ITC Analyses of the Petawawa Research Forest from Satellite and Aerial Data

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ABSTRACT

Software packages such as the ITC Suite permit the analysis of high resolution (≤ 1 m/pixel) images of forested areas and provide information close to the individual tree crown (ITC) level towards the semi-automated production of forest inventories. First developed with/for aerial images, these techniques are now applied to satellite images with good success. Here, we make a direct comparison of the results obtained from one media versus the other using the exact same geographical area.

In this paper, we report on the ITC analyses of an IKONOS image and of ADS-80 flight lines (at 40 cm/pixel) over the Petawawa Research Forest (PRF), Ontario. After pre-processing and crown delineation, ITC classifications were pursued and tested using exactly the same training/testing areas on both media. Results are reported for the following ten classes: hard and soft maples, red oak, white birch, poplar, white pine, jack pine, red pine, white and black spruce. We comment on how the much lower spatial resolution of the IKONOS multispectral data (at 4 m/pixel) affects species recognition and on how the lower panchromatic resolution (1 m/pixel) affects tree delineation and tree counts. Using forest stand polygons delineated by "conventional means" from the 2007 forest inventory, we also compare the results obtained from the IKONOS and ADS ITC analyses at the forest stand working group level (or 1st species) with that of the inventory and with each other. For the species that were well recognized by the ITC classification process the agreement averages 60% and 53% for the ADS and IKONOS, respectively, and 65% with each other.

Keywords: Enhanced Forest Inventory, Individual Tree Crown Delineation, ITC, Species Classification, Leica ADS-80, IKONOS

INTRODUCTION

The analysis of high spatial resolution (≤ 1 m/pixel) satellite or aerial images of forested areas at the individual tree crown (ITC) level is "slowly" gaining credibility in forestry circles. Its ultimate goal is the production of precise, accurate and timely forest inventories. Ideally, the process can be made almost completely automatic, with forest interpreters having only to train the ITC classifier to recognize the various species present in a given (preferably sizeable) area, assess the quality of the results and do some minor tuning accordingly (i.e., iterations). The correct recognition of species is obviously a basic component of any forest inventory, as it will influence all the other parameters one could infer for a forested area: volume, biomass, fibre quality, etc.

From a computer analysis point of view, the ITC analysis of images represents a change in paradigm from the pixel-based approaches of "conventional" remote sensing to an object-oriented approach. From a forestry point of view, there are also two different paradigms to consider (or one might also say two different scales), the fundamental question being: "do we really want information at the individual tree level (and calculate individual tree volume for example) or do we just want more precise information at the "conventional" forest stand level. Of course, the latter is probably sufficient for the moment, while the desire for the former will grow through time, but only after general acceptance of the technology.

So, at this point in time, the analysis of remote sensing images at the individual tree crown level can viewed as "some process" the computer must go through to produce precise information at the forest stand level. This also means that at this point in time precise individual crown delineation or even exact species recognition at tree scale may be of low concern as long as the overall assessment of the forest is better and faster than with the conventional photo (or soft-copy) interpretation process.

This brings two questions: a) how do the results of an ITC analysis compare with that of the conventional process, and b) how do the results differ when satellite or airborne sensors are being used, given their different spatial resolutions. This study is a preliminary attempt at partially answering these questions.

DATASETS

Satellite and aerial data were available over the Petawawa Research Forest (PRF) in Ontario, as well as LiDAR data of sufficient density to produce a Digital Canopy Model. The IKONOS image was acquired on September 05, 2002. Pan-sharpened images were created from its panchromatic image (1 m/pixel) and its multispectral images (4 m/pixel). All channels were resampled to 50 cm/pixel to facilitate the analysis and the comparison.

As part of Ontario's current forest inventory cycle, the Leica ADS-80 sensor was also flown in East-West flight lines over the PRF in 2010. Although it acquires panchromatic and multispectral stereo imagery that are typically used for softcopy interpretation, this analysis is based on the acquisition at nadir which was geocorrected and resampled to 40 cm/pixel from an acquisition at 20 cm/pixel. The flight lines were BRDF corrected and mosaicked together by the data supplier, North West Geomatics, and delivered in geocorrected 5x5km^2 tiles. Both the IKONOS and the ADS imagery were available in the typical four spectral band (near infra-red, red, green, and blue). Both had radiometric resolution (i.e., radiance) slightly superior to 8 bit and thus came in 16 bit image files. Radiances were scaled to 8 bit for these analyses.

