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Ind. Jn. of Agri. Econ.
Vol. 47, No. 2, April-June 1992

An Economic Enquiry into the Impact of Soil Alkalinity and Waterlogging

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The problem of salt affected soil[1] and waterlogging have plagued irrigated agriculture down through the ages. Historical evidence shows that in the long run, these problems lead to land abandonment (Rhoades, 1988, p. 125). In the short-term and medium-term, there are adverse productivity impacts. Presently, salinity affects productivity in about 86 million hectares (ha) of the world's irrigated land. At least two lakh to three lakh hectares of irrigated land are lost every year due to salinisation and waterlogging (Framji, 1987). In developed and developing countries together salinity and waterlogging are responsible for the decline of about 1.1 million tons of grain output each year (Brown and Young, 1990).

Indian agriculture is not an exception and several major irrigation command areas are experiencing deterioration of crop productivity due to soil salinity and waterlogging. Realising the seriousness of the problem, several questions have been raised about the efficiency of irrigation investment, particularly those on large surface irrigation systems. In fact, the magnitude of these effects are not precisely known. Available information from various sources was compiled and discussed by Joshi (1987) and Chopra (1989). Recent rough estimates reveal that these problems add up to 13 to 20 million ha (Rhoades, 1988, p. 125 and Postal, 1990, pp. 45-46). These are often localised and unidentified in aggregate statistics. These problems are likely to aggravate further as new areas are brought under canals and as existing irrigated lands are unattended. The following statement sums up the perception and prescription at the highest policy level: "In existing irrigated areas where salinity and waterlogging have resulted in good agricultural land becoming unusable, adequate drainage facilities would be provided on a priority basis and proper usage of surface and ground water encouraged, as also reclamation and revised cropping pattern for preventing recurrence of waterlogging and salinity. As precise statistical data are not yet available, States have been requested to carry out surveys for a correct assessment of irrigated lands that have fallen into disuse because of waterlogging and salinity" (Government of India, 1985, p. 74).

As a consequence, unlike other more visible soil related problems like flood, deforestation, and soil erosion, control of salt affected and waterlogged areas has not yet evoked adequate policy response (Shah, 1988). Lack of such information is the main reason why these concerns are inadequately addressed in most of the irrigation investment decisions.

The present study focuses primarily on the problem of soil alkalinity and waterlogging in a major surface irrigation system and attempts to measure its impact at the farm level in terms of resource use, productivity and profitability of crop production.

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The authors are grateful to John Mellor, N.T. Singh and N.K. Tyagi for providing necessary facilities to undertake the study, and to Mark Svendsen and the referee of this Journal for their comments on this research. The financial support by FAO is gratefully acknowledged. Primary data for this study were collected by Ram P. Chippa.

METHODOLOGY

Sharda Sahayak Irrigation Project was purposively selected in view of the controversial reports that salinity and waterlogging are threatening the sustainability of irrigated agriculture. The system envisaged the creation of irrigation potential of about 2 million hectares in the lower reaches of the main Sharda Canal Command area, covering 12 districts. Of these, Sultanpur district was randomly selected for the purpose of the study. Since we intended to assess the impact of land degradation, therefore, one block, namely, Gauriganj, was purposively chosen. The reason was that the canal irrigation-induced alkalinity and waterlogging were becoming serious constraints in future growth of agriculture in this block. Four villages, namely, Gulalpur, Bastidei, Majwara and Bhatgaon, were then randomly selected. Farmers of these villages were further stratified into two categories. These were (*i*) normal farms and (*ii*) problem-affected farms. The stratification was done on the basis of soil pH and depth of water table. Finally, 77 farmers from the first category and 33 from the second category were randomly selected on the basis of probability proportionate sampling criteria. In all, 110 farmers form the sample of this study.

