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A Simple Procedure for Mapping Tree Locations in Forest Stands

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ABSTRACT. A procedure is presented for mapping tree locations directly into a Cartesian coordinate system without requiring distance and bearing measurements in the field. An independent check of the locations of 401 trees by different field crews at different times showed the method to be both accurate (with an average difference between the two measurements of 0.01 m) and precise (with the standard deviation of the differences being 0.22 m). The method is most efficient with a three-person crew. The time required to map a given area is dependent on tree density and visibility. In well-stocked (600 to 1100 trees/ha) northern hardwood stands it is possible to map 1 hectare per day with an experienced crew. The procedure is designed for square plots, but it can be adapted easily to circular plots. FOR. SCI. 35(3):657–662.

ADDITIONAL KEY WORDS. Spatial pattern, mapped stands, mapping procedure, competition.

THE UTILITY OF SPATIAL INFORMATION within forest stands has been widely recognized in ecological investigations, in studies of intertree competition, and in the development of distance-dependent tree growth models. Such data are relatively scarce and expensive to collect using common procedures (Oderwald et al. 1980). Most common mapping procedures use measurements of distances and bearings to individual trees from common points. The most accurate of these use a transit or staff compass, are time-consuming, and require great care and well-trained personnel. Even under the best conditions, relatively small errors in bearings or distances can result in large discrepancies when the measurements are converted to Cartesian coordinates of tree locations. Tradeoffs between sighting long distances and tying in multiple-sighting locations are required. This paper presents a simple method that uses inexpensive equipment, is easy to train to field personnel, and is repeatable by different crews at different times. Some other mapping methods may be as fast, but an extensive evaluation of these methods has apparently not been reported in the literature. In the experience of the authors, no other method results in the combination of speed, accuracy and precision of this method.

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EQUIPMENT

The equipment needed for this procedure is relatively inexpensive compared to equipment needed by the more common methods. In 1988, the equipment listed below could be purchased for less than $400 (US) from a number of sources. The required equipment includes:

- Two double right-angle prisms (also called "double pentaprisms")
- Two 50 m measuring tapes (the length is arbitrary and subject to field conditions)
- Five 2 m range poles or straight homemade poles
- Disposable string and flagging

PROCEDURE

The mapping method works best with a three-person field crew, but as few as two people can perform the work if necessary. The procedure described below is for square plots with corner markers and a center stake. Use of the double right-angle prisms allows mapping directly into a Cartesian coordinate system. These prisms have three sighting viewfinders, which allow a field crew member to locate a position along an existing line perpendicular to a point in the field.

The initial step is to draw string along the plot boundaries between the corner stakes. Using the measuring tape, the center point of each plot boundary is located and marked with a vertical range pole or flagged stake. The measuring tapes are then stretched between center points on opposite sides of the plot. This results in perpendicular placement of the measuring tapes with the tapes intersecting at the center of the measurement plot. The tape placement should result with the tape zero points on a plot boundary, the tape midpoints at the center of the plot, and the tape endpoints on a plot boundary. The perpendicularity of the tapes is checked with the double right-angle prisms, and remeasurements or adjustments to the range poles or tapes are made as needed. If a tree or other obstacle makes this placement impossible, either or both tapes may be offset as long as they are perpendicular to each other and the zero points are on the plot boundaries.

For each of the two measuring tapes, a crew member, equipped with a double right-angle prism, takes a position at the zero point of each tape. The third crew member moves from tree to tree within the plot, making sure that each tree is visited. At each tree, this third member uses a range pole or flagged stake to indicate a sighting position at the center of the tree for each of the two crew members along the measuring tapes. The crew members at the measuring tapes move along the tapes and align the double right-angle prism with the tree of interest and the two range poles at the ends of the measuring tape (Figure 1). A weight attached to the prism by a string is used as a plumb bob to read the position along the measuring tape. This gives a Cartesian coordinate of the tree location in each direction which is recorded, along with the tree number and other information such as species or size, by the crew member at the tree before moving to the next tree to be mapped. For plots with a significant slope, measurements can be converted to horizontal distance using trigonometric relationships following measurement if the percent or angle of slope is known.