The LiDAR data was acquired during a previous aerial survey done by M7VI in 2006 using a Leica ALS40 at an average sampling density of 0.46 point/m^2. A Digital Surface Model (DSM) and a Digital Terrain Model (DTM) were created from the first and last returns, respectively, creating surface images. The subtraction of the two led to a Digital Canopy Model (DCM) where heights were coded by 0.25 m increment. The exact same sub-area of 7 km X 8 km encompassing most of the PRF was extracted from all datasets.

The Petawawa Research Forest (46.0° latitude, 77.4° longitude) in north-eastern Ontario, about 200 km north-west of Ottawa, has forest stands with a good diversity of species and mixtures, including some pure plantation areas. Vast quantities of information are available as it is constantly monitored and is the subject of field work on our part every summer. For this study we concentrated on the following ten species: hard maple (Mh), soft maple (Ms), red oak (Or), white birch (Bw), poplar (Po), white pine (Pw), jack pine (Pj), red pine (Pr), white spruce (Sw) and black spruce (Sb).The forest inventory used in this study was issued in 2007, came from a soft-copy interpretation done from Dendron Resource Surveys Inc.

METHODS

The Individual Tree Crown (ITC) approach to forest inventories consist in delineating individual tree crowns in high spatial resolution images (≤ 1 m/pixel), recognizing their species, regrouping them into forest stands (or other convenient entities), and attaching attributes to these stand such as species composition, stem density, crown closure, average crown sizes, height, etc. (i). The approach is embedded in a series of computer programs developed by the Canadian Forest Service (CFS) and commonly referred to as the ITC Suite (ii). It presently runs under the PCI Geomatica image analysis software as if it was one of their packages. The ITC Suite relies on the PCI software mostly to display and interact with the images, for some pre-processing and it uses their filing system. The ITC Suite also contains numerous specific pre-analysis and post-analysis programs, and programs dedicated to assessing forest regeneration.

The main steps in the ITC analysis methodology are the following (see (i), Fig. 1 and 2):

1. Image pre-processing (e.g., adaptive smoothing, BRDF corrections)
2. Creation of masks of forested and non-forested areas
3. Individual tree crown delineation
4. Creation of training/testing areas
5. Individual tree crown classification
6. Classification accuracy assessment
7. Iterations over the previous three steps until satisfied
8. Creation of forest stands
9. Attribution of forest stands with ITC statistics
10. Evaluation of species composition accuracy
11. Volume, biomass, fibre quality inferences

For this study, we realized the first 9 steps on both the IKONOS and ADS imagery, except for step 8, as we have used the forest stands from the conventional forest inventory (CFI) in our three-way comparison of species compositions: a) ADS-ITC analysis vs CFI, b) IKONOS-ITC analysis vs CFI, c) ADS-ITC analysis vs IKONOS-ITC analysis.

In this study, the LiDAR Digital Canopy Model was only used to help in the creation of non-forest masks by specifying that we were not interested in anything below 2 metres in height (although heights were reported in the attribution of forest stands in step 9). For the sake of expediency, we took the liberty of not having separate testing areas in step 6. Presumably, the resulting “imbred” confusion matrices will report slightly higher classification accuracies than otherwise, but this should not affect our inter-media (ADS vs IKONOS) classification comparisons.

Confusion matrices are also used to compare the 1st species resulting from the ITC analyses of the two media with the 1st species of the CFI as judged by the interpretation process. In these comparisons, we use what we refer to as a “10% leeway” on species dominance for reasons that are explained in the discussion section. It consists in the following rule: for a given stand, if the 2nd species in importance produced by the ITC analysis is within 10% of the 1st species AND using it as 1st species is favourable to the comparison with the CFI, use it instead. This makes the comparisons more reasonable as the human interpreters had to decide by 10% increments, while the ITC analysis is using a continuum of percentages where a fraction of a percent could decide on the 1st species.

