ENVIRONMENTAL IMPACTS OF AGRICULTURAL WATER MANAGEMENT IN INDIA – AN OVERVIEW

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Abstract *Increasing human and livestock population along with significant developments in the various fields of agriculture has brought more and more lands under irrigation using mostly canal, dam, lift, and underground water through surface irrigation methods. With these improved agricultural practices, the food grain production has increased from 50.8 m tonnes in 1950-51 to 185 m tonnes in 1994-95. In this process of increasing productivity we have exploited our natural resources indiscriminately which in turn have resulted into various environmental degradations especially soil degradation. Out of various agricultural management practices, excess and intensive irrigation has been found to contribute more degradation than use of chemical fertilizers and pesticides, deforestation and other agronomic pesticides. Various physical and chemical changes that have already occurred and measures to be adopted to prevent such changes have been highlighted. Some of the important environmental issues related to agricultural water management and agricultural development in the country have been briefly discussed.*

INTRODUCTION

Over the years, human as well as livestock population of India has increased considerably (Table 1) and by the end of the 20^{th} century it has already crossed 1000 and 600 million mark, respectively. To cater to the needs of this ever increasing human and livestock population we have to produce 240 million tonnes of food grains, 17.2 million tonnes of vegetable oil, 350 million tonnes of fuel wood, and 2000 million tonnes of fodder.

Table 1 Pressure on land in India

Year	Population (million)			Cultivated
	Human	Cattle	Buffaloes	area (mha)
1951-52	361.1	15.5	4.3	118.75
1961-62	439.2	-	-	135.40
1971-72	548.9	-	-	137.14
1981-82	658.2	-	-	140.22
1991-92	846.3	-	-	141.41
1994-95	-	20.5	8.4	142.8

Source: Anonymous (1999).

During the last three decades, significant developments have been made in different fields of agriculture. Usage of irrigation water, fertilizers, pesticides, high yielding varieties and energy efficient agricultural implements have become common practices to raise the production level. Due to technological advancement, the food grains production increased from 50.8 million tonnes in 1950-51 to 18 million tonnes in 1994-95.

In order to produce more, the natural resources have been exploited indiscriminately which have also aggravated the problems of soil erosion, soil salinity/alkalinity, water logging and pollution of surface and ground water resources (Table 2). The environmental degradation in the form of land resources and also in the form of pollution is threatening health and climate and is reducing biological diversity.

Table 2 Impact of irrigation, deforestation and other agricultural management practices on environment

Agricultural practices	Probable impact on environment activity					
	Ground water	Salinity	Water logging	Aquatic pollution	Food Contamination	Soil Erosion
Deforestation	**	**	**	**	-	***
Agronomic practices	*	*	*	*	*	**
Irrigation	***	***	***	***	**	***
Chemical fertilizer	**	*	-	**	*	-
Use of pesticides	*	-	-	*	**	-

'*' Appreciable impact; '-' No appreciable impact
Source: Deb and Joshi (1994)

IRRIGATION RESOURCES MANAGEMENT AND ASSOCIATED PROBLEMS

Water is vital for realizing the full potential of the agriculture sector in the development of country. Expansion of irrigation facilities along with consolidation of the existing systems has been the main strategy for increasing production of food grains.

Irrigation support is provided through major, medium and minor irrigation projects and command area development. With sustained and systematic development of irrigation, its potential has increased from 22.6 mha in 1951, when the process of planning began in India to about 89.44 mha (Table 3) at the end of the Eighth Plan (1992-97). At the end of Eighth Plan, there were 119 major, 176 medium and 67 extension renovation and modernization schemes continuing from the previous plans spilling over to the Ninth Plan.

In the command area development programme, emphasis has been given for utilization of irrigation potential and optimizing agricultural productivity and production from the irrigated areas by integrating all functions related with irrigated agriculture.

