Remote Sensing Brief

A Pilot Study Evaluating Ground Reference Data Collection Efforts for Use in Forest Inventory

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THE COLLECTION OF GROUND REFERENCE DATA is an essential part of any classification and mapping project involving remotely sensed data. These data are used to verify the classification, to discover confusion between classes, and as input into improving the classification. Many ways of collecting ground reference data have been used. Ground reference data are often collected from photo interpretation of large-scale aerial photographs or by flying over the area in a helicopter or fixed-wing aircraft and taking some notes. Recently, video cameras have been employed in aircraft to obtain ground reference data. In addition to these aerial techniques, data have frequently been collected on the ground. Drive-by surveys are common, as is finding someone who is familiar with the ground and asking them about various areas on the classified image. Finally, ground reference data have been collected by actually visiting the spot on the ground. Various levels of effort have been employed, from walking through an area and making a visual call of the parameters of interest (e.g., land cover, land use, vegetation species, etc.) to detailed measurements of these parameters.

Obviously, it is important that the ground reference data be correct or else they introduce systematic or random bias into the classification system. Therefore, which of these data collection techniques are valid and which are not? It is clear to the authors that, depending on the scale of the photos and the level of detail required by the classification scheme, the use of photo interpretation for generating reference data may not be appropriate. Reference data are naturally assumed to be correct and, therefore, any photo interpretation errors would be transferred to the classification. Actual ground visitation is the preferred method of data collection. It also must be realized that the collection of these ground reference data is extremely expensive and that, therefore, the collection effort must be sufficient to meet the needs of the study while being efficient enough to meet the needs of the budget.

With all these factors in mind, a pilot study was conducted to determine the level of effort needed to collect these ground reference data for forest inventory. The objective of this study was to determine if visual calls made by walking into a forest are sufficient or whether actual ground measurements need to be made. There are obviously many factors influencing the accuracy of ground data collection, including the complexity of the vegetation itself. A variety of vegetation complexities were represented in this study, and the authors believe that these results will be enlightening to those remote sensing specialists who routinely collect forest ground data only by visual calls. In fact, these results are so revealing that the authors felt compelled to write this Remote Sensing Brief to publish these results even before finishing their complete study. This pilot study was part of a larger project aimed at developing the use of digital remotely sensed data for commercial forest inventory (Biging and Congalton, 1989) and funded by NASA under the Earth Observation Commercial Application Program (EOCAP.) This program is a new NASA initiative aimed at expanding the commercial aspects of remote sensing.

Commercial forest inventory involves much more than a land-cover classification typically derived from digital remotely sensed data. A complete inventory requires that the forest type, the size class, and the crown closure of a forested area be known in order to determine the volume of the timber in that area. If a single species dominates, the forest type is commonly named by that species (Eyre, 1980). However, if a combination of species are present, then a mixed label is used (e.g., the mixed conifer type). The size of the tree is measured by the diameter of the tree at 4.5 feet above the ground (diameter at breast height, DBH) and then is divided into classes such as poles, small saw timber, and large saw timber. This measure is obviously important because large diameter trees contain more volume (i.e., valuable timber) than small diameter trees. Crown closure, as measured by the amount of ground area the tree crowns occupy (canopy closure), is also an important measure of tree size and numbers. Therefore, in this pilot study, it was necessary to collect ground reference data not only on tree species/type, but on crown closure and size class as well.

Ground reference data were collected using two approaches. In the first approach, a field crew of four would enter an area, look around, and come to a consensus for a visual call of dominant species/type, size class of the dominant species, crown closure of the dominant size class, and crown closure of all tree species combined. Dominance was defined as the species or type comprising the majority of forest volume. In the second approach, a fixed-radius plot was used to record the species, DBH, and height of each tree falling within the plot. A minimum of two plots (1/10th or 1/20th acre) were measured for each forested area. Because of the difficulty of making all the required measurements (precise location and crown width for each tree in the plot) to estimate crown closure on the plot, an approach using transects was developed to determine crown closure. A minimum of four one-hundred-foot long transects randomly located within the area were used to collect crown closure information. The percent of crown closure was determined by the presence or absence of tree crown at one-foot intervals along the transects. These measurements were then input into a computer program that summarized the results into the dominant species/type, the size class of the dominant species/type, the crown closure of the dominant size class, and the crown closure of all tree species for each forested area. The

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results of the two approaches could then be compared by using an error matrix (Story and Congalton, 1986).

Table 1 shows the results of field measurement versus visual call as expressed in an error matrix for the dominant species. Note that the matrix clearly allows the reader to identify errors of omission and commission in the classification as well as to determine overall accuracy, producer's accuracy, and user's accuracy. This table indicates that species can be fairly well determined from a visual call because there is strong agreement between the field measurements and the visual call. Of course, this conclusion requires one to assume that the field measurements are a better measure of ground reference data. The authors believe that this assumption is valid in this case. Therefore, ground reference data collection of species information can be maximized using visual calls, and field measurements appear to be unnecessary.

Table 2 presents the results of comparing the two ground reference data collection approaches for the dominant size class. As for species, the overall agreement is relatively high with most of the confusion occurring between the larger classes. The greatest inaccuracies result from visually classifying the dominant size class (i.e., the one with the most volume) as size class three (12 to 24 inch DBH) when in fact size class four (>24 inch DBH) trees contained the most volume. This visual classification error is easy to understand. Tree volume is directly related to the square of DBH. There are numerous cases when a small number of large trees contribute the majority of the volume in the stand, while there may be many more medium size trees present. The dichotomy between prevalence of medium size trees, but dominance in volume by a small number of trees, can be difficult to assess visually. It is likely that researchers and practitioners would confuse these classes in cases where the size class with the majority of volume was not readily evident. In cases like this, simply improving ones ability to visually estimate diameter would not improve ones ability to classify size class. The ability to weight numbers and sizes to estimate volume requires considerable experience and would certainly require making plot and tree measurements to gain and retain this ability.

