New Adjustable, Decimal, Collapsible Quadrat vs Three Old Quadrats – an Evaluation

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Highlight: *This paper presents an evaluation of a new adjustable, decimal, collapsible quadrat (ADCQ) of meter square size in comparison with three other quadrats employed for range vegetation sampling in Pakistan since 1966. In addition to size of quadrats, the different modes of subdivisions built in as an aid for estimation of vegetation cover within the same sized quadrats affected very significantly the different attributes of quadrats as well as quality of data recorded. The new quadrat was faster than other meter square quadrats to a highly significant extent and was as fast as canopy coverage quadrat (CCQ) with only 0.15 m² in size. The coefficient of variation for the new quadrat was significantly less than CCQ. The new quadrat was more precise in sampling major species than all other quadrats.*

Unlike the new quadrat, older meter square quadrats overestimated the cover values. Whereas CCQ was relatively better in estimating cover of minor species, the new quadrat was the best of all in estimating total vegetation cover, cover of major species and litter. It also was most efficient in sampling major species. Its efficiency computed over five vegetation criteria was significantly greater than older meter square quadrats. The constructional advantages of ADCQ over fractional quadrat (FQ) as well as the decimalized, collapsible, meter square quadrat (DCMSQ) are also of importance.

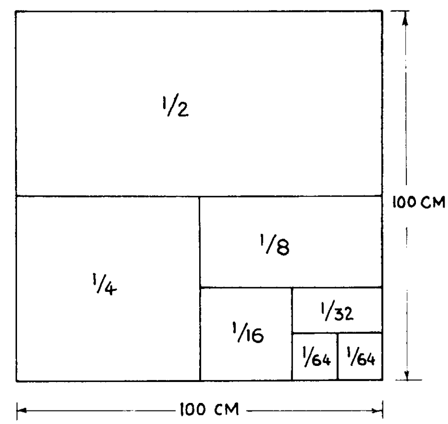

Fig. 2. *Fractional quadrat (FQ).*

Methods employing area as a sampling unit constitute one of most commonly used techniques for vegetation study. The size and shape of such a sampling unit, or a quadrat, have been a common subject of investigation, especially in study of range and pasture vegetation. Thus, quadrats employed for range analysis varied from 3/4 inch dia loop (Parker and Harris, 1959) to as big as 200 square feet (Stewart and Hutchings, 1936). The popular shapes of quadrats have been circular, rectangular, and square.

This paper presents a comparative study of four quadrats developed and used in Pakistan. A grass steppe vegetation was sampled. Whereas one of the quadrats was a rectangle of 0.15 square meter, the other three quadrats were meter square and had different subdivisions built in as an aid for cover estimation.

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Methods Compared

Canopy Coverage Quadrat (CCQ)

The canopy coverage quadrat employed for range vegetation sampling in Pakistan since 1966 (Goodwin, 1966) is 60 cm x 25 cm (Fig. 1). It was subsequently recommended by Hussain (1968) and described as modified from the Daubenmire (1959) quadrat of 50 cm x 20 cm. It has four adjustable legs of iron bars that move through iron tubes welded at four corners. Though unpartitioned, the sides of the quadrat are painted in red and white to indicate three sections of 25% each, with a fourth section indicating subdivisions of 12½%, 10%, and 5%.

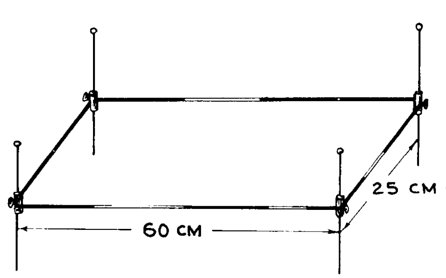

Fig. 1. *Canopy coverage quadrat (CCQ).*

Fractional Quadrat (FQ)

The fractional meter square quadrat employed for sampling of semidesert/desert vegetation of Thal rangelands in 1968 and described as "square meter method" (Higgins and Ibrahim, 1970) is legless, made of iron bar, welded, and partitioned into six successively bisective divisions to give 1/2, 1/4, 1/8, 1/16, 1/32 and 1/64th parts of a square meter (Fig. 2). The cover estimates are recorded as

