Effect of Irrigation Management and Water Table Depth on Water and Salt Distribution as Predicted by a Computer Simulation Model

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Abstract

Two water table depths and three irrigation programmes were evaluated regarding their effect on water and salt dynamics over four seasons by means of a computer simulation program developed by the United States Bureau of Reclamation (USBR). The predictions reveal a definite benefit derived from a heavy irrigation at the beginning of the season, both with regard to soil moisture and to salt buildup. Similar results were obtained when comparing short and long irrigation frequencies, favouring the former. In the case of a shallow (2 m) water table, favourable results were obtained only when salinity problems were disregarded, indicating a definite need for keeping the water table below that level. An Oakleaf soil form (Jozini series), a commonly occurring soil on many irrigation schemes in South Africa, was simulated.

Introduction

Many irrigation areas in South Africa are subject to salinization, frequently caused by unsound irrigation management. Where flood irrigation is practised, farmers often do not have the opportunity to maintain an effective water application policy compatible with both plant consumption needs and the prevention of salt buildup, even if this information were available. Research is definitely required, but lack of qualified irrigation researchers to solve the above-mentioned problems for the many different soil types encountered in local irrigation areas, prohibit the many field trials needed for such research.

Progress in computer simulation of water and salt behaviour in irrigated soils enables the modern soil scientist to increase the output of practical solutions to problems in this regard for the many different irrigated soils. Questions that must be answered before such an approach may be deemed viable, are the ability of these models to simulate the complicated processes taking place to the necessary accuracy, and the costs in terms of computer time required to produce these results.

The first question is relatively easy to answer depending on the type of model and the extent to which it has already been tested in real-world situations. For the relatively complicated situation of three-dimensional, real-time water distribution under trickler irrigation in a sandy soil, Levin, Van Rooyen and Van Rooyen (1979) have found excellent agreement between predicted and real situations using as a basis a model developed by Bresler (1975). Less complicated flood or sprinkler irrigation has been modelled for many years, and constitutes the case for which a management programme will be tested in this paper.

The second question is difficult to answer, but estimates will be made in terms of computer processing time, which, of course, varies from machine to machine.

The objectives for this study can be summarised as follows:

- to predict the effects of two water table depths and two frequencies of flood irrigation on water and salt distribution and movement, and
- to predict the effect of a single heavy flood irrigation at the beginning of the season on water and salt distribution and movement and to test the hypothesis that this could reduce salt concentrations in the root zone for the rest of the season.

Materials and Methods

Simulation Model

A simulation model for the prediction of detailed return flow salinity developed over 15 years in the United States of America (Shaffer, 1976), culminating in a version published by the Environmental Protection Agency (Shaffer, Ribbens & Huntley, 1977) was kindly supplied by the United States Bureau of Reclamation and used in this study. The complete model consists of several computer programs written in FØRTRAN IV, and in this study the programs relating to unsaturated flow, unsaturated chemistry and an interface program linking the two, were used. After conversion from the original CDC configuration to that of the Burroughs 7700 of the Department of Agriculture, the model was run from a RJE terminal situated in Stellenbosch.

The model subprograms have been verified independently in soil columns, lysimeters and small field plots, and have been found to account adequately for field situations (Shaffer, 1976). In this study the results were not verified in the field under the assumption that it has been adequately tested elsewhere. The limitations of the model has been described in detail (Shaffer, Ribbens and Huntley 1977), and will therefore not be elaborated upon in this paper.

Soil and Water Characteristics

Due to the mass of data accumulating and to be processed from each profile simulation, only one, a typical Oakleaf soil form (Jozini series) on the Oudtshoorn irrigation scheme is considered in this paper. Large areas of this soil are irrigated in South Africa and problems with salinity buildup and high water tables are frequently encountered. Tables 1 and 2 summarise the relevant physical and chemical properties of the soil, and Table 3 gives average water analyses of the two largest irrigation dams in the area, the Gamka and Stompdrift Dams.

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TABLE 1
SOIL PHYSICAL CHARACTERISTICS (OAKLEAF FORM, JOZINI SERIES)

	TEXTURE (%)				
Depth (mm)	**Coarse Sand** (2—0,5 mm)	**Med. Sand** (0,5—0,2 mm)	**Fine Sand** (0,2—0,02 mm)	**Silt** (0,02—0,002 mm)	**Clay** (<0,002 mm)
0–100	0,64	4,82	55,66	18,25	20,62
100–200	0,69	5,30	56,27	17,05	20,68
200–300	0,66	5,77	56,35	15,86	21,36
300–400	0,59	6,38	53,50	12,03	27,50
400–500	0,26	7,94	48,70	12,37	30,73
500–600	0,49	4,63	49,74	14,42	30,72
600–700	2,10	4,17	42,79	15,08	35,85

Saturated Hydraulic Conductivity = 50 mm/d
Air entry potential = 199,5 mmH_2O
B (slope of soil moisture release curve) = 6,59
Saturation percentage Θ_s = 0,41 $m^3.m^{-3}$
Permanent wilting point (PWP) = 0,14 $m^3.m^{-3}$

TABLE 2
INPUT FOR THE UNSATURATED CHEMISTRY PROGRAM

Depth (mm)	**300**	**600**	**900**	**1 200**
Ca^{++} me/ℓ)	11,34	28,44	15,84	5,23
Na^+ (me/ℓ)	10,10	13,26	13,26	10,86
Mg^{++} (me/ℓ)	1,71	4,35	2,17	0,82
HCO_3^- (me/ℓ) *	0,75	0,80	0,80	1,10
Cl^- (me/ℓ)	3,63	9,50	9,00	6,00
$CO_3^=$ (me/ℓ)	0,25	0,30	0,30	0,40
$SO_4^=$ (me/ℓ)	18,25	33,45	21,17	9,41
CEC (me/100 g)	13,14	11,66	10,50	9,02
Gypsum (me/100 gm)	0,00	0,00	0,00	0,00
g H_2O/g soil for soil extract	0,44	0,44	0,44	0,44
ρb ($g.cm^{-3}$)	1,59	1,78	1,64	1,64
SAR (mmol/ℓ)$^{1/2}$	3,95	3,27	4,41	6,24

*Soluble salts

TABLE 3
CHEMICAL ANALYSIS OF IRRIGATION WATER (IN MILLI-EQUIVALENTS PER LITRE)

Source (dam)	Ca^{++} (me/ℓ)	Na^+ (me/ℓ)	Mg^{++} (me/ℓ)	$CO_3^=$ (me/ℓ)	$Cℓ^-$ (me/ℓ)	$SO_4^=$ (me/ℓ)	SAR (mmol/ℓ)$^{1/2}$	TDS mg/ℓ
Stompdrift	3,27	8,76	2,96	3,23	6,84	5,27	4,96	1 005
Gamka	2,50	1,02	1,43	2,16	1,70	1,26	0,37	349

