THE ECONOMICS OF MANAGING DRYLAND SALINITY - A MODELLING APPROACH FOR THE LIVERPOOL PLAINS, N.S.W.

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Paper presented at the 38th Annual Conference of the Australian Agricultural Economics Society, Wellington, New Zealand, 8-11 February 1994

1 INTRODUCTION

Salinity is a natural component of Australian landscapes. Recently, however, salinisation has been on the increase in productive parts of the country. While first reports on secondary soil salinisation date back to the 1920s (Wood 1924), salinity was publicly recognised as a serious problem in the early 1980s. The estimated area of land affected by dryland salinity has risen from 426 000 hectares in 1982 to 1.2 million hectares in 1993 (Robertson 1993). For the Murray Darling Basin, the most productive region in Australia, there are 180 000 hectares in the early stages of salinity and more than one million hectares at risk (Powell 1993).

Dryland salinity is a complex land degradation problem. Soil salinisation involves time lags and spatial effects thus creating externalities in the current property rights framework, while the cause is of a non-point source pollution character. There are a range of management options available which address either the symptoms of salinisation or its causes. However, significant changes in current regional land-use practises towards increased ecological sustainability will be adopted only if the financial viability of farming can be expected to benefit.

This paper presents a mathematical programming model which has been developed to investigate the economics of salinity management options in the Liverpool Plains in N.S.W.. For a model farm located in the salinisation zone in the floodplains of the catchment, best management options are examined under a range of potential scenarios.

2 CAUSES, EXTEND AND MANAGEMENT OF DRYLAND SALINITY

2.1 The bio-physical causes of soil salinisation

While primary salinisation of soils occurs naturally, ie. without human impact, secondary soil salinisation is man-made and is likely to occur inter alia where there is a risk of salt accumulation in top soils due to a rise in the levels of saline groundwater. Rise of water tables can occur in combination with irrigation, where artificial water imports into a region govern its hydrological balance. Salinity can also be caused through changes in land use which involve the replacement of native vegetation with less water consumptive forms of vegetation which, again, results in a change of regional water balances towards increased recharge.

The bio-physical processes involved in salinisation are well understood, however it is difficult to quantify the complex interactions between a range of environmental conditions such as land use, landscape hydrology, geomorphology, historic salt loads, climatic and soil factors that determine the degree of risk of soil salinisation (Szabolcs 1989).

2.2 Behavioural explanations of soil salinisation

Three behavioural explanations why human activities cause any form of soil degradation have been generally accepted. First, even though the general processes creating salinisation are well understood, there has been and still is a lack of knowledge concerning the complex bio-physical relationships with respect to specific locations and catchments. Knowledge about the costs and the effectiveness of possible remedial measures is sketchy and hence action is inherently risky (Quiggin 1987). This insecurity preserves salinity provoking land use practices, and hampers salinity management once the problem is recognised.

Second, due to the prevailing property rights structures, there are externalities involved in the salinisation problem. Long time-lags create 'intertemporal externalities' where an agent will not suffer the consequences of his own action due to delays in the system's reaction. For present land management decisions, future costs of the available options are not, or insufficiently taken into account and hence over-exploitation of the hydrological system's natural resilience occurs. 'Spatial externalities', ie. the fact that the agents causing a problem and those suffering it are different parties, enhance socially non-optimal land use. The single farmer does not budget for the off-farm costs that he/she generates. These social costs can be internalised once an economic or legal feed-back is established that addresses the described market failure associated with the no-cost exploitation of common properties. Quiggin (1988) applied the common property approach for a description of institutional arrangement and as an analytic framework to dryland salinity.

Third, farmers use discount rates in decision making. The rate they apply depends on their preferences for present and future income. Because most practices resulting in land degradation are likely to increase present income at the expense of future income, the higher the discount rate used by the decision maker, the more rapid will be the rate of land degradation (Quiggin 1987).

