent (user accuracy); the authors concluded that neither visual nor digital classification using a monotemporal approach produced acceptable results for forest management in Belgium.

Hopkins et al. (1988) used a maximum-likelihood algorithm to classify Landsat TM data in two Lake States study sites. The first site had 15 cover types with a mixture of forest and other cover types characteristic of the southern Great Lakes region, and the second site had 11 cover types in a commercially managed forest area of the northern Great Lakes region. All seven TM channels were used in a supervised classification with a maximum-likelihood algorithm. At site 1 overall classification accuracy was 85 percent. Individual cover type accuracy ranged from 18 percent for the central hardwood cover type to 100 percent for the developed (urban) cover type. Overall classification accuracy at site 2 (11 cover types) was 93 percent, varying from 53 percent for the roads-developed cover type to 100 percent for the gravel pit cover type.

Methods

A 980-acre area in Washtenaw County, Michigan, at latitude 42°23' to 42°25' N and longitude 83°54' to 83°57' W, was selected for this study. The site straddles a large kame with slopes varying from nearly flat to over 40 percent. Overall, the site is 86 percent forested, including natural

Table 2. Spectral bandwidth and pixel size for the three data sets used.

Channels used	Landsat TM		SPOT-XS		SPOT-PAN	
	Bandwidth (nm)	Pixel size (m)	Bandwidth (nm)	Pixel size (m)	Bandwidth (nm)	Pixel size (m)
1			500–590	20	510–730	10
2	520–600	30	610–680	20		
3	630–690	30	790–890	20		
4	760–900	30				

REFERENCE DATA

Code	Cover Type	113	145	171	211	212	300	411	421	422	423	424	425	426	427	428	429	431	500	600	Total
113	Residential	10		1	4	3	78	52										3		1	154
145	Telecommunic																				0
171	Gravel Pit			14			11	5		2								1			33
211	Cropland	2			18	1	3	1													25
212	Pasture	4			1	21	30	25	2									1			84
300	Rangeland	13	1	2		2	339	283	7			1		1				24	1		654
411	Broadleaved Forest		1	1			38	1558	10	1	2	7	6		2			43			1669
421	White Pine						3	81	171	35	2	23	16	18	8		10	32			399
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
424	Scotch Pine	1					6	43	39	6	3	151	7	3	3		21	42			325
425	Aust.-Corsic. Pine								4	6			6				2	1			19
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
428	Red Cedar-Juniper								1	1	1	2	1			1	2				9
429	Mixed Conifer							21	4	3	1	7				1	3	8			49
431	Mixed Con/Brdlvd						10	197	15	3	1	9	2	1	2	1	7	49			297
500	Water																		2		2
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

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K hat = 44.6% Tau = 39.7%

Figure 1. **Contingency table for classified map from Landsat TM channels 2, 3, and 4—original data.**

broadleaved stands interspersed with conifer plantations. All of the plantations were more than 40 years old.

Reference data sets used in accuracy assessment were derived from 400-feet-per-inch enlargements of black-and-white aerial photos taken in April 1990 and 1995 to provide the closest possible agreement to conditions on the dates of satellite data acquisition. All photo interpretations were field checked. Three reference data sets were compiled by total enumeration of land cover on 10, 20, and 30 meter grids that matched the SPOT panchromatic, SPOT-XS, and Landsat TM satellite data. A grid was prepared on Unix and printed on clear mylar to represent the SPOT 10 × 10 meter raster at a scale of 1 inch = 400 feet. This grid was positioned over the enlarged aerial photo print using reference points identifiable in both the SPOT image and air photo print. Using each 10 × 10 meter grid cell as a pixel, land cover was determined for each pixel of the reference data set. A similar procedure was used to derive reference data sets for the SPOT-XS and Landsat TM data sets. The small number of pixels dominated by roads were considered part of adjacent cover types. Six cover types were identified at level I, 10 at level II, and 19 at level III. The number of pixels in each cover type for the 20-meter (SPOT-XS) and 30-meter (Landsat TM) grids is given in *table 1.*

SPOT-XS data from May 1, 1988, Landsat TM data from May 22, 1994, and SPOT panchromatic data from July 11, 1995 data were used in this study. Data for the same date from all three sensors were not available. All satellite data had been acquired in the 1B format, requiring no geometric correction. To provide the closest possible spectral match between the SPOT-XS and Landsat data, only TM channels 2, 3, and 4 were used. Spectral and spatial characteristics of the satellite data are presented in *table 2.*

