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EFFECT OF SURFACE IRRIGATION ON LAND DEGRADATION—PROBLEMS AND STRATEGIES

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The effect of surface irrigation on agricultural production has received considerable attention during the past few years. It has been established that the irrigation in association with high-yielding varieties (HYVs), chemical fertilisers, etc., has substantially increased agricultural production. Recently, there are complaints from some of the irrigation projects about the mismanagement of surface irrigation water and its negative effects on soil and socio-economic environment. The present paper is, therefore, an attempt to investigate the issue in respect of soil and socio-economic environment in some irrigation projects. Specifically, the objectives of the study are to (*a*) adduce the impact of mismanagement of surface irrigation on land degradation, (*b*) examine direct and indirect socio-economic losses of land degradation and (*c*) propose remedial measures and strategies to avoid the process of land degradation.

SURFACE IRRIGATION VIS-A-VIS LAND DEGRADATION

The major negative effects of surface irrigation and its mismanagement are shown in Figure 1. These are the problems of soil salinity/alkalinity, waterlogging and canal seepage. These problems are leading to decline in crop production, crop substitution and farm income. The resultant effects are unemployment, migration, regional disparity, loss of natural resources, ecological imbalances, etc. The problems of salinity/alkalinity and waterlogging are initially developing at a slow rate but the latter is seriously affecting the agrarian economy. These problems have been the bane of irrigated agriculture down through the years.

The available information on the extent of soil salinity and waterlogging in different parts of the country is limited. The National Commission on Agriculture, however, estimated that an area of about six million hectares is waterlogged in the country.[1] Kanwar reported that the problem of soil salinity and waterlogging is too severe because 20 million hectares of land in the canal irrigated areas have already run the risk of being degraded through the influence of salts.[2] During the post-Independence period, many of the major projects witnessed serious waterlogging and consequent soil salinity problem. The problem was alarming, particularly in the Chambal Project

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1. Government of India: National Commission on Agriculture 1976, Part V: Resource Development, Ministry of Agriculture and Irrigation, New Delhi, 1976, p. 179.