2.3 Salinisation in the Liverpool Plains

The Liverpool Plains lie in the north western slopes of NSW and form part of the Namoi catchment within the Murray Darling Basin. While the surrounding sandstone and basalt ridges are pure grazing country, there is mixed farming on the red-brown earths on the slopes and intensive cropping is prevalent on the floodways and floodplains of the catchment with their highly productive black earths. Current estimates suggest that 50 000 hectares of the 750 000 hectare basin will go out of production in this decade due to secondary soil salting unless vigorous preventative action is taken. (Schroder *et al.* 1991).

European settlement took place shortly after the region was explored by Oxley in 1818. With the European settlement came extensive clearing of native bush for grazing purposes. The Plains Grass (Stipa aristiglumis) dominated pastures on the alluvial black earths in the flood plains were initially grazed but with the availability of increasingly more machinery in the 1960s the black vertisols were surrendered to extensive cropping (Sim and Urwin 1984). Paddock sequences in the area are characterised by a long-fallow-based wheat - sorghum rotation.

In comparison to the native vegetation, the new agricultural land management systems have a higher infiltration rate of rainfall, with higher recharge causing regional groundwater levels to rise and inducing soil salinisation in the highly fertile black soils floodplains of the catchment.

Of particular interest in the region has been the Goran Basin, an almost secluded sub-catchment in the south-west of the Liverpool Plains, which displays water table rise and soil salinisation distinctively (Greiner 1993). Lake Goran, a once ephemeral lake has become a permanent feature in the catchment and its water is increasingly saline (Abbs 1993, personal comments).

As is the case in many catchments (McFarlane *et al.* 1989), there is no such thing as a clear distinction between recharge and discharge zones in the Liverpool Plains, and hence between responsible agents and salinity sufferers. Further complications in the quantification of relationships arise in catchments, where there are geological structures which act as groundwater carriers which do not coincide with topographic catchments (Lewis 1991). There is evidence for the Liverpool Plains, that such structures exist that transport water to the discharge area from adjacent, or even distant topographical catchments (Broughton 1993, personal comments).

With respect to the social costs imposed on the local communities by infrastructure damage from salinisation, it has to emphasised, that they have hitherto been nourished on the wealth that regional agriculture has created through multiplier effects. Given this range of aspects, a black-and-white-approach cannot do the analysis of the salinisation problem justice.

2.4 Recommended action for salinity management

As Nulsen (1993) makes clear, there is no single, practical, universally applicable method of managing the water balance of catchments prone to salinisation, ie., there is no 'panacea'. Generally, the problem can be addressed by reducing recharge and increasing discharge, to reduce the quantity of water stored in the saturated zone of a catchment.

Amongst the agronomic measures available to landholders, choice of plant species is of key importance. Lucerne has been propagated as an economically attractive crop with high water use due to its longer growing period than annual crops which prevents recharge.

Given the positive relationship between plant biomass production and water use, recharge is reduced in current land use systems by growing crops and pastures at their potential production levels (Nulsen 1993).

While agronomic measures may provide a means of recharge reduction, and despite the fact that there are examples where lucerne has successfully been used (in the Northern Great Plains of the United States) to reclaim saline seeps (Miller *et al.* 1981), trees are the only reliable option for reversing water table rises. Nulsen (1993) quotes examples where the ground water depth was reported to fall between 0.5 and 1.2 metres per year under newly established tree stands. Because of their high water use trees can have significant impact when applied to a relative small area in a catchment. Hence their environmental value when strategically planted might be high even if there is no or little commercial value (Williams *et al.* 1993).

While trees can be seen as a biological means of discharge enhancement, groundwater pumping provides an engineering option that is dealing with the symptoms of the problem rather than its causes (Quiggin 1991), creating new problems such as disposal of the saline effluent. George and McFarlane (1993) expect that the high cost of establishing and maintaining most systems will prevent widespread adoption. However, they see scope and justification for engineering measures when they can provide immediate relief eg. for townships from raising water tables.

It is widely recognised that only through joint action involving the whole farming community and other stakeholders can the existing and emerging challenge of dryland salinity be confronted (Dryland Salinity Management Working Group 1992). The foundation of the Liverpool Plains Land Management Committee in 1992 that co-ordinates 13 landcare groups, is a clear indication of the awareness of land holders of the importance of sustainable land management and their willingness to undertake combined action. A recent survey of land managers in the area also emphasises their progressive conservationist attitudes (Flavell 1991).

