AN EVALUATION OF THREE COEFFICIENTS AS A MEASURE OF UNIFORMITY OF WATER APPLICATION BY SPRINKLERS

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INTRODUCTION

Uniformity of water application by sprinklers has received the attention of several workers. Christiansen (3) in 1941, was the first and introduced the coefficient Cu. It is calculated from the formula:

$$Cu = 100 \left(1 - \frac{\Sigma X}{MN} \right) \quad \text{.....1}$$

in which X is the absolute deviation from the mean depth of water--M, and N is the number of observations.

Wilcox and Swailes (7), in 1947, introduced the coefficient U which is calculated from the formula

$$U = 100 \left(1 - \frac{SD}{M} \right) \quad \text{.....2}$$

in which SD is the standard deviation of the depths of water, and M is the mean. This coefficient, depending as it does on the standard deviation which involves squaring the deviations, gives added weight to extreme values.

More recently, Benami and Hore (2), in 1964, introduced the coefficient A which was claimed to have two main advantages; (a) it is a better measure of uniformity because it places more stress on values below the mean which is important when considering irrigation, (b) "the differences between distribution patterns are more pronounced when comparisons are made due to the wider range in A values obtained". The coefficient A is calculated from the formula

$$A = 166 \frac{Na\ (2Tb + DbMb)}{Nb\ (2Ta + DaMa)} \quad \text{.....3}$$

in which Na is the number of readings above the overall mean

Nb is the number of readings below the overall mean

Ma is the mean of the readings above the overall mean

Mb is the mean of the readings below the overall mean

Ta is the sum of the readings above Ma

Tb is the sum of the readings below Mb

Da is the difference between the number of readings below and above Ma

Db is the difference between the number of readings above and below Mb

In all cases the larger the coefficient the better the uniformity of water application. Coefficients Cu and U cannot exceed 100, whereas coefficient A can. Coefficients Cu and A are positive, whereas coefficient U can be negative.

Beale and Howell (1) compared five different coefficients for measurement of uniformity of water application. Two of these were Cu and U. The relationship between Cu and U was determined to be:

$$U = -25.3 + 1.27\ Cu \quad \text{.....4}$$

This is very similar to Dabbous' (4) finding of

$$U = -25.0 + 1.25\ Cu \quad \text{.....5}$$

Hart (5) in an evaluation of various coefficients concluded that ". . . the distribution under an overlapped sprinkler pattern appears to be fairly well defined by the normal distribution function".

Since the author is not aware of a study which compares the Benami and Hore A coefficient to other coefficients, a study was conducted to compare A, Cu and U. The comparisons were based on correlation and linear regression analyses, since Hart found that sprinkler irrigation patterns followed the normal distribution function.

PROCEDURE

The three uniformity coefficients (Cu, U and A) were calculated for 775 uniformity tests that had been conducted at Swift Current from 1954 to 1959. A computer program was developed for these calculations which was of particular value for calculating the coefficient A because of the complexity of the procedure involved in ranking the numbers and making the required calculations. A computer program was then used to calculate the various components in correlation analysis. In an attempt to obtain coefficients of more nearly like values in each group, the data were analyzed on the basis of sprinkler spacing. This was partially successful so more divisions were made by grouping on the basis of wind speeds and sprinkler pressures. However, no improvement was achieved, partly because the number of observations in each group became too small, so the discussion will be limited to the grouping according to sprinkler spacing.

