IRRIGATION EFFICIENCY SEMINAR
ANC - ICID
SYDNEY - MAY 1979

CAUSES AND EFFECT OF DEEP PERCOLATION LOSSES IN THE MURRUMBIDGEE REGION

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Synopsis

Any irrigation system has deficiencies and the amount infiltrating into the soil at various locations usually varies. Some percolation beyond the root zone is desirable to control salinity levels but the process leads to ground water table build up in the absence of natural drainage, necessitating artificial drainage where problems of waterlogging and secondary salinity develop. The above process occurs in all modifications in the Murrumbidgee Irrigation Areas and adjacent districts. This paper describes the amounts of water used on both horticultural tree crops and rice fields and the amount that either percolates to the deep rising water table or is being removed from a water table at shallow depth.

Percolation of excessive quantities of water above the leaching requirement beyond the root zone affects irrigation efficiency in terms of proportion of water not used for transpiration by crops. It was found that whilst these amounts are moderate in the case of horticultural crops, that deep percolation is very significant with rice crops grown in areas with still deep, but rising water tables.

Introduction

Irrigation efficiency has different meanings depending on whether application of water on the land is viewed in terms of water that is lost, not used for transpiration by plants, or in terms of economic efficiency. In the latter instance the marginal cost of water supplied at a sliding scale of charges makes it worthwhile for a farmer to use it liberally if other costs can be reduced. An efficient irrigation system may be operated to cause waste of water by deliberate human decisions.

Examples of such waste are known to exist. For ease of control a quantity of water larger than required is being run through rice fields to be lost in surface drains. Where deep percolation occurs in rice fields there is no financial incentive for landholders to restrict rice growing to less permeable areas. In horticultural areas the farmer does not directly pay for the operation and maintenance of pumps installed to control problems of waterlogging caused by irrigation practices.

Before irrigation the water table was at about 20 - 25 metres from the surface. With irrigation the water table commenced to rise, slowly at first, then at an increased rate, dependent on irrigation intensity and stratigraphical factors, until a new equilibrium near the surface was attained. This position has now been reached in much of the land in the Murrumbidgee Irrigation Area, but not yet in the Coleambally Irrigation Area.

The desirability of subsoil drainage depends on the extent to which waterlogging and salinity symptoms develop. It varies according to complex hydrological, stratigraphical and topographical interactions. The value of production lost should influence the decision of whether subsoil drainage methods should be employed. Recent increases in knowledge about artificial subsoil drainage in New South Wales are discussed by van der Lelij (1977).

A typical stratigraphic profile in the region above the level of the original water table, comprises of about 70% fine textured deposits, 17% of intermediate texture and 13% of coarse texture. From this, and measured moisture levels, it can be derived that the volumetric moisture content should increase by 8% on average to achieve saturation. Therefore 1.6 metres of water is needed to saturate the profile and over 400,000 hectares this represents 6.4×10^6 ML, more than is stored in Blowering and Burrenjuck Dams together. All this water will be lost by the time water tables have risen in all of the Irrigation Areas and Districts.

These quantities have to be seen in perspective. Percolation is only one factor affecting water usage and if it is found that its magnitude compared with other factors, such as evaporative requirements and runoff, is reasonably low, for instance by international standards, then there may be less reason for concern. In addition, some deep percolation, in the order of 1 - 2 cm per year, is desirable to balance salt inputs through the irrigation water.

It is the aim of this paper to put the deep percolation factor in ~~such~~ perspective. ~~Data is presented on water consumption~~ In horticultural areas, ~~in which~~ water tables are mostly high and ~~where~~ percolation beyond the root zone would equal the quantity of subsoil drainage effluent, assuming nil groundwater inputs or outgoings. For rice land the situation with high water tables can be compared with that in which water tables are still rising. If all other factors are equal the implication would be that any difference is attributable to deep percolation.

Horticultural Crops

The most significant horticultural crops in the M.I.A. are citrus, grapes and, to a lesser extent, peaches. They are grown on soils of light to intermediate texture and the water table mostly has risen to within a short distance of the surface because of irrigation.

