Water Quality, Agricultural Policy and Science

Rajeswari S. Raina and Sunita Sangar

This paper analyses how agricultural policy and science deal with the problem of increasing exploitation of low quality irrigation water and consequent deterioration of water quality in the States of Punjab and Haryana in India. In these cereal growing tracts the policy objective of food security is translated into production technologies, price protection and subsidies. Deterioration of water quality is countered with technocentric solutions. The paper argues that the response of science to the complexities involved in natural resource problems or in the scientific understanding of farmers partial response to technological solutions recommended to improve degraded resources, is due to the existing"administrative rationalism"of natural resource bureaucracies.This administrative rationalism,"the problem-solving discourse which emphasizes the role of the expert rather than the citizen" allows policy and science to maintain their hierarchy in determining policy goals and technological solutions with scant ecological or democratic concerns. Sustainable use of water demands institutional reform in agricultural policy and the agricultural sciences.

Introduction

This paper analyzes the relationship between water quality and the agricultural development establishment. The latter is expressed in its most

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Rajeswari Sarala Raina is an economist with the National Institute of Science, Technology and Development Studies (NISTADS), in New Delhi, India. With an inter-disciplinary training in the agricultural sciences and economics, her publications address the history of and institutional reform in agricultural science, the evaluation of agricultural research, and the organization and measurement of agricultural research effort. This paper is based on an in-house project on "*Ex-post* evaluation of soil science technologies," conducted during 1997-2001, in collaboration with Sunita Sangar (then QHS Fellow, NISTADS) whose Ph.D. thesis on the same topic has been submitted to IIT, Delhi in January 2002. Sunita Sangar has a degree in the life sciences, and is interested in science and technology policy issues related to soil and water resources. The authors are currently working on the NATP sponsored project, on an ecological economics framework for the evaluation of soil science research in India. The authors may be contacted at <rajeswari_raina@yahoo.com> and <sunitasangar@yahoo.com>.

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tangible instruments, agricultural policy and agricultural science. One of the major challenges faced by agriculture today is the degradation of the natural resource base. This degradation in turn is in large measure a consequence of the input intensive production technologies, amply abetted by protectionist policies, whether in developed or less developed countries.

The crucial ecological and social constituencies of agricultural science are acknowledged when an agenda for action draws our attention to issues that are:

- Not just about *output*, but also *process* of production
- Not just about *technology*, but also *policy*
- Not just about *global* issues, but also *national* circumstances (Serageldin, 2000)

The second section uses this perspective to explore how agricultural policy and science deal with the problem of deteriorating water quality in the alkaline tracts of Punjab and Haryana in India. Degradation of soil and water resources in these most productive "green revolution states" is directly linked to input intensive technologies and production policies (ICAR, 1998). Agricultural research does recommend technological solutions to farmers in order to reclaim or improve low quality soil and water for crop production. However, these technological solutions (such as rice cultivation in water-logged soils, gypsum application in alkaline soils) and the policies (such as special subsidies or price supports), push farmers and the ecosystems into a corner, and greater dependence on resource degrading technologies and policies.

This paper argues that the response of science to the complexities involved in natural resource problems or in the scientific understanding of farmers partial response to technological solutions recommended to improve degraded resources, can be attributed to the "administrative rationalism" of natural resource bureaucracies. The third section discusses administrative rationalism, "the problem-solving discourse which emphasizes the role of the expert rather than the citizen or producer/consumer in social problem solving, and which stresses social relationships of hierarchy rather than equality or competition" (Dryzek, 1997, p. 63). This problem solving capacity and the hierarchy in agricultural knowledge, is evident in the institutional history of agricultural science, with (i) the emergence of the full time paid investigator, the middle class professional, (ii) the myth of political neutrality, and (iii) economic legitimisation of public patronage (Raina, 1997). The deterioration of water quality becomes a non-issue when the State's policy objective of food security is translated into production technologies by State sponsored expertise, price protection and subsidies. Natural resources are mere inputs in this production imperative of policy and science.

How do the institutions or rules of the game, which are essentially production oriented, handle resource degradation problems and technological solutions for social and ecological consequences of resource degradation? The success of natural resources research and technologies therefrom is measured in crop yield; the degradation of natural resources is defined as and measured in terms of yield reduction. Within the agricultural science and agricultural policy systems is there scope for institutional change, to move from this myopic philosophy of productionism to a natural resource-based agenda in policy and research?[1]

The conclusion highlights the need for institutional reform, in agricultural policy and the agricultural sciences. There is now a felt need for institutional innovations that can ensure that agricultural science addresses its social and ecological constituencies. These institutional innovations must be enabled through a perpetual process of 'institutional learning' where we can analyse and explain as well as overcome our technological, organizational and institutional shortcomings (Hall *et al,* 2001).