RESULTS

The confusion matrix resulting from the classification of the ADS80 imagery (Table1) shows that the coniferous species are generally well classified, the white spruce classification being the poorest (50%) with significant confusion (24%) with jack pine. As typical, due to its central location in spectral space, white pine has a bit of confusion with every other species. For the deciduous trees, poplar and hard maple (e.g., sugar maple) are well recognized, while the classification of soft maple (e.g., red, silver maple), red oak and white birch is distinctively poor, with confusion among themselves and with poplar.

The confusion matrix resulting from the classification of the IKONOS imagery (Table2) shows similar patterns with additional confusion between species and thus, a weaker overall classification precision compared to the ADS (59% vs 70%). There is more confusion between the white and black spruces, and both of them are increasingly confused with jack pine. The confusion between jack pine and red pine has also increased. For the deciduous trees, the pattern is more or less the same as with the ADS, with even lower recognition of soft maple, red oak and white birch, and more confusion with poplar.

Figures 1 and 2 show the "apparent concordance" between the first species designated by the ADS ITC analysis and the first species designated by the IKONOS ITC analysis with that of the conventional forest inventory as done by interpreters. Figure 3 shows the apparent concordance between the two ITC analyses. Apart from the overestimation of white pine, Figure1 appears to show a good concordance between the 1st species estimated by the ITC analysis of ADS data and that of the interpreters, the other obvious difference being an apparent count reversal between hard and soft maple. This situation, which is also present in Figure 2, is suspected to be in part due to overestimation of the soft versus hard maples in the forest inventory, but needs to be investigated.

The IKONOS ITC analysis (Figure 2) overestimates white pine even more and appears to have less concordance with the conventional inventory, especially when it comes to small trees like the spruces. By comparison, the quantity of stands labelled "spruce dominant" in the ADS analysis (Figure 1) appears to be similar to that of the inventory. These differences are made more obvious by Figure 3. However, although these Figures are appropriate to quickly visualize problem situations, they can not be relied upon to illustrate or quantify where "real concordance" actually exist. Indeed, these figures could show an equal number of stands dominated by a given species with very few of these stands actually being the same. Thus, further analysis is done using confusion matrices.

Table 3 summarizes the matches (and confusion) for each stand of the conventional forest inventory between the first species designated by the ADS ITC classification and that of the inventory, given a ±10% leeway. If one were to assume that photo-interpreters are accurate when it comes to assessing the main species of each stand, one could consider the diagonal elements of this confusion matrix representative of the ADS classification accuracies (expressed in percentage at the bottom of the table), within certain caveats to be discussed later (see discussion section). Not willing to make this assumption, we prefer to talk of agreement between the ADS ITC classification and the interpreters regarding the dominant species of every photo-interpreted stand. Here, the overall agreement is about 52%.

At first glance, Table 3 agreements appear low and some, dramatically low. However, it is noteworthy that the strongly and weakly recognized first species are essentially the same as that of Table1. The species that had low recognition precision (≤ 55%) in Table 1 (Ms, Or, Bw, and Sw) are almost never recognized as first species, with the exception of red oak, while for the others (i.e., the well recognized species: Mh, Po, Pw, Pj, Pr, and Sb), first species status recognition is on average 60% in agreement with that of the conventional forest inventory (i.e., the interpreters).

Table 4, which summarizes the matches for each inventory stand between the first species designated by the IKONOS ITC classification and that of the inventory (given a ±10% leeway) shows similar patterns. In this case, the better recognized first species are in agreement 53% of the time with the interpreters while the overall agreement is about 45%. An important pattern, that shows up in Table 3 but is highly visible in Table 4, is the overestimation of white pine as stand's ITC first species, as already made obvious by Figures 1 and 2.

Tables 5 and 6 quantify the agreement between the ITC analysis using the IKONOS image and the ITC analysis using the ADS imagery. In the first table, a bias (10% leeway) toward the human interpretation was applied to both analyses when deciding on the 1st species to compare, while in the second table the bias was towards the ADS analysis decision. The overall agreement conveyed by Tables 5 and 6 diagonal elements are 57.5% and 64.7%, respectively. This means that the ITC classifications agree more with each other than with the interpreters (as per Tables 3 & 4) and that, when we bias them towards interpreters' decisions (Table5) we get worse agreement.

DISCUSSION

This study compared 1st species assignments from the ITC analyses of aerial and satellite data with that of the conventional photo-interpretation (soft-copy) process and, among themselves. There are numerous caveats to consider that put these comparisons in perspective.