3 ANALYSING THE ECONOMICS OF SALINITY MANAGEMENT

3.1 General considerations

As has been outlined earlier, there is a lack of information concerning the financial long-term implications of adopting potential salinity management options. This accounts for the reluctance of farmers to drastically change their current land use practises according to the recommendations that they are given. This is particularly true in times when there is little financial scope for investments and action due to harsh economic conditions as are presently predominant (Gremer 1993).

There are two kinds of quantitative approaches available when different futures are to be examined, which are simulation and programming models (Heady and Vocke 1992). Both methods can be of an inventory and descriptive character or they can be designed to have predictive value.

A range of quantitative catchment studies into salinity management have been undertaken which provide recommendations as how to change land management in the catchments and mitigate salinisation.

Simulation models like SOILEC have been applied in a number of case studies. For the Avon-Richardson catchment, Oram *et al.* (1992) calculated that its dryland salinity problem can be "controlled" by introducing one opportunity crop into the currently prevalent rotations at least every four years. This strategy also improves farm incomes. For the Dookie Hills, Oram (1993) suggests a combination of perennial pasture on the skeletal soils and lucerne on the clay loam soils to reduce recharge and improve farm profits. Oram's calculations show for the Goran Basin that opportunity cropping would reduce recharge in combination with a beneficial income effect, while lucerne would be more effective in recharge control but would come at a higher cost to landholders. However, once off-farm costs created by salinisation are incorporated into the equation, a grain crop-pasture rotation is assessed most favourable.

In case of the Kyeamba Valley, Wilson (1993) has applied the same methodology and suggests, that farmers may substantially reduce groundwater recharge and increase their gross margin income by including perennial pastures in their rotation mix.

The question that has to be asked concerning these results is, why gross margin maximising activities have not been universally adopted by farmers? The answer lies partially in the operational ease of current practices in comparison to the more management demanding alternatives which have been recommended. Other explanations that farmers in fact budget on after-tax income rather than on annual gross margin figures and consider a longer time horizon. Also, some of the recommendations involve investments, which the individual farm financial situation might not permit or which cannot generate the expected long-term benefits.

On a single-farm basis, a comprehensive financial approach has been developed by the Western Australia Department of Agriculture (Kubiki 1993). Within a specific farming framework, it places emphasis on the social and economic objectives of the farm household and accordingly develops a long-term whole-farm plan.

3.2 Rationale for a poly-period mathematical programming approach

In order to economically evaluate the costs and benefits of salinity management options available to landholders in the Liverpool Plains, a mathematical model is being developed. It captures, in abstract form, the essential characteristics of the salinisation phenomenon in its socio-economic and catchment context (Mesterton Gibbson 1989).

A normative approach is chosen in contrast to the positive simulation approaches mentioned above, so an objective function can be established which represents the behavioural framework of farming. The classic economic approach of profit maximisation has been criticised frequently in its limitation to explain human motivation for action. Nevertheless, objective functions of various forms provide an excellent means of incorporation a behavioural component into a quantitative analysis. And programming models provide a means of investigating, what "ought" to be given the particular decision framework. How close the analysis comes to reality is inter alia a question of choosing and formulating the adequate objective function and including reasonable constraints to characterise the decision framework.

Programming models are particularly suited when there are no time series available upon which econometric or statistical models can be based. Planning often relies on intelligence and scarce data as is the case when investigating a phenomenon, like salinisation, that is yet to happen (Heady and Vieke 1992).

Within the range of mathematical programming techniques, linear programming (LP) is a sophisticated analytical and planning tool used in the economics discipline. In agriculture, it has been extensively applied to farm management problems, for optimising the allocation of limited resources into competing enterprises. Equally important is the application of LPs for regional analyses to indicate optimal spatial allocation of agricultural production (eg. Meister and Heady 1992).

The rationale and aims of the Model of the Farm Economics of Dryland Salinity (MOFEDS) programming model have been discussed in Greiner (1993) with respect to the role the model results may play in managing dryland salinisation in the Liverpool Plains. While the whole-catchment model framework is outlined in the same article, this paper wants to present one model farm which is located in the salinisation area of the catchment and investigate its salinity management options under different hydrological and land management scenarios.