Sodic irrigation water and resource degradation: a case

Degradation of soil and water systems has been defined in "broad and vague" terms (Velayutham and Bhattacharya, 2000, p.41). Soils have always been viewed exclusively as the resource that supports plant growth for human demands. The definition of degradation is therefore, "the decline in soil quality caused through its misuse by humans." Broadly, it refers to the decline in soil productivity due to "adverse changes in nutrient status and soil organic matter, structural attributes, and the concentration of electrolytes and toxic chemicals" (*ibid*). This anthropocentric, commodity production based, management oriented definition of soil degradation is the most widely accepted and circulated one, despite minor differences in emphasis among these components in the definition (UNEP, 1982).

The agriculture sector is the largest water user in India. Water use for crop production alone is estimated to increase by about 140 cubic kms between 2000 and 2025 (See Table 1). While there is increasing ecological and political controversy over how this demand is to be met, there is increasing concern over the quality of water resources available for crop production.

Table 1

Demand for water (cubic kms.)

Sector	2000 AD	2025 AD
Domestic	33	52
Agricultural	630	770
Energy generation		
——consumptive use	7	15
——non-consumptive use	20	56
Industrial	30	120
Others	30	37
Total		
——with non-consumptive use	750	1050
——without non-consumptive use	730	994

Source: Stayamurthy *et al* (1995) quoted in Velayutham *et al* (2001) p. 102.

The qualitative changes in ground water reflect the changes in the values and attitudes, of policy makers, farmers, and agricultural scientists, to the resource. From being a source of protective irrigation, ground water has become the most crucial input in commercial crop production (Shah, 1993). While seepage (waterlogging / salinity) is a problem associated with canal irrigation, ground water irrigation leads to declining water tables and declining quality of aquifers due to leaching of pesticide and fertilizer residues (Ballabh, 2001).

Waters with high proportion of Na+ salts in the total salt concentration are termed sodic.[2] Ground water quality ratings from "good" to "highly alkali" are used in Indian agriculture.[3] It is estimated that 32 to 84 percent of total ground water in the country is of poor quality, ranging from marginally saline to highly alkaline (Gupta *et al* 2000). Poor quality waters are generally a feature of arid and semi-arid regions and coastal aquifers (Table 2).

The alkali waters are commonly seen in central and south-western parts of Punjab covering about 25 percent of the total area of the State. In Haryana, alkali water aquifers are found in almost 21 percent of the total area of the State (Gupta *et al*, 2000).[4] This picture of over-exploitation of ground water against the quantity of replenishable ground water is more acute at the district level.

Table 2

Ground water exploitation, quality, and annual replenishable recharge in areas underlain by saline ground water (EC >4 dS/m) in different States (1996-97)

State	Total area of the State ('000 Ha.)	Area irrigated by ground water# ('000 Ha.)	Area underlain by saline ground water (EC >4 dS/m)	Annual replenishable recharge (Mm^3 / yr)	Net irrigated area/ Net sown area (%) ('000 Ha.)
(1)	(2)	(3)	(4)	(5)	(6)
Haryana	4421	1343	1144	2452	76.2
Punjab	5036	2357	306	1351	92.9
Delhi	148	—	14	32	53.3*
Rajasthan	34224	3783	14104	4025	33.3
Gujarat	19602	2386	2430	2179	31.7
Uttar Pradesh	29441	8456	136	354	68.7
Karnataka	19179	833	880	1015	21.9
Tamil Nadu	13006	1369	41	-	52.7
Total			19344	11815	38.6*

#Tube wells + Other Wells

*Average for UTs and All-India average

Source: Col. 2,4 and 5 converted from Gupta *et al* (2000), Col.3 and 6 from Economic and Statistical Organization, Government of Haryana (2000)

> In six of the twelve districts of Punjab (Kapurthala, Jalandhar, Sangrur, Patiala, Ludhiana and Amritsar) and three districts of Haryana (Kurukshetra, Karnal and Mahendragarh) the utlization rate is above 100 %. Unfortunately, states or regions, currently facing the highest ground water depletion are agriculturally the most productive ones (Velayutham, *et al*, 2001, p. 103).