Table 3 Planwise position of irrigation potential created and utilised (million ha)

Plan		Potential created			Potential utilized		
		Major & Medium	Minor	Total	Major & Medium	Minor	Total
At the end of							
I Plan	(1951-56)	12.20	14.06	26.26	10.98	14.06	25.04
II Plan	(1956-61)	14.33	14.75	29.08	13.05	14.75	27.80
III Plan	(1961-66)	16.57	16.57	33.57	15.17	17.00	32.17
Annual Plans	(1966-69)	18.10	18.10	37.10	16.75	19.00	35.75
IV Plan	(1969-74)	20.70	20.70	44.20	18.69	23.50	42.19
V Plan	(1974-78)	24.72	24.72	52.20	21.16	27.30	48.46
Annual Plans	(1978-80)	26.61	26.61	56.61	22.64	30.00	52.64
VI Plans	(1980-85)	27.70	27.70	65.22	23.57	35.25	58.82
VII Plan	(1985-90)	29.92	29.92	76.53	25.47	43.12	68.59
Annual Plans	(1990-92)	3.74	30.74	81.09	26.32	46.54	72.86
VIII Plan (Provisional)	(1992-97)	32.83	32.83	89.44	28.37	32.32	80.69

Source: Anonymous (1999).

IRRIGATION WITH SALINE WATER AND ITS ADVERSE EFFECTS

In India, sustained growth of irrigated areas has brought considerable rise in the salinity of river water. The potential adverse effects of irrigation on water quality have been identified as increased salinity, turbidity, colour, taste, temperature, nutrients, nematodes, bacteria, viruses and pesticide ingredients all causing economic losses and deterioration of the environment.

Shalhevet and Kamburov (1976) concluded that the water could be saline with as high as 6000 mg/l TDS. Pillsbury and Blaney (1966) recommended that the upperlimit for irrigation water should be an electrical conductivity (EC) of 7.5 dS/m (about 4800 mg/l TDS). While crop yields in these cases may not all have been maximal, they provided an economic return. The EC of the irrigation water are in many cases far in excess of the maximum EC (EC Threshold), still a particular crop can tolerate and sustain optimal yields. Several authors (Ayers and Westcot, 1985; Frankel ad Shainberg, 1975; Bressler, 1979; Miles, 1977 and Dhir, 1976) reported that irrigation water containing salt concentrations in excess of conventional suitability standards can be used successfully on many crops for several years; however, the long-term effects from these practices (one or more decades) are unknown. The scale of soil management is a major factor in assessing these long-term effects.

Other long term effect on the soil, such as soil crusting, reduced water infiltration capacity, and accumulation of toxic elements pose the real problem of soil management. Soil that have a high potential for soil crusting generally has 15-30% clay and less than 1.5% organic carbon (Shainberg and Singeı, 1990). Crusting reduced water infiltration, and reduced seedling emergence are of particular concern where soils are poorly structured and irrigation water's sodium adsorption ratio (SAR) exceeds the permeability threshold corresponding to the EC. Pratt and

Suarez (1990) observed that water infiltration decreases as the exchangeable sodium percentage (ESP) increases and irrigation water salinity decreases.

The major limitation with trace elements in drainage water is disposal of the water, especially when the terminal body receiving this water is inland and subsequent evaporation concentrates the elements. This creates a major ecological hazard, as exemplified in the San Joaquin valley of California (Tanji et al., 1986) and suggests that even though irrigated agriculture may be sustained on the farm level, it can produce adverse effects on other water users or the environment at the regional scale (Van Schilfgaarde, 1990).

Another factor in crop selection is seasonal water requirements. If saline water is being considered for irrigation this usually implies that there is shortage of good quality water. Therefore, any means of reducing crop water requirements by selecting varieties with a shorter life cycle or those that can be planted at times of the year when evaporative demands are lower are particularly desirable. Since saline conditions reduce both plant growth and seasonal evapotranspiration (ET) it is important to develop information on crop water production functions under saline conditions (Letey et al., 1990).