4 MODEL OF THE FARM ECONOMICS OF DRYLAND SALINISATION (MOFEDS)

4.1 Programming model of a single farm affected by salinisation

The LP model forms a simultaneous equation system of restraint equations and an objective function to be optimised. The objective function is to maximise *I* where:

$$\text{Max} \sum_{t=1}^{T} I = \sum_{t=1}^{T} \left((P - C)Q \;\; - CA \;\; - E \;\; \right)(1 + r)^{-t} \qquad t = 0..T \qquad (1)$$

so that

$$A(t) \geq \sum_{s=1}^{k} \sum_{m=1}^{n} A_{sm} \qquad t = 0..T \qquad (2)$$

$$A_s(t) = f(GWT_{t-1}) \qquad t = 0..T \qquad (3)$$

$$R(t) = RF - \sum_{m=1}^{n} ET_m \qquad t = 0..T \qquad (4)$$

$$GWT(t) = GWT_{t-1} + R_t + L_t \qquad t = 1..T \qquad (5)$$

$$Q(t) = \sum_{s=1}^{k} \sum_{m=1}^{n} A_{sm} * Y_{sm} \qquad t = 0..T \qquad (6)$$

The objective function (equation 1) maximises the total available income after tax *(I)* generated by the model farm over a period *(t)* of *T* years. It sums up the farm's annual revenue from the sale of plant and livestock produce *(Q)* at a price *P* less the variable costs of production *(C)*, capital costs *(CA)*, and tax paid and financial obligation *(E)*. A discount rate *(r)* is applied to future incomes.

The major constraint (equation 2) in every farm management model applies to the farm size *(A)*. The area is split up into *k* salinisation stages *(s)* that may be dedicated to *n* different land management options *(m)*. The salinisation stages in year *t* are determined by the groundwater level at the end of the previous year *(GWT_{t-1})* (equation 3). The model distinguishes three salinisation stages for black soil. Stage 1 is unaffected by salinity and hence fully productive. Stage 2 represents reversible salinisation implications mainly from water logging which result in a reduced choice of potential crops and reduced yields. Stage 3 applies to irreversibly salted land which is suitable for saltland agronomy only.

Equation (4) calculates the recharge *(R)* occurring under the production area through the randomly determined annual rainfall *(RF)* and the evapotranspiration *(ET)* incurred by the various land use options. The groundwater level (equation 5) depends upon the groundwater level at the end of the previous year, the recharge caused *(R)* and lateral water movement balance or "upward leakage" applicable to the location *(L)*.

The feedback from increasing salinisation onto production and productivity is formulated in equations (2) and (6). Salinisation does not only determine different soil categories with respect to their production potential but also controls the land use options available on the soil categories and the yields from these options. If applied in a catchment context, equation (5) links the model farms together which represent the range of land management units in the Liverpool Plains (Greiner and Parton, 1993).

Resource constraints dealing with available capital, which is of major importance to the analysis, apply but have not been incorporated into the above equation listing.

The optimisation period *T* is ten years. This is considered a reasonable decision time frame when soil degradation problems are involved. It can be expected that farmers are willing to forego some short term profit from taking salt action if it can be shown that this investment yields economic and ecological benefits in the decision period.

4.2 Module structure

Salinity modelling requires that a series of requirements and conditions are met which are outlined in Greiner and Parton (1993). Some of them have already been addressed in the presentation of the equation framework, eg. the requirement that a loop be established from land use to salinisation and back to soil productivity and future land management options.

Because the system modelled is highly complex, the model consists of a series of modules which disaggregate the complex agronomy-hydrology-salinisation-economics relationship in a number of modules that deal with different aspects separately. They include:

- the agronomic features of "conventionally" farming different soil types,
- the characteristics of saltland agronomy,
- the implications of seasonal weather conditions and the dynamics of water table movement and its consequences for salinisation,
- sale of products and purchase of input factors needed in the production process,
- the whole-farm long-term financial system involving taxation, existing and new liabilities and on-farm as well as off-farm investments.