Though natural resource degradation caused due to exploitation of these poor quality waters is being checked with several technologies, there is increasing concern about stagnating productivity growth in Punjab and Haryana, the leading green revolution States in the country[5] (ICAR, 1998, Sinha, 2002). It has been argued that stagnating rice productivity in these States is the result of declining soil fertility (Abrol *et al*, 1997).

Irrigation with poor quality waters damages the soil and crop production capacity of the soil in three major ways: by *increasing salinity, making the soil alkaline,* and *bringing toxic hazards.* Ecologically, the most significant and long lasting impact of poor quality waters is through the build up of alkalinity in soils.[6] Irrigation with sodic waters containing high Na^+ (compared to Ca^+ and Mg^+) and high carbonates and bi-carbonates (CO_3^{2-} and HCO_3^-) leads to high alkalinity and sodium saturation in the soils. In the natural monsoon cycle, high levels of water penetration over two to three months (July to September) which exceeds the evapotranspiration allows considerable leaching of salts from the soils. Therefore the sodicity build up due to irrigation with poor quality water is a balance between the cycles of irrigation induced salt precipitation and fresh rain water dissolution and leaching of salts. With more than four to five years of sodic water irrigation, the soils attain a quasi-stable salt balance, and thereafter the build up of pH and ESP is very slow.[7] Thereby even the sodic water and the alkalinity of the soil maintain some semblance of balance. But this depends on the cropping pattern followed in the area.

In the rice-wheat cropping system (R-WCS) the ESP values in the soil are 2.6 adj.RNa indicating greater soil deterioration compared to other crop rotations irrigated with sodic water. It is noted that the build up of ESP and pH is sharp under rice based cropping system, especially in the upper soil layers (Gupta *et al* 2000, p. 173, Gupta and Abrol, 2000, p.278-79). This is mainly due to the larger number and greater depth of irrigation water applied for rice compared to other upland crops like cotton, maize and pearl millet in rotation with wheat (Gupta *et al*, 2000). In the rice-wheat rotation regions in arid and semi-arid agro-climatic zones, the opportunity for sodic / alkali waters to penetrate deeper is reduced due to reduced infiltration (hard pan formation). Thereby the alkali waters induce further sodicity in the upper layers when the salts get concentrated due to evapotranspiration. This high sodicity (ESP build up and pH) in the upper soil layers contradict theoretical predictions that ESP build up will be lower in the upper layers because of higher leaching factors attained in these layers (*ibid*). Therefore the "*rice-wheat system is not usually recommended for sodic irrigation*" (*ibid*, p. 166).[8]

Despite certain knowledge that rice-wheat cropping systems irrigated with sodic waters will increase the sodicity of the soils, the farmers in the

Punjab and Haryana states, egged on by a favorable price policy continue to cultivate rice and wheat. We should recall that rice cultivation in the sodic / alkaline soils of these states was recommended as part of the gypsum-based technology package for reclamation of alkaline soils (Prashad and Yadav, 1981).[9]

Technology and policy for reclamation of alkaline soils

In sodic (alkaline) soils and in areas underlain with sodic waters, farmers prefer the R-WCS because both rice and wheat are relatively more tolerant to sodicity (Gupta and Abrol, 2000). This is also *the recommended cropping pattern in the initial years of reclamation programs in* alkaline soils. In gypsum ($CaSO_4$) based reclamation, the requirement of ponded water conditions for optimum rice growth promotes the build up of CO^2 and leaching of salts resulting from the exchange of sodium with calcium (*ibid*). For reclamation to take place, water must pass through the soil profile to remove the sodium and de-sodicate the soil profile (*ibid*, p. 277). Though the yield of rice and wheat improve in the initial years, due to desodification of the soil, in the later years rice yields decline because of a decline in P levels (which is normally not needed in the irrigated R-W rotations in Natrustalfs), and standing water cannot be maintained because of improved infiltration due to the reclamation process (*ibid*). But these leaching processes and better infiltration gradually render the ground water increasingly sodic by accumulating the leached down Na^+ ions in the subsoil layers.[10] Thus, the irrigation cycle with sodic water commences in the R-WCS and this in the long term increases the soil pH and ESP of the surface layers more than the subsoil layers (Gupta and Abrol, 2000). Agricultural science has evidence that degradation (sodicity / alkalinity) is high in R-WCS, compared to soils growing other upland crops where standing water is not required (thereby eliminating excessive ESP build up in the upper layers of the soil) (Bajwa and Josan, 1989).