RESULTS AND DISCUSSION

The regression equations for the coefficient U in relation to Cu for the first two groupings (table 1) were

$$U = -25.2 + 1.25\ Cu \quad \text{.....6}$$

and $U = -25.4 + 1.26\ Cu$ 7

TABLE I. COMPARISON OF THREE COEFFICIENTS (Cu, U AND A) AS A MEASURE OF UNIFORMITY OF WATER APPLIED BY SPRINKLERS

Sprinkler Spacing	Number of tests	Relationship	r[1]	Means and standard deviations
		U vs Cu	.985[2]	U = 82.8 ± 8.6
20 x 20	90	A vs Cu	.977	Cu = 86.5 ± 6.8
		A vs U	.976	A = 109.7 ± 21.6
		U vs Cu	.987	Cu = 71.7 ± 13.4
30 x 30	159	A vs Cu	.962	A = 71.3 ± 27.5
		A vs U	.951	U = 64.6 ± 17.0
		U vs Cu	.991	U = 62.0 ± 14.6
40 x 40	95	A vs Cu	.966	A = 62.6 ± 23.5
		A vs U	.960	Cu = 68.7 ± 11.9
		U vs Cu	.897	U = 54.9 ± 22.6
50 x 50	79	A vs Cu	.963	A = 54.4 ± 22.8
		A vs U	.834	Cu = 64.7 ± 13.1
		U vs Cu	.992	A = 51.1 ± 23.5
60 x 60	29	A vs Cu	.968	U = 53.6 ± 15.3
		A vs U	.955	Cu = 62.2 ± 12.6

[1]Correlation coefficients are significant at $P \leq .01$.

[2]No difference between underlined values within each spacing.

which are very similar to equations 4 and 5.

The regression equations for the coefficient A in relation to U for the same sprinkler spacings were

$$A = -92.6 + 2.44\ U \quad \text{.....8}$$

and $A = -28.1 + 1.54\ U$ 9

Each uniformity coefficient is significantly correlated with each other coefficient at all sprinkler spacings (Table 1). There is no significant difference between correlation coefficients at the close sprinkler spacing of 20 x 20 feet. At this spacing the average uniformity coefficients were higher than the coefficient U value of 70 suggested by Wilcox and Swailes (7) as a minimum acceptable value. Comparable values for coefficients Cu and A, using regression equations 7 and 9 would be 76 and 80 respectively.

At all other sprinkler spacings there were significant differences ($P<.01$) between two of the three relationships and, as shown in Table 1, the differences were not always between the same two. At three spacings (30 x 30, 40 x 40 and 60 x 60 feet) the value of coefficient A was significantly different from U and Cu. This difference in A would be useful in the case of the 30 x 30 foot spacing because the coefficients are in the range of the acceptable value for U of 70. However, the magnitude of the A value is similar to that of Cu (71.3 as compared to 71.7) which decreases the practical usefulness of the difference between the two coefficients. It is unfortunate that the relative magnitudes shown at the 20 x 20 foot spacing (109.7 as compared to 86.5) couldn't have been maintained at the 30 x 30 foot spacing. At the larger spacings the significance of the difference between A and the other two is of questionable value because the uniformity coefficients are lower than the acceptable coefficient U value of 70 or A value of 80. Cu and U are not significantly different until the uniformity coefficients drop to the 50 and 60 range at the 50 x 50 foot spacing. This indicates that the advantage of squaring the deviations does not take effect until the application of water becomes quite variable. Since the uniformity coefficients are in the 50 to 60 range, the significance of this difference is of little if any benefit.

The average values and standard deviations of the uniformity coefficients (Table 1) show that the range covered by the coefficients is greatest for A and least for Cu. It is also noted that at the more uniform applications the A value is the highest and U the lowest, whereas at the poorer uniformities Cu is the highest and A the lowest.

CONCLUSIONS

The high degree of correlation among the three uniformity coefficients Cu, U and A proves that there is very little difference between them. This is particularly so at the more uniform applications when there was no significant difference between the correlation coefficients. There was a significant difference between the correlation coefficients at the less uniform applications, but the mean uniformity coefficients were below the acceptable values of 70, 76 and 80 for coefficients U, Cu and A respectively.

It is concluded, therefore, that any of the three uniformity coefficients is acceptable to measure uniformity of water application by sprinklers. However, it is suggested that U is the most practical coefficient to use because it is sounder statistically than either Cu or A since it is based on the standard deviation which is, according to Snedecor (6, p. 43), "one of the more efficient estimators", and because it is easier to calculate than coefficient A.

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