2. J. S. Kanwar: Soil Bulletin No. 34, Food and Agriculture Organization of the United Nations, Rome, 1977.

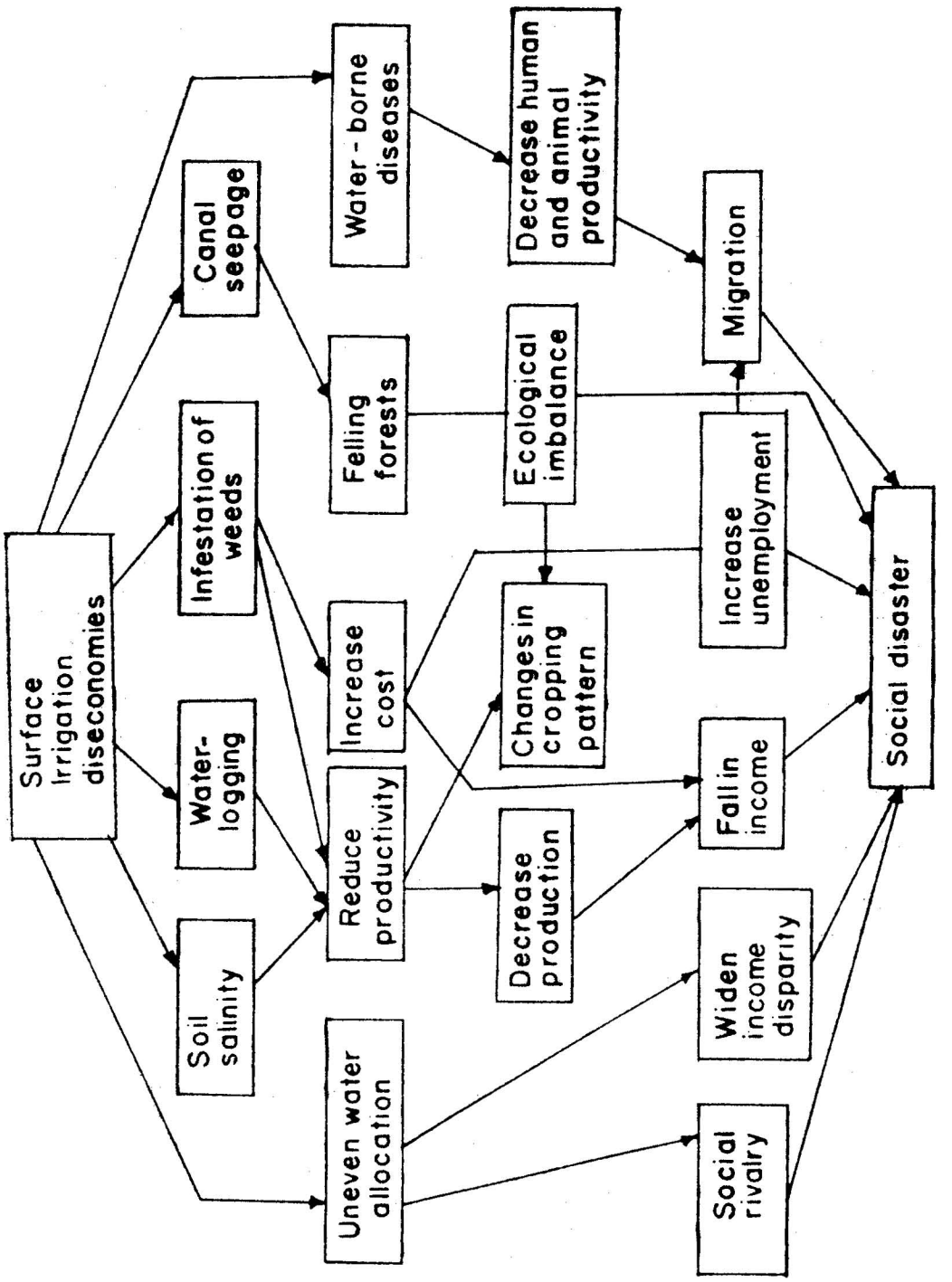

Figure 1 Schematic Diagram Showing the Negative Effects of Surface Irrigation

Command in Madhya Pradesh and Rajasthan, Tawa Irrigation Project in Madhya Pradesh, Indira Gandhi Canal Project in Rajasthan, Kosi and Gandak Projects Command in Bihar, the Tungabhadra areas in Karnataka, Sriramsagar and Nagarjunasagar areas in Andhra Pradesh, Ukai-Kakrapar and Mahi-Kadana Command areas in Gujarat, Malaprabha in Karnataka, Sharda Sahayak and Ramganga Command areas in Uttar Pradesh. The extent of soil salinity and waterlogging in these areas is estimated to be about two million hectares.[3] Recent estimates by the Administrative Staff College of India put it roughly at ten million hectares as waterlogged and about 25 million hectares suffering from soil salinity.[4] This problem is likely to aggravate further as the new areas are being brought under irrigation without proper water management and drainage measures. Such degradation processes have already converted large fertile irrigated areas into unproductive barren lands. The consequences of these alarming problems are decline in agricultural production and farm income, unemployment and migration, disparities and ecological imbalances.

DIRECT EFFECTS OF LAND DEGRADATION

The problems of salinity and waterlogging are directly affecting agricultural production of a farm producer. As the concentration of salts in the soil increases and the water-table rises, farm production declines generally in two ways: (*i*) by decline in production per unit of problem area and (*ii*) by not being able to grow any crop and keeping the land fallow. A survey in village Demol of Kheda district in Gujarat under the Right Bank of Mahi Command area shows that the productivity of important crops, *viz.*, paddy, wheat and tobacco, is declining as the concentration of salts is rising (Table I). Because of the scanty rainfall in the region for the past two years, the ground water-table has receded; therefore, the productivity of paddy in low salinity areas has not reflected in any substantial decline in yields. The farmers are aware that with normal rainfall, the water-table will rise in the absence of proper drainage measures and the productivity of paddy will also be severely affected as was the case before 1984-85.

