Issues in Student Surveys of a Permanent Experimental Stand in a Research Forest

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学生実習による演習林固定試験地調査の問題点

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要旨：学生実習による固定試験地調査を通じて，授業でのフィールド調査の割り当て方法について検討した。信州大学農学部手良沢山演習林のイチイ植林地において，参加学生 20 名を 4 班に分け，先回り探索（他の班との位置関係と未調査木の位置をもとに次の調査木を選ばせる方式）で，立木のサイズと位置の計測を実施した。全体では 94 本（班ごとに 17～28 本）の立木が調査され，胸高直径（DBH）は正規分布し，班ごとに見ても平均 DBH に有意差はなく概ね正規分布していた。立木の位置情報をもとに調査中の各班の移動の軌跡を描いたところ，調査終了まで開始時点の各班の位置関係がほぼ保たれ，軌跡が互いに交錯することはなかった。また，班ごとで調査終了までの時間差はほとんど生じなかった。次の調査木への距離（平均の水平距離 3.0～3.5 m，垂直距離 1.0～1.8 m）に班ごとに有意差はなく，調査条件に班ごとの著しい違いはなかった。また，最も調査本数の多かった班で，標識番号の誤記入が 1 件見られ，それによって欠測と重複カウントをそれぞれ 1 本ずつ生じたのと等しい状況になった。各班の意思に任せる先回り方式での調査割り当てでは，班ごとの能率に合わせて調査地が分担されることが確かめられたが，問題点として調査ミスを検出しにくいことが挙げられた。

キーワード：学生実習，森林調査，先回り探索，誤記
Key words: Practical training for students, Forest survey, MECE search, Misentry

Introduction

For effective cooperative learning, students should be organized into an environment that enhances academic and social learning experiences (Mutingi and Mbohwa 2017). Grouping methods and their educational effects have been studied (e.g. Ishida and Suzuki 2006; Matsumoto *et al*. 2008; Nakayama *et al*. 2011; Mutingi and Mbohwa 2017), but most of these studies dealt with class assignments, often with computing. In contrast, only a few studies are available on cooperative learning in fieldwork.

In fieldwork, students are often obliged to be divided into groups and to share limited materials and implements; therefore, safe and efficient cooperative learning is necessary. Furthermore, preparation of educational materials for field surveys involves additional difficulty: although educational materials should be prepared uniformly for students (Tanaka and Kawasumi 1994), it is difficult to prepare field materials systematically (Onuma *et al*. 2007). A reasonable method for allotting educational materials to student groups for fieldwork has not been established.

Terasawayama Research Forest at Shinshu University includes several ‘neglected’ permanent experimental stands of unknown state after the retirement of the responsible researchers. Afforested trees remain there unless they have fallen: it is difficult to schedule forest management or education and research without information on their current state. Educators and engineers must instruct in many areas of knowledge and techniques that are mainstays of forest management, e.g. tree planting, branch trimming, forest thinning, and forest road design. Consequently, the renewal of permanent experimental stands, despite its necessity, has been neglected in this research forest.

We are paying attention to neglected permanent experimental stands as field survey sites to evaluate methods for dividing students and educational materials. It has been reported that fieldwork provides a strategy for contributing to society within a short period, which will enhance the interest of students and make a positive impression on them (Onuma *et al*. 2007). Through the participation of students in an important survey with the distinct purpose of forest management, we should be able to enhance the educational impact on students, as well as acquire up-to-date data on these stands.

Our previous reports discussed the preparation of a stand for student surveys in a neglected permanent experimental forest: in an animal-damaged *Sciadopitys verticillata* stand afforested in 1983, the division of the survey site into equal-area zones allotted to the student groups resulted in differences in tree size and uneven distribution of animal damage among zones (Arase *et al*. 2017a,b). Thus, even when the division of a survey site by area is seemingly equitable, it can cause inequities in work quotas and experience among groups.