First, the very few published studies (e.g., (iii), (iv), (v)) estimate interpreters to be on average 50%-65% accurate on the leading species within a stand, the lower accuracies being encountered for hardwoods stands. Of course, certain "flagship" species like black spruce are often ascertained with close to 80% accuracy, mostly due to their very distinctive crown and the use of contextual information. The photo-interpreted accuracy of the second or third species is often lower. The accuracy of minor species is generally unknown. Little is known about the proportions accuracy. Thus, any comparison of results with that from the conventional forest inventory process should be considered in that light.

Secondly, depending on the province, the "percentage of composition" can be based on a species percentage of overall crown closure within a stand (e.g., Ontario), their inferred basal area (e.g., Quebec), or volume (e.g., BC). On the other hand, the ITC analysis reports on species percentages either by their contribution to the stand crown closure or by their percentage of the total number of ITCs in the stand (i.e., an individual tree approach). For our comparison here, we are fortunate to be able to use percentage of overall crown closure for both the ITC analysis and the CFI interpretation. However, they can be slightly different, as the sum of individual crown area for a given surface area is influenced by the quantity of individuals present, as by the nature of our algorithms, they need to be at least one pixel apart. The more separating pixels are present, the less the accumulated area, thus the less representative of surface area (or 100% crown closure).

Thirdly, although we have given some leeway to the comparisons by allowing, when favourable, the ITC species classed as 2nd to be considered instead of the 1st species if its presence is within 10% of the 1st one, there are situations where this was marginally or not useful at all. For example, when the first three species of a stand each have an assigned presence of 30%, what or who is to decide on the main species. This was a common situation within some mixed hardwood stands.

One of the obvious issues resulting from these comparisons is the probable overestimation by the ITC analyses of the presence of white pine as the dominant (first) species in stands (more so by the IKONOS analysis). There are numerous confounding factors that could explain such situation.

First, putting things into perspective, the interpreters agree that white pine is dominating the Petawawa Research Forest, as they have called about one third (33%) of the stands white pine dominated and as another 16% of the stands have white pine as their second most prevalent species. Secondly, if a species has a significant presence in a forested stand, it does not take much misclassification with other species to make it the dominant species. Thirdly, the fact that white pines are often emergent and appear to rest on top of the main canopy, violates the ITC delineation assumption that tree crowns are separated by areas of shaded material. There is thus more likelihood that parts of other tree crowns will be considered parts of the white pine crown, making them even bigger, leading to an over-evaluation of the presence within a stand. In fact, for that reasons and others (e.g., shade within the crowns), big white pine crowns were found to be poorly delineated in both ITC analyses.

Another comparison of Table 1 and Table 2 illustrates how the different spatial resolutions of the two media (ADS & IKONOS) affects crown delineation and thus, crown sizes. We are provided with two different types of information that have bearing on these issues: the number of crowns found within training/testing areas are reported at the bottom of the tables and the average crown sizes of the correctly classified tree crowns are reported below the two tables. Comparing this information, we immediately conclude that there are substantial differences. However, it is hard to make sense of these numbers without looking at the delineation situation *per se* on various sections of the imagery.

For softwood areas, the ADS crown delineations are relatively good, getting most of the individuals properly and containing few clusters of trees delineated as single ITCs. Thus, for softwoods, the number of trees reported by Table 1 should be a slight underestimation of reality and the crown sizes a slight overestimation. The IKONOS delineations, done at 50cm/pixel but actually from 1m/pixel data, are seen to have many more tree clusters. This is reflected in Table 2 generally reporting fewer individuals for the softwood testing areas and bigger average crown areas. Here again, white pine is an exception, as is noticeable by the dramatic differences in crown sizes between the two Tables. Because of shade within the crown, the crowns are severely over-broken in the ADS delineations and are somewhat more representative of reality with the IKONOS image.

Looking at the hardwood areas, most of the ADS delineations affect a pattern of good crowns, with some over-delineated and some under-delineated crowns, while the IKONOS delineations are generally all under-delineated. However, the white birch tree crowns, being very hard to separate visually on the ADS imagery, delineated as very big clusters of trees there, and even more so, on the IKONOS image. The hard maple crowns appear to be a strange exception. Their ADS delineations were affected by their higher reflectance resulting in more tree clusters than the other hardwood species, but more importantly, the IKONOS delineations are sometimes completely wrong as their high brightness cause the non-forest mask to obliterate part of their crowns resulting in rather meaningless crown segments.