An integration–merging process was used to improve overall land use classification and interpretability. Both the SPOT-XS and Landsat TM data sets were registered to the SPOT panchromatic data set using ground control points selected from both images. Registration accuracy was 0.42 meters for SPOT-XS and 1.28 meters for Landsat TM. The registered images were resampled to a 20-meter (SPOT-XS) and 30-meter (Landsat TM) grid using the nearest-neighbor resampling method. Integration algorithms were used to merge the images into two new ones. Registration and rectification were done in ERDAS Imagine, and the integration process was done in Microsoft Excel.

Training sets were identified for each cover type in each of the satellite images based on field checks and comparison with existing aerial photographs. Quality of the training sets was assessed in terms of spectral separability using signature evaluation tools in ERDAS Imagine.

Land cover classification was accomplished in a supervised classification with a maximum likelihood decision rule. Data from SPOT-XS and Landsat TM channels 2, 3, and 4 were first classified separately, and then merged with the SPOT panchromatic data for additional tests. These are referred to here as the "original" and "integrated" data sets.

Each classification was quantitatively evaluated based on overall and individual cover type accuracies. These assessments were based on analyses of contingency tables prepared in ERDAS Imagine using methods similar to those described by Congalton et al. (1983). A separate contingency table was prepared for each classified image. The percentage of pixels correctly classified (PCC), Tau, and Cohen's Kappa indices were determined for each contingency table (Cohen 1960). Even

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Code	Cover Type	113	145	171	211	212	300	411	421	422	423	424	425	426	427	428	429	431	500	600	Total
113	Residential	50		3	1	3	147	10										2			216
145	Telecommunic		4																		4
171	Gravel Pit			15	10		22	4													51
211	Cropland				109	3	22	5													139
212	Pasture					0															0
300	Rangeland	29		5	5	3	885	474	11	1		9					2	47		1	1472
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
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
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
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
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
431	Mixed Con/Brdlvd	1					12	337	30	7	3	34	15	9	2	1	16	130	1		598
500	Water																		3		3
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%

***Figure 2.* Contingency table for classified map from SPOT-XS channels 1, 2, and 3—original data.**

REFERENCE DATA

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Code	Cover Type	113	145	171	211	212	300	411	421	422	423	424	425	426	427	428	429	431	500	600	Total
113	Residential	339		8	37	8	122	9													523
145	Telecommunic		10																		10
171	Gravel Pit	27		70	13		60	27	2	17								1			217
211	Cropland	5			128	23	1														157
212	Pasture	104			73	46	254	346	8			13						3			847
300	Rangeland	359		12	40	10	2688	1092	47	14		31		2			1	60	5		4361
411	Broadleaved Forest	18			5		536	13621	212	62	7	82	11	13		2	68	212	6	10	14865
421	White Pine						7	558	1575	313	1	164	122	144	23		93	41			3041
422	Red Pine						3	67	606	849	32	179	145	105	21		157	25			2189
423	Jack Pine				1		11	316	106	31	102	69	20	13	15	3	53	37	8		785
424	Scotch Pine						34	566	352	101	36	1276	37	41	41	1	73	72	3		2633
425	Aust.-Corsic. Pine						1	29	185	231	29	46	230	81			134	22			988
426	Norway Spruce						1	60	559	489	4	5	97	415	1		28	10			1669
427	Douglas Fir						7	112	179	1	13	55	16	15	177		39	44			658
428	Red Cedar-Juniper						7	67	1	30	9	42	5	6		12	45	36	2		262
429	Mixed Conifer							10	10	33	5	63	5	2		7	14	5			154
431	Mixed Con/Brdlvd	1					60	933	178	22	14	170	15	29	40	4	52	313		2	1833
500	Water						1												0		1
600	Wetland				4		33	590	39	17	10	2		1	2	2	2	59		2	763
	Total	853	10	90	301	87	3826	18403	4059	2210	262	2197	703	867	320	31	759	940	24	14	35956
	PCC %	39.7	100	77.8	42.5	52.9	70.3	74.0	38.8	38.4	38.9	58.1	32.7	47.9	55.3	37.7	1.8	33.3	0.0	14.3	60.8

K hat = 48.0% Tau = 44.3%

***Figure 3.* Contingency table for classified map from Landsat TM channels 2, 3, and 4—integrated data.**

though PCC includes some pixels classified correctly solely due to chance, this is the measure of most interest to forest managers. The other measures can be used to evaluate the relative effectiveness of different classification approaches.