To improve the method of division of the survey site for student field surveys, the present study examined the method of a ‘MECE’ search based on each group’s own selections. In this method, only the first target tree was assigned to each respective group at the beginning of the survey, and then the search and determination of the next target tree was left to each group: the students were instructed to search for the next mutually exclusively and collectively exhaustively (MECE), based on the locations of other groups and adjacent unsurveyed trees. A survey of trees in the research forest was conducted as practical training for students in 2017. Some of the merits and issues identified in this program are discussed.

Method

The survey site was located in Terasawayama Research Forest at Shinshu University (Ina City, Nagano Prefecture, central Japan). Japanese yew (*Taxus cuspidata* Sieb. et Zucc.) trees had been planted at this site at a density of 0.25 trees per m^2 in 1976 over a total area of 1,000 m^2. The slope direction was ENE, at an elevation of 1,015 to 1,045 m above sea level (Arase *et al*., 2018).

A tree survey was conducted for practical student training as part of the program “Training for field science of agriculture and forestry” at the Faculty of Agriculture of Shinshu University on June 23, 2017. Twenty students, almost all beginners at fieldwork, participated in the survey. Four members of the educational staff (two teachers and two engineers) instructed the students who attended.

After arriving at the survey site, the students observed Japanese yew trees and learned the purpose and significance of the survey. Then, the students were randomly divided into four groups (groups A, B, C and D), each comprised of five persons. The survey site was not divided: each group was assigned to the

Table 1 Number of trees and their sizes at the survey site

Items		Group A	Group B	Group C	Group D	Total	Significant difference among groups (F-test)
Number of trees		24	25	28	17	94	-
DBH (cm)	average	19.9	22.2	21.9	21.4	21.3	ns
	± SD	3.4	3.2	3.2	3.5	3.4	
LH (m)	average	3.3 b	4.5 a	4.2 a	3.4 b	3.9	$p < 0.0001$
	± SD	0.3	1.2	0.6	0.9	0.8	
DC (m)							
Upper (WSW)	average	4.6 a	1.7 b	1.0 b	1.2 b	2.1	$p < 0.0001$
	± SD	1.4	1.2	0.9	0.9	1.8	
Left (NNW)	average	2.8	3.4	3.1	2.7	3.0	ns
	± SD	0.9	1.4	1.1	1.1	1.1	
Lower (ENE)	average	1.6 b	4.8 a	4.4 a	4.0 a	3.7	$p < 0.0001$
	± SD	0.9	1.6	0.6	0.7	1.6	
Right (SSE)	average	2.7	2.0	2.2	2.4	2.3	ns
	± SD	1.1	0.9	0.9	0.9	0.9	
Area of crown (m^2)	average	26.9	28.2	23.4	21.1	25.2	ns
	± SD	10.9	12.4	10.3	7.9	10.8	

Different letters denote significantly different averages as determined by Tukey's HSD test (p <0.05).
Area of crown was estimated based on the lengths of DC assuming that it forms an ellipse.

first target tree on the lowest part of the slope, with adequate space among groups. Then, the next target tree was determined by a MECE search. In this method, after the first target tree was assigned to each group, the search for and determination of the next target tree was left to each group: the students had been instructed to search for the next based on the locations of other groups and adjacent unsurveyed trees.

Diameter at breast height (DBH), height under the lowest branch (HL), radius of the tree crown at four right angles with respect to the ground (RC), and geometric location of all existing trees were measured. For measuring DBH, a caliper rule for forestry was used. Based on the RC values, the area of the crown for each tree was estimated assuming it forms an ellipse. Geometric location of trees was measured using a 3D-surveying instrument, which was assigned to each of the four groups in turn.

To evaluate the MECE search method, movement of each group during the survey was analyzed. A trace of their movements was reproduced on a map based on the x-, y- and z-coordinates of the location of surveyed trees. The length of the trace for each group was estimated by the cumulative distance from each tree to the next. Since this length is the accumulation of direct distances, it is an estimate of the minimum value without any detours or retracing of steps.