CONCLUSIONS

One striking point of this study is the similarity of patterns, whether looking at classification confusion matrices or comparisons with the existing forest inventory working groups (i.e., 1st species), between the results from ITC analyses of the ADS80 aerial sensor data and that of the IKONOS satellite images. Given that the IKONOS satellite has the poorest resolution of all of the high spatial resolution (≤ 1 m/pixel) satellites that one would possibly consider using for an individual tree crown analysis, this study probably illustrates a worse case situation for species assessment from satellite images for the production of semi-automated forest inventories.

As expected (comparing Tables 3 and 4), the 1st species assigned to stands by the ADS ITC analysis have a better overall concordance with the 1st species assigned by the interpreters (~52%) than that of the IKONOS ITC analysis (~45%), or 60% and 53% respectively, when only the well classified species are considered. However, keeping in mind that the interpreters' calls are not always accurate, it is noteworthy that the concordance between the ITC analyses from the two different media is around 65%. This is even more surprising when one takes into consideration that the species classification from the IKONOS analysis are based on essentially 4 metre pixel multispectral data. Presumably, higher spatial resolution satellites like QuickBird and WorldView-2 should do better.

Future research work on these datasets shall endeavour to get better crown delineations and species classification, independently ascertained species classification accuracies, and use ITC species, crown sizes and heights to make volume assessment comparisons with the conventional inventory process. Another study (also in Ontario) comparing the ITC analyses of two ADS flight lines over the same geographic area should give an assessment of the repeatability, thus the stability of this analysis technique.

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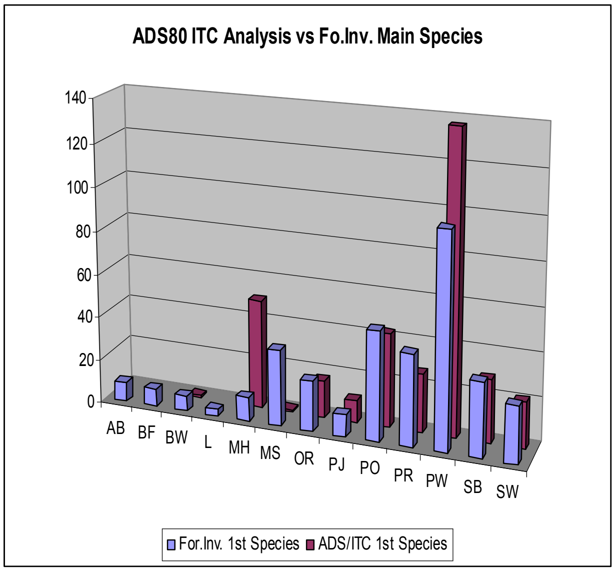

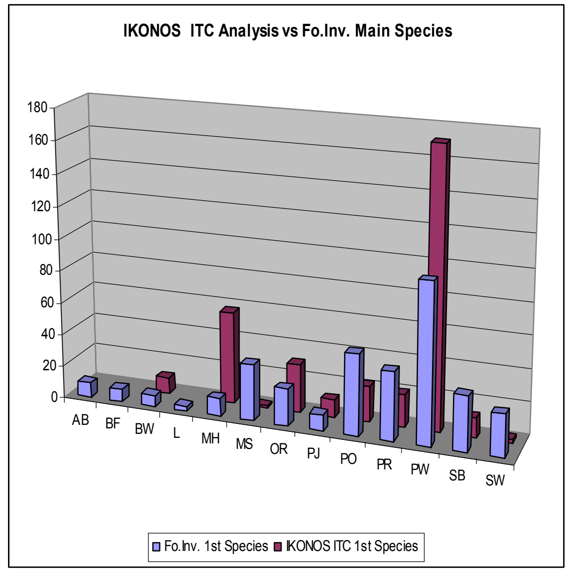

Figure 1: Number of stands by ADS-ITC analysis 1st species and conventional forest inventory 1st species (left)

Figure 2: Number of stands by IKONOS-ITC analysis 1st species and conventional forest inventory 1st species (right)