In both Punjab and Haryana, the dominant cropping pattern is rice-wheat (ICAR, 1998). This is the case in canal irrigated, water logged, saline soils and in ground water irrigated, alkaline soils where ground water table is declining. The significant increase in the share of oilseeds in Haryana is almost a direct consequence of the gypsum technology used as soil amendment in alkaline tracts. Punjab and Haryana have become predominantly rice-wheat tracts, with little or no pulse crops and hardly any of the traditional *kharif* oilseeds to augment the loss in soil organic matter. The reduction of organic-carbon content in soils has significantly reduced water and nutrient holding capacity of the soils. Moreover, beneficial soil organisms such as bacteria or fungi, earthworms, etc. are lost due to loss of organic-carbon content of the soil. In the rice-wheat tracts of Haryana and Punjab, organic-carbon content is now less than 0.2 percent (ICAR, 1998, p. 27).

In Haryana for instance, alkaline soils and waters have been treated with several reclamation measures, gypsum based technology being the most widely adopted and organizationally established, with research and extension support, Central and State Government subsidies for gypsum, public sector land reclamation organizations, and other institutional support such as credit for tube well installation, quick access to and subsidized electricity and diesel. Thereby, the Social Audit on Reclamation of Salt Affected Soils (ICAR, 1999) makes an explicit recommendation that "to encourage reclamation programs, tube well irrigation is a basic pre-requisite" (ICAR, 1999, p. 68). Yet, other research evidence discussed above tells us that Punjab and Haryana need to reduce tube well irrigation and R-WCS especially in areas underlain with poor quality waters.

Technocentric production solutions for reclamation of alkaline soils rely on gypsum application and increasing irrigation with the same sodic water to enable standing water that can leach down the salts and allow rice cultivation in this standing water. The scientific concern for degradation of natural resources and reclamation of degraded resources is couched within the administrative rationale of the agricultural sector, where increasing commodity production becomes the one and only given objective. Farmers and their perceptions or the ecological value of these resources, over and above the economic value are marginal concerns in this massive agricultural research and development establishment.

Farmers: "the accused"

The verdict of experts, favoring 'repeat application' of gypsum is a case in point (Raina and Sangar, 1999). The scientific research organization responsible for research on salt affected soils, the Central Soil Salinity Research Institute (CSSRI) of the ICAR, has recommended a one time application of 12-15 tons of gypsum per hectare, along with the other components in the package of practices for the improvement of alkaline soils. Given this recommendation and the amount of gypsum sold in Haryana since 1973, for land reclamation, the Central Government requested the State in 1994 to assess if the subsidy on gypsum was still necessary (Ministry of Agriculture, 1994).[11] The State Government organized a meeting to discuss the need for repeat application of gypsum *vis-à-vis* need for subsidy on gypsum for amendment of alkaline soils and treatment of RSC waters used for irrigating crops. The meeting, attended by scientists from SAUs, representatives of Land Reclamation and Development Corporations of different States, State Departments of Agriculture, and experts from CSSRI, affirmed the need for repeat application of gypsum (and therefore the Central Government subsidy) in the States of Haryana and Punjab. The basic arguments were that:

1. Farmers have used lower than the recommended dose of gypsum in reclamation of their soils, with the result that the soils have been partially reclaimed.
2. Many farmers in the arid and semi-arid regions of the country use alkaline waters which contain residual sodium carbonate which upon use turned the soils alkali, necessitating use of amendments on a recurring basis (CSSRI, Letter No. 2-4 (PA)/94, dated 18/4/94).

Moreover, in the National Oilseed Production Program, gypsum is being used as a fertilizer input to supplement 'sulphur' requirement of the oil seed crop. This scheme is also operated under the aegis of Agriculture Department, Haryana and a 90% subsidy is being offered to the farmers to improve the productivity of the oilseeds in the State (HLRDC, 1997).[12] Despite all the scientific evidence against irrigation with sodic waters (especially for R-WCS) the soil amendment, gypsum, which needs standing water and rice crop as part of the gypsum technology package was re-recommended for these States. Organizations like the Haryana Land Reclamation and Development Corporation (HLRDC), whose very existence is based on the procurement and sale of gypsum, was given a fresh lease of life with this recommendation by the experts for repeat application of gypsum. Expertise and the agricultural administration play their own complacent role in this vicious circle of irrigation induced soil degradation.

Discussions with farmers reveal that they are acutely conscious of the increasing sodicity of soil and water, and declining growth rates of productivity–especially for rice. Changing the cropping pattern, "bringing maize and gram back" is a recommended solution. But farmers face a narrow range of profitable options, especially in the wake of seasonal debts to be cleared. Conservation, in this case involving massive changes in the use of poor quality irrigation water, also involves

> high transaction costs ... in negotiations between farmers and non-farmers or among farmers, uncertainty about the available farming options, and great difficulty and low value of conducting small scale trials to test some of these options (Pannell, 1998).