Results

Tree data

At the survey site, 94 Japanese yew trees were measured in total. Groups A, B, C and D respectively measured 24, 25, 28, and 17 trees through their survey (Table 1). Each group completed the survey almost simultaneously, which required approximately five hours.

Significant differences were detected in average LH and two directions out of four right-angle measurements of RC among groups (ANOVA, $p < 0.0001$). Average LH in groups B and C (4.2 to 4.5

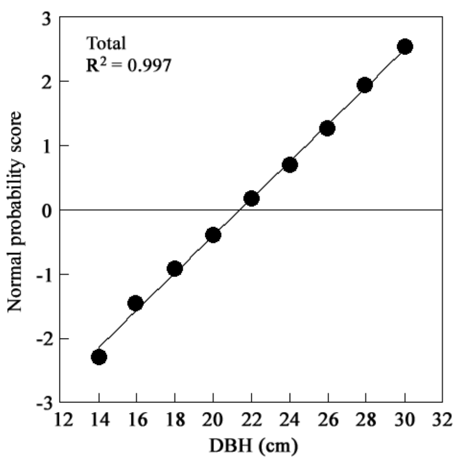

Fig. 1 Normal Q-Q plots for DBH data in the entire survey site

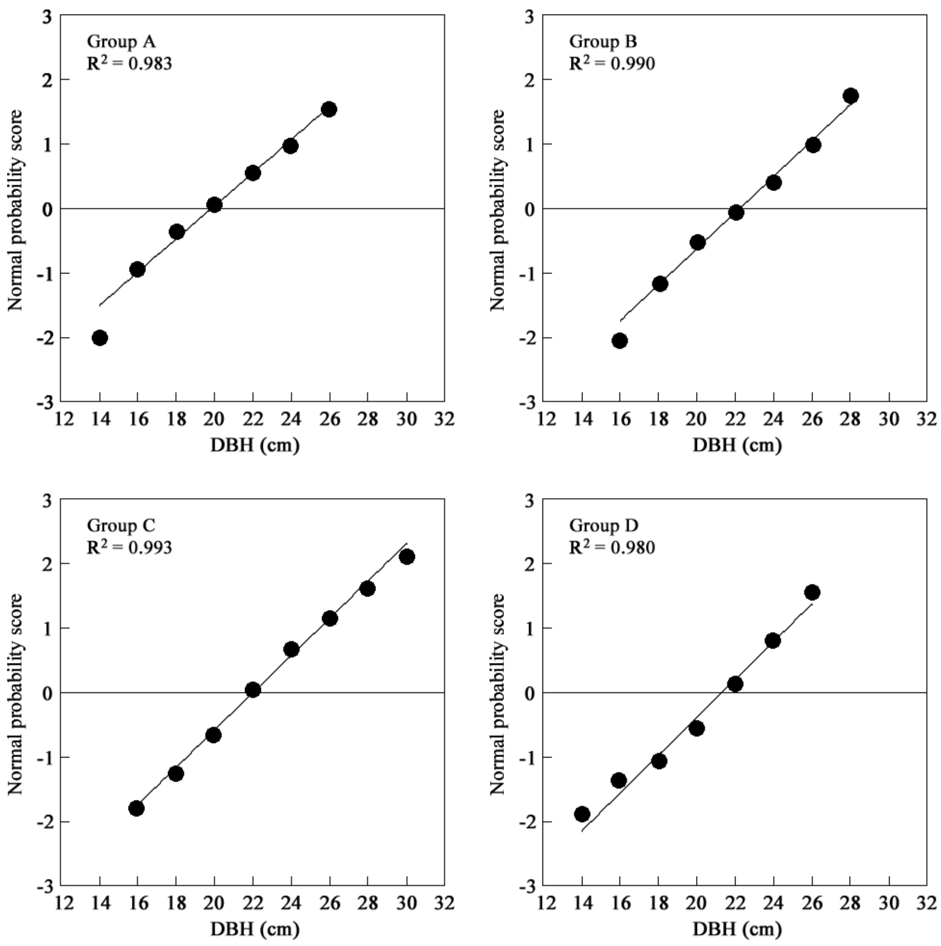

Fig. 2 Normal Q-Q plots for DBH data for each group

m) was significantly larger (Tukey's HSD, $p < 0.05$) than in groups A and D (3.3 to 3.4 m). In group A, the average RC toward the upper direction of the slope (4.6 m) was significantly larger than in other groups (1.0 to 1.7 m), while it was significantly smaller on the lower part (1.6 m) than in other groups (4.0 to 4.4 m) (Tukey's HSD, $p < 0.05$). However, no significant differences were detected in the area of the crown among groups (21.1 to 28.2 m^2 on average).

To examine the distribution of DBH measured in each group, normal probability Q-Q plots (in which the plots are arrayed in a line if they fit a normal distribution) are shown in Figs. 1 and 2. The plots were closely arrayed in a straight line (R^2 =0.997) overall (Fig. 1). In each of the four groups, the plots were arrayed roughly in a straight