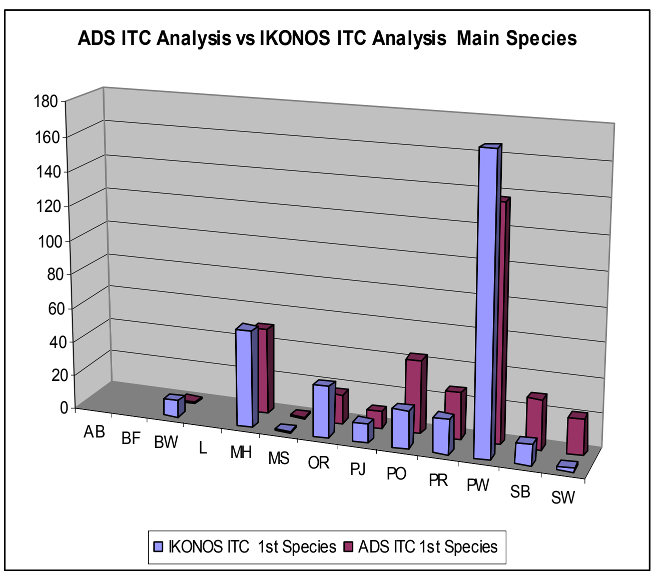

Figure 3: Number of stands by IKONOS-ITC analysis 1st species and ADS-ITC analysis 1st species

Table 1: Confusion Matrix from the ADS80 Classification (10 classes)

Mh	Ms	Or	Bw	Po	Pw	Pj	Pr	Sw	Sb	**Class**
167 (79.9%)	4 (1.3%)	0 (0.0%)	1 (1.8%)	0 (0.0%)	3 (1.0%)	8 (0.4%)	4 (0.8%)	0 (0.0%)	0 (0.0%)	Mh
23 (11.0%)	105 (33.5%)	41 (11.0%)	9 (15.8%)	37 (4.9%)	7 (2.3%)	0 (0.0%)	9 (1.7%)	1 (0.2%)	1 (0.3%)	Ms
0 (0.0%)	65 (20.8%)	201 (53.7%)	5 (8.8%)	50 (6.6%)	15 (4.9%)	1 (0.1%)	8 (1.6%)	1 (0.2%)	0 (0.0%)	Or
5 (2.4%)	61 (19.5%)	23 (6.1%)	28 (49.1%)	40 (5.3%)	14 (4.6%)	0 (0.0%)	1 (0.2%)	0 (0.0%)	0 (0.0%)	Bw
0 (0.0%)	21 (6.7%)	88 (23.5%)	6 (10.5%)	571 (75.8%)	4 (1.3%)	1 (0.1%)	17 (3.3%)	0 (0.0%)	0 (0.0%)	Po
1 (0.5%)	15 (4.8%)	3 (0.8%)	4 (7.0%)	7 (0.9%)	195 (64.1%)	7 (0.4%)	4 (0.8%)	41 (10.0%)	10 (3.2%)	Pw
3 (1.4%)	1 (0.3%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	13 (4.3%)	1455 (78.0%)	40 (7.8%)	100 (24.4%)	0 (0.0%)	Pj
3 (1.4%)	21 (6.7%)	11 (2.9%)	2 (3.5%)	35 (4.6%)	23 (7.6%)	202 (10.8%)	409 (79.4%)	12 (2.9%)	1 (0.3%)	Pr
1 (0.5%)	1 (0.3%)	0 (0.0%)	0 (0.0%)	2 (0.3%)	17 (5.6%)	121 (6.5%)	14 (2.7%)	207 (50.5%)	31 (10.1%)	Sw
0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (1.6%)	10 (0.5%)	0 (0.0%)	33 (8.0%)	250 (81.2%)	Sb
6 (2.9%)	19 (6.1%)	7 (1.9%)	2 (3.5%)	10 (1.3%)	8 (2.6%)	61 (3.3%)	9 (1.7%)	15 (3.7%)	15 (4.9%)	UN
209	313	374	57	753	304	1866	515	410	308	5109

Average Accuracy: 64.5% Kappa Coefficient: 0.664

Overall Accuracy: 70.2% Kappa Variance: 0.000056 Pixel size is 0.4 x 0.4 METRE

Average Crown Area (of correctly classified crowns)

