

**MANAGEMENT OF ENVIRONMENTAL
IMPACTS OF RICE GROWING IN
SOUTH EAST AUSTRALIA**

Conference Paper



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Management of environmental impacts of rice growing in south east Australia

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Summary

The ponding of rice creates a potential of down percolation, rising groundwater and salinisation. The degree of risk associated with accessions depends on groundwater discharge in the landscape and the degree by which these contribute to land salinisation. A sustainable balance needs to be struck between accessions and discharge, keeping in mind that salinisation of a small (say 10%) proportion of the landscape may be acceptable.

Percolation tests in rice soils for different crops have demonstrated that duplex heavy clay soils of the plain are the least permeable, but a proportion of other soils allow high rates of percolation, up to several metres of water over a season. These percolation rates reduce to about 10% of the initial values following the development of high watertables. High ground water levels now are a well established feature in large parts of the irrigation areas and districts.

The main objective of rice environmental management is control of land salinisation, and this is achieved by managing accessions. Two main strategies are used. Firstly, rice is being restricted to the least permeable part of the landscape. Secondly, the total area of rice is restricted.

Until now it has not been possible to routinely measure accessions in individual fields. In the absence of this direct method of managing rice land suitability three alternative management tools are being used, rice water consumption, land classification by soil texturing and the hydraulic loading principle.

Rice water consumption records provide an estimate of accessions but the accuracy achieved is outside the desirable limit of 0.5 ML/ha. Its main use has been to set targets for total rice water use. This target at present is 16 ML/ha, which implies a percolation component ranging from 0-4 ML/ha.

Soil texturing provides important information regarding the top 3-4 metres of soil and is the main tool on which rice land classification for deeper watertable areas is based. The method relies on the assumed correlation between the texture and thickness of superficial clays and permeability. This underlying assumption has proved to be reasonable for many parts of the Riverine Plain (eg the south), but not so for some soil groups, eg the self-mulching clays.

Rice water consumption and soil texturing for land classification have limited applicability in high watertable conditions where groundwater flow due to accessions is caused by aquifer transmissivity, hydraulic gradient as well as the soil permeability. Management of rice areas based on soil texture alone would lead to serious misinterpretation at many sites. Because of these limitations it was found to be necessary to control the proportion of land under rice. This is the 'hydraulic loading concept'.

The "hydraulic loading" concept restricts the areas of rice and hence the total volumes of accessions below the maximum that can be dissipated in the remainder of the landscape without the development of too high groundwater levels resulting in salting. The hydraulic loading concept also includes a sensible rotation of rice across the whole of the rice approved area to manage salts that may have come up with the rising groundwater and capillary rise.

A variety of best management practices exist which should be used to minimise accessions. Bay tests or other means may be used to find "hot spots" of localised high percolation. Puddling of soil could be employed to remedy such areas. Elevated lands should be excluded from rice since accessions from these areas will pressurise the aquifer of the average plain level. Low lying lands will tend to become salt affected in the long run unless groundwater pumping is employed.

1. Introduction

About 120,000 hectares of rice are being grown in the Riverine Plain of South East Australia, involving the use of some 2 million ML of irrigation water, which is between 50 and 75 % of water used. Because water is ponded on the land there is a potential of down percolation and rising groundwater levels. This in turn leads to an increased risk of salinisation in a semi environment where huge quantities of salts are locked up in the profile but may be mobilised in the rising groundwater.

The Department of Water Resources over several decades has made conscious efforts to minimise the risk by applying restrictions to rice growing to minimise accessions and the salinity risk. The main tool used was the elimination of more permeable soils for rice growing. Criteria were initially based on soil textural conditions mainly, but subsequently topographic conditions, aquifer conditions, groundwater levels and salinity were also considered. Gradually a policy for classification, monitoring and management developed and was implemented.

Over the last ten years the development of policy guidelines increasingly has involved the rice industry itself and other agencies such as NSW Agriculture and the CSIRO. At present the Department of Water Resources still has the overall responsibility for policy development and implementation, and the mechanism of consultation occurs through the Rice Environmental Policy Working Group. In the near future the focus will shift the responsibility for management and implementation will be transferred to privatised Irrigation Management Boards in each Region.