Use of poor quality water may lead to salinization, and increase in alkalinity, swamping, destruction of soil aggregates and soil cementation. These side effects may be short lived in the beginning, but may persist over a longer period. Irrigation of poor quality water may have diverse chemical and physiochemical reactions with soil minerals, their water solutions, soil organic substances and with intra soil biomass. The water of rivers, reservoirs and wells is always a solution of chemical compounds. It is saturated with gases, carbon dioxide, oxygen, hydrogen sulphide and methane at low temperature.

The air dry soil of arid and semi-arid regions with an automorphic-evaporative type of water balance changes into automorphic flushing transpirational type following applications of irrigation water of 10-100 mm per irrigation and over 50-1000 mm for the growing season. In soil profile, capillary – suspended or capillary-backed moisture emergence and solution tends to flow upward to plant roots and soil surface. This leads to considerable increase in evaporation from the soil surface. The silt in the irrigation water settles on the soil surface and during prolonged irrigation, the thickness of the silt layer may rise to several cm. This interferes with soil aeration, permeability, respiration of young roots and emergence of seedlings. The biochemistry of newly irrigated soils also undergoes appreciable change. It is know that desert soils have small humus content and semi sterility. Upon irrigation the humus content of sierozems and chernozems usually decreases further due to secondary salinization. The proportion of humic acids to fulvic acids undergoes appreciable change.

In general, optimum irrigation enhances soil biological activity and increase soil microbes and diversity of their groups. On the other hand continued over irrigation stimulates the sparsely distributed microorganisms.

In India, more than 8 mha area is suffering from varying degrees of soil salinity and alkalinity (Sehgal, 1990; Singh, 1992). The increasing canal irrigation system, faulty water management practices and irrigation intensive crop rotations are the causes of this secondary salinization. The saline/alkali soils not only limit the normal growth of plants but also pose toxicity problems of some of the elements like selenium, boron, molybdenum and fluoride. Alkali soils contain higher amounts of selenium (>1 ppm). Grazing of forages grown on such soil results into alkali based diseases.

Boron may be found to the extent of 10 ppm in salt affected soils while in normal soils it is less than 2 ppm. Some of the calcareous alkali soils, particularly under waterlogged conditions contain excess of molybdenum. The plants may accumulate molybdenum in higher quantity toxic to cattle. Its toxicity in ruminants results into diarrhea. Nayyar (1977) reported that 17 to 43 % samples of berseem collected from different calcareous flood plains of Punjab had toxic levels of molybdenum (Table 4).

Table 4 Molybdenum content of berseem grown on calcareous flood plains of Punjab

Districts	No. of samples	Mo content (ppm)	% of Samples Toxic (> 10 ppm)
Ludhiana	35	0.50-14.20	17.2
Ropar	14	1.25-20.70	21.4
Kapurthala	13	2.10-13.00	15.4
Hoshiarpur	7	4.30-16.00	42.9
Ferozpur	24	2.90-19.50	20.8
Amritsar	12	3.40-12.90	41.7
Mean	105	0.50-20.70	26.6

Source: Nayyar (1977)

Fluoride toxicity is found in areas where groundwater is highly saline. According to Tewari (1988), 20% of the area in India can be designated as endemic fluoride affected and about 5-8% of the Indian population is drinking water containing 1.5 mg/kg or more or fluoride. Gupta (1988) reported that the concentration of fluoride ranges from trace to > 10 ppm in natural waters. The cases of fluorosis have been reported from Punjab, Haryana, Rajasthan, Bihar, Madhya Pradesh and Andhra Pradesh where soils, underground waters and plant materials contain excess of fluoride (Kanwar and Mehta, 1968; Susheela, 1987).