line (R^2 =0.980 to 0.993), though the plots deviated a little at the left end (i.e. smaller DBH) in groups A and B, and the plots deviated at both ends (i.e. smaller and larger DBH) in group D (Fig. 2). This means that the sizes of trees roughly followed a normal distribution in all four groups.

Movement of each group

Traces of each group's survey are shown in Fig. 3. Each of the four groups moved rather regularly, keeping their positional relationship at the beginning and not showing any complicated traces. In detail, group C, which surveyed the most trees, followed a winding and wide-ranging course: the groups on both sides (groups A and D) seemed obliged to follow rather straight and narrow-ranging courses, as if their movements were forestalled by group C.

Table 2 shows the length of the movements for each group during the survey. The cumulative horizontal movement was similar in groups A, B and

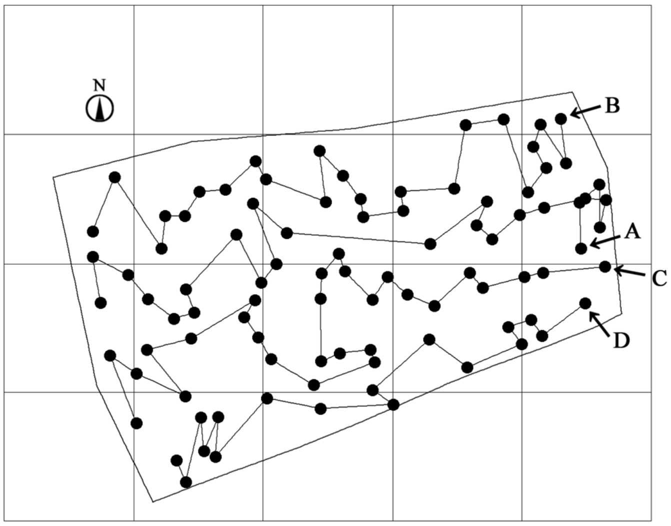

Fig. 3 Traces of the horizontal movement of each group during the survey. Closed circle indicates the position of each tree. The length of one side of the grid equals 10 m.

C (75 to 80 m), while it was a little shorter in group D (56.8 m). Cumulative vertical movement was similar in all groups (24 to 34 m). The average distance from each tree to the next ranged from 3.0 to 3.5 m in the horizontal direction and 0.5 to 1.8 m in the vertical direction among groups, and did not show any significant differences among groups (F-test).