The modules are linked through a network of activities and/or constraints. Each module consists of a data section and a separate spreadsheet programming matrix. The model is solved by eXtended Application (XA), a programming software based on the simplex algorithm.

4.3 Discrete Stochastic Programming

Recharge is not a continuous phenomenon but rather of sporadic nature. Recharge events occur after high-intensity storms and in high-rainfall seasons. Climatic variability therefore explains the occurrence of recharge as do land use and soil type (Thorburn et al. 1991). A discrete stochastic programming (DSP) approach is taken to incorporate a range of seasonal rainfall figures into the model.

Three season types are defined for both summer and winter seasons with direct impact on recharge from the range of vegetation covers and crop yields. The season definitions are based on the seasonal rainfall observed in the region over the past 100 years. The driest 25 % of years form the "dry-season" option, the 25 % years recording the highest seasonal rainfall are summarised in the "wet-season" and the remaining 50 % form the "average-season".

The DSP approach captures the high rainfall variability in the region which is characterised by a coefficient of variation of 0.28. It provides a basis for investigating the impact of weather scenarios on the salinisation process and the efficiency and economics of management options (Greiner and Parton 1993) and is not primarily designed to assist with modelling an expertise factor in farm decision making (Kingwell *et al.* 1991).

4.4 Seasonal Recharge Figures

For the purpose of estimating seasonal rather than average annual recharge under different land management systems, the comprehensive soil-plant simulation model PERFECT, which simulates "Productivity, Erosion, Runoff Functions to Evaluate Conservation Techniques" (Littleboy *et al.* 1989) is adjusted to this requirement and applied. The climatic database of PERFECT combines the daily rainfall over the past 100 years with the soil conditions of the Liverpool Plains, and hence it is able to estimate recharge as a function of seasonal rainfall for specific land uses.

For the black earths in the Liverpool Plains, functional relationships between the amount of seasonal rainfall and crop yields could be established. In the case of recharge, however, the correlation coefficients were too low (R2 between 0.2 and 0.3) to justify a regression. This indicates that the amount of rainfall per season is not the predominant variable to explain the variation in recharge to groundwater under soils with high moisture storing capacity. Hence, a non-parametric approach was adopted, where the simulated recharge of the 25 % wettest, 25 % driest and the average seasonal rainfall years were averaged.

For red-brown earths the correlation between rainfall and yields as well as rainfall and recharge were sufficiently significant to formulate regressions (Greiner 1994).

4.5 Non-Cropping Land Use Options

The range of land uses which PERFECT covers for yield and recharge estimation is restricted to the most important winter and summer crops. Besides, the soil water model can be applied to pasture options and lucerne growing to calculate recharge under perennial vegetation cover. For a wide range of land uses including various degrees of tree cover and different saltland agronomy option, the recharge figures had to be estimated. The only reliable data base available that covers a comprehensive range of vegetation covers was established by Greenwood (1988). In order to transfer his findings in Western Australia onto a rather different location like the Liverpool Plains, the PERFECT recharge estimates were used for ranking the crops and other land uses and thereby estimating recharge/discharge values. Admittedly, this is a rough procedure - considering the absence of more reliable data sources, it is regarded as appropriate approach for estimating model coefficients.

5 SELECTED PRELIMINARY RESULTS

5.1 Introductory notes

MOFEDS is still being developed and currently undergoes testing and evaluation of existing parts, revisions and further development. The preliminary results which are presented below are based on an optimisation period of three years which is applied to test the correct temporal flows within the model concerning both water table and salinisation related processes as well as farm financial flows. The model farm which is investigated in this testing phase is located in the salinisation zone of the Liverpool Plains. For ease of result interpretation, the area is assumed to be 1000 hectares of black soil.

Some of the technical coefficients are of preliminary character, namely the salinisation rates for both reversible and irreversible salinisation once critical water levels are exceeded. Potential land use options are restricted to traditional crops with the first optimisation year set at the wheat-sorghum-longfallow-rotation. In the following years the paddock rotations can change to short-fallow systems which currently exclude legumes for opportunity cropping. On reversibly salinised, ie. waterlogged area, the only cropping option is barley. Saltland agronomy options apply to irreversibly salted area or the salinised land can be left unused. Sensitivity testing is applied for the initial water table which describes the risk of soil salinisation during the optimisation period.