Results and Discussion

No attempt was made to compensate for the effect of slope or aspect on the brightness values recorded by the sensors. Nevertheless, overall classification accuracy for the six level I classes was 91.5 percent for SPOT-XS and 89.2 percent for Landsat TM channels 2, 3, and 4 using the original data. At level II, with 10 classes, accuracy was 84.7 percent with SPOT-XS and 77.8 percent with Landsat TM original data. When all 19 level III classes were included, accuracy was 70.1 percent

REFERENCE DATA

Code	Cover Type	113	145	171	211	212	300	411	421	422	423	424	425	426	427	428	429	431	500	600	Total
113	Residential	532		8		6	154	7									1				708
145	Telecommunic	6	10																		16
171	Gravel Pit	49		77	10		37	1	1	1		1							1		178
211	Cropland	10			255	2															267
212	Pasture	30			35	78	7														150
300	Rangeland	208		5	1	1	3162	636	14	1		15					1	43	4	1	4092
411	Broadleaved Forest	1					451	16610	152	59	8	166	25	9	6		27	467	7	11	17989
421	White Pine						4	32	2092	281	16	53	166	147	43		171	12			3017
422	Red Pine							17	747	1248	13	12	36	214	8		36	5			2336
423	Jack Pine							123	49	25	110	91	75	77	5	1	89	72	1		718
424	Scotch Pine						4	110	67	78	14	1162	67	16	10	10	131	48			1717
425	Aust.-Corsic. Pine							36	86	82	16	251	222	45			87	18			843
426	Norway Spruce							12	226	309	36	13	16	301			70	3			986
427	Douglas Fir						3	48	335	31		19	5	2	224		5	8			680
428	Red Cedar-Juniper							34	11	4	14	202	21	6	4	15	33	6			350
429	Mixed Conifer						6	119	34	40	17	31	10	25	1		33	16	3		335
431	Mixed Con/Brdlvd	1					11	618	260	51	18	181	45	23	19	3	79	242	2	2	1554
500	Water						4												6		10
600	Wetland																			0	0
	Total	836	10	90	301	87	3843	18403	4074	2210	262	2197	688	865	320	29	763	940	24	14	35956
	PCC %	63.6	100	85.5	84.7	89.7	82.3	90.3	51.4	56.5	42.0	52.9	32.3	34.8	70.0	51.7	4.3	25.7	25.0	0.0	73.4

K hat = 62.6% Tau = 62.1%

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***Figure 4.* Contingency table for classified map from SPOT-XS channels 1, 2, and 3—integrated data.**

with SPOT-XS and 57.1percent with Landsat TM original data (channels 2, 3, and 4). At all three levels of classification, overall accuracy with SPOT-XS data was greater than with Landsat TM channel 2, 3, and 4 data. As the bandwidths of the SPOT-XS channels are quite similar to those of Landsat TM channels 2, 3 and 4, it seems likely that the difference in ground resolution between SPOT-XS (20 meters) and Landsat TM (30 meters) is the main source of the difference in overall classification accuracy.

When the integrated data sets (SPOT-XS and Landsat TM registered to SPOT panchromatic data) were used, overall classification accuracy at level III increased by 3 percent in each case, to 73.3 percent and 60.8 percent, respectively. This result is important primarily because it reveals no loss of accuracy due to the resampling necessary to integrate the multispectral data sets with the SPOT panchromatic data.

Contingency tables used in the accuracy assessments for level III classifications with both the original and integrated data sets are presented in *figures 1–4*. Statistical analyses indicate that the results with integrated data sets were significantly better ($p = 0.01$) than with the original data. Individual classification accuracies for each cover type are shown at the bottom of the contingency tables. Accuracy with both SPOT and TM data was better for types characterized by high crown density covering large areas, such as broadleaved forest. The contingency tables reveal that each sensor proved to be better at discriminating some cover types than others. Within-class variation was a factor in many cases.

The white pine cover type, for example, included three types of stands: sawtimber with large variations in crown closure and many boles covered with poison ivy and Virginia creeper rising into the crowns, unthinned small-pole stands with high crown closure, and mixed large-pole stands with 75 percent white pine and 25 percent red pine having large variations in crown density and understory vegetation. Such variation is not unusual, but caused some white pine pixels to be classified as broadleaved (vines in crown) or red pine.