SOIL EROSION

Out of 328.73 mha geographical area of the country, 118.75 mha was under cultivation during 1951-52. In 1994-95 it increased to 142.8 mha. By this process of agricultural expansion (Kelkar, 1983) about 24.33 thousand ha forest area has been brought under cultivation during the period 1951-72. The extensive cultivation on sloppy lands has resulted into serious problems of soil erosion. About 175.06 m ha land in the country is suffering from soil erosion and land degradation (Mukherjee, 1985). Out of this, 111.3 m ha is affected by water erosion and 38.70 m ha by wind erosion. According to Dhruvanarayana and Rambabu (1983), about 5334 m tonnes (16.35 t/ha/year) of soil are lost annually. This results into both on site and off site effects. Out of the total eroded soil, 10% is deposited in reservoirs, 29% is permanently lost into the sea while 61% is translocated from one place to the other. As a result, the economic life of reservoirs is reduced (Abrol, 1990) and various socio economic and political problems arise in the command areas. Due to erosion, the sub soil which is poor in organic matter and plant nutrients is exposed.

FERTILIZER POLLUTION

Though chemical fertilizers are the key input for increasing agricultural production in India, yet excess and indiscriminate use of these fertilizers have caused serious problems especially under irrigated conditions. In India, the consumption of fertilizer nutrients has increased from 2.26 million tonnes in 1970-71 to 16.3 million tonnes in 1997-98 (Table 5). Out of this N (Nitrogen) alone shares approximately 70.7%, P (Phosphate) 20.9% and K (Potassium) 8.36%. The average growth rate in total fertilizer consumption in Indian agriculture during Eighties had been 8.48% and the same was continuing in Nineties. The use of chemical fertilizers has caused considerable damage to the environment through air, water and soil pollution.

Table 5 Fertilizer consumption (m tonnes) in India during 1970-71 to 1997-98

Year	N	P	K	Total
1970-71	1.48	0.54	0.24	2.26
1975-76	2.15	0.47	0.28	2.89
1980-81	3.68	1.21	0.62	5.52
1985-86	5.66	2.01	0.81	8.47
1995-96	9.82	2.90	0.16	13.38
1997-98	-	-	-	16.30

Source : FAI Fertilizer statistic 1994-95, Fertilizer News, 1996, Anonymous, 1999.

AIR POLLUTION

Nitrous oxide originating from agricultural soils can cause considerable damage to the ozone layer in the stratosphere (Bowman, 1990; Smith, 1990). Gaseous losses of nitrogen from applied fertilizers through volatilisation, denitrification and chemodenitrification add NH_3 (ammonia), N_2O (nitrous oxide), N_2 (dinitrogen), NO (nitric oxide) and NO_2 (nitrogen dioxide) to the atmosphere. Pollution due to nitrous oxide and other nitrogenous gases has aggravated the problem under irrigated soils especially under waterlogged condition.

WATER POLLUTION

Various fertilizers especially the nitrogenous fertilizers are the main source of NO_3 pollution in groundwater and other water bodies (Pain and Thomson, 1989). Bijay Singh and Sekhon (1979) reported that nitrate leaching is more when rainfall exceeds evapotranspiration, where irrigation is practiced, lands are devoted to shallow rooted crops, soil having low water holding capacity and high infiltration rates and where chemical fertilizers are applied in amounts and ways that result in the accumulation of nitrate N in the soil. According to Handa (1987) the nitrate concentration in well water samples from selected locations in Punjab, Haryana and Western Uttar Pradesh was several times higher than the upper safe limit (Table 6). Singh (1987) reported that the mean concentration of NO_3 in groundwater from Central Punjab was 3.88 mg/l during 1982 against 1.02 mg/l in 1975. They also reported that 10% of groundwater samples contained NO_3 concentration of 10 mg/l which is the upper limit of NO_3 in drinking water prescribed by WHO (1963).

