Methods to convert American Class A-pan and Symon's tank evaporation to that of a representative environment†

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Abstract

Methods were introduced to correct for significant evaporation differences which resulted from non-representative environmental evaporimeter installation practices.

Linear regression formulae that were developed to correct for the different evaporimeter's monthly evaporations to comply with that of a representative environment were found to apply country-wide when tested against real case studies on stations in close proximity to each other, but with different immediate environments.

Inter-evaporimeter conversion formulae are presented to enable the extension of evaporation data bases.

Guidelines are presented to assist in the choice of evaporation stations. Summer rainfall regions with an annual precipitation exceeding 500 mm and winter rainfall regions with an annual precipitation exceeding 240 mm were identified as areas with grass environment. This is based on the natural grass environments as well as boundaries of low dryland crop production potential areas integrated with soil types. Under the mentioned rainfall conditions it will be possible to maintain grass cover as an evaporation station environment without supplementary irrigation.

Introduction

Errors introduced by the incorrect choice of evaporimeter station environment on the measured evaporation were identified by Bosman (1987).

The importance of maintaining a representative environment around American Class A-pans and Symon's tank and other pan evaporimeters was emphasised by the World Meteorological Organisation (WMO) and in its publications, of 1971 and 1983, it was stated "cover at the evaporation station should be maintained as near as possible to the natural cover common to the area. Grass, weeds, etc. should be cut sufficiently frequently to keep them below the level of the pan rim. Under no circumstances should the instrument be placed on a concrete slab or asphalt, or on a layer of crushed rock".

The following computations will be adversely affected by not complying with the specifications outlined by the WMO:

- The over or underestimation of evaporation in applying Müller and Alberts (1968) pan-dam factors for the calculation of reservoir water balances.
- Production of evaporation distribution maps such as those published by Groenewald (1970) and Venter (1980).
- Estimating evapotranspiration by applying Baier (1963) empirical or similar models in hydrometeorology.
- Consumptive use of water by plants in the application of plant-pan-factors (Israelsen and Hansen, 1962) for irrigation scheduling. This may lead either to over-irrigation due to overestimating water requirements or to under-irrigation with resultant plant water stress.
- Inter-station evaporation correlation to estimate missing evaporation data may be biased due to differences in environmental installation rather than distances between stations.
- Under or overdesign of reservoirs due to the use of environmentally non-standard evaporation data with possible economic as well as water supply consequences.

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Objectives

This study represents the analysis and measurements collected over two hydrological years (1982/83 and 1983/84) and serves as an extension of work published by Bosman (1987).

The objectives of this study are to:

- Develop formulae to convert evaporation measured by non-standard installation of American Class A-pan and Symon's tank evaporimeters to those conditions demanded by a representative station environment as defined by WMO (1983).
- Test the developed conversion formulae for country-wide application.
- Define environmental criteria for the selection of representative evaporation station covers for the areas in question.

Materials and methods

Study area

As was outlined by Bosman (1987) the experiment of different installation practices applied to American Class A-pan (A-pans) (Roberts, 1960; Chow, 1964; Gangopadhyaya *et al.*, 1966) and Symon's tanks (S-tanks) (Roberts, 1960; Gangopadhyaya *et al.*, 1966) was executed in a fully equipped meteorological station at Roodeplaat Dam (25° 37'S, 28° 22'E) 20 km north-east of Pretoria.

This area can be classified as a semi-arid region which represents a large part of South Africa.

Materials

The A-pan and S-tank evaporimeter treatments were duplicated and randomised in fifteen 10 m x 10 m stations within the above-mentioned weather station.

The ground cover which was used complied with the WMO (1983) standards i.e. kikuyu lawn for the area in question, as well as non-standard environments of bare soil and soil covered with 20 mm crushed stone, 50 mm deep. A-pans on crushed stone

TABLE 1
MEAN A-PAN AND S-TANK EVAPORATION (MM) FOR THE HYDROLOGICAL YEARS 1982/83 AND 1983/84

	Treatment environment						Statistics	
Evaporimeter type	Grass	Soil	Soil + screen	Stone	S.D. ± mm	C.V. (%)	Calc. F	LSD ± mm
A-pan evaporation	2 060	2 159	1 803	2 383	15	<1	512**	72
Percentage*	100	105	88	116	-	-	-	-
S-tank evaporation	1 614	1 848	1 601	1 832	21	1	80**	68
Percentage*	100	115	99	114	-	-	-	-

* Percentage: Grass cover taken as 100%.
S.D. = Standard deviation.
C.V. = Coefficient of variation (%).
Calc. = Calculated F-value compared with expected: F(0,01; d.f.3;3) = 29,5**.
LSD = Least significant difference: 5% level of significance.