5.2 Model assumptions

Two sets of model runs are presented below. The first three runs assume "average" rainfall conditions for both winter and summer season over the optimisation period. For the following runs "wet" conditions apply during the winter season to test the effects on salinisation and farm incomes. The three runs within each weather scenario look at

(a) a situation where the initial water table is two metres below the critical level so that there is no immediate threat of salinisation given continuous water table rise and the fallowing system can be revised using the currently predominant crops,

(b) a situation where the initial water table is set equal to the critical level so that salinisation will occur and the feedback of salinity on soil productivity can be shown - again, the fallowing system is being revised, and

(c) the same groundwater condition as in (b) apply but lucerne can be established as a high-water-use-crop.

The objective function maximises available household income over the three years. For future incomes a discount rate of 5 % applies. Available income is derived from earnings before interest and tax (EBIT), interest received and paid, income tax applicable, and repayment obligations. Price conditions of 1993 apply (Patrick 1993) and an annual price rice of 4 % for costs and 3 % for commodities is assumed.

An initial debt of $ 150,000 applies to the financial conditions of the model farm, taxation is in accordance with the present regulations applicable (Australian Master Tax Guide 1993). Initial savings is set at $ 1000. Household consumption equals $ 35,000 in the first year and increases by 5 % pa.

The critical groundwater l[illegible] is 2 m. Every millimetre (mm) of exceedence incurs waterlogging (reversible salinisation) on 0.3 hectares of black soil. When the water table rises above 1.9 m from soil surface, irreversible salinisation affects 0.15 hectares for every mm of water table rise. It is assumed that only a percentage of the farming area is susceptible to salinisation. Hence, maximum areas for both forms of salinisation apply. Lateral groundwater replenishment equivalent to 10 mm recharge applies (Broughton 1993, personal comments).

5.3 Model results

The results of the land-use scenarios given "average" rainfall conditions are summarised in Table 1. Table 2 presents the equivalent "wet" winter season scenarios. The tables show the land use over the three model years in the upper table section and display the farm financial implications in the bottom section. Some trends are visible from the results:

(1) There is a trend away from long-fallow rotation systems. The higher crop yields under long-fallow conditions are outweighed by a larger harvest received from an increased area planted under short-fallow conditions. The transition to short-fallow based paddock sequences requires a period of several years.

(2) Lucerne is a profitable land use option and the high initial investment costs and the risk related to establishment pay off even over a three-years-only optimisation period.

(3) With only marginally changed cropping systems which include decline in long-fallow and introduction of lucerne on part of the area, salinisation remains a process on the increase. More dramatic changes in land use are required to manage the problem.