Table 6 Nitrate content of well waters

District	State	NO_3-N (mg/l)
Aligarh	Uttar Pradesh	61
Meerut	Uttar Pradesh	157
Mehendragarh	Haryana	296
Ambala	Haryana	223
Bhatida	Punjab	128
Sangrur	Punjab	98

Source: Handa (1987)

SOIL POLLUTION

The physical, chemical and biological properties are adversely affected by long term continuous use of fertilizers. Contamination of soils by heavy metals through fertilizers such as cadmium (Cd) and lead (Pb) from phosphatic fertilizers is getting increasing attention of environmentalists (Kostial, 1986). Williams and David (1973) reported that heavy metals applied to the soil through different derivatives of rock phosphate accumulate almost completely in the surface soil and in forms easily available to plants. The availability of heavy metals was found to be more in light textured, acidic soils as compared to heavy textured, alkaline soils (Rana and Kansal, 1983). According to Arora (1975) and Bijay Singh and Sekhon (1977), the low analysis and straight fertilizers add more lead and cadmium to soil than high analysis and mixed fertilizers (Table 7).

Table 7 Lead and cadmium content (MG/KG) of fertilizers

Fertilizer	Lead		Cadmium
	(a)	(b)	
Urea	-	4	1
Calcium ammonium nitrate	116	200	6
Muriate of potash	117	88	14
DAP	195	188	109
Super phosphate	487	609	187
Rock phosphate	962	1135	305

Source: (a) Arora, 1975; (b) Bijay Singh and Sekhon, 1977

PESTICIDAL POLLUTION

With the advent of high yielding crop varieties and adoption of intensive cropping practices, peculiar pest problems demanding high pesticide use came to the forefront causing the use of more chemical pesticides (Table 8). The plant protection increased from 2-4 mha in 1956 to 80 mha in 1987. Among the pesticides used in India, insecticides share the maximum (80%) followed by fungicides (10%) and herbicides (7%). The use of high doses of agrochemicals in agriculture has accrued to health hazards and ecological imbalances.

Table 8 Pesticides consumption in India

Year	Consumption (kg)
1980	292084
1985	493990
1986	480552
1987	719906

There are many instances of fresh water pollution due to leaching, run off etc. in the catchment areas. Bidai (1982) reported nearly 1000 and 1300 ppb of BHC and Methyl parathion in Kaveri water near Srirangapatnam in Mysore and 20-200 ppb of BHC in drinking water in Hasan district of Karnataka.

CONCLUSIONS

There has been tremendous development in various fields of the Indian agriculture but at the same time considerable damage has also been done to our natural resources during this process due to extensive use of irrigation water. Maximum utilization of irrigation potential for optimizing agricultural production has caused salinity, soil degradation, soil toxicity associated with trace elements and increase in pesticide ingredients, all causing deterioration of the environment. Therefore, it is imperative to take a holistic view of the entire set of inputs applied into agriculture so that food production is sustained and environmental security is maintained.

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REFERENCES

Abrol, I.P. (1990) In: Int. Symp. on Water Erosion and Resources Conservation, Dehradun, Oct. 1990.

Anonymous (1999) In: India, A Reference Annual. Compiled and edited by Research, Reference and Training Division and published by Publication Division Ministry of Information and Broadcasting, Government of India.

Arora, C.L. (1975) Indian J. Agric. Sci., 45, 80-85.

Ayers, R.S. and Westcot, D.W. (1985) FAO Irrigation and Drainage Pap 29, FAO, Rome.

Bidai, P. (1982) Times of India, 15-17 Dec., 1982.

Bijay Singh and Sekhon, G.S. (1977) Fert. News, 23(2), 7-11.

Bijay Singh and Sekhon, G.S. (1979) Agric. Environ, 4, 207-225.

Bouwman, A.F. (1990) Soils and Green House Effect. Wiley, Chichester.

Bressler, M.B. (1979) Water Resources. Burr. Reclamat., Eng. Res. Cent., Denver.