TABLE 2
LINEAR REGRESSION ANALYSIS TO CONVERT MONTHLY EVAPORATION FROM AMERICAN CLASS A-PAN (A-PAN) AND SYMON'S TANK (S-TANK) EVAPORIMETERS TO THAT OF A REPRESENTATIVE ENVIRONMENT

Evaporimeter	Intercept	Slope	Correlation coefficient (r)	S.E. ±mm	Coefficient of determination r^2
Class A-pan:					
Crushed stone to grass	-7,5120	0,9015	0,9849**	8,6	0,9700
Crushed stone to bare soil	-7,2943	0,9443	0,9826**	9,7	0,9655
Grass to bare soil	2,0203	1,0390	0,9897**	7,5	0,9795
Bare soil to grass cover	1,6304	0,9427	0,9897**	7,5	0,9795
Bare soil, (screened) to bare soil (unscreened)					
(13 mm(A	5,6990	1,1640	0,9680**	12,6	0,9370
(25 mm)B	6,0185	1,1438	0,9978**	3,3	0,9956
S-tank:					
Crushed stone to grass	5,5013	0,8450	0,9824**	8,4	0,9651
Crushed stone to bare soil	9,3199	0,9426	0,9841**	8,9	0,9685
Grass to bare soil	5,6977	1,0969	0,9850**	8,6	0,9702
Bare soil to grass	-1,0270	0,8845	0,9850**	10,1	0,9702
Bare soil (screened) to bare soil (unscreened)					
(13 mm)A	-0,9596	1,1559	0,9718**	11,8	0,9444
(25 mm)B	5,4586	1,1722	0,9982**	2,3	0,9964

S.E. = Standard error of estimate.
Calculated r-value compared with expected: A)**$r_{0,01}$ (d.f. = 22) = 0,515;
B)**$r_{0,01}$(d.f. = 10) = 0,708.

ARegression present study 1982/83 to 1983/84 (n = 24).
BCalculated from Whitmore and De Villiers (1964) (n = 12).

treatments were placed on 1,2 m x 1,2 m concrete slabs, on which four 75 mm x 100 mm beams were cast (Bosman, 1987).

One set of bare soil A-pan as well as S-tank treatments were protected with 13 mm x 0,5 mm mesh screens in square frames.

Bare soil and crushed stone treatments were kept free of weeds by hoeing and by herbicide application.

The kikuyu lawn of grass treatments was mowed regularly to a height of 30 mm. The density of evaporimeter treatments prevented irrigation, therefore the kikuyu lawn was rainfall dependent for its survival.

Methods

Mean hydrological year A-pan and S-tank evaporation was obtained for seasons 1982/83 and 1983/84 for the respective replications and installation treatments. Two-way analysis of variance was applied to the experimental groups i.e. A-pan and Symon's tank data (Snedecor and Cochran, 1867). Percentages were calculated to indicate deviations of evaporation from grass, which is the standard environment for the Roodeplaat experimental area.

Formulae were generated to convert monthly evaporation from evaporimeters that have a non-representative station cover i.e. crushed stone, to an environment according to the guidelines laid down by the WMO (1983) for all possible conversions for A-pans and S-tanks. These included A-pans and S-tanks protected with 13 mm screens.

Conversion of monthly evaporation from 13 mm mesh protected screen evaporimeters to that of unprotected evaporimeters is supplemented by regression equations converting 25 mm mesh screens to that of unprotected evaporimeters. This was achieved by employing 25 mm mesh evaporimeter information published by Whitmore and De Villiers (1964). Statistical tests (F-tests; Snedecor and Cochran, 1967) were applied to slope functions of 13 mm and 25 mm mesh regressions. This implies that the parallelism that exists between the regression lines in question is only due to the influence introduced by different screen mesh sizes on evaporation. It is postulated, therefore, that the 12-month data set used for 25 mm mesh formulae is acceptable for the purpose of this study: The study itself provides for replicated treatments over a period of 24 months.

The respective F-values for A-pan ($F(d.f.=1;32)=<1$) and S-tanks ($F(d.f.=1;32)=1,06$) were less than $F_{0,05}(d.f.=1;32)=6,27$, and therefore not significant.

Inter - evaporimeter conversions between A-pans and S-tanks and *vice versa* were produced to extend their respective data bases. Regression equations to convert daily 13 mm mesh screened A-pan to non-screened pan evaporation were produced. For screen mesh sizes other than the 13 mm and 25 mm catered for thus far, Bosman (1987) provided a method to convert annual screen protected A-pan evaporation to that of unprotected pans. Monthly evaporation could then be adjusted *pro rata*.