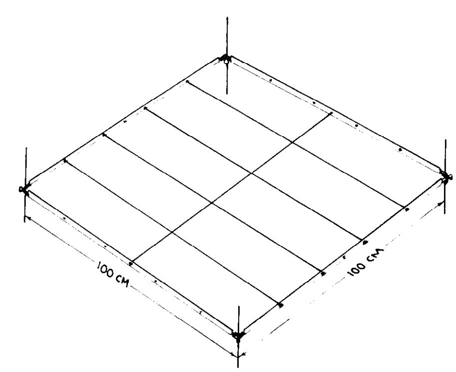

Fig. 3. *Meter square quadrat (DCMSQ).*

number of smallest square units (1/64 square meter). These cover units are subsequently converted into percent cover values.

Decimalized, Collapsible, Meter Square Quadrat (DCMSQ)

The decimalized, collapsible, meter square quadrat, designed in 1969 and used since then to sample steppe, semi-desert, and desert range communities, has four adjustable legs, movable through tubular corners (Fig. 3). The quadrat is partitioned by means of thin, iron partition bars fixable into opposite side strips of the quadrat with nuts, to give ten equal rectangles each 50 cm x 20 cm. All parts are collapsible. The cover estimates are made directly in percentages.

Adjustable, Decimalized, Collapsible Quadrat (ADCQ)

The adjustable, decimalized, collapsible quadrat is meter square and an improved but simpler version of DCMSQ (Fig. 4). To add sturdiness, the four side strips of quadrat are welded and hinged and make the quadrat foldable. Five of the ten equal rectangles are painted or corded through holes in opposite side strips, to indicate the subdivisions of 4, 4, and 2%. The central rectangle indicates an even 1%. The cover estimates are made directly in percentages. Incidentally, each of the ten rectangles is equal to Daubenmire's canopy coverage quadrat.

Procedures

The *Cenchrus ciliaris* steppe was sampled with four experimental quadrats in July, 1972. Six persons studied vegetation with each of the quadrats in such a way that choice of observer and his quadrat were at random. To eliminate fatigue factor, the sampling was done in the morning, two hours (8.00 - 10.00) only. The quadrats were placed systematically at predetermined, 5-ft intervals along three transects permanently fixed by means of pegs and metallic tapes. The estimations were made for total aerial