109.83	61.06	32.57	94.82	55.75	40.26	32.71	43.31	40.82	28.86	(Pixels)
17.57	9.77	5.21	15.17	8.92	6.44	5.23	6.93	6.53	4.62	(Sq METRE)

Table 2: Confusion Matrix from the IKONOS Classification (10 classes, pan-sharpened bands)

Mh	**Ms**	**Or**	**Bw**	**Po**	**Pw**	**Pj**	**Pr**	**Sw**	**Sb**	**Class**
117 (73.1%)	1 (0.6%)	3 (3.4%)	1 (3.6%)	4 (1.3%)	3 (3.1%)	13 (1.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	Mh
4 (2.5%)	36 (22.9%)	2 (2.3%)	1 (3.6%)	16 (5.1%)	0 (0.0%)	0 (0.0%)	8 (1.8%)	1 (0.3%)	0 (0.0%)	Ms
8 (5.0%)	6 (3.8%)	21 (23.9%)	7 (25.0%)	20 (6.3%)	9 (9.3%)	1 (0.1%)	4 (0.9%)	0 (0.0%)	0 (0.0%)	Or
7 (4.4%)	13 (8.3%)	10 (11.4%)	9 (32.1%)	10 (3.2%)	6 (6.2%)	7 (0.6%)	2 (0.4%)	1 (0.3%)	1 (0.5%)	Bw
1 (0.6%)	44 (28.0%)	26 (29.5%)	5 (17.9%)	251 (79.4%)	0 (0.0%)	0 (0.0%)	3 (0.7%)	0 (0.0%)	0 (0.0%)	Po
6 (3.8%)	15 (9.6%)	21 (23.9%)	1 (3.6%)	10 (3.2%)	67 (69.1%)	22 (1.9%)	10 (2.2%)	5 (1.7%)	4 (2.1%)	Pw
1 (0.6%)	6 (3.8%)	1 (1.1%)	1 (3.6%)	0 (0.0%)	5 (5.2%)	621 (52.9%)	58 (12.7%)	57 (19.5%)	21 (11.1%)	Pj
7 (4.4%)	23 (14.6%)	4 (4.5%)	1 (3.6%)	2 (0.6%)	4 (4.1%)	237 (20.2%)	355 (77.7%)	5 (1.7%)	0 (0.0%)	Pr
0 (0.0%)	3 (1.9%)	0 (0.0%)	1 (3.6%)	0 (0.0%)	1 (1.0%)	100 (8.5%)	6 (1.3%)	125 (42.8%)	32 (16.9%)	Sw
1 (0.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	157 (13.4%)	1 (0.2%)	87 (29.8%)	128 (67.7%)	Sb
8 (5.0%)	10 (6.4%)	0 (0.0%)	1 (3.6%)	3 (0.9%)	2 (2.1%)	17 (1.4%)	10 (2.2%)	11 (3.8%)	3 (1.6%)	UN
160	157	88	28	316	97	1175	457	292	189	2959

Average Accuracy: 54.2% Kappa Coefficient: 0.511

Overall Accuracy: 58.5% Kappa Variance: 0.000120 Pixel size is 0.5 x 0.5 METRE

Average Crown Area (of correctly classified crowns)

50.33	57.33	111.81	114.78	78.67	55.19	23.88	27.64	23.70	23.83	(Pixels)
12.58	14.33	27.95	28.69	19.67	13.80	5.97	6.91	5.92	5.96	(Sq METRE)

Table 3: Forest Inventory 1st Species vs ADS80 ITC Analysis 1st Species (by CC ±10%)

	Forest Inventory 1st Species										
ITC	Mh	Ms	Or	Bw	Po	Pw	Pj	Pr	Sw	Sb	#of stands
Mh	7	6	5	1	7	13	0	3	2	6	50
Ms	0	1	0	0	0	0	0	0	0	0	1
Or	0	0	14	0	2	0	0	1	0	0	17
Bw	0	0	0	0	1	0	0	0	0	0	1
Po	2	3	2	2	27	2	0	3	2	0	43
Pw	2	25	2	4	12	71	3	4	12	2	137
Pj	0	0	0	0	0	1	5	3	1	0	10
Pr	0	0	0	0	1	4	0	20	2	0	27
Sw	0	0	0	0	0	7	2	8	4	0	21
Sb	0	0	0	0	0	0	0	0	3	26	29
# of stands	**11**	**35**	**23**	**7**	**50**	**98**	**10**	**42**	**26**	**34**	**336**
Agreement	**63.64%**	**2.86%**	**60.87%**	**0.00%**	**54.00%**	**72.45%**	**50.00%**	**47.62%**	**15.38%**	**76.47%**	