The unsaturated flow subprogram was used in the mode to receive a single "average" soil moisture characteristic curve in the form of the slope, intercept and air entry potential obtained from a log-log plot of potential (in cm water) atgainst volumetric water content (Θ), expressed in $m^3.m^{-3}$. Duplicate retentivity curves determined on undisturbed soil cores taken every 100 mm to a depth of 700 mm were averaged at each of nine different potentials to give an average retentivity curve for the profile. The log-log curve of the water was then plotted as in Figure 1. The linearity of the plot, a prerequisite for the use of this method (Shaffer *et al.*, 1976) is clearly illustrated. Experimentally determined saturated hydraulic conductivity values on undisturbed 0,03 m^3 soil cores using distilled water gave an average of 50 mm/d, confirmed by several separate determinations with Stompdrift Dam water. Determinations of saturation percentage on undisturbed soil cores gave an average Θ of 0,41 $m^3.m^{-3}$. The permanent wilting point (PWP) as estimated at 1 500 kPa pressure was 0,14 $m^3.m^{-3}$, below which all water movement is assumed to cease.

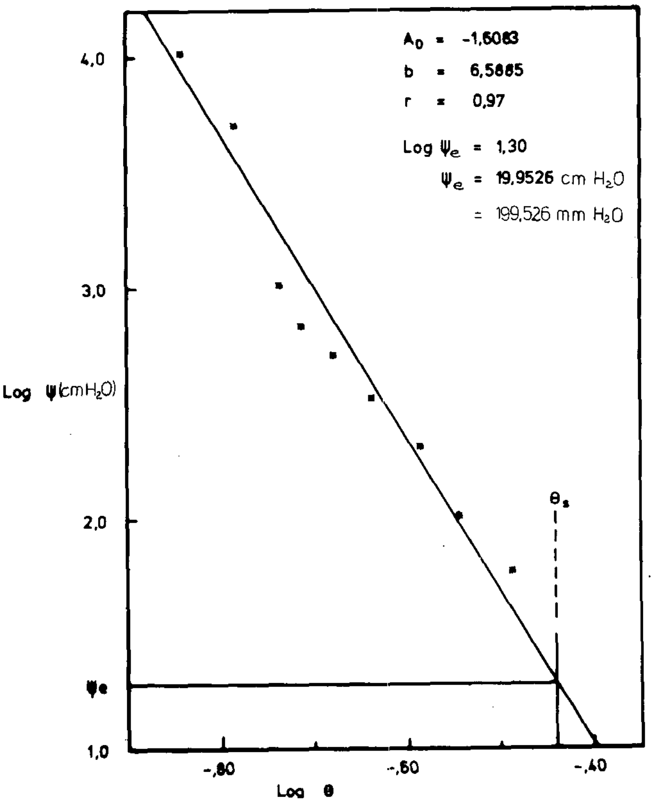

Figure 1
Log-log plot of soil water characteristic curve obtained by averaging Θ values over seven depths at nine potential values.

Irrigation Practices

In accordance with current practices in the Oudtshoorn area, one of the irrigation practices simulated was a 90 mm application every three weeks during the normal irrigation season from August to December (day numbers 243 – 360) as well as an alternative treatment consisting of 180 mm applications every six weeks. Initial water contents were taken as field water capacity (FWC) as obtained from undisturbed soil moisture retention values at – 30 kPa soil moisture potential. No irrigation was applied outside the normal vegetative period for the crop concerned (lucerne), but rainfall was at all times accounted for. Two water table depths, 2 160 mm and 4 320 mm were used and for the 2 160 mm water table a separate run was made applying 180 mm at the beginning of the irrigation season followed by 90 mm every three weeks thereafter (Table 4), as suggested by Bresler & Yaron (1972). Both Gamka and Stompdrift Dam waters were utilised in separate simulations.

Fortnightly consumptive use values, determined experimentally, were used (Table 5).

A root extraction pattern of 40, 30, 20 and 10 per cent for consecutive 300 mm layers was assumed for lucern (Shaffer *et al.*, 1976).

Simulation Procedure

Unsaturated flow program

The soil profile was partitioned into 80 mm layers to water table depth. Soil data obtained at 700 mm were extended to the lower depths in all simulations, a reasonable assumption for this soil type.

Unsaturated chemistry program

Chemical reactions such as dissolution and precipitation as well as ion exchange and ion pair formation are simulated and

TABLE 4
IRRIGATION DATES (SIMULATED)

180 mm/6 weeks				90 mm/3 weeks				180 mm, 90 mm/3 weeks			
1975	1976	1977	1978	1975	1976	1977	1978	1975	1976	1977	1978
29/9/75	9/4*	31/8	31/8	29/9/75	14/1	31/8	31/8	29/9/75	14/1	31/8**	31/8**
10/12/75	31/8	13/10	13/10	3/11/75	9/4*	20/9	20/9	3/11/75	9/4*	20/9	20/9
	12/10	21/11	21/11	8/12/75	31/8	13/10	13/10	8/12/75	31/8**	13/10	13/10
	22/11				20/9	1/11	1/11		20/9	1/11	1/11
					12/10	21/11	21/11		12/10	21/11	21/11
					1/11	7/12	7/12		1/11	7/12	7/12
					22/11				22/11		
					13/12				13/12		

*90 mm application
**180 mm application

TABLE 5
CONSUMPTIVE USE VALUES FOR THE OUDTSHOORN DISTRICT FOR THE CULTIVATION OF LUCERNE UNDER FLOOD IRRIGATION (mm)

Month	First half	Second half
January	45,0	49,0
February	39,0	34,0
March	31,0	25,0
April	22,0	21,0
May	21,0	21,0
June	21,0	23,0
July	25,0	29,0
August	35,0	47,0
September	56,0	83,0
October	87,0	96,0
November	42,5	47,5
December	52,5	57,5

amounts are calculated at the prevailing moisture content at the specific depth and point in time, in $\mu g/cm^2$ per segment. At any time therefore, two layers not having the same moisture content (which is virtually a certainty) cannot be compared in terms of salt concentration. To facilitate comparison all dissolved salts were recalculated to a reference point, namely the specific saturation percentage of that particular segment, and expressed in me/ℓ saturation extract. Real root contact salinities (osmotic potentials) are therefore different than would appear from the results where comparisons amongst treatments and soil layers are made.

