OPTIMUM SAMPLING ESTIMATION USING SIX QUADRATE SELECTION TECHNIQUE IN MEDICINAL PLANTS DIVERSITY ASSESSMENT IN A LOGGED-OVER RESERVED FOREST, JERANTUT, PAHANG.

Kamziah Abd Kudus, Norhajar Eswani, M. Nazre,
A.G. Awang Noor and I. Faridah Hanum
Faculty of Forestry, University Putra Malaysia,
43400 Serdang, Selangor, Malaysia

Corresponding author: Kamziah Abd Kudus
Email: kamziah@putra.edu.my
Postal address: Faculty of Forestry, University Putra Malaysia,
43400 Serdang, Selangor, Malaysia
Telephone: +60389467169

This research is financed by the Research University Grant Scheme,

Universiti Putra Malaysia (03/01/07/0039RU).

Abstract. Optimal sampling is to estimate the parameters of interest as accurately as possible under the constraint of budget and time. This study attempts to determine an optimal sampling technique for medicinal plant biodiversity assessment using six technniques in Tekai Tembeling Forest Reserve (TTFR), Jerantut, Pahang. Four one-hectare plots were established within the forest area between 340 a.s.l – 520 a.s.l. Each plot divided into quadrate sized 10x10m. Analysis of six techniques quadrate selection were applied for each plot and the number of medicinal species collected, the diversity indices and the evenness indices were compared to the 100% inventory. Results showed that the highest number of species for six quadrate selection technique possessed by row technique (224), while 100% inventory recorded 236 species. The 75% random quadrate selection technique showed the highest diversity index estimated by Shannon (H'), 6.75 where the diversity index higer than 100% inventory. While, for evenness, Camargo index showed the 50% random technique quadrate selection technique possessed the highest value (0.4) which is higher than 100% inventory. The best technique suggested in this study was row quadrate selection technique which capture 224 medicinal species with H'= 6.596 and evenness index 0.366. MD, MSD and MSPD also computed from the data to evaluate which is the best technique. As a conclusion, row quadrate selection technique was the recommended technique as an alternative to the 100% inventory.

Keywords: optimum sampling, medicinal plant, diversity, logged-over forest

1. Introduction

In biological and ecological studies, complete inventories require tremendous effort and in almost cases, very difficult to attain because of time and cost constraints. In addition, the plant community in Malaysian rainforest is generally distributed in random and in many cases there are undiscovered species found in many inventories work (Chao 2005). According to Stein and Ettema (2002) optimal sampling can be utilized to collect maximum information from limited resources. The need of optimal sampling for forest inventory is to save cost and time. In forest inventory, optimal sampling very little examined. Most of the research focuses on estimating the species richness such as Chao *et al.* (2005), Paillet *et al.* (2010), Williams *et al.* (1996) and others. Optimal sampling was closely related to area. By referring species area curve, the point of the graph reached a stable condition or flatten out was the same point where the area reaches the optimum condition. In the other words, optimal sampling gained at the moment the graph reach asymptote. Most of the studies related to optimal sampling usually using a statistical approach such as Mandallaz (2008) using local poisson model to obtain an optimal sampling.

A study was conducted in the Tekai Tembeling Forest Reserve (TTFR) using species area curve to evaluate the optimal sampling. There is no actual model of statistic applied for this present study. According to Guan *et al.* (2001), the purpose of designing an optimal sampling for inventory is to estimate accurately the parameter of interest with limited budget and time. Budget and time classified as constraints. In present study in TTFR, the parameter need to observe is area and species. The strategy is optimal if an inventory strategy can satisfied the cost and time constrains and at the same time could obtain an optimal number of species. Thus, the optimality design is importance whether the estimates meet the requirements. This study was design to find the most efficient technique should be applied which can capture almost equal number of species richness of medicinal plants with 100% inventory.

2. Methods

The hill dipterocarp forest area is located in Jerantut, Pahang Darul Makmur. The total forested area for Tekai Tembeling Forest Reserve is 90,120 ha. Logging operation ceased in the study area between two to five years ago. Four plots of 1 hectare each (i.e. 100m x 100m) were established at the elevation between 300m to 550m a.s.l. Each of the 1-hectare plots was divided into 10x10m subplots or quadrates. Medicinal plants were gathered for each subplot.