No plantation was truly a monoculture. Each included a small mixture of broadleaved trees and other conifer species that had seeded in as volunteers and reached the codominant crown class, and the presence of vines in the crowns was not limited to white pine stands. Also, some broadleaved stands had significant conifer components, especially Norway spruce and white pine, with many of these trees in the codominant crown class.

Austrian and jack pine occurred in several narrow strips less than 20 meters wide, making recognition difficult and resulting in low classification accuracy. Many residential pixels with houses were surrounded by large trees or lawns; these pixels were often classified as forest, rangeland, or even pasture and were considered incorrectly classified when compared to the reference map.

Conclusion

Based on the work described, it seems reasonable to conclude that overall accuracy of land cover–use classification is greater with smaller pixel size. Although the increases in accuracy were not large, they are meaningful when one is trying to reach an overall accuracy of 90 percent.

This result should not be interpreted to mean that SPOT-XS is superior to Landsat TM for forest species classification. Landsat TM has seven spectral channels, whereas SPOT-XS has only three. This increase in spectral information was ignored during this study because the primary goal was to assess the effect of smaller pixel size (increased spatial resolution) on classification accuracy. Results suggest that merging the spectral information from Landsat TM with higher spatial resolution data is worth the effort.

Literature Cited

ANDERSON, J.R., E.E. HARDY, J.T. ROACH, and R.E. WITMER. 1976. *A land use and land cover classification system for use with remote sensor data.* Geological Survey Professional Paper 964. Washington, DC: US Government Printing Office.

BORRY, F.C., B.P. DE ROOVER, R.R. DE WULF, and R.E. GOOSSENS. 1990. Assessing the value of monotemporal SPOT-1 imagery for forestry applications under Flemish conditions. *Photogrammetric Engineering and Remote Sensing* 56(8):1147–53.

COHEN, J. 1960. A coefficient of agreement of nominal scales. *Educational and Psychological Measurement* 20(1):33–46.

COMMITTEE ON REMOTE SENSING PROGRAMS FOR EARTH RESOURCE SURVEYS (CORSPERS). 1976. Vegetation inventory and assessment. In *Resource and environmental surveys from space with the Thematic Mapper in the 1980s. Report of the National Research Council,* 25–42. Washington, DC.

CONGALTON, R., R.G. ODERWALD, and R.A. MEAD. 1983. Assessing Landsat classification accuracy using discrete multivariate analysis statistical techniques. *Photogrammetric Engineering and Remote Sensing* 49(12):1671–78.

DONDURUR, M. 1994. Determination of classification accuracy for land use/cover types using Landsat-TM, SPOT-XS and multipolarized and multi-channel synthetic aperture radar (SAR) data. PhD dissertation, University of Michigan.

HOPKINS, P.F., A.L. MACLEAN, and T.M. LILLESAND. 1988. Assessment of Thematic Mapper imagery for forestry applications under Lake States conditions. *Photogrammetric Engineering and Remote Sensing* 54(1):61–68.

LILLESAND, T.M., P.F. HOPKINS, M.P. BUCHHEIM, and A.C. MACLEAN. 1985. The potential impact of Thematic Mapper, SPOT and microprocessor technology on forest type mapping under Lake State conditions. In *Pecora 10: Remote Sensing in Forest and Range Resource Management Proceedings, Fort Collins, Colorado,* 43–57.

MA, Z. 1985. An evaluation of Landsat TM and MSS data for land cover/use classification. Master's thesis, School of Natural Resources, University of Michigan.

MA, Z., and C.E. OLSON JR. 1989. A measurement of spectral overlap among cover types. *Photogrammetric Engineering and Remote Sensing* 55(10):1441–44.

NUGROHO. 1992. Influence of a texture measure on accuracy of forest cover classifications from SPOT data. PhD dissertation, University of Michigan.

OLSON, C.E., JR. 1992. Minimizing classification errors arising from skewed distributions of satellite-observed brightness values. In *Proceedings of the ASPRS/ACSM Global Change Symposium, August 3–8, Washington, DC,* 116–121.

OLSON, C.E., JR., and Z. MA. 1989. Normality assumptions in supervised classification of remotely sensed terrain data. In *Quantitative remote sensing: An economic tool for the nineties. IGARSS '89,* 638–41.

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