Results and Discussion

Soil Moisture Conditions

Concerning the effect of water table depth on general moisture conditions at different profile depths it was established that for a water table at 4 320 mm, both irrigation frequencies (the first irrigation commencing at day 243) had no effect on water content at a depth of 1 200 mm, which remained at PWP below 1 200 mm. In most cases changes were observed to a depth of 1 000 mm as shown in Figure 2. At a water table depth of 2 160 mm, the situation was entirely different. In Figure 3, Θ values up to a depth of 2 160 mm for 10 days after a 180 mm irrigation (at day 243) can be followed. It is clear that in this case Θ values were significantly influenced to a depth of 1 760 mm, giving a uniform moisture profile at about Θ = 0,30 after 10 days. From Figure 4 it can be deduced that the 2 160 mm water table affected Θ values up to a depth of 880 mm as seen from high Θ values outside the irrigation season at the latter depth. The high capillary conductivity of the soil is thus responsible for moisture replenishment over a vertical distance of more than 1 000 mm, preventing the 880 mm layer from reaching permanent wilting point. A deep water table could not supply sufficient water and Θ at 880 mm fell to PWP outside the irrigation season. The results depicted in Figure 4 also show that while the 320 mm layer is influenced by rainfall, the 640 mm layer stays at PWP outside the irrigation season, while layers deeper than 640 mm are replenished from the water table at 2 160 mm. The sharp increase in Θ in the 640 mm layer from day 130 onwards is ascribed to a time lag for rainfall in reaching the deeper layers. It is important to note that the 180 mm irrigations also influence the 1 200

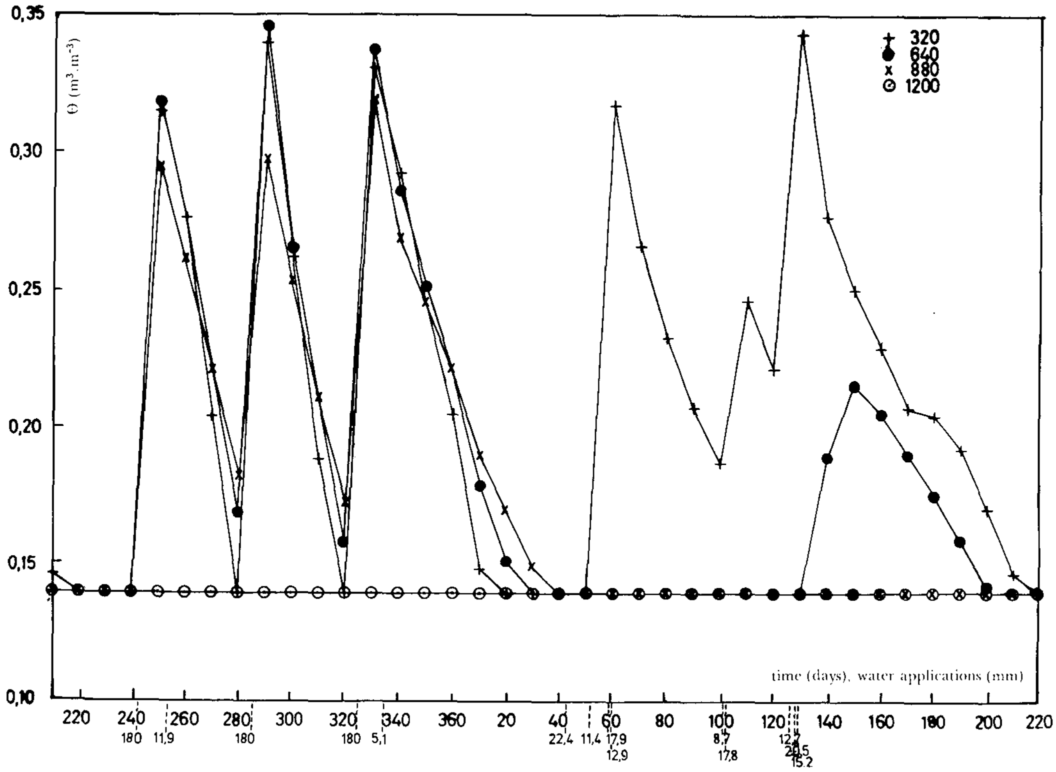

Figure 2
Plot of soil water content Θ, $m^3.m^{-3}$) against time (days). Irrigation frequency 180 mm every 6 weeks, water table depth 4 320 mm. Small print on x-axis indicates irrigation applications and rainfall in mm.

mm layer, indicating a deeper penetration of irrigation water not found with the deeper water table (Figs. 2 and 4). This is probably due to higher Θ values throughout the profile, leading to higher unsaturated conductivity and consequently faster penetration of irrigation water.

Simulation results employing an irrigation frequency of 90 mm every three weeks do not significantly change the results reported above, the only exception being generally smaller fluctuations in the lower Θ values in the shallower layers between irrigations (Fig. 5). At the 640 mm depth the same situation is encountered except for generally higher Θ values than with the lower irrigation frequency.

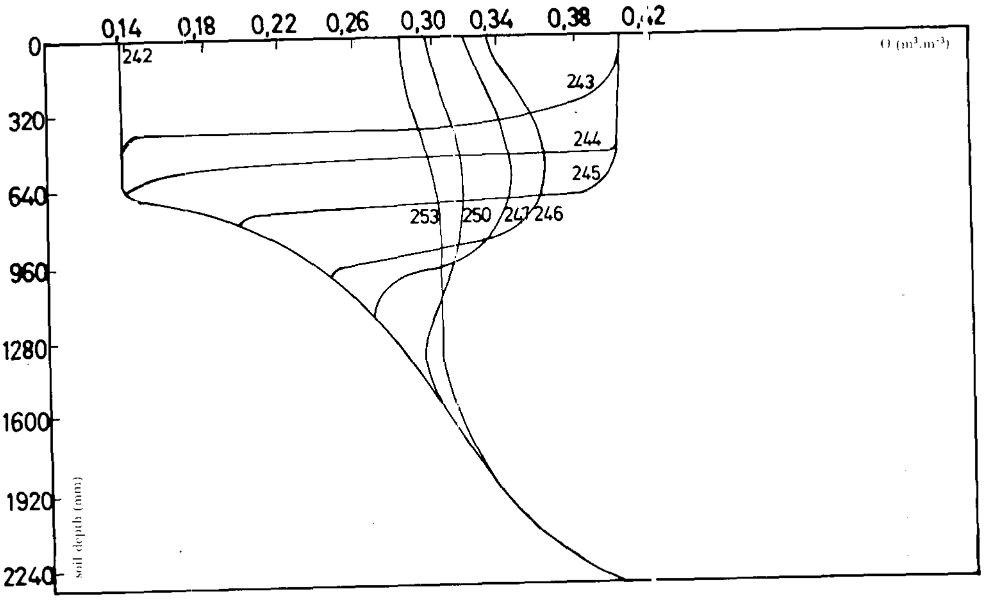

Figure 3
Plot of soil water content (Θ, $m^3.m^{-3}$) against depth (mm) after an irrigation application of 180 mm on day 243, for 10 days afterwards.