This paper reviews the environment for rice growing in South East Australia including the percolation and groundwater processes after which the objectives and the current principal means of environmental management are discussed.

2. The Environment for Rice Growing

The Riverine Plain of South East Australia comprises an area of some 10 million hectares, of which 1.5 million hectares are irrigated, but not all of this every year.

Most soils of the Riverine Plain have characteristics less favoured for a wide variety of irrigated crops, the permeability being low, bulk density high, sodicity causing dispersion, root penetrability being poor, and climatic conditions being harsh. As a result pastures and rice have thrived better than other crops. Whilst techniques exist to improve the soils and an about 20% proportion of the landscape is well suited for horticulture, vegetable and row crop production, rice and pastures are the most profitable for the majority of the landscape.

Despite this soil variability is high and more permeable clay soils (suitable for crops other than rice) may be located within the confines of a generally low permeable landscape. The delineation of occurrence of shallow sands which cause higher percolation is difficult. It is no surprise that accessions to groundwater have been high in the past.

The top 30-60 metres of sediments of the plain was deposited by streams over alternating dry and wetter climatic conditions. The surface expression of these prior stream is still visible, but the present river systems are independent of this and their floodplains actually are incised into the previously deposited sequence of materials. The result is that clay plains dominate but that at most locations sandy materials occur at some depth below the surface, creating potential aquifers for lateral groundwater flow and salt transport. Where sands are close to the surface the permeability of the clays may be higher and increased accessions from ponded rice fields should be expected.

The clay soils and subsoils tend to be sodic in nature, and this phenomena is more pronounced to the south and west. The better, more permeable self-mulching clay soils are situated side by side with the much less permeable duplex floodplain clay soils. The better clay soils may be found in the north east of the floodplain, the depressed areas and along the floodplain of the Murrumbidgee River.

The prior stream soils are often underlain by sandy deposits close to the surface. In the Berriquin District these soils have allowed high percolation from irrigated pastures and channel seepage. The levee soils associated with the prior stream may graduate from clay soils to loams at about 1-2.5 metres depth, in turn underlain by clay material. Such soils may allow small rates of accessions only. The levee soils to the north west of the plain are very sodic and in many situations the A-horizon has been swept away by wind erosion processes. In general soils become more saline to the west. The factors, salinity, lesser rainfall and sodicity combine and cause the western plains to be covered by saltbush vegetation only in its natural state.

The groundwater depth before irrigation was over 20 metres to the east and about 10 metres to the west. The pressure level of deeper and more permeable aquifers at 60-150 metres depth tends to be below the indicated level in the east and above this level in the west, thereby creating groundwater and salinity movement from east to west.

Percolation would move from one aquifer to the next deeper aquifer following preferential flow paths. The movement through the more shallow aquifers is limited by the gradients (which are small) and transmissivity, which ranges from less than 5 m²/day in thin aquifers to over 300 m²/day in prior stream aquifers. The median would be in the order of 20-50 m²/day.

In significant proportions of the Irrigation Areas and Districts the groundwater levels have now risen to within 2 metres from the surface. Soil salinity is increasing in an increasing area of land. The current estimate is that 12% of area in the MIA, 11% of Coleambally, and 8% of the Berriquin Area will have serious salting within 30 years. Another 10-15% will have salinity levels sufficient to reduce yield potential of many irrigated crops (van der Lely, 1993).

3. Percolation and Groundwater Flow

Percolation from rice is determined by the permeability of the surface horizons. Measurements of percolation for a variety of soil and stratigraphical conditions has resulted in values summarised at Table 1 (from van der Lely, 1988).

Table 1: Summary of percolation rates found from infiltration tests in Riverine Plain soil groups (mm/season)

Type of Soil	Median	10% decile	90% decile
Transitional Red Brown Earth (*)	50	25	120
Self Mulching Clays	300	120	1950
Prior Stream Soil	600	250	2000
Levee Soil	180	60	1050

(*) other duplex heavy clay soils in the plain would have similar values as found for Transitional Red Brown Earths.

It is found that the duplex heavy clay soils are the least permeable, percolation values being between 20-200 mm/season, median about 50 mm/season.

Other soils allow higher rates, varying between 30 and 3000 mm/season. Each of these other soils comprise a proportion where percolation would be considered excessive. For further discussion about the definition for "excessive", see section 5.