Information from this study as well as that of Whitmore and De Villiers (1964) and Rabie (1967), as well as extrapolated values from Gangopadhyaya *et al.* (1966) and that of Howell *et al.* (1983) was used to formulate a similar model for correcting screened (E_o) to unscreened (E_c) S-tank evaporation:

$$E_c = E_o.E_d$$

where $E_d = 100/(100-\wedge y)$

and $\wedge y = 15,2587-0,1410x$; 13 mm $\leq x \leq$ 50mm mesh size.

where $\wedge y$ = percentage reduction by screen protection to annual S-tank evaporation.
E_d = deficiency factor.
E_c = corrected annual S-tank evaporation.
E_o = uncorrected annual S-tank evaporation

The test statistics are:

Standard error of regression (SE):S.E.		= ±0,3%
Correlation coefficient (r):	$r(d.f.=3)$	= -0,987
Level of statistical significance:	$r_{0,01}(d.f.=3)$	= ±0,959
Coefficient of determination (r^2):		= 0,974

Six-monthly screened and unscreened A-pan and S-tank monthly evaporation data for calendar and hydrological years were correlated. These correlation coefficients were compared with hydrological year correlation coefficients (z-tests; Huysamen, 1976) to prove whether or not the seasonal formulae will yield better results.

Evaporimeter stations in close proximity of each other, but with different immediate station environments were used to test the monthly evaporation conversion formulae generated at Roodeplaat Dam for local as well as country-wide application.

Testing evaporimeters under local conditions was carried out by using data collected during the study period 1982-1984 and the following hydrological year 1984/85 at the weather station at Roodeplaat Dam and at the Directorate of Hydrology's station A2E13. The latter is situated at the weather station at Roodeplaat Dam and was covered with crushed stone. The evaporation from A-pans and S-tanks was converted to that for a grass environment to conform to the conditions which would be in accordance with guidelines laid down by the WMO (1983) for the region in question for the 1984/85 season.

Results

Mean annual A-pan and S-tank evaporation for the hydrological seasons 1982/83 and 1983/84 collected under different immediate environmental conditions are summarised in Table 1.

Conversion formulae to correct A-pan and S-tank monthly evaporation to that of a representative environment as well as inter-pan correlation and regression equations are presented in Table 2, Table 3 and Table 4 respectively and that of daily A-pan screen protected to unscreened A-pan evaporimeters in Table 5.

The comparison of seasonal *versus* annual conversion formulae for screened A-pan and S-tank is summarised in Table 6. To test formulae for country-wide application, monthly evaporation was converted to the standard evaporation environment. Annual evaporations obtained from this conversion are summarised in Table 7.

The percentage error introduced by different screen mesh sizes on A-pan and S-tank evaporation is illustrated in Fig. 1. Monthly averages of the different environmental treatments of A-pan and S-tank evaporation for the hydrological years 1982/83 and 1983/84 and the long-term mean 1962/63 to 1979/80 are shown in Fig. 2 and Fig. 3, respectively. The efficiency of evaporimeter conversion formulae on transforming observed evaporation from a crushed stone station environment to that of monthly A-pan and S-tank grass environment by using different data sets than were used for correlation determinations, is illustrated in Fig. 4 and Fig. 5 for the respective evaporimeters.

Discussion

Annual evaporation from A-pans under stone and bare soil

TABLE 3
CONVERSION OF AMERICAN CLASS A-PAN (A) TO SYMON'S TANK (S) MONTHLY EVAPORATION (mm)

Conversion	Statistics				
	Intercept	Slope	Coefficient of determination r^2	Correlation coefficient r	S.E.[a] ±mm
A-grass to S-grass	-16,2354	0,8793	0,949	0,974**	10,4
A-grass to S-bare soil	-16,4190	0,9896	0,969	0,984**	9,0
A-bare soil to S-grass	-16,0921	0,8361	0,945	0,972**	10,7
A-bare soil to S-bare soil	-16,0776	0,9399	0,963	0,981**	9,8
A-bare soil screen protected to S-grass	-12,6578	0,9819	0,902	0,950**	14,3
A-bare soil screen protected to S-bare soil	-10,2329	1,0906	0,898	0,948**	16,3
A-crushed stone to S-grass	-25,5997	0,8066	0,953	0,976**	10,0
A-crushed stone to S-bare soil	-25,2448	0,8992	0,954	0,977**	16,3

Where grass, bare soil and crushed stone signify the evaporation station ground cover.
S.E.[a] = Standard error of estimate. Calculated r-value compared with expected:
$^{**}r_{0,01}$(d.f. = 22) = 0,515 (Snedecor and Cochran, 1978)