TABLE I. AVERAGE PRODUCTIVITY OF IMPORTANT CROPS IN DEMOL VILLAGE OF KHEDA DISTRICT DURING 1986-87

(*qtl./ha.*)

Crop	Normal soil	Saline soil		
		Low salinity	Moderate salinity	High salinity
Paddy	36·61	33·55	18·30	5·80
Wheat	24·70	12·23	—	—
Tobacco	13·25	—	—	—

3. P. K. Joshi and A. K. Agnihotri, "An Assessment of the Adverse Effects of Canal Irrigation in India", *Indian Journal of Agricultural Economics*, Vol. XXXIX, No. 3, July-September 1984, pp. 528-536.

4. B. Bowonder and C. Ravi: Waterlogging from Irrigation Projects: An Environmental Management Problem, Centre for Energy and Technology, Administrative Staff College of India, Hyderabad, 1984.

Similarly, the productivity of important crops in Gauriganj block of the Sharda Sahayak Command area shows a declining trend (Table II). Such a declining trend in crop productivity, and keeping the land fallow will have serious repercussions on the agricultural economy in the long run. It will decrease farm production and income, and lead to more unemployment of the rural labourers. Therefore, to avoid such a situation, suitable measures should be undertaken.

TABLE II. AVERAGE PRODUCTIVITY OF DIFFERENT CROPS IN GAURIGANJ BLOCK OF DISTRICT SULTANPUR DURING 1986-87

(*qtl./ha.*)

Crop	Normal soil	Saline soil	Waterlogged area
Paddy			
HYV	24·5	12·8	15·3
Local	20·6	6·2	5·2
Wheat	25·7	7·3	4·1
Potato	80·5	60·9	—
Berseem	1,440·0	400·0	—

INDIRECT EFFECTS OF SOIL SALINITY

The presence of soil salinity on the farm affects the production on the salinity and waterlogged affected patches, as presented above, and also changes decisions regarding resource use on the normal soils of an individual farm producer. To examine the short-term economic losses due to the presence of soil salinity on the normal soils, a study was carried out in four villages of Gohana region of Sonepat district in Haryana during 1984-85. It was observed that the farms having soil salinity problem had a sizable fallow land. The extent of total fallow land including both *kharif* and *rabi* was as high as 25.3 per cent on farms with the salinity problem, as compared to only four per cent on farms without salinity problem. This reduced the gross cropped area; and cropping intensity declined from 192 per cent on farms without salinity problem to 149 per cent on farms having more than 20 per cent salt affected area.

(*i*) *Resource Use*

The resource use in the normal soils is severely affected by the presence of soil salinity on the farm. To assess the effect of soil salinity (as independent variable) on resource use (as dependent variable) in normal soil, several relationships were estimated and the best-fit, *i.e.*, semi-log function, is selected and presented in Table III.

TABLE III. RELATIONSHIP BETWEEN FARM RESOURCES AND SALINITY

Factor	Intercept	Coefficient of salinity	Response of salinity (%)
		Paddy	
Fertiliser	665·03	—0·103	— 9·78
Irrigation	612·70	—0·312	—26·80
Labour	1090·75	—0·059	— 5·73
		Wheat	
Fertiliser	1010·36	—0·179	—16·38
Irrigation	188·30	—0·029	— 2·86
Labour	319·34	—0·065	— 6·29

The estimated functions for two crops, *viz.*, paddy and wheat, reveal that there is a negative relationship between resource use and extent of salinity. The use of fertiliser declines by 9.78 per cent in paddy and by about 16.38 per cent in wheat, as the extent of salinity increases by one hectare. Similarly, the use of irrigation declines by 2.86 per cent for wheat cultivation and by 26.80 per cent for paddy cultivation as the extent of salinity on the farm increases by one hectare. The corresponding figures for labour utilisation are —5.73 and —6.29 per cent for paddy and wheat respectively. Such a phenomenon suggests that as the extent of soil salinity on the farm increases, the use of resources for paddy and wheat decreases in the normal soil.