Table 1: Model results under "average" rainfall conditions

	Run A			Run B			Run C		
Conditions									
Land Management Options	reverse cropping/fallowing system (no opportunity crops)			reverse cropping/fallowing system (no opportunity crops)			introduce lucerne reverse cropping/fallowing system		
Initial water table depth	4 m			2 m			2 m		
Objective Value ($)	110,731			107,540			113,264		
	Year 01	Year 02	Year 03	Year 01	Year 02	Year 03	Year 01	Year 02	Year 03
Salinisation									
Salt-unaffected area (ha)	1000	1000	1000	980	945	910	981	962	932
Reversibly salinised area (ha)	0	0	0	20	40	60	19	38	55
Irreversibly salt affected (ha)	0	0	0	0	15	30	0	0	13
Water table rise (mm)	101	101	95	101	100	96	97	91	86
Land Use (ha)									
Wheat (long fallow)	333	333	283	333	327	278	312	288	249
Wheat (short fallow)	0	0	50	0	0	37	0	0	38
Sorghum (long fallow)	333	333	283	333	327	289	312	288	251
Sorghum (short fallow)	0	0	50	0	0	26	0	0	32
Sunflower	0	50	50	0	49	47	0	43	42
Lucerne establishment	0	0	0	0	0	0	65	65	0
Lucerne crop	0	0	0	0	0	0	0	50	100
Farm Finances ($)									
Sales Revenues	247,720	274,040	280,914	247,720	273,224	277,409	231,618	289,042	348,073
Variable Production Costs	93,400	100,802	104,295	93,400	101,995	105,442	87,329	90,366	95,102
Fixed Costs	61,655	63,490	67,100	61,633	63,708	66,351	58,167	57,386	60,939
Earnings before Interest and Tax	92,687	109,748	109,519	92,687	107,521	105,616	86,122	141,290	192,032
Interest received	100	448	1,288	100	386	1,052	100	84	1,860
Interest paid	22,500	20,904	18,813	22,500	20,904	18,813	30,675	39,235	36,099
Taxable Income	70,287	89,293	91,993	70,287	87,003	87,855	55,548	102,139	157,793
Tax paid	24,646	33,389	34,631	24,646	33,389	32,727	17,866	39,298	64,899
Loan Repayments	15,229	13,936	12,542	15,229	13,936	12,542	21,385	26,157	24,066
New Debt	4,589	0	0	4,589	0	0	127,704	10,500	0
Total Owing	139,359	125,423	112,881	139,359	125,423	112,881	256,318	240,661	212,595
Total Savings	7,968	9,820	34,354	1,000	6,732	7,586	0	1,684	33,828

Table 2: Model results under "wet" winter rainfall conditions

	Run A			Run B			Run C		
Conditions									
Land Management Options	reverse cropping/fallowing system (no opportunity crops)			reverse cropping/fallowing system (no opportunity crops)			introduce lucerne reverse cropping/fallowing system		
Initial water table depth	4 m			2 m			2 m		
Objective Value ($)	230,365			218,726			264,057		
	Year 01	Year 02	Year 03	Year 01	Year 02	Year 03	Year 01	Year 02	Year 03
Salinisation									
Salt-unaffected area (ha)	1000	1000	1000	968	928	874	970	954	885
Reversibly salinised area (ha)	0	0	0	32	63	94	30	58	86
Irreversibly salt affected (ha)	0	0	0	0	9	32	0	8	29
Water table rise (mm)	101	101	95	159	157	155	151	142	138
Land Use (ha)									
Wheat (long fallow)	333	333	283	333	320	283	312	282	259
Wheat (short fallow)	0	0	50	0	0	18	0	0	12
Sorghum (long fallow)	333	333	283	333	320	302	312	282	270
Sorghum (short fallow)	0	0	50	0	0	0	0	0	0
Sunflower	0	50	50	0	37	45	0	23	41
Lucerne establishment	0	0	0	0	0	0	65	65	0
Lucerne crop	0	0	0	0	0	0	0	50	100
Farm Finances ($)									
Sales Revenues	315,892	331,687	362,902	315,892	335,954	341,896	295,359	349,690	423,929
Variable Production Costs	93,400	96,202	103,826	93,400	101,031	105,369	87,329	88,693	94,951
Fixed Costs	6.,655	63,490	65,403	61,655	63,627	65,317	58,167	57,321	59,692
Earnings before Interest and Tax	160,859	171,995	193,673	160,859	171,296	171,210	149,863	203,675	269,285
Interest received	1,768	5,644	10,912	1,768	5,625	10,248	956	3,788	9,020
Interest paid	22,500	20,250	18,225	22,500	20,250	18,225	32,675	35,783	32,204
Taxable Income	140,126	157,389	186,360	140,126	156,671	163,234	120,144	171,682	246,101
Tax paid	56721	64713	78039	56721	64,382	67,401	47,580	71,288	105,520
Loan Repayments	15,000	13,500	12,150	15,000	13,500	121,550	20,450	23,855	21,470
New Debt	0	0	0	0	0	0	109,000	0	0
Total Owing	135,000	1,215,000	109,350	135,000	121,500	109,350	238,550	214,695	193,226
Total Savings	34,354	78,530	139,702	34,354	78,142	78,142	17,114	48,153	84,111

(4) Above average rainfall conditions exacerbate the salinisation problem.