For the quadrate selection method, there were divided into two approaches; systematic and random. Four techniques comprise in systematic approaches and two techniques comprise in random approaches. In systematic approaches quadrate selected based on odd number quadrate (Figure 1a), even number quadrate (Figure 1b), quadrate in alternate column (Figure 1c) and quadrate in alternate row (Figure 1d). For random approaches, 50% and 75% quadrate selected from each plot. The selection of quadrate was based on table of random number. After the selection of quadrate made, the duplicate species of medicinal plants were removed.

The species area curve was constructed from the data. Each of the species area curve develop from six approaches. Comparison made between all species area curve. The graphs which approach an asymptote were considered as the best method for sampling technique in term of medicinal plants. All of the techniques were evaluated by mean deviation (MD), mean square deviation (MSD) and mean square proportional deviation (MSPD) to justify which is the best technique.

- Mean deviation

Mean deviation (MD) is the measure of bias. MD will be positive if the estimator overestimates and negative if the estimator underestimates.

$$MD = \sum_{j=1}^{P} \frac{(E_j - O_j)}{P}$$

E_j = estimated species richness
O_j = true species richness
P = number of quadrates

- Mean square deviation

Mean square deviation (MSD) measures the closeness of the estimator to the true species richness. The estimators are more precise with small MSD than those with large MSD.

$$MSD = \sum_{j=1}^{P} \frac{(E_j - O_j)^2}{P}$$

E_j = estimated species richness
O_j = true species richness
P = number of quadrates

- Mean square proportional deviation

Mean square proportional deviation (MSPD) was calculated to evaluate relative deviation. The lowest MSPD indicates that the superior the estimator.

$$MSPD = \sum_{j=1}^{P} \frac{\left[\frac{E_j - O_j}{O_j}\right]^2}{P}$$

E_j = estimated species richness
O_j = true species richness
P = number of quadrate

3. Results and Discussions

From the analysis, four of six techniques approached an asymptote condition in the species accumulation curve. Figure 2 showed the result of species area curve constructed from each quadrate selection techniques. The black line indicates the actual number of medicinal species observed from the study. Results showed that there were three techniques from systematic quadrate selection and one technique from random quadrate selection which almost reach an asymptote condition. The species area curve for quadrate selection according to even and odd numbers of quadrate, row of plots and 75% random selection of each plots indicates the graph reached an optimal point and then move flattened.

Due to the logging activity, there were many unique species left in the subplot. Sometimes, one of the species was extracted or harvested but only one plant belongs to the respected species remained and included in the plot study. When the technique of quadrate selection was used for analysis, there could be chances that the quadrate which contains the unique species was absent or not counted according to the procedure selected. As a result, the species area curve plotted could reach an asymptote. In short, the smaller the number of unique species emerges, the earlier the species area curve reached an asymptote or optimal condition. These four techniques could be applied in the inventory study for medicinal plants diversity in hill logged over forest to reduce cost and time taken for inventory works.

Table 1 tabulated the maximum number of species recorded using various sampling techniques for analysis. The actual species recorded for 100% inventory was 236. None of the six techniques applied obtained the same number of species with 100% inventory. However, the best technique which gave almost similar to 100% inventory in term of number of species was systematic technique using row plot selection. The row technique was the most optimum method because it gave the highest number of species (224) and asymptote achieved (Figure 1d).

Table 2 showed the diversity indices, Shannon-Weiner and Simpson's computed for each technique. From the six techniques applied, the highest diversity index was possessed by 75% random selection by plot (H'= 6.746). The 100% inventory showed lower diversity index (H'= 6.653) compared to 75% random sampling technique by plot but possessed similar diversity index with column of plot technique (H'= 6.653). Figure 2 indicates the graph of number of species recorded for 75% random plot sampling has an asymptote. However, the number of species observed (215) was smaller than those of 100% inventory (236). Column technique showed the same value of Shannon diversity index (H') with 100% inventory even though the number of species recorded (194) was lower than the 100% inventory. Therefore, the sampling technique used influenced the diversity index, and not the number of species recorded. The odd-numbered quadrates chosen from plot indicate the lowest diversity index. Generally, lowest diversity showed the lowest number of species counted. However, the odd-numbered quadrates selection captured a greater number of species of some quadrate selection technique. The greater percentage of coverage within plot could be enough to cover much number of species.

Table 3 showed the evenness index computed for each technique. The highest evenness index among the six techniques was possessed by 50% random quadrate selection within each plot. The diversity for 50% random quadrate selection was the lowest, therefore the number of species captured was smaller compared to other techniques. There are more species repetition for this technique, thus indicates the species distribution was more even. When compared to 100% inventory, 50% quadrate technique possessed higher evenness index. Even though the 50% random quadrate sampling technique had greater evenness index but the number of species was lower than those of the 100% inventory.