(*ii*) *Farm Productivity*

It has been observed that the productivity of paddy and wheat on farms having more saline area is lower as compared to the farms without any problem of salinity. To examine the effect of salinity and response of different factors, namely, fertiliser, irrigation, labour and other expenses on the productivity of paddy and wheat, several forms of production functions were estimated and the best-fit Cobb-Douglas forms were selected for the purpose of discussion (Table IV). It is observed that the productivity of wheat de-

TABLE IV. FACTORS DETERMINING PRODUCTIVITY OF PADDY AND WHEAT

Functional form: $Y = \prod_{i=1}^{4} X_i^{a_i} \exp (A + b_s D_s)$

Crop	Intercept	Regression coefficient of					R^2
		Fertiliser	Irrigation	Labour	Other expenses	Salinity dummy	
Paddy	0·0617	0·1217* (0·0744)	0·1746*** (0·0536)	0·5937*** (0·1396)	0·0794 (0·0718)	—0·0483@ (0·0407)	0·6983
Wheat	0·0550	0·0956@ (0·0756)	0·1214* (0·0666)	—0·0147 (0·0999)	0·7234*** (0·2563)	—0·0857@ (0·0718)	0·3683

Note:— *** Significant at 1 per cent probability level.
* Significant at 10 per cent probability level.
@ Significant at 20 per cent probability level.
Figures in parentheses are the standard errors of the estimates.

clines by 8.57 per cent and that of paddy by 4.83 per cent on farms witnessing the problem of salinity. It was assumed that the response of different factors of production would remain same in both the categories of farms (*i.e.*, salinity affected and normal) as the estimated production functions represent normal soils.

The above evidences reveal that the presence of salinity on the farms affects the resource use pattern and it decreases crop productivity even in normal soils.

STRATEGIES FOR AVOIDING SOIL DEGRADATION

The causes of soil salinity/alkalinity and waterlogging are different in the irrigation command areas, and therefore, their remedial measures are different. This section briefly discusses the possible salinity and waterlogging control measures.

(*i*) *Horizontal Drainage*

In areas where underground water is of poor quality, provision of horizontal drainage is a most effective measure to overcome the problems of soil salinity and waterlogging.[5] In waterlogged areas, drainage removes excess water and creates favourable conditions for crop cultivation. Similarly, drainage followed by leaching with good quality water removes excess salts from the root zone. Sub-surface land drainage in the past in most of the irrigation command areas has not received much priority. However, most of the irrigation command areas are now giving due priority to this important component of irrigation management. The costs and benefits of installing sub-surface drainage[6] are presented in Table V.

TABLE V. COST AND BENEFIT OF SUB-SURFACE DRAINAGE

Spacing (metres)	Installation cost (Rs./ha.)	Benefit-cost ratio*		Employment generation (man-days/ha.)
		Cotton-wheat rotation	Bajra-mustard rotation	
25	21,913	2·18	2·22	303
50	13,551	3·26	3·36	186
75	9,371	4·01	3·78	127

* Life of drainage system is considered to be 50 years.

5. O. P. Singh, "Studies on Hydrological Aspects of Saline Soil Reclamation in Gohana Region of Haryana", Annual Reports 1979 to 1982, Central Soil Salinity Research Institute, Karnal; and K. V. G. K. Rao, "Design and Performance of Sub-Surface Drainage System", Annual Reports 1983 to 1985, Central: Soil Salinity Research Institute, Karnal.

6. P. K. Joshi, O. P. Singh, K. V. G. K. Rao and K. N. Singh, "Sub-Surface Drainage for Salinity Control: An Economic Analysis", *Indian Journal of Agricultural Economics*, Vol. XLII, No. 2, April-June 1987.

However, the costs and benefits will differ from region to region depending upon the spacing of drains, soil type, cropping pattern, etc. It is suggested that while planning new irrigation projects in areas where problems of salinity and waterlogging are expected, provision of sub-surface drainage should be made a pre-requisite not only to avoid huge social cost on irrigation development but to realise the objective of increasing the efficiency of water.