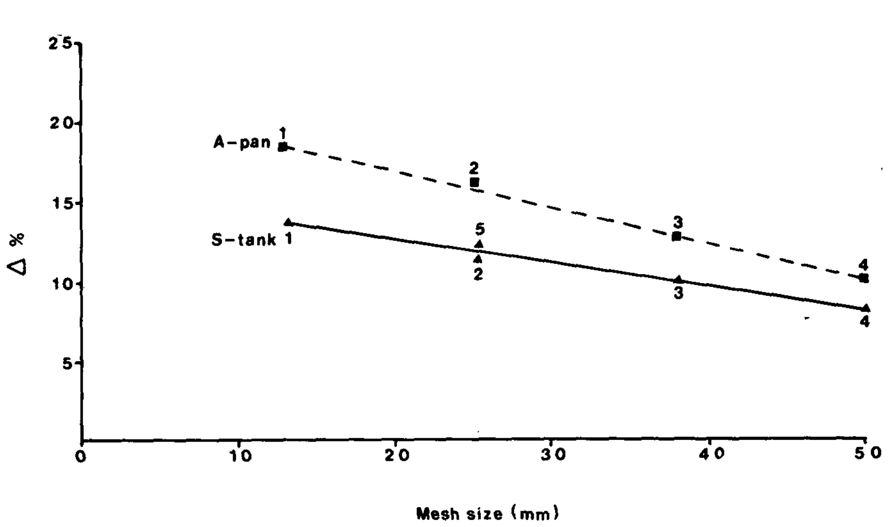

Figure 1
Percentage error (Δ%) introduced annually on evaporimeters by screen mesh size (mm) after Bosman (1987) for A-pan and in this study the S-tank

treatments exceeded that of grass by 5 per cent and 16 per cent respectively, whilst screened pans underestimated evaporation by 12 per cent when compared with that for a standard grass environment. These differences proved to be statistically significant at 1 per cent level of probability (Table 1).

No significant statistical differences were calculated between annual evaporation from S-tanks surrounded by bare soil and crushed stone and that of grass and screen protected tanks. However, significant differences did exist between the first two and last two sets of evaporimeters (Table 1). In the case of A-pans, however, the main results can be summarised as evaporation from crushed stone > bare soil > grass cover > screened pans. Bare soil unscreened A-pans exceeded that for bare soil screened by 356 mm on average per year and in the case of S-tanks the exceedance was 247 mm (Table 1).

Differences in annual evaporation introduced by different protected screens were correlated and regression equations were produced to correct annual S-tank and A-pan evaporation (Fig. 1). It is therefore possible to correct annual S-tank and A-pan evaporation for mesh sizes from 13 mm to 50 mm irrespective of the natural environment. Monthly screened evaporation can then be corrected *pro rata* once the correct annual evaporation is known.

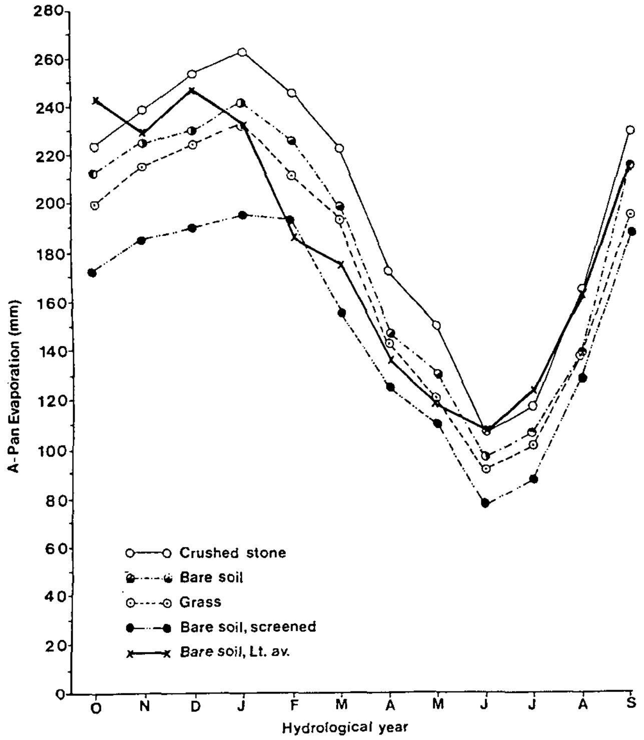

Figure 2
Monthly means, Class A-pan evaporation: Mean of the 1982/83, and the 1983/84 years and long-term average (Lt.av. 1962/63 to 1979/80)