Table 4 showed the results of MD, MSD and MSPD computed for six techniques of sampling. All of the MD value showed the negative sign which indicate all of the inventory techniques were underestimate true species richness. From the value of MSD, row technique possessed the lowest MSD from other technique. Thus indicates row quadrate selection technique more precise than other technique. Lowest MSPD also indicates the technique more precise. From the six technique applied, row quadrate selection technique was the best technique because the MSPD value was the lowest and approximately zero.

4. Conclusion

Quadrate selection method suggested that the sampling procedure by alternate row of each plot was the most efficient sampling technique. A total of 224 species was recorded from this technique which was the highest compared to the other five other techniques. In terms of diversity, 100% inventory was more diversed than row selection technique, however the difference was small. The evenness index for row selection was higher than 100% inventory.

Table 1. Number of species recorded for each technique applied

Inventory technique	Number of species recorded
100% inventory	236
Even number quadrate	183
Odd number quadrate	205
Alternate row quadrate	224
Alternate column quadrate	194
50% random selection in each plot	172
75% random selection in each plot	215

Table 2. Diversity indices for six techniques used

Technique	Index	Plot1	Plot2	Plot3	Plot4	All
All (100%)	Shannon's H'	4.632	6.189	6.019	5.993	6.653
	Simpson's Index	0.869	0.976	0.976	0.975	0.979
Even no. quadrate	Shannon's H'	4.484	6.194	3.952	5.689	6.642
	Simpson's Index	0.854	0.977	0.744	0.969	0.978
Odd no. quadrate	Shannon's H'	4.646	6.037	5.937	5.867	6.589
	Simpson's Index	0.883	0.972	0.975	0.975	0.979
Alt. row quadrate	Shannon's H'	4.447	6.199	5.772	5.899	6.596
	Simpson's Index	0.850	0.975	0.975	0.974	0.978
Alt. column quadrate	Shannon's H'	4.610	6.183	5.986	5.910	6.653
	Simpson's Index	0.877	0.977	0.978	0.974	0.979
50% random selection	Shannon's H'	2.576	3.440	4.723	4.096	6.673
	Simpson's Index	0.609	0.830	0.961	0.919	0.984
75% random selection	Shannon's H'	2.959	3.654	4.986	3.986	6.746
	Simpson's Index	0.717	0.844	0.958	0.876	0.984

All: The diversity indices for study site (combination of all plots)

Table 3. Evenness indices for six techniques used

Technique	Index	Plot 1	Plot 2	Plot 3	Plot 4	All
All (100%)	Camargo E'	0.228	0.309	0.412	0.370	0.354
	Simpson's Index	0.066	0.218	0.346	0.304	0.200
Even no. quadrate	Camargo E'	0.239	0.348	0.233	0.354	0.378
	Simpson's Index	0.067	0.257	0.036	0.287	0.210
Odd no. quadrate	Camargo E'	0.244	0.321	0.429	0.410	0.354
	Simpson's Index	0.083	0.211	0.352	0.354	0.206
Alt. row quadrate	Camargo E'	0.238	0.335	0.427	0.404	0.366
	Simpson's Index	0.066	0.228	0.392	0.334	0.203
Alt. column quadrate	Camargo E'	0.240	0.336	0.465	0.378	0.354
	Simpson's Index	0.078	0.248	0.427	0.299	0.200
50% random selection	Camargo E'	0.212	0.352	0.606	0.414	0.400
	Simpson's Index	0.080	0.222	0.656	0.366	0.311
75% random selection	Camargo E'	0.242	0.287	0.475	0.368	0.378
	Simpson's Index	0.113	0.167	0.444	0.213	0.282

All: The evenness indices for study site (combination of all plots)

Table 4. Result of MD, MSD and MSPD analysis for six techniques sampling

Inventory technique	MD	MSD	MSPD
Even no. quadrate	-0.265	14.045	0.000252
Odd no. quadrate	-0.155	4.805	0.000086
Alt. column selection	-0.21	8.82	0.000158
Alt. row selection	-0.06	0.72	0.000013
50% random selection	-0.32	20.48	0.000368
75% random selection	-0.07	1.47	0.000026

10m

10m

1	2	3	4	5	6	7	8	9	10
20	19	18	17	16	15	14	13	12	11
21	22	23	24	25	26	27	28	29	30
40	39	38	37	36	35	34	33	32	31
41	42	43	44	45	46	47	48	49	50
60	59	58	57	56	55	54	53	52	51
61	62	63	64	65	66	67	68	69	70
80	79	78	77	76	75	74	73	72	71
81	82	83	84	85	86	87	88	89	90
100	99	98	97	96	95	94	93	92	91

Figure 1a. Quadrate selected based on odd number quadrate.