One of the problems to be dealt with is that Transitional Red Brown Earths and Self-mulching clays occur together in the landscape as a soil association. This feature is most prominent in the north eastern parts of the Riverine Plain, the Murrumbidgee and Coleambally Irrigation Areas.

Rice water consumption values of crops on all farms has been monitored for decades. Records show that where watertables are deep the rice water consumption may be in the order of 16-30 ML/ha in the northern part of the plain (average 18-20 ML/ha), whereas the values to the south and west have been lower, in the order of 12-20 ML/ha (median 14-17 ML/ha). Since the average evaporation demand is in the order of 12 ML/ha and the allowance for other factors only 1-3 ML/ha it is clear that with deep

watertable conditions considerable deep percolation could occur. For the Coleambally Irrigation Area during the 1970's the estimated percolation rates based on rice water consumption was 4 ML/ha (van der Lely, 1979).

In many parts of the irrigation area the pressure levels in shallow aquifers has risen to within 2 metres from the surface. This altered hydrology of the groundwater system has affected the rate of percolation. For example, if the restrictive clay layers are 5 metres thick the percolation rate would start decreasing when the pressure level in the aquifer rises to within 5 metres from the surface. Once the pressure level is at 1 metres the percolation rate has dropped by 80%. In high watertable conditions the pressure level under a rice field may be close to the land surface, the whole profile being saturated. It is quite probable that percolation rates reduce to less than 10% of the values initially encountered.

Rice water consumption records show that farms who previously recorded averages of 20 ML/season now use in the order of 13-16 ML/season. Since the evaporation demand is about 12 ML/ha (Humphries et al, 1994), these new values may include 0-4 ML/ha of percolation. Groundwater modelling has shown that the typical loss of percolation from rice fields in high watertable areas is about 1-1.5 ML/ha (van der Lely, 1981, Prathapar, in preparation).

Where rice is grown on elevated areas the percolation may not reduce to the same extent with the development of high watertable conditions. Higher gradients for downward movement will be maintained, resulting in relatively more accessions per hectare.

All percolated groundwater needs to be dissipated and or stored in the groundwater system. Dissipation under high watertable conditions occurs laterally to other fields, depressed areas and deeply incised drains where capillary rise and salting may occur.

Dissipation also occurs to the much deeper aquifer if there is a pressure gradient. This movement is usually small but not insignificant in terms of the groundwater salinity balance. In some areas such as Coleambally it may be in the order of 1 to 5 cm per year. For further information see van der Lely (1987) and Lawson (1992). Finally the dissipation of groundwater flow could be to groundwater pumps which remove the groundwater, thereby protecting the land from salinisation. Unfortunately this option is limited by the difficulties with disposal of salts.

The 1-1.5 ML/ha percolation from rice in high watertable areas does not appear to be a large amount but nevertheless it would represent a permanent salt transfer if the flow was to be one-directional. One directional flow occurs from east to west, from rice fields to depressions and from high parts in the landscape to the average landscape. The east west movement and the movement to depressed areas comprising about 10% of the landscape cannot be avoided, however the one-directional flow from elevated areas can be avoided by not growing rice in these locations.

Within the landscape of average elevation rotation of rice areas may overcome the impact of the groundwater transport. With some transport of groundwater salts to depressed areas and to the deeper aquifer systems it is quite possible that the net salt transport balance is near zero or even slightly positive, however this depends on local conditions. Groundwater pumping of small volumes would tip the balance and make the system sustainable for 80-90% of the landscape.

Calculation based on analytical and numerical models have shown that the total amount of accessions does not increase proportionally as the proportion of land under rice increases (van der Lely, 1981, Prathapar et al, in preparation). A similar volume of accessions needs to be dissipated in each case, however because with increasing rice the area of non rice area decreases the dissipation is over a smaller area. The capillary rise rate increases and the watertable increase in height. It was found that where more than about 25% of the landscape is used for rice growing the watertable levels in a significant part of the landscape are within 0.75-1.25 metres from the surface. It was concluded that further increases of rice would jeopardise the productive potential of the other land and increase the salinity risk to unacceptable levels.