To elucidate the separate effects of alkalinity and waterlogging, the data of the second category were analysed plotwise, depending upon the existence of these problems. It may be mentioned that waterlogged soils were marginally affected by alkalinity as reflected by the soil pH. But crop damage in this category was mainly due to high water table. The waterlogged soils which were severely affected by alkalinity were not included in the present study. Data constraint was the main limitation to exclude this category. The results of this study are, therefore, discussed for three soil environments, namely, normal, alkaline and waterlogged. The farm survey covered the 1985-86 cropping year.

THE APPROACH

Several analytical approaches have been used to discern the true impact of soil salinity and waterlogging. Pincock (1969) utilised whole farm budgets to analyse the impact of salinity on net farm income. More *et al.* (1974) used linear programming based procedures for estimating economic damage on multi-crop farms. Variants of this approach have also been applied by Boster and Martin (1978) and Oyarzabad and Young (1978). Dynamic programming models have been used by Yaron (1985) and Yaron and Olian (1973) to analyse the long-run implications of leaching of salts with irrigation of annual and perennial crops. Hussain and Young (1985 *a, b*) and Joshi (1987) estimated losses due to soil salinity using production function approach. While the former used electrical conductivity as one of the variables, the latter estimated the impact with the help of dummy variable.

In this study an alternative production function approach has been used. The change in gross output between normal and problem-affected soils was decomposed into: (*i*) changes due to salt affected soils or waterlogging and (*ii*) changes due to reallocation of inputs. The land use pattern, resource use pattern, crop productivity and profitability were worked out for different soil environments. To sort out the contribution of these effects, we have followed production function approach. Separate production functions have been estimated for different soil types. These have been specified in a log-linear form as follows:

Normal soil

$$\text{Log } Y_n = \text{Log } A_n + a_n \text{ Log } S_n + b_n \text{ Log } F_n + c_n \text{ Log } L_n \quad \text{.... (1)}$$

Salt-affected soil

$$\text{Log } Y_s = \text{Log } A_s + a_s \text{ Log } S_s + b_s \text{ Log } F_s + c_s \text{ Log } L_s \quad \text{.... (2)}$$

Waterlogged soils

$$\text{Log } Y_w = \text{Log } A_w + a_w \text{ Log } S_w + b_w \text{ Log } F_w + c_w \text{ Log } L_w \quad \text{.... (3)}$$

where Y is gross income (Rs./ha), S is value of seed (Rs./ha), F is value of fertiliser (Rs./ha), L is cost of labour (Rs./ha). n, s and w denote normal, salt-affected and waterlogged soils respectively; A is scale parameter and a, b, and c are output elasticities with respect to different inputs.

Taking the difference between (2) and (1) and between (3) and (1) and adding some terms and subtracting the same terms (Bisaliah 1977), yield the following:

Equations (2) and (1):

$$\text{Log } Y_s - \text{Log } Y_n = (\text{Log } A_s - \text{Log } A_n) + (a_s \text{ Log } S_s - a_n \text{ Log } S_n + a_s \text{ Log } S_n - a_s \text{ Log } S_n) + (b_s \text{ Log } F_s - b_n \text{ Log } F_n + b_s \text{ Log } F_n - b_s \text{ Log } F_n) + (c_s \text{ Log } L_s - c_n \text{ Log } L_n + c_s \text{ Log } L_n - c_s \text{ Log } L_n) \quad \text{.... (4)}$$

Equations (3) and (1) :

$$\text{Log } Y_w - \text{Log } Y_n = (\text{Log } A_w - \text{Log } A_n) + (a_w \text{ Log } S_w - a_n \text{ Log } S_n + a_w \text{ Log } S_n - a_w \text{ Log } S_n) + (b_w \text{ Log } F_w - b_n \text{ Log } F_n + b_w \text{ Log } F_n - b_w \text{ Log } F_n) + (c_w \text{ Log } L_w - c_n \text{ Log } L_n + c_w \text{ Log } L_n - c_w \text{ Log } L_n) \quad \text{.... (5)}$$

