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SUBJECT II

TECHNOLOGY AND ENVIRONMENTAL MANAGEMENT IN AGRICULTURE

Agricultural Technology and Environmental Quality: An Institutional Perspective*

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The green revolution strategy in India has worked exceptionally well in increasing food production and food security, saving forest and land resources owing to improvement in productivity, creating farm and non-farm employment opportunities and setting the stage for dynamism in the agrarian economy. However, the achievements of the green revolution were largely confined to the well endowed and irrigated areas. Such a localised impact of bio-chemical technologies accentuated disparities between irrigated and dryland areas. This issue has been studied and debated extensively.[1] The environmental consequences of agricultural technologies and the institutional arrangements governing the management of natural resources to adopt these technologies, however, have received little attention.[2] Given the need to increase agricultural productivity so as to feed the growing population, an understanding of interplay between technical and institutional arrangements is important for better policy formulation. This paper examines some of the environmental consequences of bio-chemical technologies and argues that these problems are associated with inadequate understanding and investment in evolving appropriate institutional arrangements.

I

INSTITUTIONAL PERSPECTIVE ON NATURAL RESOURCES AND TECHNOLOGY

The key concepts used in this paper to understand the environmental consequences of agricultural technologies are institutional arrangements, property rights structures and authority systems. These concepts have their roots in institutional economics (Commons, 1950; Bromley 1991). Natural resources,like land and water are managed and controlled through technical and institutional arrangements. The technical arrangements provide tools and knowledge or technological components which define how land, water or other resources are used as factors of production. The institutional arrangements define who can control the resources and how the technique is applied. Technological and institutional arrangements must complement each other if resources are to be used efficiently and sustainably (Gibbs and Bromley, 1989). The nature of institutional arrangements defines the extent of property regime over land, water and related resources. A property regime is a system or a set of institutional arrangements or working rules of rights and duties characterising the relationship of co-users to one another with respect to a specific natural resource (Bromley, 1991). Property rights in resources exist either under state property regime (where the secure

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claim rests with government) or private property regime (claim rests with individual or corporation) or common property regime (individuals have claims on collective goods as members of organised group) or open access (or no property regime with no secure claims) (Bromley, 1991). The basic requirement for any property regime is an authority system (for example, Central or State Governments/panchayats/resource development committees/user groups) that can guarantee the security of expectations for the rights holders (resource users). When the authority system breaks down, a particular resource regime starts degenerating. Under such a situation, new institutional arrangements are used to define the resource regimes over natural resources and the authority systems protect the interests of those (resource users) holding the rights under a particular regime.[3]

In the Indian context most of the agricultural technologies and specifically crop-centred or seed-centred or resource intensive technologies[4] are adopted by the individual farmers under private property regime and the incentives in terms of subsidised inputs and diffusion of technological components have also been targetted towards private landowners. Individual cultivators under private property regime may over-exploit land, water and other resources and can potentially create spatial and temporal damages.[5] Institutional arrangements play a much greater role in the adoptation of resource conservation technologies where collective actions are required for sustainable development of agriculture and other natural resources oriented programmes. Most agricultural technologies including resource intensive and resource conservation technologies have an element of interdependence between (among) farmers or between (among) users. In an interdependent situation third party effects are important, transactions costs are significantly high, human and ecological concerns are serious and relevant unique damage function is difficult to estimate, irreversibilities might be important and markets are generally missing if intergenerational issues are involved. With full ownership, the owner can prevent others from using, benefiting from or damaging the resource without making compensation. When such uncompensated benefits or damages occur, these are called spill over effects or externalities or interferences. Whenever property rights are not clearly defined or enforceable, externalities or divergences between private and social costs or third party effects arise (Bromley, 1991). It is these market and policy failures which provide the rationale for improvement of institutional structures and property rights within interdependent situations.[6] This also becomes necessary to make sure that the current technical and institutional arrangements are not counterproductive. To this end the concepts discussed herein are used to examine the environmental consequences of agricultural technologies.