10m

10m

1	2	3	4	5	6	7	8	9	10
20	19	18	17	16	15	14	13	12	11
21	22	23	24	25	26	27	28	29	30
40	39	38	37	36	35	34	33	32	31
41	42	43	44	45	46	47	48	49	50
60	59	58	57	56	55	54	53	52	51
61	62	63	64	65	66	67	68	69	70
80	79	78	77	76	75	74	73	72	71
81	82	83	84	85	86	87	88	89	90
100	99	98	97	96	95	94	93	92	91

Figure 1b. Quadrate selected based on even number quadrate.

1	2	3	4	5	6	7	8	9	10
20	19	18	17	16	15	14	13	12	11
21	22	23	24	25	26	27	28	29	30
40	39	38	37	36	35	34	33	32	31
41	42	43	44	45	46	47	48	49	50
60	59	58	57	56	55	54	53	52	51
61	62	63	64	65	66	67	68	69	70
80	79	78	77	76	75	74	73	72	71
81	82	83	84	85	86	87	88	89	90
100	99	98	97	96	95	94	93	92	91

Figure 1c. Alternate column quadrate.

1	2	3	4	5	6	7	8	9	10
20	19	18	17	16	15	14	13	12	11
21	22	23	24	25	26	27	28	29	30
40	39	38	37	36	35	34	33	32	31
41	42	43	44	45	46	47	48	49	50
60	59	58	57	56	55	54	53	52	51
61	62	63	64	65	66	67	68	69	70
80	79	78	77	76	75	74	73	72	71
81	82	83	84	85	86	87	88	89	90
100	99	98	97	96	95	94	93	92	91

Figure 1d. Alternate row quadrate.

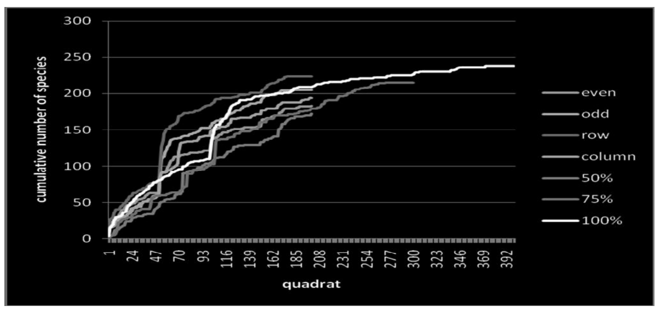

Figure 2. Species area curve constructed from each techniques of quadrate selection

References

Chao A (2005) Species richness estimation. Encyclopedia of Statistical Sciences, ed. N. Balakrishnan, C.B. Read and B. Vidakovic, pp. 7909–7916. Wiley, New York.

Chao A, Chazdon RL, Colwell RK, Shen, TJ (2005). A new statistical approach for assessing compositional similarity based on incidence and abundance data. Ecology Letters 8:148-159.

Guan BT, Wang C, Lin S (2001). Is There a Globally Optimal Forest Inventory Strategy? International Union of Forest Research Organisation: Statistical Methods, Mathematics and Computing. IUFRO 4.11 Conference, Greenwich.

Mandallaz D (2008). Sampling Techniques for Forest Inventories. Chapman and Hall/CRC. ISBN: 978-1-58488-976-2. p.256.

Paillet Y, Berges L, Hjalten J, Odor P, Avon C, Bernhardt-Romermann M, Bijlsma R, Bruyn L, Fuhr M, Grandin U, Kanka R, Lundin L, Luque S, Magura T, Matesanz S, Meszaros I, Sebastia MT, Schmidt W, Standovar T, Tothmeresz B, Uotila A, Valladares FK, Virtanen R (2010). Conservation Biology 24(1): 101-112.

Stein A, Ettema C (2002) An Overview of Spatial Sampling Procedures and Experimental Design of Spatial Studies for Ecosystem Comparisons. Agriculture, Ecosystems and Environment, 94: 31-47.

Williams P, Gibbons D, Margules C, Rebelo A, Humphries C, Pressey R (1996). A comparison of richness hotspots and complementary areas for conserving diversity using British birds. Conservation Biology 10: 155-174.