Rearranging terms in equation (4) yield the following:

$$\text{Log } (Y_s/Y_n) = \text{Log } (A_s/A_n) + [(a_s - a_n) \text{ Log } S_n + (b_s - b_n) \text{ Log } F_n + (c_s - c_n) \text{ Log } L_n] + [a_s \text{ Log } (S_s/S_n) + b_s \text{ Log } (F_s/F_n) + c_s \text{ Log } (L_s/L_n)] \quad \text{.... (6)}$$

and, similarly the terms of equation (5) give:

$$\text{Log } (Y_w/Y_n) = \text{Log } (A_w/A_n) + [(a_w - a_n) \text{ Log } S_n + (b_w - b_n) \text{ Log } F_n + (c_w - c_n) \text{ Log } L_n] + [a_w \text{ Log } (S_w/S_n) + b_w \text{ Log } (F_w/F_n) + c_w \text{ Log } (L_w/L_n)] \quad \text{.... (7)}$$

Equations (5) and (6) apportion approximately the differences in gross income per hectare between normal and salt-affected, and between normal and waterlogged soils, into two

components. The sum of the first two bracketed components on the right-hand side indicates the land degradation effect. The third bracketed term measures the contribution of changes in input levels between the two situations.

Salt-Affected and Waterlogged Area

Several studies have been carried out to estimate the extent of salt-affected and waterlogged area in the Sharda Sahayak Irrigation Project. Studies conducted by Remote Sensing Agency revealed that in an area of about 1.43 million ha, about 54,000 ha (52 per cent) was facing the problem of surface waterlogging. Similarly, a study carried out in 120 villages under four districts of the irrigation system showed that the area under winter crops has gone down by about 54 per cent between 1976-77 and 1981-82 due to waterlogging. Another study covering 208 villages under five districts of the irrigation system found that more than 16,000 ha of winter crops had been lost. In addition to the problem of rise in groundwater table and surface waterlogging, about 2,16,000 ha had been affected by salts.

Studies have shown that there has been a rapid rise in the groundwater table since the inception of the canal system. It has also been reported that though the number of tubewells has grown in the region, it has actually gone down in the area covered by the canal systems. Over-use of canal irrigation and under-use of groundwater has disturbed the water balance of the area causing waterlogging and increase in salinisation in the command area. The reason for under-exploitation of rather good quality groundwater is very low water rate on canal irrigation. The rate is Rs. 143.26 per hectare for paddy, wheat, barley, vegetable, etc. The canal rate is Rs. 56.81 per hectare for cotton and Rs. 237.12 per hectare for sugarcane. On the other hand, the cost of tubewell irrigation is worked out to be about Rs. 825 per hectare for paddy and Rs. 460 per hectare for wheat. Such a wide difference in the cost of irrigation has led to the farmers to discontinue the use of groundwater, resulting in an increase in water table and alkalinity.

SOIL DEGRADATION AND RESOURCE USE PATTERN

Deterioration in physical production environment leads to changes in resource use. The nature and extent of problem soils, and its effects on the use of land and other resources on the sample farms are examined.

Nearly 87 per cent of the sample farm households reported the presence of salt and waterlogging problems on their farms and 53 per cent of the total farm area was affected. Salt accumulation was the main problem in 34.4 per cent of the area and waterlogging affected 18.3 per cent of the area. On 23 per cent of the farms the problem was non-existent or negligible. At the other extreme, on 15 per cent of the farms, more than 90 per cent of the farm area was problem-ridden. On 53 per cent of the farms, salt affected and waterlogged soils accounted for over 50 per cent of the farm area. These figures suggest that the problem is pervasive and also that it does not take too long to manifest itself. This further suggests that soil related diseconomies in canal irrigation systems cannot be viewed as long-term problems.