PERFORMANCE

The performance of this mapping procedure is illustrated using data from well-stocked (600–1100 stems/ha) northern hardwood stands. Locations of every tree on 18 individual 50 m × 50 m square plots were mapped. Loca-

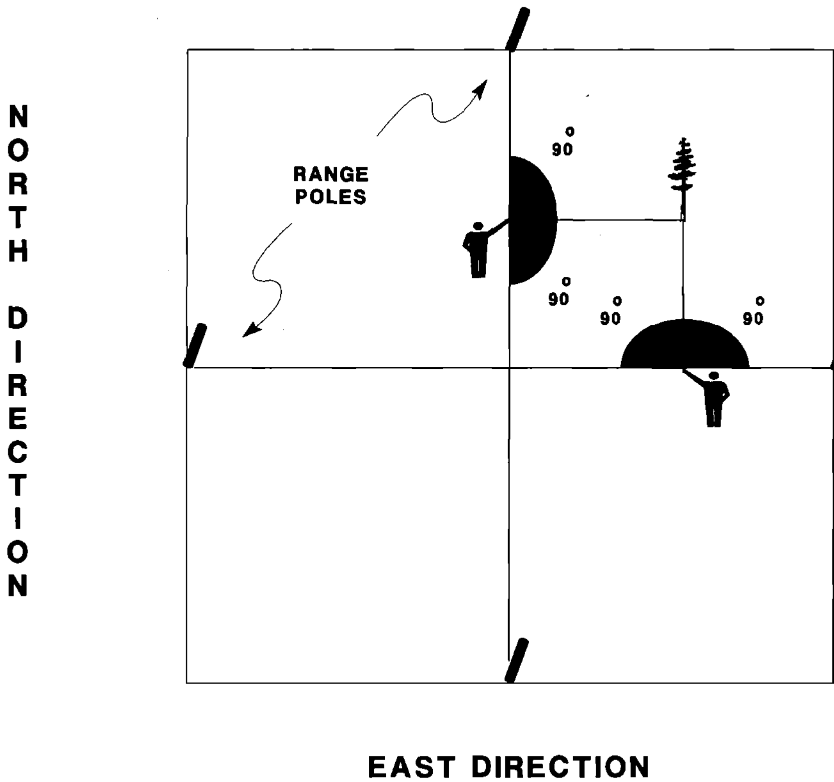

FIGURE 1. Illustration of the field procedure.

tions of every tenth tree in the center 30 m × 30 m area as well as the nearest tree to each plot corner, boundary midpoint, and corner of the 30 m × 30 m center area were remapped by different crews at a later time for each of the 18 plots. This remapping involved a repeat of the entire procedure, including the placement of the measuring tapes and determinations of the plot boundary lines. The differences in tree coordinates, in each direction, between the original and the repeat mapping procedures are used to evalute the performance of the procedure.

Over the 18 plots, the locations of a total of 401 trees were remapped. Since each tree has two coordinates, this gave a total of 802 remeasurements. The results of the remeasurements (Table 1) indicate that the procedure is repeatable with an average difference of 0.01 m between the original coordinates and the remeasured coordinates and a standard deviation of these differences of 0.22 m. The results for the individual plots are more variable. When comparing among the 18 plots, large average differences and large average absolute differences between the two measurements accompanied by a typical standard deviation indicates that the tape placement was slightly (0.1 to 0.2 m) different between the two measurements. This apparently happened on plots 1, 2, 5, 6, and 17.

Another source of error is in data recording. As can be seen in Figure 2, 82% of the measurement pairs differed by 0.2 m or less, and 91% differed by 0.3 m or less. There were several differences (9 out of 802) that were 1.0 m or larger. On revisiting some of these large differences, all were apparently caused by data entry errors during one of the measurements. These errors increase the standard deviation of the differences and can be due to either

TABLE 1. Summary of the performance of the mapping methods on eighteen 50 m × 50 m northern hardwood plots.