It may seem strange, that despite the knowledge of partial application of the gypsum amendment by farmers little social science research has been attempted to understand the reasons (or suggest solutions) for this problem.[13] What is the tenacity of this vicious circle (of gypsum-sodic water irrigation-rice cultivation-ESP accumulation-wheat cultivation-sodic water irrigation)? Farmers stand accused, by this massive agricultural administration and expertise, of "using lower doses" of the amendment and of "irrigating with alkaline waters." What are the options available to these farmers, thus accused of irreverence to the dictates of agricultural science and cornered by productionist policy regimes?

The rapporteur's report of the session on "technology and environmental management in agriculture" at the 57th Annual Conference of the Indian Society of Agricultural Economics, held at G.B. Pant University of Agriculture and Technology, Pantnagar (UP), in December 1997, highlights the following research directions:

a. research studies on farmer's perception in managing natural resources;
b. research on local institutional arrangements and their capacity to absorb available technologies for managing agricultural environment;
c. review the rigid Government procedures and political interference in the conservation of natural resources;

d. explore the environmental protection legislation in agriculture—especially multi-disciplinary studies to set safe minimum standards for environmental pollution and develop regulations/mechanisms to enforce them;
e. land-use planning according to the land capability classification;
f. institutionalization of ex-ante environmental impact assessment, including both positive and negative aspects of the proposed technology (Joshi, 1998, p.19-22).

The institutionalization of the agricultural sciences, especially its relationship with its social and ecological constituencies, make it unlikely that our agricultural research and development organizations will take up any of these suggestions for research and environmental management in the agricultural sector.

Agricultural policy and the administrative rationalism of natural resource bureaucracies

Commodity production concerns articulated in policies and decisions in agricultural research organizations, are the institutions (rules of the game) that govern the organization and conduct of soil and water research.[14] This commodity production focus is justified by the view that"problems of rural poverty and hunger,"the ultimate social goals of agricultural research, are largely"problems of production" (Altieri, 1987, p.89). Modern agricultural S&T systems and their patronage come with well-defined research and development policies. In these systems of patronage, the patron's expectations about research and development goals are translated to research decisions. Scientists, in their capacity as research managers augment the patron's capacity to make decisions about agricultural policy and research policy. The magnitude of agricultural output is then the evidence of successful science, while the processes of production and consequences of these production processes are addressed again within the same technocentric mode. In order to ensure continuation and increase in funding/support the community of experts provide evidence of achievements that meet the patron's research and development goals. National policy of food security, translated into the expert's goal of increased yields and legitimized by the economist's estimation of returns to investment in research, summarizes the agricultural research effort in most less developed countries.

The organization of agricultural science and technology reveals an implicit hierarchy in the generation of knowledge and technology, as well as the dissemination and utilization of this technology in society. It is the expert, the agricultural scientist or research manager who makes decisions in the interest of public welfare. Here, the service or mission of the agricultural research organization is clearly defined– it could be national food security, export competitiveness, or more specifically, land saving technologies, etc. Decision-making here, seeks no democratic legitimization, despite the fact that several sectors of the society are affected by the technologies generated by the research organization. A few experts and their corresponding sub-patrons (bureaucrats and politicians) in the Government make all decisions. Participation of some elite non-expert groups or representatives of groups is practiced to a limited extent in some applied and adaptive research programs. But this elite participation is cosmetic and does not influence research decisions in any major way (Jasanoff, 1990, and Foirino, 1996).

Decisions are made about how the services of science can best be utilized to enhance or achieve the public good or mission defined for the organization. Thus, the research organization is meant to deliver, through "the rational management in the service of this clearly defined public interest, informed by the best available expertise. Managers and experts have well defined roles within the administrative monolith" (Dryzek, 1997, p. 74) (See Box 1). A key instrument deployed effectively in the decision-making mode of administrative rationalism is the complacency of the bureaucracy and expertise. There is concern (about food production targets, declining growth rates of R-W productivity, water quality, soil salinity and alkalinity, etc.), and reassurance (the promise of technologies such as salt tolerant transgenic R-W varieties, the need for repeat application of gypsum, the need for new levelers and new planting methods, etc.). Even in natural resources research the externalities of the production oriented agricultural research and production policies are either ignored, or assumed to be located in the ill-disciplined socio-political sphere, beyond the control of the rationally administered and disciplined world of science. The experts, who recommend repeat application of gypsum in areas irrigated with sodic waters, therefore, are justified in not asking how farmers adopt reclamation technologies, or why they only partially adopt the recommended technology. The hierarchy of the experts (who represent and work for achieving the State's public welfare goals), the people and the ecology, is maintained perfectly within the agricultural research administration.[15]