Land use changes and crop-mix are examined under different soil environments at the farm level. This exercise adduces the nature of short-term adjustments that farmers make as soil degradation problems emerge. Table I presents data on seasonal land use and cropping

pattern on the basis of disaggregated plot-level data. It shows how normal, salt-affected and waterlogged lands are utilised. As expected, normal plots are intensively cultivated - 96 per cent of the area is cropped in *kharif* and 81 per cent in the *rabi* season, giving an intensity level of 177 per cent over the year. On salt-affected and waterlogged lands, the cropping intensity is 84 per cent and 54 per cent respectively. In *rabi*, cropping options on salt-affected and waterlogged area are limited; therefore, large area is kept fallow.

TABLE I. LAND USE AND CROP-MIX ON 'NORMAL', 'SALT-AFFECTED' AND 'WATERLOGGED' LANDS

Particulars (1)	Normal plots (2)	Alkaline plots (3)	Water-logged plots (4)
Seasonal fallow (per cent)			
Kharif	4	47	52
Rabi	19	68	95
Cropping intensity (per cent)	178	84	54
Area under important crops[a] (per cent)			
Paddy (HYV)	32	27	47
Paddy (local)	20	34	43
Wheat	28	28	9
Barley	*	3	Nil
Pea	6	3	1
Other pulses	3	Nil	Nil
Mustard/linseed	2	2	*
Other crops	9	3	Nil

a Expressed as percentage to gross cropped area.
* Less than one per cent.

Paddy claimed the largest share in the total cropped area in all kinds of soils. Under waterlogged situation, 90 per cent of the cropped area was paddy. The table reveals that with the increase in the extent of salt and waterlogging, acreage allocation for paddy increases. Greater tolerance to salts and waterlogging is the reason for this. Interestingly, the preference for local varieties of paddy was more on salt-affected and waterlogged lands. Of the total paddy area, about 56 per cent and 48 per cent were allocated to local varieties in salt-affected and waterlogged soils respectively. On normal soils, it was 36 per cent. Thus while adverse soil conditions are major constraints in the spread of high-yielding varieties (HYVs), area allocation to local varieties is significant.

Wheat was the most important crop during winter season in all types of soils, though its relative share declined in waterlogged soils. Prolonged waterlogging precludes the possibility of growing wheat. Barley, a relatively tolerant crop, claims some area under salt-affected condition.

The table clearly shows that crop production opportunities are severely restricted under degraded soil conditions. Under salt-affected and waterlogged soils, crops like pulses, sugarcane, potato and a number of other crops are not grown.

The incidence of these problems has its impact on land resources in two ways. In extreme situations, it leads to abandonment of cultivation. In the study area, 29 per cent of the farm area was uncultivated due to degraded soil conditions - a phenomenon of relatively recent origin. Secondly, even on cultivated land, the intensity of land use goes down substantially as these problems grow. In these situations, the intensification effects of irrigation are lost. Thus in both quantitative and qualitative sense, land degradation aggravates land scarcity.

In an area where over 93 per cent of the holdings are less than 2 ha in size and about 87 per cent of the population is dependent upon agriculture for its livelihood, land degradation is a very serious threat.

Use of non-land resources is cut back due to the abandonment of cultivation of highly degraded soils. The results presented in Table II indicate that the use of modern inputs like fertilisers and machines is lower on degraded soils. Aggregate input use falls by 21-22 per cent. The decline is higher for HYV of paddy as compared to traditional varieties in the *kharif* season, and for wheat as compared to barley in the *rabi* season. In general, farmers tend to revert to low-output traditional varieties and practices as soil conditions deteriorated.

TABLE II. AGGREGATE RESOURCE USE PATTERN ON DIFFERENT TYPES OF SOILS

(Rs./ha)

Input	Normal soil	Alkaline soil	Water-logged soil
(1)	(2)	(3)	(4)
Seed	272	207	119
Manure	126	159	134
Fertiliser	287	141	114
Labour	675	580	777
Bullock/tractor	278	233	140
Irrigation	140	138	141
Other costs[a]	219	122	137
Total	1,997	1,580	1,562

a. Includes machine, pesticides, depreciation, interest and other costs.