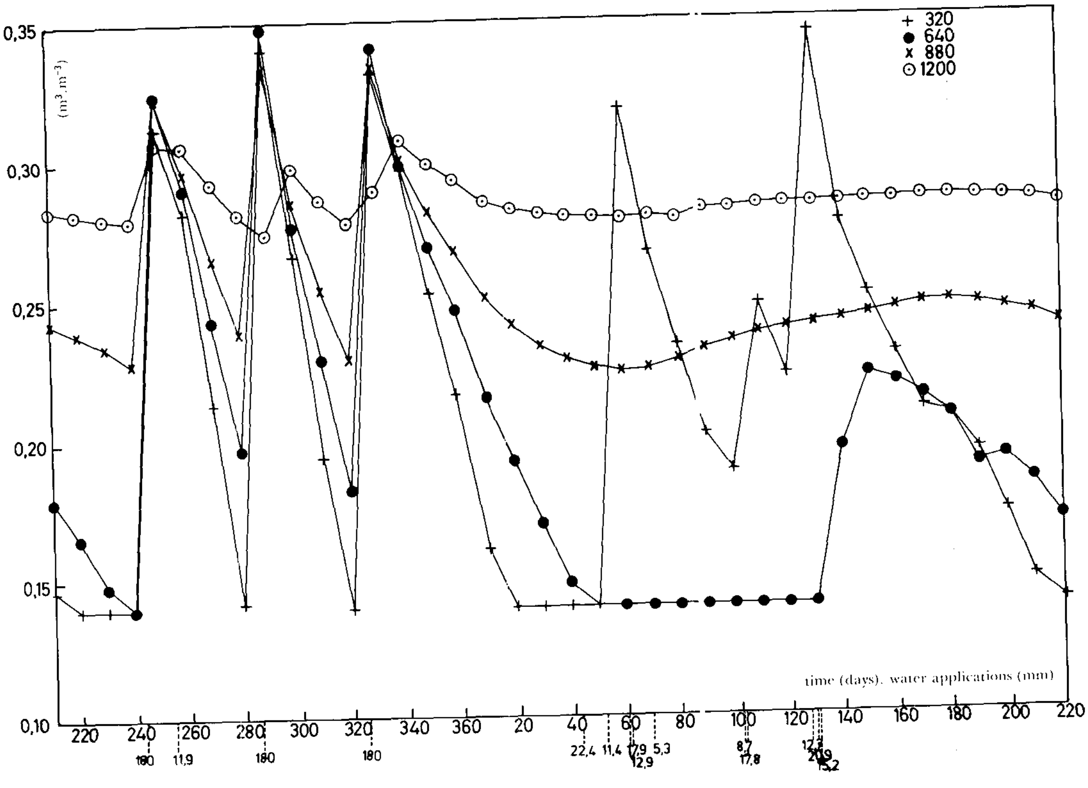

Figure 4
Plot of soil water content (Θ, $m^3.m^{-3}$) against time (days) for the 1977/78 irrigation season. Water depth 2 160 mm, irrigation cycle 180 mm every six weeks. Small print on x-axis indicates irrigation applications and rainfall in mm.

The effect of a heavy 180 mm irrigation application at the beginning of the irrigation season had a significant effect on Θ values throughout the season. Higher water conductivity thus established earlier in the season resulted in corresponding deeper penetration of irrigation water as well as rainfall, leading to increased Θ values, especially in the 880 mm layer during the irrigation season (Figs. 5 and 6).

Although it cannot be deduced from Figure 6, it was found that this beneficial condition during the irrigation season was carried over to the following year.

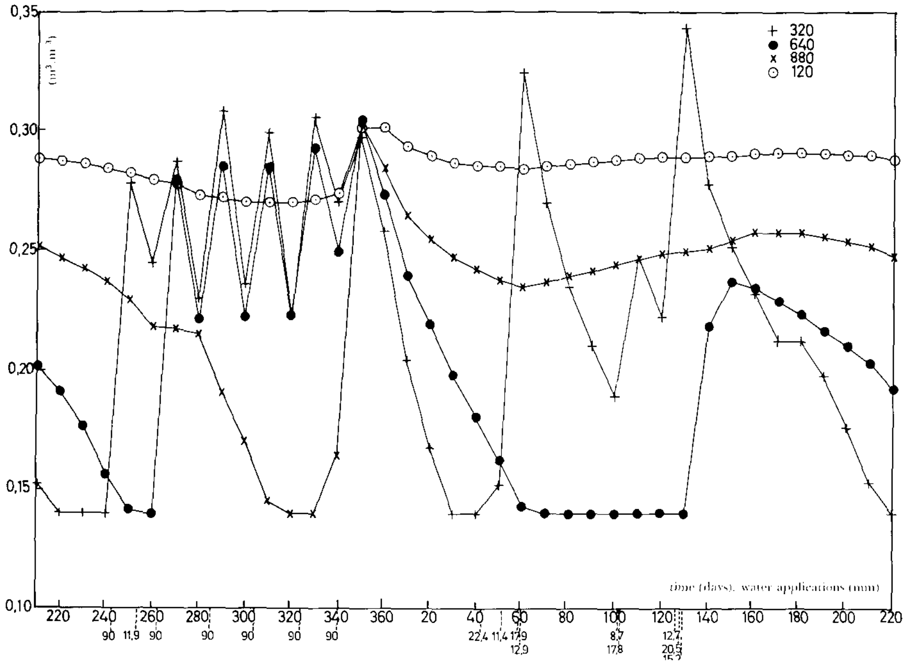

Figure 5

Plot of soil water content (Θ, $m^3.m^{-3}$) against time (days) for the 1977/78 irrigation season. Water table depth 2 160 mm, irrigation cycle 90 mm every three weeks. Small print on x-axis indicates irrigation applications and rainfall in mm.