4. Objectives

The main objective of any land and water management plan for agriculture is that of economic, environmental and intergenerational sustainability. The farms involved in irrigation industry have to be economically viable. It is also essential that other groups of people, usually located down "stream" or down "groundwater flow", are not being affected in a deleterious way. If they are, then the consequences have to be able to be mitigated, or the benefits of the causal factors have to outweigh by far the economic, environmental and social disbenefits. Finally there has to be inter-generational equity, and the next generation should be handed a system in the same condition or better than was received by the present generation.

Because many factors in the environment are occurring very slowly and insidiously the environmental consequences often are difficult to prove scientifically are not realised by the general population until they are well established, hence it is difficult to achieve for instance the inter-generational objective. This is one of the reasons why the "Precautionary Principle" in environmental law making has come to the fore in recent times. This principle states that where the consequences of an activity are potentially serious and irreversible, and scientific knowledge is inadequate to assess the magnitude of the consequence, then regulatory inaction cannot be justified.

Rice growing is but one of many crops irrigated on the Riverine Plain. Rice however takes a special position, because of the large volumes of water involved, and the fact that water is ponded on the land surface for up to 120 days, thereby creating the maximum possible gradients for downward percolation to occur. Rice environmental management does not preclude improved management of other crops but focuses on the main contributor of groundwater accessions.

The primary effect of rice growing is groundwater accessions. The main concern why rice environmental management is required relates to soil salinisation and a high proportion of the landscape potentially becoming unproductive. Accessions eventually are to be balanced by the discharge phenomena which cause soil (and stream) salinity. Rising groundwater levels are the first step towards the final equilibrium balance and are indicative of the hazard that exists.

If the salinisation process is driven by groundwater levels, which are caused by accessions, then clearly the control of accessions to within limits of sustainable discharge values is the primary objective for any rice environmental management policy to achieve the all encompassing irrigation sustainability objective.

Unfortunately, direct measurement of percolation and soil permeability using infiltrometers in every field is not practicable and also of insufficient accuracy. Alternative, practical and measurable criteria have to be used. These include the monitoring of rice water consumption, soil texture, and areas of rice, and possibly some other factors.

The conclusion is that it is only by indirect criteria that the main objectives of sustainability can be achieved. In the Riverine Plain the development of these criteria took several decades (eg see Humphries, 1994).

5. Managing Rice Environmental Impacts

Three main tools exist for rice environmental impact management, rice water consumption, soil texturing and the hydraulic loading principle.

Records of rice water consumption in areas where percolation must be small show a standard deviation of about 1.5 ML/ha. If the average loss to groundwater in high watertable areas is about 1-1.5 ML/ha it follows that the desirable accuracy for the assessment of percolation would be about 0.5 ML/ha. Reliance on rice water consumption to estimate percolation therefore may be suitable where deep percolation rates are high, but is unsuitable as a management tool in high watertable conditions.

A target rice water consumption policy was introduced in 1985, with targets gradually being lowered to 16 ML/ha over 6 years. This policy has put pressure on landholders who were previously using excessive amounts. The targets were set such that most landholders could meet them. The target could be lowered because the lowering coincided with the increases in high watertable conditions in Coleambally and the MIA. The reduction in percolation therefore was not brought about by improved management.

Other, additional methods of assessing accessions are needed to manage the balance between accessions and discharge.

A second and very important tool to assess rice land suitability has been soil texturing of the profiles to three metres depth. The objective is to allow rice growing only on soils which are known to have a low permeability. A set of criteria was developed on basis of infiltration tests for a range of soils and deep watertable conditions.

The first criteria was to identify whether a soil profile of a site is a duplex soil with a heavy clay B-horizon from 0.1 to 0.5 metres. This layer is usually sodic, dispersive and has the lowest permeability. If this layer is present 2.0 metres of clay in the top 3 metres is sufficient to be confident that percolation will be low. If this heavy clay B-horizon is not present then the restriction for downward flow is deeper in the profile and dependent on compaction and dispersion of the deeper layers. Self-mulching soils are of this category. With such conditions the criterion has been that 3 metres of clay are needed in the top 3.5 metres. Finally, if the B-horizon is distinct, but only a medium clay 3 metres of clay are needed unless the deeper profile is a clay, in which case 2-2.5 metres may be considered sufficient to be confident.