Plot	Average diameter (cm)	Stems/ha	No. of checked coordinates	Average D^a	Average $\|D\|$	s_D
				..................(m).................		
1	19.3	828	52	−0.13	0.22	0.27
2	18.4	840	54	−0.12	0.18	0.22
3	18.8	800	60	−0.02	0.15	0.23
4	19.9	772	40	−0.02	0.16	0.21
5	21.2	652	36	0.11	0.18	0.20
6	19.3	900	46	−0.21	0.28	0.26
7	16.9	1028	42	0.05	0.15	0.24
8	18.5	852	40	0.05	0.19	0.24
9	19.2	728	38	−0.03	0.16	0.25
10	19.6	796	42	−0.01	0.16	0.26
11	19.8	756	42	0.05	0.15	0.21
12	22.7	616	38	0.09	0.13	0.26
13	20.8	888	40	0.02	0.09	0.15
14	17.8	928	46	−0.03	0.14	0.22
15	19.4	952	44	0.03	0.15	0.23
16	16.5	980	48	0.07	0.10	0.20
17	19.4	864	44	0.10	0.19	0.22
18	16.2	1104	50	−0.01	0.07	0.10
ALL	18.9	849	802	−0.01	0.16	0.22

[a] D = Original coordinate − remeasured coordinate.

the transposition of numbers or misentry on the electronic data recorder used in the study. An occasional plot (plots 13 and 18, for instance) with an average difference near zero accompanied by low average absolute differences and low standard errors had very consistent tape placement and very few data recording errors.

On the 50 m × 50 m plots used here, the tapes intersected at the plot center and resulted in tree locations being up to 25 m from the measurement tapes. The measurements at all distances from the tapes appear to be unbiased as indicated by average differences between the two measurements being near zero (Table 2). Precision, as indicated by average absolute differences and the standard deviation of differences, appears to decrease with increased distance from the measurement tape. The crew members also reported some difficulty at short distances because the range pole at the tree center appeared much larger in the viewfinder of the right angle prism than the two range poles along the measurement tape at the plot boundaries. This could have caused a slight increase in standard deviation when sighting 0–5 m as indicated in Table 2. There appears, therefore, to be an optimal sighting distance due to the limitations of the right angle prisms, which seems to have been between 5 and 10 m for these plots. Similar problems with the viewfinder can occur when near a range pole at one end of a measurement tape and far from the one at the other end. This, along with the general difficulties of sighting long distances, contributes to the decreased precision at longer distances from the measurement tape.

SUMMARY AND RECOMMENDATIONS

The method described in this paper provides a procedure for mapping tree locations in forest stands that does not require expensive equipment or