Sustainability and direct concerns about natural resource degradation (due to modern agricultural science and technology inputs or agricultural policies), are handled by well defined agencies of the administrative State. Thus sustainable agriculture is defined as another problem solving exercise within the existing framework of administrative rationalism. When the administration of agricultural science and technology generation is viewed as yet another government service, accountability of the expert(s) to the people and to nature to achieve sustainable agriculture, is no greater than the accountability to achieve the production/productivity maximising goals of conventional agriculture. There is, therefore, no apparent need for ecological or social feedback that can alter agricultural research decisions or decision-making processes.

Ensconced within the safe and convenient model of governance, of administrative rationalism to be specific, agricultural science can claim to cater to the demands for sustainable agriculture, without changing any of its fundamental discourses in the organization, conduct and performance of agricultural science. The world of agricultural science is assumed to be free from politics. It is responsible only for solving technical (as distinct from social) problems- be it for conventional agriculture or sustainable agriculture. Accordingly, nothing is serious enough to warrant fundamental changes in the way agricultural policy, science, production or food systems are organised.

This administrative rationalism has however led to the intellectual and institutional isolation of the agricultural sciences. Intellectually, the agricultural sciences the world over, are isolated from other liberal arts and sciences in the general universities. The agriculture sector now has its own scientific research organizations, its own professional, trade and social organizations, and its own political system (Mayer and Mayer, 1976, p. 87). We agree with the Mayers' that the formidable strength of this agricultural

Box 1
Dryzek's Discourse Analysis of Administrative Rationalism applied to Agricultural Science

1. Basic Entities Recognized or Constructed	Crucial counterparts in agricultural science
• Liberal capitalism	- assured private markets / profits
• Administrative State	- protectionist policies, regulated markets, public investment and infrastructure
• Experts	- institutionalization and authority
• Managers	- bureaucratic organization & management
2. Assumptions about Natural Relationships	
• Nature subordinate to human problem solving	- pervasive commodity-based research and production-productivity orientation
• People subordinate to State	- most favorable tracts, most responsive crops to meet national objectives
• Experts and managers control State	- more and new bureaucracies to manage disaggregated compartmentalized problem components.
3. Agents and their Motives	
• Experts and managers	- exclusive professional / career advancement interests
• Motivated by public interest, defined in unitary terms.	- Cost-Benefit Analysis in project appraisal, Prioritization of research programs.
4. Key Metaphors and other Rhetorical Devices	
• Mixture of concern and reassurance	- food security *vs.* transgenic crop varieties or environmental research
• The administrative mind	- science as yet another Government service - reluctance to face complexity.

Source: Adapted from Dryzek, 1997.

complex is difficult to break or reform. Any attempt or even suggestion for institutional reform, for changes in the rules of the (isolated and complacent) game, is seen as 'external threat,' and is, therefore, to be countered with scientific morality. In cases where scientific morality may fail, as in case of extreme resource degradation, consequent poverty or starvation, there is always *the excuse of "inadequate information." That this justification is backed by the disciplinary constructs of neo-classical economics and the commodity oriented policy regimes makes it all the more formidable and difficult to challenge.*

Conclusions

This paper analyzed the case of water quality—sodicity—to explore the relationship between agricultural policy, science and resource degradation. It presented scientific research evidence of further degradation of soil and water resources when R-WCSs are subject to sodic irrigation. It explained how the hierarchy of expertise and complacency of achievement within prescribed policy goals for increased production, helps science to accuse farmers (who are already cornered by the policy regime, the semi-arid climate and marginal quality soil/water resources) for not adopting recommended solutions.

Farmers in their absolute dependence on commodity production have no recourse but to seek the most salt-tolerant crops (rice and wheat), the most accessible and subsidised amendments or inputs, and price protection. It is not without reason that farmers in Haryana and Punjab lobby for more subsidies and price protection; their soils, once rich and fertile, are becoming increasingly degraded, their waters increasingly alkaline or saline. Science then becomes an ally, one convenient component in this convergence of motivations to maintain the political lobbying by the farming community and to further degrade natural resources. Concerned agricultural sciences informed by and in close interaction with the social sciences, must now lead this debate about the relationship between technology and policy. An important recommendation to ensure food security in India, is to give up the "1970s model of agricultural development," based exclusively on cereal production, agricultural research to test and release varieties (especially of wheat and rice), and subsidies and price supports that encourage mindless exploitation and degradation of natural resources (Sinha, 2002). The agricultural research system has to change, moving out of this institutional inertia, to face the complexities of resource degradation and agricultural policy. Science can help farmers deliberate various policy decisions and technology options that affect their livelihoods and the status of their natural resources. But this demands institutional and organisational changes in the agricultural science system.