Water is delivered through Dethridge outlets or flow meters from the Water Resources Commission supply system. Each year the water consumption of these crops is assessed and compared with crop requirements calculated using the methods described by Fleming (1968). The results for the year 1977/78 are presented in Table 1.

Table 1. Calculated and recorded water consumption of citrus, grapes and peaches during 1977/78 in the M.I.A. (mm)

	Citrus	Grapes	Peaches
Number in Sample	34	13	6
Recorded Average Delivery	945	758	824
95% upper limit	1006	821	669
95% lower limit	874	695	979
Calculated requirement (Fleming)	940	891	916

Crop factors used were derived from Fleming (1968). The assumed average effectiveness of rainfall was taken as 80%, irrigation runoff as 10%, and deep percolation removed by tile drains 16%. Evaporation and rainfall data were collected at the C.S.I.R.O. Division of Irrigation Research. For citrus and peaches the recorded deliveries are in the range of prediction using Class A pan evaporation and rainfall, for vines the calculated requirement is in excess of the 95% confidence range of water deliveries.

The rainfall effectiveness and irrigation runoff coefficient have been set arbitrarily. Any significant amount of deep percolation or runoff of rainfall only occurs when it is heavy or moderate in amount, particularly shortly after irrigation. Falls are usually less than 25 mm, even during the summer and tend to replenish the soil moisture deficit before waste occurs. Irrigation runoff varies from insignificant on farms without surface drainage to significant on some other farms, with 10% being the estimated average.

The quantity of water discharged as subsoil drainage effluent has been measured on seven farms for four years by measurement of electricity consumption of calibrated tile drainage pumps. The variability of the factors involved is great and by no means easy to understand but the following result, shown in table 2, was found from work carried out by van der Lelij and Ellis (1974).

Table 2. Irrigation, Rainfall and Quantity Drained (in mm) for about 80 hectares served by seven independent tile drainage installations totalled for 1968-1971.

	Summer	Autumn	Winter	Spring
Rainfall	520	612	369	451
Irrigation	955	195	32	506
Total	1475	807	401	957
Subsoil Drainage	207	107	98	184
% Drained	14.0	13.3	24.4	19.2

The data, which cannot all be shown here but of which table 2 gives a summary, showed that the quantity of subsoil drainage depends on both rainfall and irrigation, but also evaporative conditions. During the winter a larger percentage of rainfall may be expected to be drained. In this table it was the winter of 1969 that boosted the average of four years to 24.4%.

The winter figures are dominated by rainfall, the summer figures by irrigation. During autumn rainfall dominates and during spring about equal rainfall and irrigation resulted in 19.2% subsoil drainage. Analysis of all figures, which were collected on a weekly basis, led to the conclusion that rainfall and irrigation contribute about the same proportion to tile drainage effluent, this being 16% on average.

In addition to the above conclusion, it can also be observed that higher amounts of drainage discharges occur during spring and summer when the irrigation component is most significant. Twice as much water is pumped from the drains during the summer, compared with the autumn and winter. So whilst tile drainage pumps are being provided by the Water Resources Commission to protect horticultural land against the hazards of waterlogging during sporadically occurring winters with high rainfall, these pumps are in fact being used to remove percolation resulting from irrigation practices.

The proportion of leaching being achieved, viz., 16%, is much higher than the leaching requirement, which with irrigation water quality at 60 ppm and a water application of 500 mm and subsoil salinity of 2500 ppm would be 10 - 20 mm/annum. Table 2 suggests that about ten times this amount is being drained. It has indeed been observed that subsoil salinity under tile drainage decreases with time after installation. The drainage criteria to protect land against waterlogging are more stringent than the criteria to protect land against salinity, resulting in overdrainage as far as the latter aspect is concerned.

Some doubt still exists with regard to the relative contributions of irrigation and rainfall to subsoil drainage but the 16% figure may be used as a guide. Comparison of tables 1 and 2 then results in the observation that calculated and actual deliveries are of this same order, which would lead to the conclusion that perhaps there is no excessive wastage by either irrigation runoff or deep percolation.