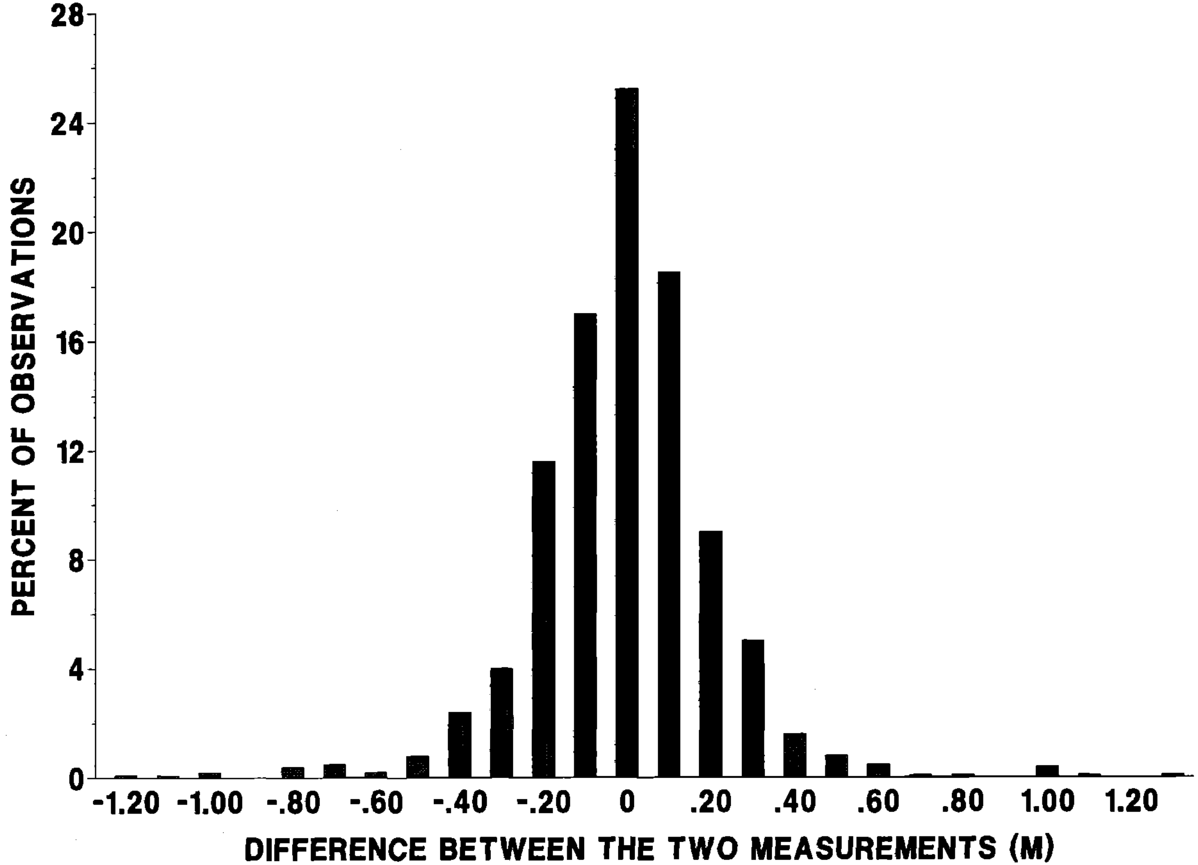

FIGURE 2. Distribution of differences between the original coordinate and the remeasured coordinate.

TABLE 2. Summary of differences between the two observations by distance from the measurement tape.

Sighting distance (m)	No. of checked coordinates	Average D^a	Average $\lvert D \rvert$	s_D
			......(m)......	
0–5	224	−0.00	0.13	0.20
5–10	119	−0.03	0.12	0.16
10–15	216	−0.01	0.14	0.20
15–20	119	0.00	0.16	0.25
20–25	124	0.00	0.26	0.37

[a] D = Original coordinate − remeasured coordinate.

specially trained field personnel. The procedure is repeatable by different crews at different times and, while other mapping procedures may be as fast or as accurate, provides a combination of speed, accuracy, and precision that the authors have not found in any other method. Following the evaluation of the procedure described here, there are several recommendations that can further reduce the time required to map a stand and possibly lead to increased accuracy and precision in the tree coordinates.

1. Mapping is most efficient in the spring and fall when brush is at a minimum. In stands with a heavy understory, it may be necessary to divide a plot into subplots (such as four quadrants) to expedite sighting. This requires relocation of the measurement tapes and careful record-keeping of the location coordinates mapped in the different subplots. Tape relocation may also be required by steep terrain, complex topography, or very dense stands.
2. Accuracy and precision near the plot boundaries can be improved by locating the range poles or flagged stakes marking the boundary midpoints 2 to 5 m outside of the plot while maintaining the alignment with the measuring tapes. This would give a longer sighting distance to the range poles or flagged stakes when working along the measurement tapes near the plot boundary and possibly eliminate some of the problems with the viewfinder of the right angle prisms. Locating a range pole or flagged stake at plot center could also reduce the difficulty with long sighting distances and lead to increased precision near the plot boundaries.
3. To ensure that each tree is mapped and to increase the speed of mapping, number or tag each tree on the plot prior to the mapping procedure. While conducting the mapping procedure, a visual check can then be made to ensure that no trees are inadvertently omitted from the map. In this study, the trees were numbered on all 18 plots prior to mapping; during the mapping procedure, several trees were identified that had been missed during the initial numbering.
4. The methods presented here can be easily adapted to circular plot configurations. Prior numbering of trees is especially helpful, but not required, when mapping circular plots. Many electronic data recorders have the capability of checking if a tree's location is a greater distance from the plot center than the plot radius, thus allowing plot boundaries to be determined during the mapping procedure. When mapping in circular plots, the measuring tapes are placed perpendicular to each other, intersecting at the center of the plot, with the zero points on the plot boundary. Following the field work, if the center of the circular plot is desired to coincide with the origin of the coordinate system, the value of the coordinates for the center point can be subtracted from each of the mapped locations, thus relocating the origin of the coordinate system at plot center.

LITERATURE CITED

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