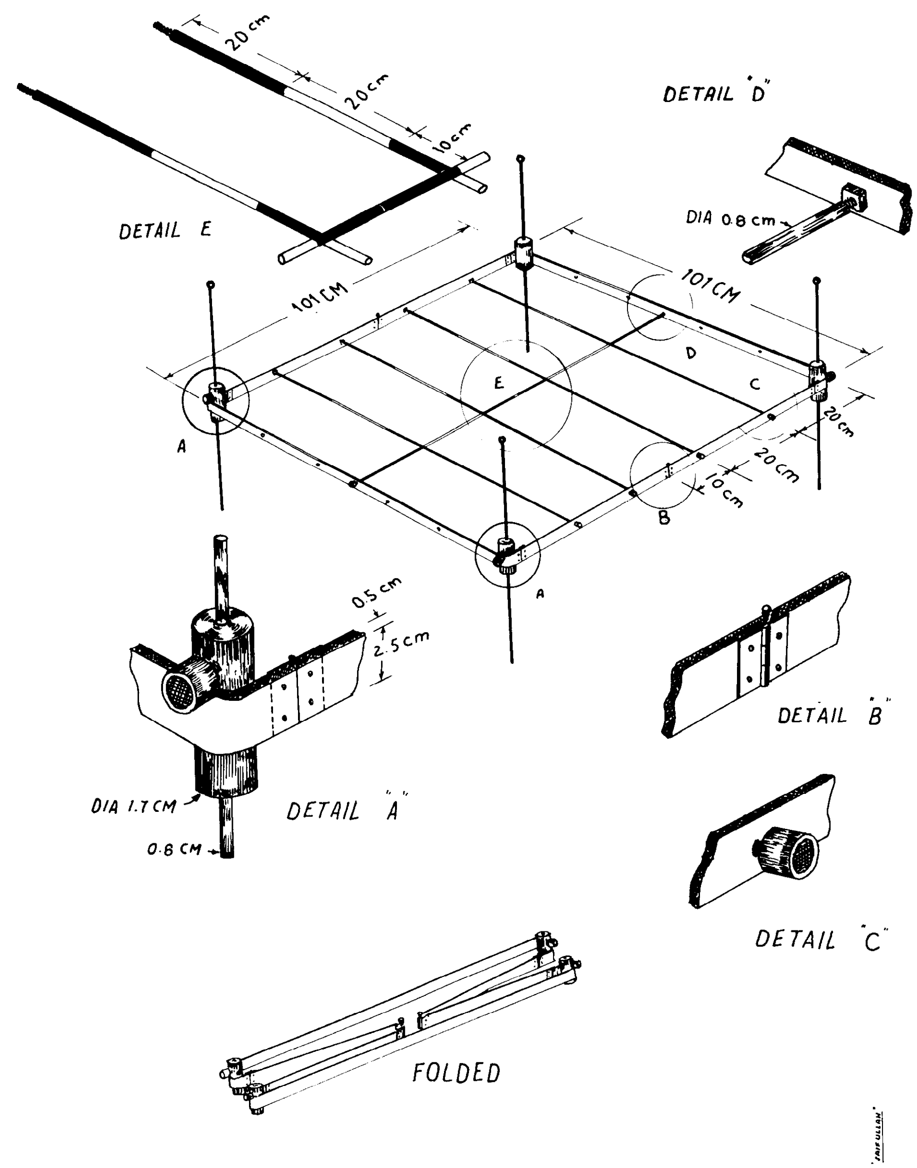

Fig. 4. *New adjustable decimal collapsible quadrat (ADCQ).*

cover of vegetation (TAC), cover of *Cenchrus ciliaris,* cover of minor species, litter cover, and bare soil. Time taken by each observer to study 60 quadrats at a stretch was recorded. The data computations and analyses were done on electric calculators. The analyses of variance (ANOVA) and Duncan's new multiple range tests were done at significance levels of P=0.01 (VHS), P=0.05 (HS) and

Table 1. Mean values of eight test criteria for four different quadrats employed to sample grass steppe vegetation.

Test criteria	Quadrats compared[1,2] CCQ	FQ	DCMSQ	ADCQ	ANOVA[3]
Field time (Tf) in minutes for 100 quadrats.	62.50 a	91.66 b	106.66 c	75.16 a	F (3,15) = 10.50 ***
Field time including conversion time for FQ in minutes (Tfc) for 100 quadrats.	62.50 a	138.00 c	106.16 b	75.16 a	F (3,15) = 17.56 ***
Equivalent number of quadrats (Ne).	20 b	15 a	14 a	15 a	F (3,15) = 10.56 ***
Equivalent field time (Tef) in minutes.	12.13 a	13.22 b	14.29 c	11.12 a	F (3,12) = 10.42 ***
Equivalent field time including conversion time for FQ in minutes (Tefc).	12.13 a	17.35 c	14.29 b	11.12 a	F (3,12) = 25.19 ***
Coefficient of variation (C V).	0.88 b	0.66 a	0.65 a	0.72 a	F (3,12) = 5.75 **
Precision (N/S^2) for major species.	1.15 b	0.88 b	0.99 b	1.97 a	F (3,15) = 7.40 ***
Precision (N/S^2) for minor species	48.28 a	13.08 b	16.51 b	18.83 b	F (3,15) = 2.43 *

[1] CCQ = canopy coverage quadrat; FQ = fractional quadrat; DCMSQ = decimalized, collapsible, meter square quadrat; and ADCQ = adjustable, decimalized, collapsible quadrat.
[2] Any two means followed by the same letter within a test criterion are not significantly different by Duncan's new multiple range test.
[3] *** VHS at P = 0.005 level; ** HS at P = 0.025 level; * S at P = 0.10 level.