(ii) Conjunctive Use of Irrigation Water

To avoid the problems of soil salinity/alkalinity and waterlogging in regions where underground water is of good quality, conjunctive use of groundwater and surface water should be encouraged. The problem of salinity/alkalinity and waterlogging in some parts of Sharda Sahayak command areas has developed because of replacement of tubewell irrigation by surface irrigation. The underground water utilisation in such regions acts as vertical drainage and lowers the water-table and does not allow salts to move to the soil surface.

(iii) Canal Lining

Seepage loss from irrigation water conveyance and distribution system is the biggest contributor to the groundwater recharge and rise in the groundwater-table. Therefore, reduction of seepage losses by means of lining the different components of the system is expected to provide great relief by way of reduced groundwater accessions and increased supply to irrigate additional areas. Evaluation of watercourse lining programme in various irrigation projects in Haryana indicates that there has been an increase in irrigated area ranging from 19 to 30 per cent during *kharif* and from 17 to 49 per cent during *rabi* season.[7] Similarly, studies carried out in the neighbouring State of Punjab have shown an increase of 24 per cent in irrigation intensity.[8] It may be mentioned that priority for complete lining of canal and watercourses should be given in areas where the groundwater quality is poor.

(iv) On-Farm Water Management

Improved water management beyond the canal outlet is a basic prerequisite to increase irrigation efficiencies. In order to increase water efficiency and avoid rise in the water-table and salinity, improved water distribution in the field is most essential. Advanced irrigation methods, like sprinkler and drip, which can apply any desired quantity of water may help in attaining high application efficiency and in avoiding soil degradation

7. D. K. Gupta, "Impact of Lining of Watercourses on Agricultural Output—A Case Study", *Wamana*, Vol. 2, No. 4, October 1982, pp. 1 and 8-16. N. K. Tyagi, "Genesis of Waterlogging and Salinity in Ghaggar Yamuna Alluvial Plain", in Seminar on Conjunctive Use of Surface and Ground Water Resources, Central Ground Water Board, Ministry of Water Resources, New Delhi, February 11-13, 1986.

8. H. S. Ahluwalia, "Utility and the Gains of the Lining of Watercourses of in the Canal System in Arid Areas of the State of Punjab", in Irrigation on Arid Lands, Central Board of Irrigation and Power, New Delhi, November 24-25, 1983, pp. 67-69.

problems. In the absence of these methods, precision of land levelling for irrigation should be a pre-requisite for efficient surface water utilisation. In addition to on-farm water management, appropriate agronomic practices should be followed to avoid the problem of soil salinity and waterlogging.

(v) Organisational Change

Very often, it is observed that the relationship between irrigation development and role of users is ignored while framing the water allocation and appropriation. Attention is usually given to technical, agricultural and economic considerations, leaving out the institutional and social aspects. Organisationally, there is a gap between what happens at the level of senior officials and what happens in the community which receives the water. This leads to disproportionate availability of water among users. There is, therefore, a great need and scope to form community irrigation associations or water users co-operatives. In such an organisation, the water users would be directly responsible for maintaining and operating the system. There are examples of Japanese Irrigation Co-operatives in Japan,[9] and Irrigation Societies in Philippines.[10] In India, Mohini Irrigation Water Users Co-operative in Gujarat has given encouraging results. Such experiments should be replicated in other irrigated areas to exploit the full potential of water resources.

Similarly, the water users should be allowed to participate in decision-making processes related to water scheduling, rotation periods and other aspects of water management. Further, the water users should be given training for efficient utilisation of water. To achieve complete success in irrigation management, a cadre of soil and water management field specialists at State, district and block levels should be introduced.

9. R. K. Breardsley and John W. Hall, "Japanese Irrigation Co-operatives," in E.W. Coward, Jr. (Ed.): Irrigation and Agricultural Development in Asia, Cornell University Press, London, 1980, pp. 127-152.

10. H. T. Lewis, "Irrigation Societies in the Northern Philippines," in E. W. Coward, Jr. (Ed.): Irrigation and Agricultural Development in Asia, Cornell University Press, London, 1980, pp. 153-171.