Given the history and institutionalization of agricultural science it is an uphill task to seek an ecological sensitivity in agricultural science and the technology it generates. The response of agricultural science has been in line with the policy demand for national food security, translated as increasing production and productivity, especially of major irrigated cereals, while maintaining a strictly anthropocentric definition of resource degradation. The political and economic legitimization of science and technology is to date built on the foundation of "expert opinion based on objective facts." The administrative rationalism of natural resource bureaucracies the world over, is evident in the "institutional and policy hardware," which have a very tangible existence (Dryzek, 1997, p.75). This hardware then becomes a major barrier to incorporating local knowledge into natural resources research and development effort, whether local knowledge is not identified, is implicit in the research project, or is explicit in a neo-populist participatory fashion (Blaikie *et al*, 1997). This hardware characterizes farmers and the population in India as "mouths to be fed." Policy and science then refuse to see these "mouths" and their absolute dependence upon and relationship(s) with their natural resources. The concern for resource degradation is countered effectively by the rhetoric of population explosion. Yet, the cultivation of (relatively low yielding, extravagantly priced) basmati rice using poor quality waters in the breadbasket of the country belies the expert's concern about the hungry millions. The first year of the new millennium in India is marked by 60 million tons of food grains stored by the state, over 300 million people undernourished or starving, 187 million hectares of land in various stages of degradation, declining water table and deteriorating quality of surface and ground water.

Conservation and sustainable use of water demands institutional reform in all the relevant actors and agencies, especially, increased and democratic participation of stakeholders in all policy and technology decisions (Raina, 2000). That science and technology have had their share to contribute to the growing water crisis is now axiomatically accepted. The replacement of hedonistic productionism with tempered sustainability as the philosophy of research entails the replacement of commodity focus with natural resource focus. There have been several pointers to a new knowledge policy for natural resource use and conservation that will begin with adequate decentralized indicators of sustainability. Are agricultural science and agricultural policy open to these indicators? Will research managers and policy makers give up existing hierarchies and actually heed participatory information and processes? The transition to policies and scientific research for sustainable agriculture is bound to be slow and painful. In practice, the relationship between policy and science in the agriculture sector is one that is in the order of coalition building, negotiation and persuasion in the 'competitive arena of politicking' (Gass, Biggs and Kelly, 1997). Policymaking and scientific research must be ecologically and democratically informed to conserve the quality and quantity of our water resources.

Notes

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1. The philosophy of productionism that informs modern agricultural science states that continuing enhancement of production is the guiding principle for agricultural science. This belief in technocentric productionismand continued moral pride in production is a form of self-deception (Thompson, 1995, p. 70). Technocentric productionism with "headlong and unreflective application of...technology for increasing production, is anti-environmental" (*ibid*) and anti-democratic.
2. The quantity of salts dissolved in irrigation water, measured as salt concentration in mg/ litre or meq / litre, or in terms of the electrical conductivity of the water(mmhos/ cm or dS/m) is the criterion used to define water as fresh, brackish, or saline. Saline water contains cations like Na+, Ca2+ and Mg2+ and anions like Cl-, $SO_4$2-, HCO_3-, and CO_3-. Water with high concentration of the carbonates and bicarbonates of Na+, which lead to a steady build up of Exchangeable Sodium Percentage (ESP) in the soil are called sodic or alkaline waters (Gupta et al, 2000).
3. Table: Grouping of poor quality waters

Water quality		EC_{iw} (dSm^{-1})	SAR_{iw} (mmol $litre^{-1}$)	RSC (meq $litre^{-1}$)
Main	Subclass			
Good	—	<2	<10	<2.5
Saline	Marginally saline	2-4	<10	<2.5
	Saline	>4	<10	<2
	High SAR saline	>4	>10	<2.5
Alkali	Marginally alkali	<4	<10	2.5-4
	Alkali	<4	<10	>4
	Highly alkali	Variable	>10	>4

Source: Gupta *et al* (2000), p. 166 and Gupta *et al* (1994), p. 6.
EC_{iw} denotes Electrical Conductivity in irrigation water, SAR is Sodium Adsorption Ratio and RSC is residual sodium carbonate content in the water.