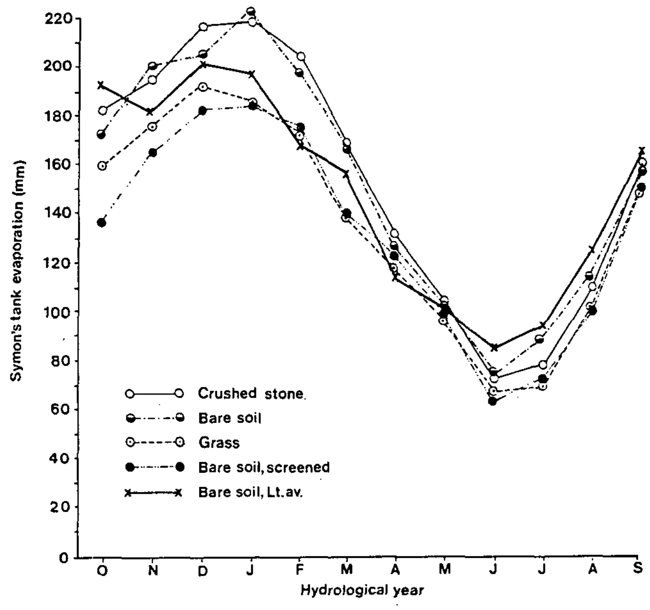

Figure 3
Monthly means, Symon's tank evaporation: Mean of the 1982/83, and the 1983/84 years and long-term average (Lt.av. 1962/63 to 1979/80)

When A-pans are compared on a monthly basis, the differences between A-pan treatments representing crushed stone; bare soil with and without screen protection; and grass; were greater between evaporimeters in summer and autumn months than in winter and early spring (Fig. 2). The seasonal S-tank evaporation exhibited a similar but less pronounced variation (Fig. 2 and Fig. 3).

Pan-dam factors that are used in daily reservoir water balance calculations for South African reservoirs are available for S-tanks only (Müller and Alberts, 1968). To enable these calculations, where S-tank evaporation is absent, as well as for the use in evapotranspiration models such as Baier (1963), formulae were produced to convert A-pan to S-tank data (Table 3). Likewise, S-tank to A-pan conversions were effected to enable the determination of plant consumptive use where A-pan data are not available (Table 4). Both sets of conversion formulae serve as means of expanding evaporimeter data bases, especially where evaporation mapping requires maximum possible data.

Irrigation programming requires daily estimates of plant consumptive use on a pan-crop factor basis. Formulae have been developed to enable these calculations where only daily screened A-pan evaporation is available (Table 5).

The question whether seasonal models would provide a better conversion result or not was put to the test. The lowest correlated coefficients, that of screened to non-screened evaporimeters were selected for A-pan and S-tank treatments to improve conversion estimates. The correlation coefficients of the different seasonal periods were compared by z-testing, using the existing annual correlation as base. In none of the tested combinations did any form of seasonalisation significantly improve that of the annual derived correlation coefficients and, therefore, it could not be expected to improve on other annual regression equations. In one combination, that of October to March for A-pans, a significant reduction in predictability was found (Table 6).

In all the cases where conversion formulae were tested for local and country-wide application, statistically significant improvements in monthly evaporation were found (Table 7).

Under local conditions the conversions for the experimental period 1982 to 1984 as well as the hydrological year 1984/85 where stone environment evaporation was converted to that for standard grass environment, the statistically significant differences (χ^2: Downie and Heath, 1970) which existed prior to standardisation were non-existent thereafter. In the case of Roodeplaat Dam A-pan evaporation, annual differences were reduced from 254 mm and 322 mm to 67 mm and 1 mm for the respective periods. For Roodeplaat Dam S-tank reductions from 307 mm and 213 mm to 72 mm and 5 mm were effected (Table 7).

The effectiveness of the conversions from stone to grass environment for monthly A-pan and S-tank evaporation is quite clear from Fig. 4 and Fig. 5 for the respective evaporimeters.

Conversion formulae were applied to long-term evaporation data collected before the evaporation stations' soil cover was changed from bare soil to crushed stone (Department of Water Affairs, 1985). Significant differences in montly evaporation between stations in close proximity to each other which existed due to non-representative station environments were successfully eliminated by the appliction of the correct conversion formula.

The best results were obtained where bare soil tank evaporation was converted to grass. In the case of Potchefstroom (grass station cover) vs. Boschkop (bare soil cover) the initial difference in annual S-tank evaporation of 246 mm between stations was reduced to 9