(5) The increased crop yields in high rainfall seasons translate into big financial benefits for the farm that are not outweighed by increased salt-affected areas over the three year period. Lucerne is particularly profitable in above-average rainfall years.

(6) Lucerne growing shows a mitigating effect on the rate of salinisation but lucerne cannot be expected to control salinisation in a situation with high lateral groundwater replenishment rates as it is given in the floodplains in the Liverpool Plains.

(7) The farm financial calculations show close-to-reality investment behaviour where investments are taken once they prove profitable and are affordable, and where debts are used to reduce the annual tax bill.

5.4 Discussion of the results and implications for model development

The model reactions as displayed above are reasonable in that they describe plausible decision taking behaviour in a short term (3 years) planning horizon. The optimisation period of three years proves too short to economically justify any serious salinity abatement action. It can be expected, that other land use options at all salinisation stages will be adopted once the optimisation period will involve ten years. While tax-deductions on expenses related to salinity management (ie. tree planting and fencing) do not provide any incentives in the short term, this might change with increased number of years under investigation.

The model results show rational farm financial management. This is important in that the major aim of this modelling exercise is to provide decision support for salinity-affected of salinity-threatened farmers. Taxation issues and full-budget considerations including investment potential are an essential component of farm management. MOFEDS will be able to provide management information related to production and financing issues over a period of ten years if a medium-term income perspective is accepted.

The model results show a linear trend in salinisation once the water table threshold is exceeded by groundwater rise. While the rise in water table calculated by the model is in the range of what has been observed on the Liverpool Plains, the salinisation rate will require some fine-tuning.

The assumed farm size in the model testing phase is 1000 hectares which is only 22 hectares below the holdings area of the statistical model farm representing a cluster of 101 cropping farms in the plains (ABS 1993), so it can be claimed that the testing is done in a sensible farm structural framework. The model has to be extended to applications for other farm types including mixed farms (grazing and cropping) and farms where other soil types apply as well. It is important to state, that MOFEDS, in order to capture the essentials of salinity management in the Liverpool Plains, investigates into model farms rather than existing farms which would require a farm-specific data input with results that would not necessarily be applicable to a whole land management unit with the catchment.

The final perspective of this modelling exercise remains the vision, that a total catchment model can be developed by linking farm models through the lateral groundwater movement component to develop an answer to the question, what land use systems in which parts of the catchment at which extend would maximise the medium-term income of the whole farming community. This approach will also reveal the would-be winners and losers in a catchment-optimal setup. External costs of dryland salinisation which relate to infrastructure damages born by the wider regional community are not subject of this approach.

6 SUMMARY

This paper introduces the concept of a mathematical programming Model to investigate the Farm Economics of Dryland Salinisation (MOFEDS) in the Liverpool Plains in NSW. Land management plays the key role in the development of salinisation through determining recharge to the groundwater system of a catchment. While a range of salinity management options have been recommended and simulation models have shown their beneficial effects with respect to reduced groundwater rise and increased farm net incomes, farmers have been reluctant to adopt the recommendations. MOFEDS provides a tool to investigate medium-term farm optimal land management strategies under salinisation circumstances in that it applies an objective function of after-tax-income-maximisation to a 10 year planning period. Its important features are the feedback of salinisation on agricultural production and the whole farm economics of potential management action. Preliminary model runs have investigated farm management over a three-year period which is too short to economically justify investment into long-term salinity management. Lucerne is shown to be a preferred land use option as an alternative to grain crops but cannot control salinisation. Wet years exacerbate the rate of salinisation once a critical water level is exceeded. Yield increases from high rainfall outweigh lost production through salinisation in the short term. MOFEDS depicts farm financial strategies in a realistic manner in that debt is used to reduce tax payments and can be expected to provide useful decision support for long-run orientated farm management

7 ACKNOWLEDGMENTS

The author was granted a Feodor-Lynen Fellowship by the Alexander von Humboldt-Foundation to undertake this research and gratefully acknowledges the co-funding provided by the National Soil Conservation Program. Thanks are owed to members of the N.S.W. Departments of Conservation and Land Management and Water Resources for cooperation in the project.

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