These criteria were applied and resulted in rice area maps for each farm showing the rice approved area, which delineates where land can or can not be used for rice growing. Some land was classified in an intermediate category, for which a rotation of once every four years applied.

Reliance on soil texture to assess accession potential depends on the consistency of the correlation between texture and permeability. This works reasonably well in the southern parts of the Riverine Plain, but in the north a problem occurred with self mulching clays, as may be seen from Table 1. Many of the self-mulching soil sites allow high percolation and consequently should be classified as unsuitable for rice.

It was also found however that in high watertable conditions the use of soil texture classification is also insufficient as a sole criterion. The risk is land salinisation which depends on capillary rise, which depends on groundwater levels, which in turn depends on groundwater flow to the site. Groundwater flow depends on more factors than soil permeability alone. The aquifer transmissivity and hydraulic gradient also need to be considered (van der Lely, 1988). Management of rice areas based on soil texture alone would lead to serious misinterpretation of some sites, particularly those in depressed areas (where gradients are small to negative), areas underlain by large aquifers (where more care is needed), and land that has become salinised (and where a leaching regime may be beneficial).

A decision flow chart for rice land suitability was developed for practicing field officers. Assessed values for soil permeability, topographic factors, groundwater and soil salinity and aquifer transmissivity are used in the chart to make decisions regarding land suitability at specific sites (van der Lely, 1988).

As discussed the main objective for rice environmental management in high watertable areas is to find a sustainable balance between accessions and discharge. Because of land classification rice is restricted to the less permeable soils of the plain but within these areas the percolation values can not be assessed accurately from rice water consumption data. In these circumstances the only remaining tool to manage the total volumes of accessions from rice is by managing the area of rice, or rather, the proportion of rice approved land that is grown to rice each year. This proportion reflects the "hydraulic loading" principle.

Groundwater modelling has been carried out which suggests that rice should not be more than about 20-23% of the total landscape (Prathapar, 1993), which is about the same as 30% of the smaller area of land classified and approved for rice growing (van der Lely, 1981).

Currently the three management tools are used in conjunction. Rice water consumption is used to identify farms where reclassification of the rice approved land may be needed. Soil texturing is the main tool to identify whether land should be reclassified, or whether puddling or another technique should be recommended to reduce accessions. The "hydraulic principle" tool is adopted as an overall management strategy to ensure that the impacts from rice growing on the rice approved land is not resulting in too high volumes of accessions, to the extent that the irrigation areas become unsustainable.

Outside the areas and districts a large expansion of rice growing has occurred since 1988, partially caused by the collapse of the wool industry. For these farms the rice water consumption tool has not been useful because of lack of accurate data. The soil textural tool has been effective, because watertables in most of these lands are still deep (but rising). The rice areas on these farms have been restricted to 100 hectares for each 972 ML licence, or 25% of the assessed farm area suitable for rice, whichever is the smallest.

6. Constraints for Implementation.

The set of three tools for rice environmental management tools just described appears to be functioning reasonably well and has been endorsed by the rice industry since 1989. Where farmers were still growing more rice than the hydraulic loading limit compromise formulas were found for the interim. The main process has been to measure and police rice area and to make sure land classified as unsuitable was not used.

Conflicts arise frequently between the administering agency and landholders who may be subjected to a change of classification. Scientific tests to determine the outcome are often confusing. Landholders may demand the benefit of the doubt in cases where precaution should be applied.

It would be justified to vary the percentage of the land under the hydraulic loading principle. Such variation would depend on variations in aquifer transmissivity and leakage to the deep aquifer. Application of such variations has not been adopted so far.

The "hydraulic loading" principle aims at managing land salinity but is not a watertable control option per se. Land salinisation consequently is not expected to become a major problem, but watertable levels may be high enough to make the growing of higher value crops such as grape vines and horticulture less viable. Such crops require deeper watertable conditions. If tile drainage was installed in areas with predominantly rice the groundwater flow to the site and the additional sub-surface drainage disposal difficulties would make the new enterprise much less viable from economic and environmental angles.

Soil texturing criteria are not applied consistently between the various regions. Various factors have caused this, for instance the differences in water availability between the regions which made hydraulic loading less relevant and differences in soil texturing techniques. The Murray Region has decided not to apply the hydraulic loading principle until 1994 and relies on rice water consumption and soil texturing as the sole management tools. This is now likely to be changed.