P=0.10 (S).

Results and Discussions

Test Criteria

Table 1 presents summarised results for eight different test criteria along with analyses of variance and Duncan's new multiple range tests.

Field Time (Tf).

The analysis of variance (ANOVA) indicated very highly significant (VHS) differences among quadrats in field time required to study 100 quadrats. The differences among observers were nonsignificant (NS). Duncan's test (Table 1) showed that whereas Tf for CCQ was minimum there was no significant difference between CCQ and ADCQ. The CCQ was faster than FQ as well as DCMSQ at the VHS level. The ADCQ was faster than DCMSQ and FQ at VHS and significant levels, respectively. Thus, among three meter square quadrats, ADCQ was the fastest and was as fast as CCQ with only $0.15 m^2$ area.

Field Time including Conversion Time (Tfc)

Unlike the other three quadrats which estimate cover in percent, FQ estimates cover as number of unit squares (1/64 m^2). For comparable data additional time is required to convert units-data into percent cover values. The average time of conversion for six observers per 100 quadrats of FQ when calculated directly was 50 minutes. The minimum average time of 23.83 minutes per 100 quadrats was spent when already prepared conversion tables were provided to the computors. The field time for FQ, therefore, was computed by adding the minimum conversion time.

The ANOVA indicated differences in Tfc among four quadrats at the VHS level but differences among six observers were NS. Duncan's test (Table 1) showed that although CCQ took the minimum time, there was no significant difference between CCQ and ADCQ. Both CCQ and ADCQ were faster than DCMSQ as well as FQ at the VHS level. Even DCMSQ was faster than FQ at the VHS level. Thus FQ was the slowest of all.

Equivalent Number of Quadrats (Ne)

The number of quadrats required to estimate percent cover within 10% of true mean at 95% level of confidence were calculated for all quadrats, for each observer, and for each of the five vegetation criteria studied as recommended by International Biological Program (Milner and Hughes, 1968). Average number for six observers was called equivalent number (Ne). The ANOVA (Table 1) indicated differences in Ne among quadrats compared as well as vegetation criteria analysed at the VHS level. Duncan's test showed that Ne for CCQ was greater than for all other quadrats at VHS level. Differences among FQ, DCMSQ and ADCQ were nonsignificant. As compared to ADCQ, the additional number of CCQ required to sample various vegetation criteria were: Total cover of vegetation (33%), cover of *Cenchrus ciliaris* (64%), cover of minor species (24%), litter cover (14%) and bare soil (16%).

Equivalent Field Time (Tef)

The ANOVA (Table 1) indicated differences in Tef, i.e., time required to study equivalent number (Ne) of different quadrats in field, among quadrats compared as well as vegetation criteria analysed at the VHS level. The Duncan's test showed that ADCQ took the minimum time but there was no significant difference between ADCQ and CCQ. The ADCQ was faster than FQ and DCMSQ at VHS level. CCQ was found significantly faster than FQ and VHS faster than DCMSQ. The FQ was also significantly faster than DCMSQ. As compared to ADCQ, other quadrats took additional time: CCQ (9%), FQ (18%), and DCMSQ (27%).

Equivalent Field Time including Conversion Time for FQ (Tefc)

The field time in minutes required to study equivalent number (Ne) of quadrats, including conversion time for FQ (Tefc) was computed and averaged over six observers for comparisons. The ANOVA (Table 1) indicated differences in Tefc among quadrats as well as vegetation criteria at the VHS level. Duncan's test showed that ADCQ was the fastest but there was no significant difference in Tefc between ADCQ and CCQ. The ADCQ was faster than FQ as well as DCMSQ at the VHS level. CCQ was found to be faster than FQ at VHS level and significantly faster than DCMSQ. Even DCMSQ was faster than FQ at VHS level. Thus FQ was the slowest. As compared to ADCQ, on the average, the other three quadrats took additional time: CCQ (9%), DCMSQ (28.5%), and FQ (56%).