Whilst this conclusion appears valid some caution needs to be exercised. Dethridge wheels of horticultural farms under-register when operated at very low rates of delivery. To compensate for this,extra care was applied in selecting the farms in the sample of Table 1. Any bias which may exist would give a higher wastage figure. The opposite applied to Table 2. A higher actual delivery than shown would have resulted in lower percentages of irrigation and rainfall being wasted. Under such circumstances it is possible that the 16% figure for deep percolation is too high an estimate and that the 10% figure for farm runoff is too low, considering that the calculated requirements and actual delivery of Table 1 match reasonably close.

Other observations in the district would show that although the above may be valid for the average situation, many farmers may under-irrigate their crops. Moisture stress on many properties occurs at regular intervals, especially during prolonged dry conditions when no compensating adjustment is made to the irrigation schedules. The range of the 95% confidence limits of Table 1 gives an indication to what extent this may occur.

The apparent underwatering of wine grapes may have been prompted by the desire to improve grape juice quality.

Rice Farms

Rice growing in the subject areas is responsible for the consumption of 70 - 80% of the total water delivered to all farms. Water is required for evapotranspiration, germination flushings, and inundation over about 120 days. Inevitable losses, such as surface drainage and deep percolation, can be influenced to some extent by management, and also by confining rice to heavy clay soils of low permeability.

Evans (1971) describes a lysimeter experiment to correlate rice field evapotranspiration with class A pan evaporation. Talsma and van der Lelij (1976a) discuss results of water balance work on rice fields and error estimation of the factors involved. Lang, Ho and Evans (1974) discuss the same, including the effect of advective energy. During January and February rice field and class A pan evaporation are approximately the same, whilst the former is less during the crop development stage of November and December.

van der Lelij and Talsma (1977), in regard to infiltration rates into different soil types, found that self mulching soils are more permeable than the transitional red brown earths which possess a heavy clay B horizon. Talsma and van der Lelij (1976b) made a special study of infiltration into self mulching soils and found that it averaged 2 - 3 mm/day under rice growing after initial wetting.

Over recent years, with larger areas of rice being grown, it has been found that pressure levels in aquifers have risen at an increased rate. The highest rates of 3 - 4 metres/year are found in the more recently developed Kooba subdivision of the M.I.A., which is adjacent to areas with a longer irrigation history, in which water tables are now close to the surface. In the Coleambally Irrigation Area rises of 1 - 2 metres per year are not uncommon. Some of the infiltrated water is known to dissipate laterally beyond the irrigation area (Jones and van der Lelij (1978)). A steep gradient in the ground water levels exists in the mentioned Kooba subdivision, suggesting that some of the rise there is caused by lateral dissipation from areas in which water tables are now close to the surface. Considering this an average rate of rise of 1 - 2 metres/year under present conditions is believed to be realistic.

Water consumption for rice varies from District to District. Reasons may be differences in climatic conditions, variation in accuracy of Dethridge outlets, different flow rates through these outlets, relative accuracy of recording of deliveries on channel attendants cards and differences in deep percolation.

The deep percolation factor is maximal where water tables are still deep. It is minimal where water tables are close to the surface. In the Widgelli-Hanwood area the latter condition is found and in the Kooba area of the M.I.A., the Coleambally Irrigation Area and the southern part of the Benerembah Irrigation District the former condition. The factors other than percolation are believed to be about the same for all of these four Districts.

The choice of Districts in a comparison, as is attempted here, has to be made with care. In the Bilbul-Yenda area, for instance, farms consist of many portions, each with a separate Dethridge outlet and flow rates are less, affecting accuracy of recording. This District has been deliberately omitted from the Sample.

Deliveries to rice for 1977/78 are shown in Table 3, with other relevant statistics.

Table 3. Rice Water Consumption 1977/78 (mm) for various M.I.A. Areas and Districts.

Area	Number of Farms In Sample	Geometric Mean *1	95% Confidence Limits	Arithmatic mean*1
Widgelli-Hanwood	34	1549	1461-1642	1618
Kooba	36	2024	1915-2138	2054
Benerembah South	46	1929	1824-2040	1963
Coleambally	312			2160
Coleambally North only	156			2290
Coleambally South only	156			2020

*1 all values are derived from Dethridge outlet recordings.