PRODUCTIVITY AND PROFITABILITY

The results on productivity and profitability of crop production were more dramatic. According to farmers' perceptions, yields of paddy and wheat halved in about eight years' time due to increasing soil degradation. Current data indicate that paddy and wheat yields went down by more than 51 per cent and 56 per cent, respectively on salt-affected soils (Table III). With a decline in yield of only 18 per cent, barley emerged as the most tolerant crop. Net income from HYV of paddy fell by 54 per cent on waterlogged and by 87 per cent on salt-affected lands (Table IV). Cultivation of traditional paddy varieties resulted in a net loss on salt-affected lands; for wheat, the net income in this situation fell by 92 per cent. Barley registered the lowest decline in net income per hectare. These results indicated that, with the exception of barley, it was not economically viable to cultivate salt-affected lands. The losses due to soil degradation are illustrated by the finding that the unit cost of production rises by 59 to 61 per cent for paddy and by 85 per cent for wheat when cultivation is extended on salt-affected soils. As compared to these, waterlogging results in 18-19 per cent rise in the unit cost for paddy.

The estimated regression equations for each soil type are presented in Table V. All the three variables, namely, seed, fertiliser and labour, were statistically significant in the equation for normal soils. In the other two cases, labour was the only significant variable. This indicates that the response behaviour with respect to inputs changes significantly as soil condition deteriorates. The specification used in this model does not adequately capture

these differences. The value of adjusted R^2 ranges from 83 per cent for waterlogged soil equation to 41 per cent for salt-affected plots equation. Although the variables were specified in different ways, higher R^2 could not be attained possibly because of data limitations.

TABLE III. AVERAGE PRODUCTIVITY OF MAJOR CROPS ON DIFFERENT TYPES OF SOIL ON FARMERS' FIELDS IN THE STUDY AREA

Soil type	Productivity (kg/ha)			Coefficient of variation (per cent)
(1)	Average (2)	Maximum (3)	Minimum (4)	(5)
		Paddy (HYV)		
Normal	2,773	4,200	1,333	26.7
Alkaline	1,349	2,033	727	29.3
Waterlogged	1,630	2,280	857	29.1
		Paddy (Local)		
Normal	1,958	3,428	960	34.6
Alkaline	1,067	2,300	240	53.6
Waterlogged	1,450	2,639	650	43.7
		Wheat (HYV)		
Normal	2,596	3,621	800	27.1
Alkaline	1,139	1,739	571	32.8
Waterlogged	580	831	421	32.5
		Barley		
Normal	1,297	1,460	1,190	11.7
Alkaline	1,066	1,400	732	31.3

TABLE IV. COSTS AND RETURNS FROM MAJOR CROPS UNDER DIFFERENT SOIL CONDITIONS

Crop (variety)/ Soil type	Gross income (Rs./ha)	Costs (Rs./ha)	Net income (Rs./ha)	Net income-cost ratio	Cost/kg (Rs.)
(1)	(2)	(3)	(4)	(5)	(6)
Paddy (HYV)					
Normal	4,159	2,315	1,844	0.79	0.83
Alkaline	2,024	1,770	245	0.14	1.32
Waterlogged	2,445	1,592	853	0.54	0.98
Paddy (local)					
Normal	2,835	1,915	920	0.48	0.93
Alkaline	1,494	1,598	-104	-0.06	1.50
Waterlogged	2,029	1,613	416	0.26	1.11
Wheat (HYV)					
Normal	4,024	1,963	2,061	1.05	0.76
Alkaline	1,765	1,603	162	0.10	1.41
Waterlogged	899	1,296	-397	-0.31	2.23
Barley					
Normal	1,945	1,014	931	0.92	0.78
Alkaline	1,599	949	650	0.68	0.89