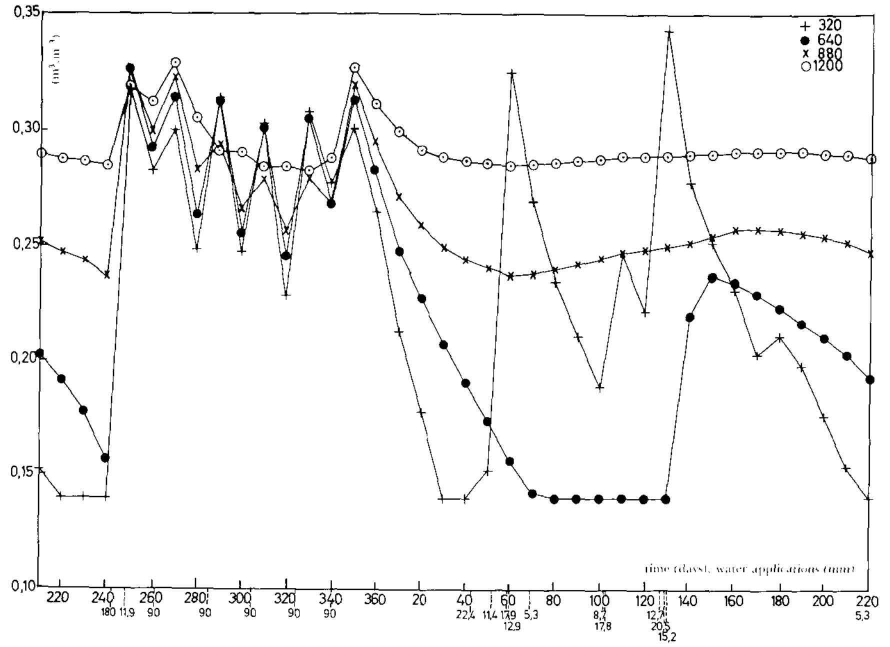

Figure 6

Plot of soil water content (Θ, $m^3.m^{-3}$) against time (days) for the 1977/78 irrigation season. Water table depth 2 160 mm, irrigation cycle 180 mm followed by 90 mm every three weeks. Small print on x-axis indicates irrigation applications and rainfall in mm.

Salinity Profile

Although the data in Table 3 could give the general impression that the Gamka Dam water is of much higher quality than that of the Stompdrift Dam, the relatively high carbonate content could result in rapid calcium precipitation especially in soil layers where frequent occurrences of low Θ values are found. This theory is confirmed by the results given in Table 6, where the data show a rapid increase in the sodium adsorption ratio (SAR)*, a parameter closely related to adverse soil physical conditions (Richards, 1954), in the region of the 1 000 mm depth without much difference between the two waters. These above results were obtained from a four-season simulation with a water table at 2 160 mm. The better water distribution caused by the shallower water table if offset by a higher SAR. Results of a similar simulation with a 4 320 mm depth water table (Table 7) shows much less detrimental SAR values at the approximately 1 000 mm depth.

TABLE 6
SAR vs DEPTH WITH STOMPDRIFT AND GAMKA WATER AFTER 22 IRRIGATION APPLICATIONS AT 90 mm A TIME FOR A 2 160 mm WATER TABLE DEPTH. SAR CALCULATED AT SATURATION PERCENTAGE

Depth (mm)	Stompdrift	Gamka
240	3,311	0,684
480	4,316	1,920
720	10,195	7,262
960	12,203	10,796
1 200	5,540	5,427
1 440	4,280	4,280
1 680	4,263	4,263
1 920	4,382	4,382
2 160	4,587	4,587

TABLE 7
SAR vs. DEPTH WITH STOMPDRIFT AND GAMKA WATER AFTER 22 IRRIGATION APPLICATIONS AT 90 mm A TIME FOR A 4 320 mm WATER TABLE DEPTH. SAR CALCULATED AT SATURATION PERCENTAGE

Depth (mm)	Stompdrift	Gamka
240	3,30	0,65
480	4,05	1,65
720	6,00	3,30
960	8,05	6,22
1 200	5,25	5,05
1 440	3,53	3,60
1 680	3,70	3,70
1 920	3,75	3,75
2 160	3,83	3,83

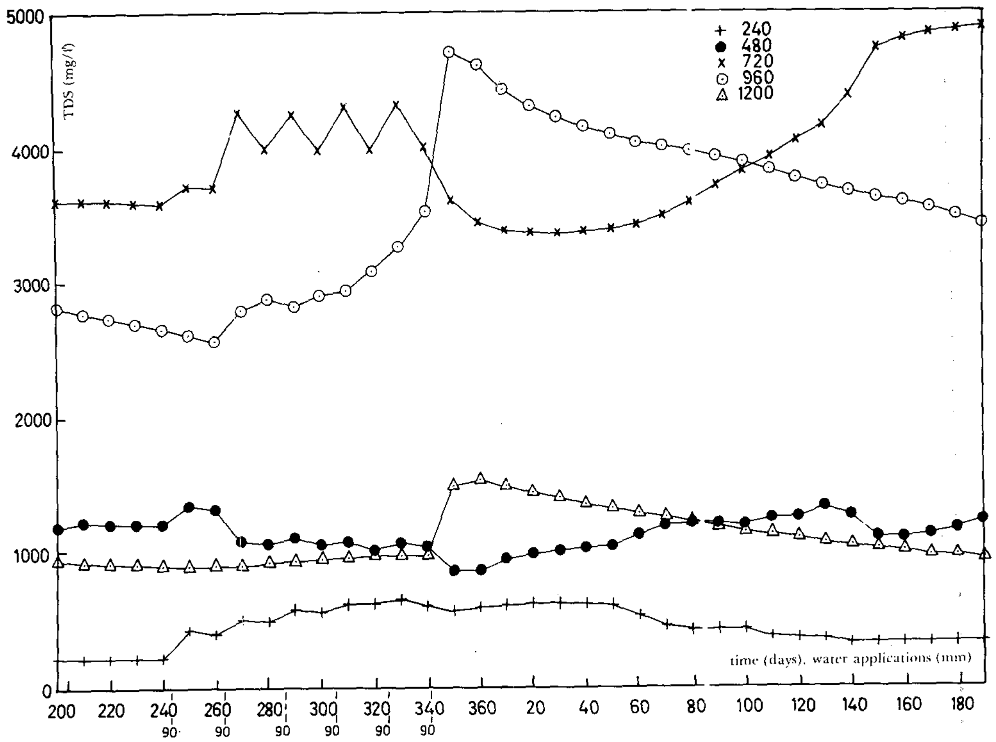

Figure 7
Plot of total dissolved solids (TDS) in mg/ℓ against time for the 1977/78 irrigation season. Water table depth 2 160 mm, irrigation cycle 90 mm every three weeks as indicated in small print on x-axis. Stompdrift Dam water.

$$^*SAR = \frac{Na}{\left(\frac{Ca + Mg}{2}\right)^{1/2}} \ (\text{mmol}/\ell)^{1/2}$$