Deb, D.L. and Joshi, H.C. (1994) In: Natural Resources Management for Sustainable Agricultural and Environment (Ed. D.L. Deb). Angkor Publishers (P) Ltd., New Delhi, 277-294.

Dhir, R.D. (1976) In: Proc. Int. Manag. Conf. Managing Saline Water on Irrigation, Texas Tech. Univ. Lubbock, 608-609.

Dhruvanarayana, V.V. and Rambabu. (1983) J. Irrig. Drain. Engg. ASCE, 109, 419-434.

Frenkel, H. and Shainberg, I. (1975) Irrigation with Brackish Water. In: Int. Symp. Beer-Sheva Isr. Negev. Univ. Press, Jerusalem, 175-183.

Gupta, I.C. (1988) Current agriculture, Series No. 1, Alfer Publishers and Distributors. Bikaner.

Handa, B.K. (1987) Fert. News, 32, 11-29.

Kanwar, J.S. and Mehta, K.K. (1968) Ind. J. Agiric. Sci., 38, 881-887.

Kelkar, V.M. (1983) Mazingira, 7(3), 54-66.

Kostial, K. (1986) In: Trace elements in human and animal nutrition (Ed. W. Mertz), Academic Press, London, 319-325.

Letey, J., Khapp, K. and Soloman, K. (1990) Agricultural Salinity Assessment and Management (Ed. K.K. Tanji KK (ed). ASCE. Manu. Rep. Eng. Practices 71.

Miles, D.L. (1977) Interagency Agreement Report. EPA-AIG-D4-0544, Denver.

Mukherjee, B.K. (1985) Statistics of Soil and Water Conservation (Watershed Management-Land Resources-Land Reclamation) in India. 9th Ed., Ministry of Agriculture and Rural Development. Govt. of India, New Delhi.

Nayyar, V.K. (1977) PAU J. Res., 14.

Pain, B.F. and Thomson, R.B. (1989) In: Nitrogen in Organic Wastes Applied to Soils (Eds. J.A. Hausen and K. Henrikson), Academic Press, London, 202-212.

Pillsbury, A.F. and Blaney, H.F. (1966) Proc. ASCE(IR) 98, 77-90.

Pratt, P.R. and Suarez, D.L. (1990) Agricultural Salinity Assessment and Management (Ed. K.K. Tanji) ASCE Manu. Rep. Eng. Practices 71.

Rana, R.L. and Kansal, B.D. (1983) J. Ind. Soc. Sci., 31, 439-443.

Sehgal, J. L. (1990) In: Technologies for Wasteland Development. ICAR, New Delhi, 1-20.

Shainberg, I. And Singer, J.J. (1990) Agricultural Salinity Assessment and Management (Ed. K.K. Tanji) ASCE Manu. Rep. Eng. Practices 71.

Shalhevet, J. and Kamburov, J. (1976) Int Comm. Irrig. Drain., 106.

Singh, I.P. (1987) Indian J. Agric. Econ., 42, 404-409.

Singh, N.T. (1992) In: Degradation and Restoration of Arid Lands (Ed. H.E. Drgme) Int. Conf. Arid and Semiarid Land Studies. Texas Tech. Univ., USA, 179-248.

Smith, S.J. (1990) Adv. Soil Sci., 14, 1-43.

Susheela, A.K. (1987) In: Proc. Symp. Recent Advances in Mineral Nutrition. C.S. Haryana Agric. Univ. Hissar.

Tanji, K.K., Lauchli, A. and Meyer, J. (1986) Environment 28(6), 6-1, 34-39.

Tiwari, A. (1988) In: Proc. Int. Symp. on Nutrient Management for Sustained Productivity. ISS, PAU, Ludhiana.

Van Schilfgaarde, J. (1990) Agricultural Salinity Assessment and Management (Ed. K.K. Tanji) ASCE Manu. Rep. Eng. Practices 71.

Williams, C.H. and David, D.J. (1973) Aust. J. Soil Res., 11, 43-56.