Tables 3 and 4 show the results of comparing the two collection approaches for crown closure. Table 3 presents the crown closure of the dominant size class results while Table 4 shows the results of overall crown closure. In both matrices, there is very low agreement (46 to 49 percent) between the visual call

TABLE 1. ERROR MATRIX SHOWING RESULTS OF DOMINANT SPECIES/TYPE FOR THE TWO GROUND REFERENCE DATA COLLECTION APPROACHES.

Visual Call \ Field Measurement	TF	MC	LP	DF	PP	PD	OAK	row total
TF	14	0	0	0	0	0	0	14
MC	0	10	0	0	0	2	0	12
LP	0	0	1	0	0	0	0	1
DF	0	1	0	8	0	0	0	9
PP	1	1	0	0	0	0	0	2
PD	0	0	0	1	0	0	0	1
OAK	0	0	0	0	0	0	0	0
column total	15	12	1	9	0	2	0	39

Species/Type

TF = true fir
MC = mixed conifer
LP = lodgepole pine
DF = Douglas fir
PP = Ponderosa pine
PD = PP and DF
OAK = oaks

OVERALL ACCURACY = 33/39 = 85%

PRODUCER'S ACCURACY

TF = 14/15 = 93%
MC = 10/12 = 83%
LP = 1/1 = 100%
DF = 8/9 = 89%
PP = 0/0 = --
PD = 0/2 = 0%
OAK = 0/0 = --

USER'S ACCURACY

TF = 14/14 = 100%
MC = 10/12 = 83%
LP = 1/1 = 100%
DF = 8/9 = 89%
PP = 0/2 = 0%
PD = 0/1 = 0%
OAK = 0/0 = --

TABLE 2. ERROR MATRIX SHOWING RESULTS OF DOMINANT SIZE CLASS FOR THE TWO GROUND REFERENCE DATA COLLECTION APPROACHES.

Visual Call \ Field Measurement	1	2	3	4	row total
1	1	0	0	0	1
2	1	3	1	0	5
3	0	0	17	5	22
4	0	0	1	11	12
column total	2	3	19	16	40

Size Classes

1 = 0-5" dbh
2 = 5-12" dbh
3 = 12-24" dbh
4 = >24" dbh

OVERALL ACCURACY = 32/40 = 80%

PRODUCER'S ACCURACY

1 = 1/2 = 50%
2 = 3/3 = 100%
3 = 17/19 = 89%
4 = 11/16 = 69%

USER'S ACCURACY

1 = 1/1 = 100%
2 = 3/5 = 60%
3 = 17/22 = 77%
4 = 11/12 = 92%

TABLE 3. ERROR MATRIX SHOWING RESULTS OF CROWN CLOSURE OF THE DOMINANT SIZE CLASS FOR THE TWO GROUND REFERENCE DATA COLLECTION APPROACHES.

Visual Call \ Field Measurement	O	L	M	D	row total
O	10	8	3	0	21
L	2	8	1	1	12
M	0	3	1	1	5
D	0	1	0	0	1
column total	12	20	5	2	39

Crown Closure Classes

O = Open
L = Low
M = Medium
D = Dense

OVERALL ACCURACY = 19/39 = 49%

PRODUCER'S ACCURACY

O = 10/12 = 83%
L = 8/20 = 40%
M = 1/5 = 20%
D = 0/2 = 0%

USER'S ACCURACY

O = 10/21 = 48%
L = 8/12 = 67%
M = 1/5 = 20%
D = 0/1 = 0%

TABLE 4. ERROR MATRIX SHOWING RESULTS OF CROWN CLOSURE FOR ALL SIZE CLASSES FOR THE TWO GROUND REFERENCE DATA COLLECTION APPROACHES.

Visual Call \ Field Measurement	O	L	M	D	row total
O	0	1	1	0	2
L	1	3	7	0	11
M	0	0	8	10	18
D	0	0	0	6	6
column total	1	4	16	16	37

Crown Closure Classes

O = Open
L = Low
M = Medium
D = Dense

OVERALL ACCURACY = 17/37 = 46%

PRODUCER'S ACCURACY

O = 0/1 = 0%
L = 3/4 = 75%
M = 8/16 = 50%
D = 6/16 = 38%

USER'S ACCURACY

O = 0/2 = 0%
L = 3/11 = 27%
M = 8/18 = 44%
D = 6/6 = 100%

and the field measurements. Consequently, it appears that field measurements must be used to obtain adequate measures of crown closure and that visual calls, although less expensive and quicker, do not provide the required accuracy.

In conclusion, it must be emphasized that this is only a small pilot study. Further work needs to be conducted in this area to evaluate ground reference data collection methods and to include the validation of aerial methods (i.e., photo interpretation and videography). Alternative measurements techniques were evaluated using contingency table analysis (i.e., error matrices). The results presented demonstrate that making visual calls of species are relatively easy and accurate, except where many species occur simultaneously. Size class is more difficult to assess than species, because of the implicit need to estimate the size class with the majority of volume. Crown closure is by far the toughest to determine. It is most dependent on where one is standing when the call is made. Field measurements, such as the transects used in this study, provide a better means of determining crown closure. This study has shown that at least some ground data must be collected using measurements, and it has suggested that a multi-leveled effort may result in the most efficient and practical method for collection of ground reference data. Our work is continuing and we plan to provide more definitive guidance on the extent of effort and level of detail needed to collect reliable ground reference data.

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