TABLE V. LOG-LINEAR PRODUCTION FUNCTIONS FOR NORMAL, SALT-AFFECTED AND WATERLOGGED LANDS

Soil type (1)	Constant (2)	Seed (3)	Fertiliser (4)	Labour (5)	$\bar{R}^2$ (6)
Normal	2.5572	0.9100	0.2433	0.2013	0.43
		(4.675)	(3.365)	(1.604)	
Salt-affected	3.3640	0.5655	0.0367	0.4563	0.41
		(1.155)	(0.419)	(2.129)	
Waterlogged	3.3359	0.3394	0.0084	0.6781	0.83
		(0.348)	(0.040)	(3.922)	

Figures in parentheses are t-values.

The results of decomposition exercise are reported in Table VI. The estimated model could account for 88 per cent of the difference in mean income between normal and salt-affected soils, and for 84 per cent between normal and waterlogged situations. The table indicates that the problem of salts accounted for as much as 63 per cent of the difference in gross income between normal and salt-affected plots. The corresponding figure for waterlogged soils was about 64 per cent. These values indicate that with the same level of resources as used on normal soils, gross output would decline by 63-64 per cent on problem soils. Only about 19 to 25 per cent of the output differences could be attributed to curtailment of input use on degraded soils. These figures underscore the extent of loss caused by the salt-affected and waterlogged soils.

TABLE VI. DECOMPOSITION OF OUTPUT DIFFERENCES INTO SOIL DEGRADATION AND INPUT CHANGE EFFECTS

Item	Percentage attributable	
	Salt-affected vs Normal	Waterlogged vs Normal
(1)	(2)	(3)
Source of change		
1. Salt/waterlogging	-63.4	-64.40
2. Changes in inputs	-25.0	-19.50
(*i*) Seed	-15.7	-27.94
(*ii*) Fertiliser	-2.5	-0.90
(*iii*) Labour	-6.8	+9.20
Total difference explained	-88.4	-83.90

With a sizeable output decline attributable to the degradation phenomenon, it is clear that ameliorative measures must focus on arresting and reversing this process. In this context, had the conjunctive use of canal and tubewell irrigation encouraged right from the beginning, the present problem and threats to agricultural production could have been avoided. Biased water pricing in favour of canal irrigation is, by and large, responsible for such a situation. In a situation like that of the Sharda Sahayak Command, vertical drainage through shallow irrigation pumps should be encouraged. Still the degraded areas could be brought back to high production levels and the investment on the project could be safeguarded.

CONCLUSIONS

The above results are based on a small sample and can not be generalised for the Sharda Sahayak Canal system as a whole. Yet the results are so startling that some policy inferences can be drawn.

The study broadly suggested four policy conclusions. First, in areas where these problems occur, the adverse effects are substantial. It is, therefore, important that such areas are identified in different canal command areas in the country. This will require strengthening the statistical reporting and soil testing capabilities in different command area authorities. Sophisticated monitoring techniques are now available for evaluation of soil health. It will be necessary to combine these with on-field verification.

Second, research on development of salt-tolerant varieties has a narrow crop focus. It would be necessary to expand this effort to cover more crops. Similarly, there is a need to develop some adaptive research capacity at the command area level so as to enable evaluation of reclamation technologies under field conditions. This calls for close working relationship between research and command area administration.

Third, there was no evidence on adoption of improved technology for cultivation of salt-affected and waterlogged soils in the study area. This could be due to neglect by the extension service.

Finally, steps to prevent canal seepage, rationalise irrigation price policy and canal operation and improved drainage are crucial. The results of this study suggest that it would be worthwhile to invest in these improvements. However, a proper evaluation requires data on the extent of problem soils and output effects at the command area level. Such studies need to be initiated. Investment decisions in the irrigation sector have become more complex and these kinds of data have become essential for evaluating different options.