In the survey, there was an unexpected problem that led to including invalid data for one tree in group C: a tree that group B had already surveyed was also measured by group C, and therefore one tree seemed to have been omitted from the survey (the probability was 1/28 =3.6%). At the beginning of the survey, the students had been told to measure the trees 'mutually exclusively and collectively exhaustively'. The error passed unnoticed on-site, probably because the total number of surveyed trees was correct. The error was detected at a later date during input and arranging of the data. After comparing the records in the field notes and the traces of the groups' movement, we determined that the error was actually caused by misentry of the tree identification number: the survey was correctly conducted, but the mistaken identification number entry was puzzling.

Discussion

In the present study, we employed the method of a MECE search to determine successive target trees. Though this approach is not a random sampling but rather the accumulation of subjective decisions by each group, the average size of the trees allotted to each group was similar (Table 1) and roughly

Table 2 Movement of each group during the survey

Items		Group A	Group B	Group C	Group D	Significant difference among groups (F-test)
Number of trees		24	25	28	17	-
Length of moving (m)						
Horizontal		76.3	75.1	80.1	56.8	-
Vertical		27.6	24.2	34.8	28.5	-
Distance to the next tree (m)						
Horizontal	average	3.3	3.1	3.0	3.5	ns
	± SD	2.1	1.4	1.4	1.6	
Vertical	average	1.2	1.0	1.3	1.8	ns
	± SD	1.5	0.8	1.1	1.4	

followed a normal distribution (Fig. 2). Some significant differences were observed in the height under the lowest branch (HL) and radius of the tree crown (RC) among groups, but this likely is due to a bias in shape of tree growth, not necessarily inequitable allotment of trees. Since tree architecture is comprised of modules (branches and leaves) that are produced to obtain resources such as light and space, it can be altered plastically according to the surrounding environment (Ishii *et al*. 2006). Such plasticity is presumed to influence HL and RC, i.e. the edges competing with adjacent trees.

The trace of each group's movement (Fig. 3) demonstrates that each group kept its positional relationship during the survey. The students were only told to identify the next target tree based on the locations of other groups and adjacent unsurveyed trees: it is surprising that the students surveyed the trees while always conscious of the positional relationship among groups at the beginning.

There was little difference in the number of measured trees (Table 1) and the cumulative movement among groups (Table 2). However, each group accomplished the survey almost simultaneously, and average DBH size and the average distance from each tree to the next was similar (Tables 1 and 2). This implies that the survey conditions were similar among groups: the MECE search satisfied the viewpoint that educational materials should be prepared uniformly for students (Tanaka and Kawasumi 1994). Therefore, it is considered that the differences in achievements (the number of measured trees and the cumulative movement) reflect the difference in efficiency of cooperation in each group. Improvement of the method used for grouping the students might reduce the difference.

As an issue with the method, misentry of the identification number of a tree and overlooking of this during the survey occurred. In this method, no definitively divided survey area was allotted to each group: this involves the risk of misentries and even duplicated measurements or omissions that may go unnoticed when they occur. This problem was not observed in our previous reports (Arase *et al*. 2017a,b), in which the survey site was divided definitively, i.e. all trees to be measured were assigned beforehand to each group.

Consequently, a MECE search qualifies for allotment of work according to the efficiency of cooperation within each group, but might carry an increased risk of introducing mistakes.

Conclusions

To improve the division of survey sites in a forest survey by students, a MECE search was employed for practical training. The students were divided into four groups comprising five persons, then assigned the first target tree; the determination of the next target tree was left to each group. The students had been instructed to identify the next target tree mutually exclusively and collectively exhaustively (MECE), based on the locations of other groups and adjacent unsurveyed trees. Some merits and issues of this training program included:

1. The supply of uniform materials for education: the conditions of the forest survey in each group were similar using the MECE search. This method allotted work according to the efficiency of cooperation in each group.
2. The movement of each group: each group kept its positional relationship during the survey, with traces of their movements not showing any complicated overlap.
3. Introduction of mistakes: a MECE search might enhance the risk of misentries or duplicated measurements or omissions, since few trees to be measured were assigned beforehand.

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