Coefficient of Variation (C V)

The coefficients of variation (C V) were computed for four categories of quadrats, for each observer and for different vegetation criteria. The ANOVA (Table 1) indicated highly significant differences among quadrats and nonsignificant differences among observers. The differences among vegetation criteria were at the VHS level. Duncan's test showed that CCQ had the highest C V, which was greater than those for DCMSQ as well as FQ at the VHS level and significantly more than that of ADCQ. Differences among DCMSQ, FQ, and ADCQ were nonsignificant.

For vegetation criteria, minor species (cover 1.21%) had higher C V than all other criteria at VHS level. Differences for total aerial cover (TAC), major species (CECI), and litter were nonsignificant. The C V for bare soil was minimum and lower than all others at VHS level.

Precision (N/S^2) of Quadrats for Major Species.

The precision values were computed for *Cenchrus ciliaris* constituting 86.44% of vegetation. The ANOVA (Table 1) indicated differences among quadrats at VHS level; nonsignificant differences were found among observers. Duncan's test showed that ADCQ was the most precise. Its precision was found greater than FQ and DCMSQ at the VHS level and greater than CCQ at the highly significant level. The differences in precision of CCQ, DCMSQ and FQ were nonsignificant. Their relative precision values were: FQ (100%), DCMSQ (113%), CCQ 131%), and ADCQ (223%).

Precision (N/S^2) of Quadrats for Minor Species:

The precision values were also computed for minor species (cover 1.21%) constituting 13.56% of vegetation. The ANOVA (Table 1) indicated significant differences in precision of quadrats compared, but differences among observers were nonsignificant. Duncan's test showed that CCQ was the most precise in estimating cover of minor species and FQ was the least precise. Whereas CCQ was more precise than FQ at a highly significant level, it was better than DCMSQ and ADCQ at a significant level. The differences among ADCQ, DCMSQ, and FQ were nonsignificant.

Estimates of Parameters

Table 2 presents summarised estimates of vegetation parameters, along with analyses of variance and Duncan's new multiple range tests.

Vegetation Cover

The analysis of variance (ANOVA) indicated very highly significant (VHS) differences among quadrats in estimation of percent total aerial cover (TAC) of vegetation. The differences among observers were also highly significant (HS). Duncan's test showed that mean TAC estimated with FQ or DCMSQ were VHS greater than those estimated with ADCQ or CCQ. The differences between ADCQ and CCQ, as well as between FQ and DCMSQ, were nonsignificant (NS). As compared to ADCQ, the overestimations by DCMSQ and FQ were 49.56% and 52.96%, respectively.

Cover of Major Species

The ANOVA indicated VHS differences among quadrats in estimation of percent aerial cover of major species. The differences among observers were nonsignificant. Duncan's tests showed that mean percent cover estimated with FQ or DCMSQ was greater than that estimated with ADCQ or CCQ. The differences between ADCQ and CCQ, as well as FQ and DCMSQ, were nonsignificant. As compared to ADCQ, the overestimations by DCMSQ and FQ were 46.66% and 51.66% respectively.

Cover of Minor Species

The ANOVA indicated HS differences among quadrats in estimation of percent aerial cover of minor species. The differences among observers were also highly significant. Duncan's test showed that FQ gave VHS higher estimates than CCQ or ADCQ, and significantly higher estimates than DCMSQ. The differences among other three quadrats were nonsignificant.

Litter Cover

The ANOVA indicated nonsignificant differences among quadrats in estimation of percent cover of litter. However the Duncan's test indicated that FQ estimated significantly higher than CCQ. Other differences among quadrats were nonsignificant. The differences among observers, however, were very highly significant.

Bare Soil

The ANOVA indicated nonsignificant differences among quadrats in estimation of percent bare soil area. The differences among observers were also nonsignificant. The Duncan's test also showed nonsignificant differences among quadrats.

Observers' Variations

The highly significant differences among observers for estimation of total vegetation cover, cover of minor species, and litter cover were consistently due to overestimation by two of the six observers who had no previous training in reading the vegetation. The variation, therefore, will normally be eliminated with practice and experience.