4. For instance, the two districts, Karnal and Kurukshetra with almost 100 percent of the *kharif* area under rice and 97 percent of *rabi* area under wheat, have an irrigation intensity of 99 percent (GIA/ GCA) (Economic and Statistical Organization, 2000). The groundwater exploitation rate (net annual draft as a percentage of net annual recharge) in these two districts (121% for Kurukshetra and 130 percent for Karnal) is the highest in Haryana. Tubewell irrigation accounts for 95 percent of irrigated area (tubewells + canals) in Kurukshetra and 85 percent of irrigated area in Karnal (Tanwar, 1998). The area under alkaline soils is also correspondingly high in these districts, accounting for 14.63 percent and 26 percent respectively of total area under alkaline soils in the State (SDOAH, 1996). The average depth of the water table in Kurukshetra and Karnal has fallen by 10m. and 3 m. respectively during the period 1974-1998. (*ibid*). Increasing depth of water table in these semiarid districts directly implies increasing sodicity of the water that is pumped up for irrigation.
5. For district-wise compound growth rates of productivity of rice and wheat in Haryana and Punjab over the 1970s, 1980s and 1990s see ICAR, 1998 (Tables 3 and 4, pp. 14 and 17).
6. As in alkaline waters, the alkaline soils also have high RSC levels and have high ESP.
7. The increase in exchangeable sodium percentage (ESP) adversely affects soil physical properties, including water infiltration and soil aeration. On drying the soils become very hard and on wetting the soil particles get dispersed and clog the pores that affect root respiration and development. This results in yellowish appearance of the wheat crop, scorching and leaf burning at the early seedling development stage, etc (Gupta

et al, 2000). High pH and ESP also contribute to nutrient deficiency, especially of Nitrogen, Calcium and Zinc

8. The ESP build up in rice crop lands is an additional burden leading to quality deterioration of the saline and sodic waters as well as the soils in the area. A wheat crop receiving 5 irrigations (each 7cms) with saline water of EC_w 4 dS/m, will result in the addition of about 9 tons of salt / ha (Gupta *et al*, 2000,p.163).
9. The essential components of the gypsum based "package of practices" for crop production are:
   i. Land levelling and bunding,
   ii. Assured irrigation preferably through installation of tubewells which also acts as a vertical drainage measure,
   iii. Application of soil amendment (gypsum) in right quantity and right manner,
   iv. Use of appropriate nutrient management approach such as 25 percent more N fertilizer than recommended dose, application of micronutrients like zinc,
   v. Cultivation of short-statured, high yielding salt tolerant rice and wheat varieties,
   vi. Judicious water management, appropriate agronomic and cultural practices and, Rice-wheat-dhaincha (as a green manure crop) cropping system at least for the first 3-4 years.
10. The need for further research on leaching requirements, efficiency and bypass, monitoring of key chemical parameters such as ESP and EC in the different soil layers and saturation extracts, has been emphasised (Kijne *et al*, 1998).
11. Subsidised sale of gypsum to farmers, initiated by Haryana State, was boosted with Central-State joint subsidy scheme for gypsum since 1985.
12. The oil seed technology mission was initiated in 1986,mainly to make the country self sufficient in edible and non-edible oils and to minimize the export of the same, Haryana a non traditional oilseed growing state was taken up as a part of National Oil Seed Development Programme in which 180 districts of 17 states were taken up.The country was divided into 8-zones and Haryana was covered under zone 1 with H.P.,J&K and Punjab. Haryana reported a five-fold increase in oilseed production in 1988-89 (HAU, 1991, p.38).
13. There are however recommendations that such sociological analysis be undertaken with the participation of the farmers/ farming communities with decentralized and accurate information on status of resources and farmers (ICAR, 1999).
14. 'Institutions are sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups'(Edquist and Johnson, 1997, p. 46). Institutions are the "working rules for going concerns"; institutions define organizations (Bromley, 1985).'(O)rganizations are formal structures with an explicit purpose and they are consciously created.They are players or actors' (Edquist and Johnson, 1997, p.47). The distinction between organizations and institutions is important to understand organizational and institutional change.'If organizations are the players and institutions the rules, then how are the rules changed?' (*ibid* p.57).
15. In this context it is worth asking what has changed in the social capital for natural resources research and development in India, and whether the NARS is aware of the gains or losses of social capital (See Biggs *et al*, 1997).

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