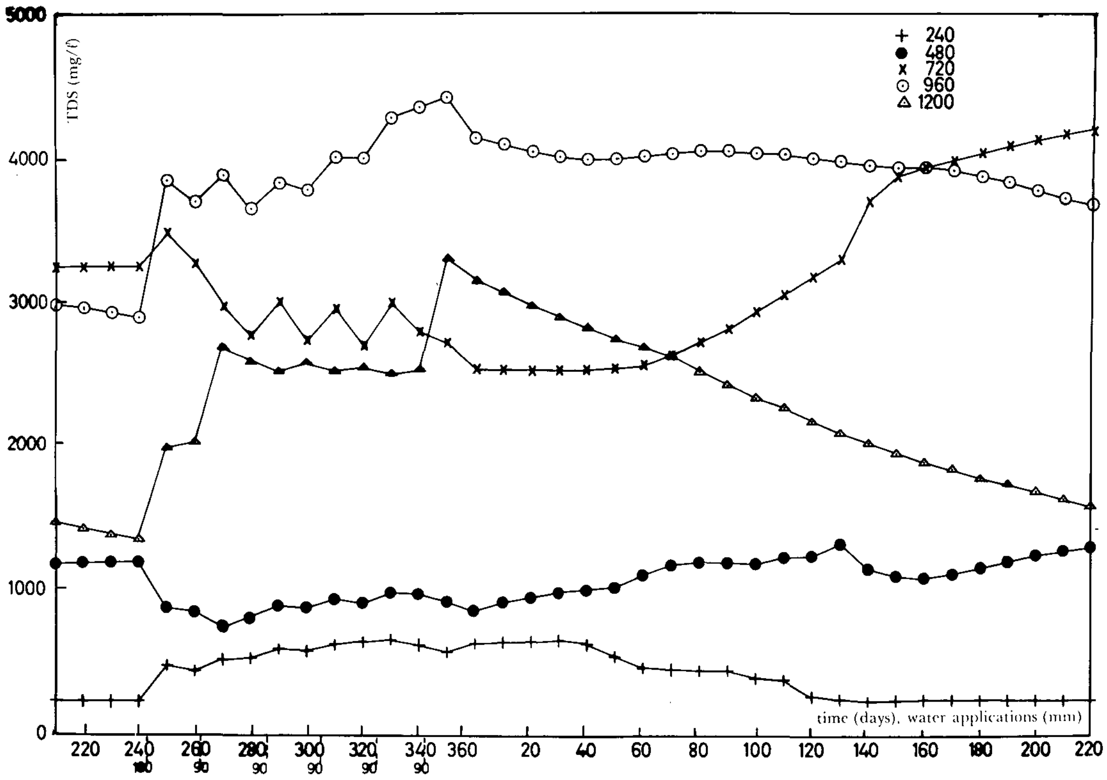

Figure 8

Plot of total dissolved solids (TDS) in mg/ℓ against time for the 1977/78 irrigation season. Water table depth 2 160 mm, irrigation cycle 180 mm followed by 90 mm every three weeks, as indicated in small print on x-axis. Stompdrift Dam water.

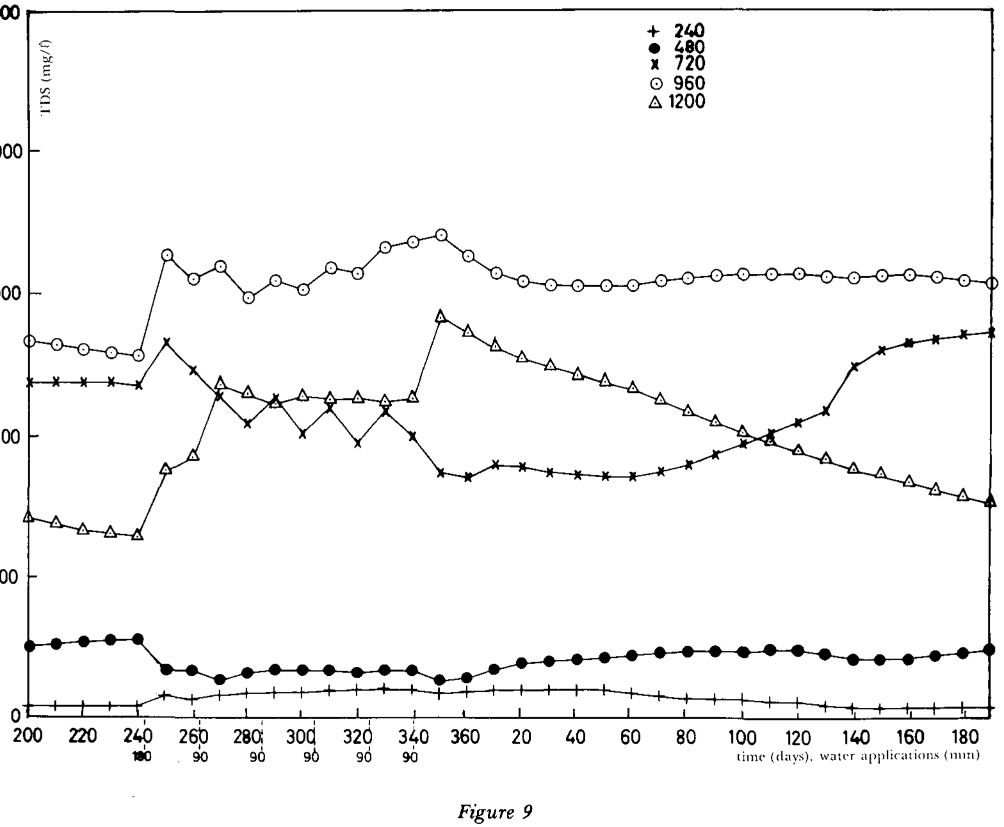

Figure 9

Plot of total dissolved solids (TDS) in mg/ℓ against time for the 1977/78 irrigation season. Water table depth 2 160 mm, irrigation cycle 180 mm followed by 90 mm every three weeks, as indicated in small print on x-axis. Gamka Dam water.

Regarding the effect of a heavy irrigation at the beginning of the season on the salt regime in the soil, the results represented in Figures 7 + 8 confirm the detrimental effect of this practice in deep soil layers as far as salt load is concerned. Total soluble salts are generally higher with this irrigation method, except for the 1 200 mm layer, possibly influenced by the shallow water table. However, when the salt load figures for the Stompdrift Dam water are converted to real osmotic potentials at prevailing moisture contents, it can be seen that in comparison with 90 mm every three weeks this irrigation practice resulted in lower values of osmotic pressure in the irrigation season up to a depth of at least 720 mm (Table 8). Outside the irrigation season differences were minimal, while high salt contents at the two lower depths are probably due to leacheate from the upper layers. Similar results obtained with the Gamka Dam water indicate that an initial heavy irrigation is generally beneficial (Figure 9, Table 9).