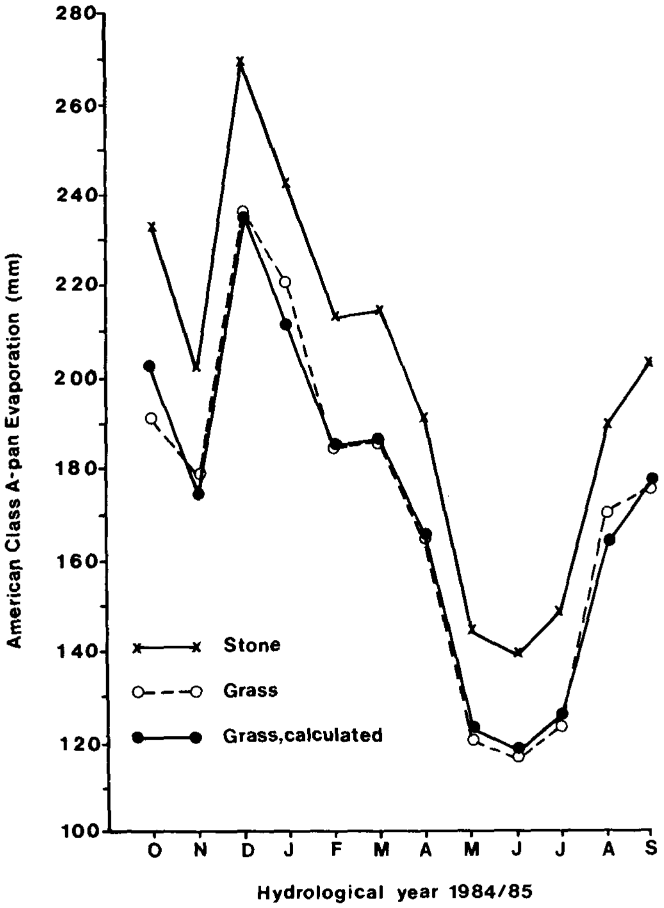

Figure 4
American Class A-pan evaporation measured and converted from crushed stone to grass environment: 1984/85

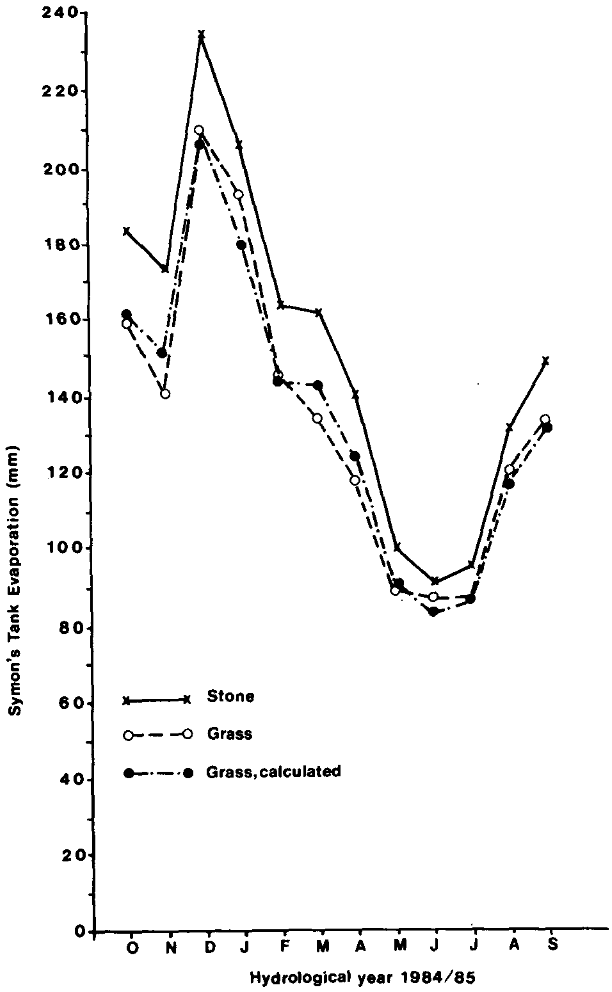

Figure 5
Symon's tank evaporation measured and converted from crushed stone to grass environment: 1984/85

TABLE 4
CONVERSION OF SYMON'S TANK (S) TO AMERICAN CLASS A-PAN (A) MONTHLY EVAPORATION (mm)

	Statistics				
Conversion	Intercept	Slope	Coefficient of determination r^2	Correlation coefficient r	S.E.[a] ± mm
S-grass to A-grass	26,3622	1,0786	0,949	0,974**	11,4793
S-grass to A-bare soil	28,1064	1,1303	0,945	0,972**	12,4558
S-bare soil to A-grass	21,4442	0,9789	0,969	0,984**	6,3593
S-bare soil to A-bare soil	23,1198	1,0247	0,963	0,981**	10,1886
S-bare soil screen protected to A-grass	18,4216	1,1464	0,939	0,969**	12,4748
S-bare soil screen protected to A-bare soil	19,5514	1,2039	0,940	0,969**	13,0638
S-crushed stone to A-grass	28,5417	0,9360	0,965	0,982**	9,4242
S-crushed stone to A-bare soil	31,5204	0,9340	0,947	0,973**	12,1026

Where grass, bare soil and crushed stone signify the evaporation station ground cover.
S.E.[a] = Standard error of estimate. Calculated r-value compared with expected:
**$r_{0,01}$(d.f. = 22) = 0,515