Table 4: Forest Inventory 1st Species vs IKONOS ITC Analysis 1st Species (by CC±10%)

	Forest Inventory 1st Species										
ITC	Mh	Ms	Or	Bw	Po	Pw	Pj	Pr	Sw	Sb	#of stands
Mh	5	10	6	2	5	14	1	6	3	5	57
Ms	0	0	0	0	0	0	0	1	0	0	1
Or	5	3	15	0	4	2	0	0	0	0	29
Bw	0	4	0	2	0	1	0	1	1	1	10
Po	0	2	0	0	14	1	0	2	3	0	22
Pw	1	16	2	2	26	80	0	14	13	17	171
Pj	0	0	0	0	0	0	8	3	0	0	11
Pr	0	0	0	0	1	0	1	15	3	0	20
Sw	0	0	0	0	0	0	0	0	2	0	2
Sb	0	0	0	0	0	0	0	0	1	11	12
# of stands	**11**	**35**	**23**	**6**	**50**	**98**	**10**	**42**	**26**	**34**	**335**
Agreement	**45.45%**	**0.00%**	**65.22%**	**33.33%**	**28.00%**	**81.63%**	**80.00%**	**35.71%**	**7.69%**	**32.35%**	

Table 5: IKONOS agreement with ADS 1st species (both bias towards interpreters by 10%)

IKONOS 1st Species	ADS-ITC Analysis 1st Species: Mh	Ms	Or	Bw	Po	Pw	Pj	Pr	Sw	Sb	#of stands
Mh	6	0	2	1	2	11	0	0	0	0	**22**
Ms	0	0	0	0	0	0	0	1	0	0	**1**
Or	5	0	12	0	6	7	0	0	0	0	**30**
Bw	1	0	0	0	2	3	0	2	1	1	**10**
Po	2	0	0	0	14	3	0	2	1	0	**22**
Pw	1	1	3	0	18	110	2	8	12	16	**171**
Pj	0	0	0	0	0	2	4	1	4	0	**11**
Pr	0	0	0	0	1	1	4	13	1	0	**20**
Sw	0	0	0	0	0	0	0	0	2	0	**2**
Sb	0	0	0	0	0	0	0	0	0	12	**12**
# of stands	**15**	**1**	**17**	**1**	**43**	**137**	**10**	**27**	**21**	**29**	**301**
Agreement	**40.0%**	**0.0%**	**70.6%**	**0.0%**	**32.6%**	**80.3%**	**40.0%**	**48.1%**	**9.5%**	**41.3%**	

Table 6: IKONOS agreement with ADS 1st species (bias towards ADS by 10%) for labelled stands only

IKONOS 1st Species	ADS-ITC Analysis 1st Species: Mh	Ms	Or	Bw	Po	Pw	Pj	Pr	Sw	Sb	#of stands
Mh	10	0	2	0	3	8	0	1	0	1	**25**
Ms	0	0	1	0	0	0	0	0	0	0	**1**
Or	6	0	9	1	2	3	0	1	0	0	**22**
Bw	1	0	0	2	1	1	0	2	0	1	**8**
Po	1	0	0	0	21	1	0	3	1	0	**27**
Pw	1	1	2	0	13	128	1	11	20	16	**193**
Pj	0	0	0	0	0	0	10	1	3	0	**14**
Pr	0	0	0	0	0	1	1	12	1	0	**15**
Sw	0	0	0	0	0	0	0	0	2	0	**2**
Sb	0	0	0	0	0	0	0	0	0	13	**13**
# of stands	**19**	**1**	**14**	**3**	**40**	**142**	**12**	**31**	**27**	**31**	**320**
Agreement	**52.6%**	**0.0%**	**64.3%**	**66.7%**	**52.5%**	**90.1%**	**83.3%**	**38.7%**	**7.4%**	**41.9%**	