Regarding the effect of irrigation frequency on salt regime, results of a four year simulation represented in Tables 10 to 13 indicate that 180 mm every six weeks leads to a lower total soluble salt regime. Osmotic potential at real water contents may partially offset this effect owing to higher Θ values expected for the higher frequency irrigation practice. However, present results are not conducive to firm conclusions in this regard. Comparing the results in Tables 10 and 12 as well as Tables 11 and 13 a general benefit in favour of a deeper water table is indicated, the total dissolved solids being generally higher with shallower water tables.

TABLE 8
OSMOTIC POTENTIALS[1] FOR EACH SOIL LAYER AS AFFECTED BY IRRIGATION PRACTICE.
WATER TABLE AT 2 160 mm STOMPDRIFT DAM WATER

Day No.	Treatment			Depth (mm)		
Year 1977		240	480	720	980	1 200
240	90[2]	−0,64	−3,80	−8,20	−4,42	−1,31
	180[3]	−0,65	−3,28	−7,75	−4,92	−1,78
	180/90[4]	−0,66	−3,73	−7,36	−4,81	−1,95
260	90	−0,64	−2,46	−8,86	−4,56	−1,32
	180	−0,62	−1,20	−4,46	−5,05	−2,46
	180/90	−0,63	−1,31	−4,51	−4,99	−2,51
280	90	−0,85	−2,07	−7,24	−5,19	−1,38
	180	−0,99	−2,17	−5,65	−5,67	−2,57
	180/90	−0,85	−1,41	−4 19	−5,18	−3,48
300	90	−0,96	−1,99	−7 44	−5,95	−1,44
	180	−0,82	−1,30	−4 24	−5,68	−3,15
	180/90	−0,96	−1,54	−4 30	−5,71	−3,64
320	90	−1,18	−2,00	−7 40	−6,75	−1,49
	180	−1,56	−2,35	−5 46	−6,47	−3,20
	180/90	−1,18	−4,41	−6 24	−3,67	−3,67
340	90	−0,89	−1,74	−6 62	−7,02	−1,49
	180	−0,70	−1,20	−3 48	−5,82	−3,82
	180/90	−0,88	−1,57	−4 23	−6,51	−3,59
360	90	−0,90	−1,44	−5 07	−6,53	−2,08
	180	−1,08	−1,65	−4,32	−6,23	−3,87
	180/90	−0,92	−1,36	−3 68	−5,78	−4,20

[1] Osmotic pressures calculated as 5,625 x 10^{-4} x mg/ℓ (Richards, 1954). Table values to be multiplied by 100 for kPa.
[2] 90 mm every three weeks.
[3] 180 mm every six weeks.
[4] 180 mm followed by 90 mm every three weeks.

TABLE 9
OSMOTIC POTENTIALS FOR EACH SOIL LAYER AS AFFECTED BY IRRIGATION PRACTICE. WATER TABLE AT 2 160 mm. GAMKA DAM WATER

Day No.	Treatment	Depth (mm)				
		240	480	720	980	I 200
240	90[1]	−0,21	−1,78	−6,39	−4,10	−1,29
	180[2]	−0,21	−1,44	−5,75	−4,40	−1,72
	180/90[3]	−0,21	−1,76	−5,39	−4,28	−1,87
260	90	−0,20	−1,10	−6,81	−4,25	−1,31
	180	−0,19	−0,30	−0,43	−4,29	−2,27
	180/90	−0,19	−0,53	−3,41	−41,8	−2,43
280	90	−0,26	−0,86	−0,50	−4,68	−1,37
	180	−0,24	−0,91	−4,20	−4,77	−2,38
	180/90	−0,26	−0,58	−3,18	−4,23	−3,07
300	90	−0,30	−0,77	−5,53	−5,28	−1,43
	180	−0,25	−0,47	−3,21	−4,62	−2,84
	180/90	−0,30	−0,60	−3,20	−4,55	−3,22
320	90	−0,37	−0,74	−5,41	−5,86	−1,48
	180	−0,49	−0,92	−3,94	−5,19	−2,91
	180/90	−0,37	−0,62	−3,21	−4,89	−3,27
340	90	−0,28	−0,61	−4,81	−5,97	−1,48
	180	−0,22	−0,42	−2,88	−4,60	−3,35
	180/90	−0,27	−0,55	−3,05	−5,02	−3,21
360	90	−0,29	−0,51	−3,77	−5,34	−1,95
	180	−0,34	−0,63	−3,16	−4,88	−3,40
	180/90	−0,28	−0,48	−2,47	−4,44	3,59

[1] 90 mm every three weeks.
[2] 180 mm every six weeks.
[3] 180 mm followed by 90mm every three weeks.

TABLE 10
TOTAL DISSOLVED SOLIDS (mg/ℓ) OVER 4 YEARS. IRRIGATION FREQUENCY 180 mm EVERY SIX WEEKS, WATER TABLE AT 4 320 mm

Depth (cm)	1975 (2)[1]		1976 (6)		1977 (9)		1978 (2)	
	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift
240	208	565	169	544	195	525	161	524
480	639	985	232	688	440	761	217	700
720	1 557	1 718	909	1 677	582	1 697	499	1 565
960	1 918	2 025	1 978	2 485	2 032	3 018	2 057	3 450
1 200	1 306	1 322	1 983	2 212	2 289	2 837	2 718	3 735
1 440	693	693	738	738	781	781	805	805
1 680	624	624	599	599	587	586	574	574
1 920	630	630	609	609	596	596	587	587
2 160	628	628	610	610	601	601	592	592
2 400	624	624	611	610	604	604	598	598
2 640	624	624	615	615	609	609	605	605
2 880	629	629	620	620	616	616	614	614
3 120	634	634	628	628	624	624	628	628
3 360	642	641	637	636	632	632	634	634
3 600	651	651	646	646	643	643	638	638
3 840	665	665	661	661	651	657	655	655
4 080	685	685	682	682	682	682	682	682
4 320	720	720	724	724	726	726	728	728

[1] Number of irrigation applications in brackets.