TABLE 5
CONVERSION OF DAILY A-PAN EVAPORATION: SCREENED)[a] TO NON-SCREENED)[b] A-PAN

Month	d.f.)[c]	Intercept	Slope	Correlation: Determination r^2	Correlation: Coefficient r	S.E.)[d] ± mm.d^{-1}
October	60	0,6558	1,0089	0,9228	0,9606**	0,63
November	58	0,7283	1,0023	0,8777	0,9369**	0,80
December	60	0,9219	1,0236	0,8330	0,9127**	1,20
January	60	1,1472	0,9408	0,8933	0,9451**	0,55
February	55	0,9478	0,9187	0,9249	0,9617**	0,51
March	60	-0,2973	1,1234	0,9577	0,9786**	0,40
April	58	0,5659	0,9435	0,8310	0,9116**	0,47
May	60	0,2343	1,0210	0,8776	0,9368**	0,14
June	58	0,3758	1,0240	0,7267	0,8525**	0,49
July	60	0,6166	0,8935	0,8403	0,9167**	0,37
August	60	0,5829	0,9482	0,8922	0,9446**	0,42
September	58	0,3841	0,0081	0,9140	0,9560**	0,49

)a Screened = 13 mm x 0,5 mm mesh screen above bare soil environment;
)b Non-screened = A-pan above grass.
)c d.f. = degrees of freedom = n-2
)d S.E. = Standard error of estimate: ± mm.d^{-1}
Calculated r-value compared with expected:
**$r_{0,01}$(d.f.=55)=0,339; **$r_{0,01}$(d.f.=58)=0,331; **$r_{0,01}$(d.f.=60)=0,325.
**(Extrapolated from (Snedecor and Cochran, 1967).

TABLE 6
CONVERSION OF ANNUAL EVAPORATION FROM SCREENED TO UNSCREENED CONDITIONS COMPARED SEASONALLY

	d.f.	Intercept	Slope	Correlation coefficient r	S.E. ± mm	Coefficient of determination r^2	z
A-pan:							
January to June	10	2,1256	1,2025	0,9790**	11,5	0,9584	<1
July to December	10	-5,1921	1,1973	0,9546**	15,9	0,9113	<1
October to March	10	81,1094	0,7775	0,7864**	7,6	0,6184	2,4*
April to September	10	16,4213	1,0295	0,9790**	8,3	0,9584	<1
Years	22	5,6990	1,1640	0,9680**	12,6	0,9370	-
S-tank:							
January to June	10	-8,6180	1,2086	0,9889**	8,3	0,9779	1,39
July to December	10	2,7309	1,1511	0,9748**	11,1	0,9502	<1
October to March	10	20,4827	1,0602	0,9224**	9,5	0,8508	1,41
April to September	10	13,7650	0,9726	0,9442**	10,8	0,8915	<1
Years	22	-0,9596	1,1559	0,9718**	11,8	0,9444	-

Calculated r-values compared with expected: **$r_{0,01}$(d.f.=10) = 0,708; **$r_{0,01}$(d.f.=22) = 0,515
Calculated z_{1-a} - values compared with expected: *z_{1-a} =1,65 (Huysamen, 1976).

TABLE 7

CORRECTING MONTHLY EXPERIMENTAL AND LONG-TERM CLASS A-PAN AND SYMON'S TANK EVAPORATION (E_o) TO THAT OF A REPRESENTATIVE ENVIRONMENT (E_c), AND THE TESTING OF THE VALIDITY OF FORMULAE APPLICATIONS ELSEWHERE IN THE REPUBLIC OF SOUTH AFRICA

Evaporation station					Statistics						
Number[a]	Name	Period	Environ-ment	Mean[b] annual rainfall mm	E_o mm	/Λ/	χ_0^2 mm	E_c mm	/Λ$_c$/	χ_c^2	Type of Convertion
Class A-pan:											
Experiment	Roodeplaat Dam	1982-84	Grass	627	2 060		40,20	2 060		13,14	Crushed stone
A2E13	Roodeplaat Dam	1982-84	Stone	627	2 314	254	-	1 999	67	-	to grass cover
Weather station	Roodeplaat Dam	1984-85	Grass	653	2 064		45,09	2 064		1,50	Crushed stone
A2E13	Roodeplaat Dam	1984-85	Stone	653	2 386	322	-	2 063	1		to grass cover
Symon's tank:											
Experiment	Roodeplaat Dam	1982-84	Grass	627	1 580		73,90	1 580		12,69	Crushed stone
A2E13	Roodeplaat Dam	1982-84	Stone	627	1 887	307	-	1 652	72	-	to grass cover
Weather station	Roodeplaat Dam	1984-85	Grass	653	1 614		27,97	1 614		3,21	Crushed stone
A2E13	Roodeplaat Dam	1984-85	Stone	653	1 827	213	-	1 609	5		to grass cover
Symon's tank:											
B3E02	Loskop Dam	1938-58	Grass	727	1 561		64,59	1 561		12,65	Bare soil to
B3E03	Loskop Dam	1939-58	Soil	661	1 887	326	-	1 642	81	-	grass cover
C1E01	Vaal Dam	1939-80	Soil	670	1 705		67,16	1 498	82	9,43	Bare soil to
C2E01	Vaal Barrage	1930-80	Grass	700	1 416	289	1 416				grass cover
C2E04	Potchefstroom Agriculture	1959-68	Grass	638	1 662		34,31	1 662		2,19	Bare soil to
C2E06	Boschkop Dam	1959-68	Soil	686	1 908	246	-	1 671	9	-	grass cover
C9E01	Kimberley Water Works	1931-57	Grass	397	1 686		-	1 950		-	Grass cover
C9E02	Kimberley Newton Reservoir	1932-59	Soil	456	2 060	374	69,10	2 060	111	10,35	to bare soil
G2E03	Molteno Reservoir (Cape Town)	1953-80	Grass	806	1 414		38,35	1 414		4,6	Bare soil
G2E07	DF Malan Airport (Cape Town)	1956-80	Soil	499	1 653	239	-	1 450	36	-	to grass cover
U2E02	Cedara Agriculture	1952-80	Grass	816	1 198	-	24,81	1 198	-	2,25	Bare soil to
U2E03	Midmar Dam	1964-80	Soil	888	1 381	183	-	1 208	10	-	grass cover