Reliability of Parameter Estimates.

Table 2 presents the mean values of parameters estimated through 360 quadrats of each category and averaged over six observers. The estimations of percent cover values for major as well as minor species provide contrasting comparisons. A reference to Table 1 indicates that whereas ADCQ was the most precise in sampling major species, CCQ was the highest in precision for minor species. Thus, respective quadrats gave the best estimates for major and minor species.

Both DCMSQ and FQ overestimated the percent cover values when compared to ADCQ. These corresponding overestimations were: DCMSQ (46.67%) and FQ (51.72%). The CCQ underestimated by 7.34%. As compared to CCQ, the corresponding overestimations of minor species were: DCMSQ (65.29%), FQ (138.84%), and ADCQ (18.18%).

Like quadrat precision, the length of confidence intervals at 95% level of probability computed around mean estimated parameters (Table 2) gives an indirect measure of quadrat accuracy. The four categories of quadrats were accurate in the decreasing order of ADCQ, DCMSQ, CCQ and FQ. For all five vegetation criteria, FQ was consistent in showing longest confidence intervals or was the least accurate. Whereas CCQ was relatively more accurate in estimating minor species (percent cover less than 2.00), ADCQ was the best for total vegetation, major species (percent cover more than 9.00), and litter.

Efficiency of Quadrats

The efficiency values of quadrats (QE) defined in terms of quadrat precision ($P=N/S^2$), equivalent quadrat number (Ne), and equivalent time (Tefc) as QE= P/Ne Tefc, were computed for different vegetation criteria as well as over-all criteria (Table 3).

All Criteria

The relative percent values of QE were: FQ (100), DCMSQ (105), CCQ (128), and ADCQ (174). Although differences among six observers were nonsignificant, Duncan's new multiple range test showed significant differences among quadrats' efficiencies. The differences among FQ, DCMSQ, and CCQ were nonsignificant. The ADCQ, though, just missed being more efficient than CCQ at 90% level of probability, it was significantly more efficient than FQ as well as DCMSQ. Thus, ADCQ, when compared with the other three quadrats, was more efficient by 46 to 74%.

Major Species.

Whereas differences among observers were nonsignificant, the analysis of variance indicated very highly significant differences in quadrat efficiency for sampling major grass species [$F(3,15)$ = 16.35]. The ADCQ was more efficient than all other quadrats at VHS level. The differences among other three quadrats were nonsignificant.

Other Criteria.

The analysis of variance and Duncan's tests indicated nonsignificant differences of QE among six observers as well as four quadrats in sampling total vegetation cover, minor species, litter, and bare soil.

Table 2. Population parameter estimates with 95% level of confidence intervals for four different quadrats employed to sample grass steppe vegetation.

Parameters	Mean values for quadrats[1, 2] CCQ	FQ	DCMSQ	ADCQ	ANOVA [F(3,15)]
Percent total aerial cover.	9.34 a ±2.29	14.81 b ±2.77	14.48 b ±2.55	9.68 a ±1.65	18.07 ***
Percent cover of major species.	8.08 a ±2.02	13.23 b ±2.30	12.79 b ±2.22	8.72 a ±1.46	17.46 ***
Percent cover of minor species.	1.21 a ±0.44	2.89 b ±0.60	2.00 a ±0.52	1.43 a ±0.54	5.39 **
Percent cover of litter.	3.82 a ±0.74	5.42 b ±0.86	5.06 ab ±0.81	4.28 ab ±0.66	1.98 NS
Percent cover of bare soil.	76.41 a ±5.41	68.80 a ±5.80	76.35 a ±4.17	74.50 a ±5.58	2.15 NS
Average value of confidence intervals.	±2.18	±2.466	±2.05	±1.978	

[1] CCQ = canopy coverage quadrat; FQ = fractional quadrat; DCMSQ = decimalized, collapsible, meter square quadrat; and ADCQ = adjustable, decimalized, collapsible quadrat.
[2] Any two means followed by the same letter within a test criterion are not significantly different by Duncan's new multiple range test.
[3] *** VHS at P = 0.005 level; ** HS at P = 0.025 level; * NS at P = 0.10 level.