Ideally paddock water use is determined to an accuracy of 0.5 ML/ha and all classifications based on observed data of assessed accession rates. Such approach would provide, over time, a rice accession potential map which may be used for management purposes. Any land with accessions above a limit of say 1.5 ML/ha over a season would need to be classified as unsuitable. It is believed that the adoption of this management tool is a long way off, because the measurement techniques to achieve results at the required accuracy are not yet available.

The present set of management tools are not perfect, but they are believed to provide scope to manage the landscape to a sufficient standard, so that the future sustainability of irrigated agriculture including rice can be anticipated with some confidence.

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CHECK LIST FOR RICE LAND SUITABILITY

Q1 ARE PRESSURE LEVELS IN THE AREA HIGH OR LOW ?

IF LOW (deeper than 2.5m) go to Q2
IF HIGH (within 2.5m) go to Q3

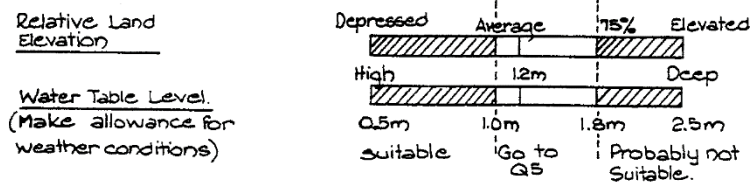
Q2 IS THERE AT LEAST 2 METRES OF GOOD MC + HC IN TOP 3 METRES ?

YES —→ Suitable
NO —→ Rotation (1.2 - 2.0 m) or Unsuitable.

**Q3 PRESSURE LEVELS ARE WITHIN 2.5 METRES
IS THERE AT LEAST 2.0 METRES OF GOOD HC + MC IN TOP 3 METRES ?**

YES —→ Suitable
NO —→ Go to Q4

Q4 LOOK AT BAR CHARTS AND DETERMINE POSITIONS IN THIS CASE



Q5 GROUNDWATER SALINITY IN 3 METRE HOLES

HIGH : Above 5000 - 10000 —→ There is a case to approve rice growing, this year at least.

LOW : Go to Q6

Q6 TOPSOIL SALINITY LEVELS (EM 38 Survey)

HIGH : > 4 mS/cm = EC_{ex}, there may be a case to approve this year only.
LOW : Go to Q7

Q7 LATERAL GROUNDWATER MOVEMENT THROUGH AQUIFER TO ADJACENT LAND

a) Small Aquifer : Couple of metres of loam only —→ Negotiate rotation
b) Medium to large aquifer : Make an assessment using the formula:

$S_o = \frac{1}{2} H \sqrt{\frac{T}{C}}$ with T = transmissivity (m^2/day)
 C = vertical flow resistance in clay (m)
 H = depth to watertable (m)
 S_o = flow under rice field boundary ($m^3/m/day$)

Use table below to calculate T and C

Gravel	$K = 50 - 100$	m^2/day	$T = t \times K$
CS	$K = 25$	"	
FS	$K = 2.5$	"	
FSL	$K = 0.5$	"	
LC	$K = 0.1$	m/day	$C = t/K$
MC	$K = 0.01$	"	
HC	$K = 0.001$	"	

t = Thickness of layer

Example Profile:

0-0.5 DRB HC $0.5/0.001 = 500$
0.5-1.5 RB MC $1.0/0.01 = 100$
1.5-2.5 LB LC $1.0/0.1 = 10$
2.5-3.5 yB FSC
3.5-5.5 L FS $2 \times 2.5 = 5$
5.5-8.5 L CS $3 \times 25 = 75$
8.5-9.0 Gravel $0.5 \times 50 = 25$
WT = 1.0 metre deep.

$C_1 = C_2 = 610 m^2/day$
 $T = 105 m^2/day$

CRITERIUM : $S_o < 0.10 m^3/day$ OK For RICE
 $S_o 0.10 - 0.20 m^3/day$ ROTATION
 $S_o > 0.20 m^3/day$ REFUSE

Therefore $S_o = \frac{1}{2} \times \sqrt{105/610} = 0.20$

FIGURE 5