[1]Evaporimeter station number: Department of Water Affairs (1985).

[2]Rainfall: Department of Water Affairs (1985); Comparing observed (χ_0^2) and corrected (χ_c^2) monthly evaporation with expected: $\chi^2_{0,05}$(d.f. = 11) = 19,68 (Downie and Heath, 1970).

/Λ/ = Absolute difference between evaporation stations.

/Λ$_c$/ = Absolute difference between stations after evaporation correlation formulae were applied.

Note: Annual corrected evaporation = sum total of individually corrected monthly evaporation mm when Boschkop evaporation was converted to grass cover. Likewise, evaporation differences which existed annually between Cedara (grass) and Midmar Dam (soil) were reduced from 183 mm to 10 mm per annum, applying the same conversion as for Boschkop. Where monthly evaporation for Kimberley Waterworks was converted from grass to bare soil at Kimberley's Newton Waterworks, a reduction from 374 mm to 111 mm was achieved. (Kimberley and surroundings are situated in an arid region where a permanent grass evaporation station cover cannot be maintained under prevailing rainfall conditions without supplementary irrigation. Bare soil as a station cover is therefore the appropriate environmental station cover for the region in question. Criteria for station environmental selection are detailed under **Recommendations).** Chi-squared tests applied to observed and calculated monthly evaporation were not statistically significant, an indication that the conversions were effective at the 5 per cent level of statistical probability (Table 7).

Conclusions

Statistically significant differences in evaporation introduced by non-standard environmental installation practices as was established by Bosman (1987) were confirmed in this extended study. The introduction of conversion formulae in this study was therefore more than justified.

Not only did this study provide viable formulae for conversion purposes, it also provided an opportunity to develop formulae for daily and/or monthly 13 mm and monthly 25 mm mesh screened evaporimeters evaporation to be converted to unscreened conditions. The latter is supplemented by correcting annual S-tank and A-pan evaporation from screened to that for non-screened protected evaporation for mesh sizes ranging from 13 mm to 50 mm.

Inter-evaporation formulae offer conversion between A-pan and S-tank evaporation, whereby existing data bases can, with confidence, be extended.

No statistically significant improvements were achieved by applying seasonal correlation techniques to the two years of screened vs. non-screened A-pan and S-tank data.

The applicability of the conversion formulae from non-standard to standard environments for local and country-wide use, proved to be positive. Significant differences between stations in close proximity to each other were non-existent after montly evaporation was converted to representative environmental conditions by the application of formulae developed for this purpose.

Recommendations

No evaporation information should be used before the environmental conditions i.e. crushed stone, grass, bare soil or screen protected, under which it was collected, are known. If this information is not available, stations in close proximity thereof should be considered as guides.

Stations which do not conform to the description of the environment laid down by the WMO (1983) can be standardised by using certain environmental guidelines.

If guided by the minimum annual rainfall under which cropping is economical without supplementary irrigation i.e. 500 mm for summer rainfall regions (Whitmore, 1957) and 240 mm for winter rainfall regions (Hagan *et al.,* 1967), it is possible to select a tentative threshold above which grass should be considered as evaporation station environment. However, refinement of these isohyetal criteria can be achieved, especially in marginal areas, by integrating South African grasses (Acocks, 1975) and boundaries of low dry-land crop production potential areas (Schoeman and Scotney, 1987) with rainfall and soils.

However, as was stressed in WMO (1983) and confirmed by Bosman (1987), evaporation stations must be constructed and evaporimeters installed in an environment representative of the area in question.

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