Table 3. Comparative quadrats efficiency (QE = P/Ne Tefc) in sampling grass steppe vegetation for its various criteria.

Analytic criteria	Quadrats compared[1,2]			
	CCQ	FQ	DCMSQ	ADCQ
Average over all criteria for six observers.	0.0319 ab	0.0249 b	0.0261 b	0.0433 a
Percent cover of major species.	0.0043 b	0.0036 b	0.0053 b	0.1679 a
Percent cover of minor species.	0.0493 a	0.0331 a	0.0355 a	0.0394 a
Percent cover of litter.	0.7853 a	1.1282 a	0.8456 a	1.1785 a
Percent total vegetation cover.	0.5102 a	0.4278 a	0.6233 a	0.1277 a
Percent area of bare soil.	0.0849 a	0.0256 a	0.0824 a	0.0555 a

[1] CCQ = canopy coverage quadrat; FQ = fractional quadrat; DCMSQ = decimalized, collapsible, meter square quadrat; and ADCQ = adjustable, decimalized, collapsible quadrat.
[2] Any two means followed by the same letter within a criterion are not significantly different by Duncan's new multiple range test.

Conclusions

Various analytic criteria established statistically significant differences among four quadrats compared. In addition to size of quadrats, the different modes of subdivisions built in as an aid for estimation of vegetation cover within the same sized quadrats affected very significantly the different attributes of quadrats as well as quality of data recorded.

In respect to field time, ADCQ was faster than other meter square quadrats and was as fast as CCQ with its 0.15 m^2 area. The FQ was the slowest. The number of quadrats required to constitute a sample of the same adequacy level was greater for CCQ than for the other three quadrats. A similar number was needed for the three meter-square quadrats. The time required to study an equivalent number of different quadrats differed. Whereas ADCQ took the minimum time, the difference with CCQ was not significant. The ADCQ was faster than FQ and DCMSQ. As compared to ADCQ, on the average, the other three quadrats took additional time of: CCQ (9%), DCMSQ (28.5%), and FQ (56%).

Whereas differences in coefficients of variation among three meter-square quadrats were nonsignificant, ADCQ had significantly less value than CCQ. For sampling major species, the ADCQ was more precise than FQ, DCMSQ, or CCQ. Their relative precision values were: FQ (100%), DCMSQ (113%), CCQ (131%), and ADCQ (223%). The CCQ, however, was more precise than other quadrats in sampling minor species. Differences among FQ, DCMSQ, and ADCQ were nonsignificant.

Statistically different estimates of vegetation parameters were made by different quadrats. Estimates of total vegetation cover and cover of major species were higher by FQ and DCMSQ. Both ADCQ and CCQ gave similar estimates. Whereas similar estimates of minor species were made by other three quadrats, FQ gave higher estimates. All quadrats gave nonsignificantly different estimates of bare soil.

Though observer differences were generally nonsignificant, the differences in estimation of total vegetation cover, minor species cover, and litter by two of the six observers were due to lack of previous training. This variation can be eliminated with experience and training.

Because of statistically higher precisions, the best estimates of vegetation parameters for major and minor species were given by ADCQ and CCQ, respectively. Based on length of confidence intervals calculated around all parameter estimates, the four quadrats were accurate in the decreasing order of ADCQ, DCMSQ, CCQ and FQ. For all five vegetation criteria, FQ was consistent in giving longest confidence intervals or was the least accurate. Whereas CCQ was relatively more accurate in estimating minor species, ADCQ was the best for total vegetation, major species, and litter.

The ADCQ was the most efficient in sampling major species. The differences among quadrats' efficiency for sampling bare soil, litter and minor species, however, were nonsignificant. The quadrat efficiency of ADCQ computed over all vegetation criteria was significantly greater than DCMSQ or FQ. The ADCQ was more efficient than CCQ, DCMSQ and FQ by 46%, 66%, and 74%, respectively.

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