Received May 1991. Revision accepted February 1992.

NOTE

1. Salt affected soils are distinguished into alkaline and saline depending on the nature and concentration of salts in the soil.

REFERENCES

Bisaliah, S. (1977), "Decomposition of Output Change under New Production Technology in Wheat Farming: Some Implications to Return on Research Investment", *Indian Journal of Agricultural Economics*, Vol. 32, No. 3, July-September.

Boster, M.A. and W.E. Martin (1978), "Multi-source and Multi-quality Agricultural Water Use Decisions", *Water Resources Bulletin*, Vol. 14, No. 1, February.

Brown, Lester R. and John E. Young (1990), "Feeding the World in the Nineties", in Lester R. Brown *et al.* (Eds.) (1990). *State of the World*, W.W. Norton & Co., New York.

Chopra, Kanchan (1989), "Land Degradation: Dimensions and Causalities", *Indian Journal of Agricultural Economics*, Vol. 44, No. 1, January-March.

Framji, K.K. (1987), *Irrigation Development and Environment: Commemorative Volume*, Central Board of Irrigation and Power, New Delhi.

Government of India (1985), *Seventh Five Year Plan, 1985-90, Vol. II*, Planning Commission, New Delhi.

Hussain, R.Z. and R.A. Young (1985*a*), "Salinity Damages to Irrigated Crops: Economic Measurements from a Farm Survey in Pakistan", Working Paper 85-4. Department of Agricultural and Natural Resource Economics, Colorado State University, Fort Collins, U.S.A.

Hussain, R.Z. and R.A. Young (1985*b*), "Estimates of the Economic Value of Productivity of Irrigation Water in Pakistan from Farm Survey", *Water Resources Bulletin*, Vol. 21, No. 6, December.

Joshi, P.K. (1987), "Effects of Surface Irrigation on Land Degradation - Problems and Strategies", *Indian Journal of Agricultural Economics*, Vol. 42, No. 3, July-September.

Moore, C.V.; J.H. Snyder and P.C. Sun (1974), "Effects of Colorado River Water Quality and Supply on Irrigated Agriculture", *Water Resources Research*, Vol. 10, No. 1, February.

Oyarzabad, F. and R.A. Young (1978), "International External Diseconomies: The Colorado River Salinity Problem in Mexico", *Natural Resources Journal*, Vol. 18, No. 1.

Pincock, M.G. (1969), "Assessing Impact of Declining Water Quality on Gross Value Output of Agriculture - A Case Study", *Water Resources Research*, Vol. 5, No. 1, February.

Postal, Sandra (1990), "Saving Water for Agriculture", in Lester R. Brown *et al.* (Eds.) (1990), *State of the World*, W.W. Norton & Co., New York.

Rhoades, J.D. (1988), "The Problem of Salts in Agriculture", in *Science and the Future*, Encyclopedia Britannica, Inc., London.

Sampath, R.K. and K.C. Nobe (Eds.) (1985), *Irrigation Water Management in Developing Countries: Current Issues and Approaches*, Westview Press, Inc., Boulder, Colorado, U.S.A.

Shah, Tushaar (1988), "Managing Conjunctive Water Use in Canal Commands: Analysis for Mahi Right Bank Canal, Gujarat", IFPRI-TNAU Seminar on Policy Related Issues in Indian Irrigation, Ootacamund, April 26-28.

Yaron, D. (1985), "Economic Aspects of Irrigation with Saline Water", in R.K. Sampath and K.C. Nobe (Eds.) (1985), *Irrigation Water Management in Developing Countries: Current Issues and Approaches*, Westview Press, Inc., Boulder, Colorado, U.S.A.

Yaron, D. and A. Olian (1973), "Economic Evaluation of Water Quality in Irrigation", *American Journal of Agricultural Economics*, Vol. 53, No. 3, August.