The averages for Kooba, Benerembah South and Coleambally, where water tables are still deep, are comparable and in the order of 2000 mm. The result compares with an average of only about 1600 mm in the Widgelli-Hanwood District, where water tables are high. A difference of about 400 mm may be attributable to deep percolation loss.

A deep percolation loss of 400 mm represents about 20% of delivery. It is an average, a large variation between farms being observed. Some areas with soils of low permeability have very low percolation loss, in other areas the loss may be as high as 1600 mm, with total consumption 3200 mm.

There is possibly not enough incentive for farmers to restrict their rice to land of lesser permeability, especially in the Irrigation Districts. The sliding scale of charges, with the final deliveries about four and a half times cheaper than the first, ensures that a farm having a consumption of 3200 mm gets a water account only 27% higher than a farm having a consumption of 1600 mm.

There is some policing of rice growing, an attempt being made to restrict rice to soils of lesser permeability, with variable results.

For the more recently developed lands within the Coleambally Irrigation Area and the Kooba subdivision about 30% of the area is under rice, therefore the deep percolation from rice fields results in a 0.3 x 400 = 120 mm average accession to the water table. Accessions from other sources such as channels and other crops are believed to be small. With 8% being the required average increase in volumetric moisture content to achieve saturation, the 120 mm gives a water table rise of 1.5 metres. This calculation gives a result which is very close to the observation already discussed.

Deep percolation under rice fields in areas with water tables still rising is about twenty times higher than the leaching requirement, and it should therefore result in downward movement of salts to deeper levels. Unfortunately, the pattern of infiltration is so variable that doubt exists whether permanent downward leaching of salts can be realised. The process is likely to be much more effective in some places compared to others, with significant areas with salts remaining at high levels in the profile, when high equilibrium ground water conditions have been reached.

The difference between north and south Coleambally (Table 3), which was found to be significant at the 1% level, is believed to be caused by differences in soil characteristics, self mulching soils being common in the north but almost absent in the southern part. Similar differences could occur between other districts but they have not been analysed.

<u>References</u>

Evans, G.N. (1971) "Evaporation from rice at Griffith, N.S.W." Agric. Meteorol., 8:117-127.

Fleming, P.M. (1968) "Crop water requirements and Irrigation." In <u>Agricultural Meteorology</u> Proc. W.M.O. Seminar, Melb. 1966, pub. WMO and Comm. Bureau of Meteorology, Melb. 1968 in 2 vols., 2:591-618.

Jones, S.J. and van der Lelij, A. (1977) "Coleambally Irrigation Area, Groundwater Hydrology 1960-1976." Internal report W.R.C. Coleambally, N.S.W.

Lang, A.R.G., et al, (1974) "The influence of local advection on evapotranspiration from irrigated rice in a semi arid region." Agric. Meteorol., 13:5-13.

van der Lelij, A. and Ellis, R.L. (1974) "Effluent from tile drainage systems in the M.I.A. - Salinity Aspects." Proc. Agr. Eng. Conf. Sydney, N.S.W. Aug. 1974, 97-103; also Internal report W.R.C. Griffith, N.S.W. 1973.

van der Lelij, A. and Talsma, T. (1977) "Infiltration and water movement in Riverine Plain soils used for rice growing." In Proc. "The Hydrology of the Riverine Plain of S.E. Aust." Griffith, N.S.W. 1977. Available through Univ. bookshops.

van der Lelij, A. (1977) "Artificial subsoil drainage in N.S.W." In Proc. "The hydrogeology of the Riverine Plain of S.E. Aust." Griffith, N.S.W. 1977. Available through Univ. bookshops.

Talsma, T. and van der Lelij, A. (1976a) "Water balance estimates of evaporation from ponded rice fields in a semi arid region." Agric. Water manag., 1:89.

Talsma, T. and van der Lelij, A. (1976b) "Infiltration and water movement in an <u>in situ</u> swelling soil during prolonged ponding." Aust. J. of Soil Res., 14:377.