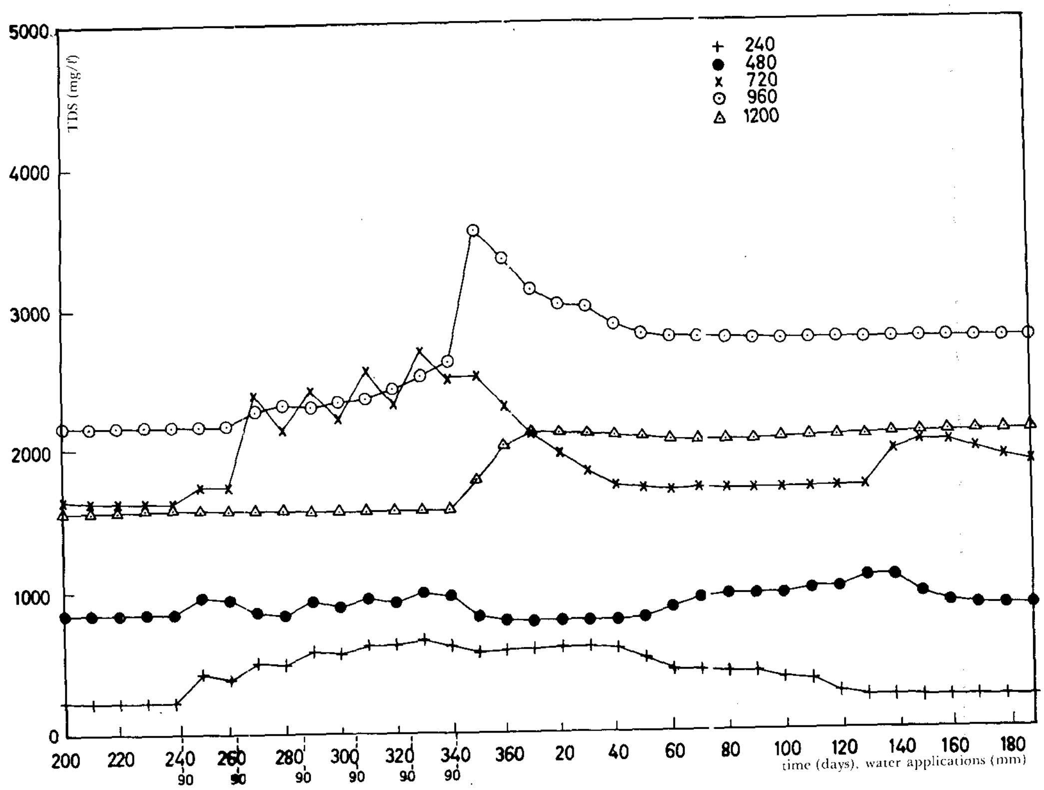

Figure 10
Plot of total dissolved solids (TDS) in mg/ℓ against time for the 1977/78 irrigation season. Water table depth 4 320 mm, irrigation cycle 90 mm every three weeks. Stompdrift Dam water.

TABLE 11
TOTAL DISSOLVED SOLIDS (mg/ℓ) OVER 4 YEARS. IRRIGATION FREQUENCY 90 mm EVERY 3 WEEKS, WATER TABLE AT 4 320 mm

	1975 (3)[1]		1976 (1)		1977 (17)		1978 (23)	
Depth (cm)	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift
240	297	698	177	566	179	583	178	582
480	1 227	1 411	272	776	248	786	245	789
720	1 340	1 426	1 679	2 203	1 618	2 298	1 356	2 430
960	977	978	2 350	2 805	2 436	3 340	2 560	3 979
1 200	1 011	1 011	1 354	1 399	1 791	2 005	2 135	2 592
1 440	697	697	741	741	780	779	799	799
1 680	628	627	604	604	590	590	578	578
1 920	636	636	614	614	602	602	592	592
2 160	634	634	616	616	607	607	599	599
2 400	630	630	618	618	610	610	604	604
2 640	632	632	623	623	617	617	611	611
2 880	638	638	630	630	623	623	619	619
3 120	644	644	638	638	632	632	628	628
3 360	653	653	648	648	643	643	638	638
3 600	666	665	661	661	656	656	652	652
3 840	683	683	678	678	674	674	670	670
4 080	711	711	707	707	704	704	702	702
4 320	765	765	765	765	765	765	765	765

[1] Number of irrigation applications in brackets

TABLE 12
TOTAL DISSOLVED SOLIDS (mg/ℓ) OVER 4 YEARS. IRRIGATION FREQUENCY 180 mm EVERY SIX WEEKS, WATER TABLE AT 2 160 mm

	1975 (2)[1]		1976 (6)		1977 (9)		1978 (12)	
Depth (cm)	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift
240	212	570	184	575	172	553	209	551
480	660	1 014	370	1 712	327	858	327	876
720	1 779	1 948	1 789	2 240	1 950	2 664	2 072	3 063
960	2 376	2 478	2 675	3 102	3 260	4 154	3 737	5 129
1 200	1 441	1 457	2 228	2 400	2 427	2 759	2 628	3 181
1 440	703	703	934	957	816	839	818	855
1 680	653	636	736	665	644	678	642	643
1 920	679	679	679	679	678	678	678	678
2 160	732	732	732	732	732	732	732	732

[1] Number of irrigation applications in brackets.

TABLE 13
TOTAL DISSOLVED SOLIDS (mg/ℓ) OVER 4 YEARS. IRRIGATION FREQUENCY 90 mm EVERY THREE WEEKS, WATER TABLE AT 2 160 mm

	1975 (3)[1]		1976 (11)		1977 (17)		1978 (23)	
Depth (mm)	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift	Gamka	Stompdrift
240	297	699	181	576	182	591	182	591
480	1 234	1 419	320	845	304	868	309	886
720	1 726	1 821	2 221	2 701	2 564	3 446	2 939	4 203
960	1 513	1 513	3 270	3 687	3 772	4 614	4 387	5 729
1 200	968	968	1 435	1 486	1 436	1 536	1 502	1 662
1 440	655	655	690	691	662	662	661	661
1 680	646	646	652	652	647	648	648	648
1 920	686	686	689	689	688	688	688	688
2 160	753	753	754	754	754	754	754	754

[1] Number of irrigation applications in brackets.

Computer Time

The total simulation time for one soil profile employing all three F0RTRAN programs necessary to complete one run simulating four years, was approximately 30 min for the shallow and more than one hour for the deep water table on the Burroughs B7700 of the Department of Agricultural Technical Services.

Conclusions

1. Although the ultimate total salt loads are slightly higher employing the high frequency irrigation program, actual osmotic potentials reveal that this practice leads to distinctly lower root contact salt concentrations owing to generally higher water contents (Tables 8 and 9).

2. In terms of lower osmotic potentials, the practice of a heavy irrigation at the beginning of the season should bring dividends for the irrigation farmer on this particular soil, more so if the problem of salinity and low quality water does not apply.

3. All results indicate a detrimental salt distribution caused by a shallow water table, even at the relative "safe" depth of more than 2 m (compare Figures 7 and 10). Where salinity is not a factor, benefit could be derived from this condition in the form of a substantial water supply from the water table between irrigations.

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