II

RESOURCE INTENSIVE TECHNOLOGIES

Land and Water Degradation

Investment in canal and groundwater irrigation development has enhanced the productive capacity of land resources which enabled the nation to achieve steady agricultural growth. However, impacts of irrigation systems, particularly of canal irrigation, are besieged with a number of environmental problems. Subsidised canal irrigation and subsidised electricity (in some cases free) for tubewells, remunerative output price support, availability of high-yielding varieties (HYVs) seeds and higher returns encouraged the farmers to opt for water intensive crops. Cases of rise in the watertable and soil salinity in some command areas of Punjab, Haryana, Uttar Pradesh, Maharashtra, Gujarat, Tamil Nadu and Andhra Pradesh have been reported due to inadequate provision of drainage and shift in the cropping pattern in favour of water intensive crops like rice, sugarcane and wheat (Joshi and Agnihotri, 1985; Gangwar and Toorn, 1987; Joshi and Singh, 1991). Nearly one-fourth of the cultivable command area under all canal projects in India is suffering from waterlogging and soil salinity (Dhawan, 1995). The adverse effects of irrigation induced soil salinity and waterlogging are evident at the farm level in the form of decline in crop productivity, reduction in input use levels, restricted choice of crops, land abandonment and low farm income.[7] Also investments in major irrigation projects have long gestation period and it takes considerable time before direct production impacts starts appearing (Gulati *et al.*, 1995). The economic gains from surface irrigation in many projects do not commensurate with the large public investments and subsidy given to the farmers (Ahmad and Singh, 1986; Mishra, 1986; Chambers, 1988; Gulati, 1989; Vaidyanathan, 1994; Dhawan, 1995).

Weed infestation and water borne diseases are also serious environmental problems in canal irrigation projects (Joshi and Agnihotri, 1985). Water hyacinth, cattails, water lettuce, water fern and tap grass appeared to be most threatening weeds in various states at the canal heads and in minors, distributories and farmers' fields. Aquatic weeds threaten irrigation and drainage system, fisheries, navigation, and directly or indirectly aid the growth of several harmful insects, for example, termites, ballworms, pigeonpea borers, katra, white grubs, shoot fly, root aphids, borers and painted berg, etc., and damage the crops.[8] Increased incidence of malaria and filaria has become common in some canal irrigated areas (Rai, 1983; Ramalingaswami, 1984; Ahmad and Singh, 1987).

It is not that the irrigation induced land degradation occurred in the absence of technologies which could have prevented or reclaimed waterlogging and soil salinity. Studies have clearly suggested that technologies for reclamation of saline and waterlogged lands are financially viable at individual farm level (Joshi and Agnihotri, 1982; Joshi *et al.*, 1987; Tyagi *et al.*, 1995). Community approach through farmers' participation can effectively manage these problem soils (Joshi, 1997). Research has, however, shown that the conditions and the institutional foundation for community approach are generally absent for such efforts to succeed (Shah and Ballabh, 1986). Government interventions to promote reclamation technologies flow through input support and extension of subsidy. However, most of these interventions are targetted towards individual farmers, whereas the problem of waterlogging and soil salinity and their management go beyond the boundaries of private property structure. While group oriented technologies to manage problem soils are infrequently adopted, appropriate institutional structures need to be formulated to organise the farmers for collective action. Farmers' co-operation can play a crucial role in managing the problem of irrigation induced land degradation and in exploiting the full potential of irrigation (Datta and Joshi, 1993). The technological components and improved delivery system for inputs may be organised through co-operatives or users' groups (Joshi, 1997). These institutional arrangements can effectively transform the private incentive to the collective ones as well as the private property can be managed as common pool resources under community management system.

The physical and technical attributes of canal irrigation put water resource under the category of common pool resources which is used by numerous farmers under the private property regime. Efficient and equitable water distribution of canal water among different categories of farmers (small or large, powerless or powerful, locationally and economically advantaged or less advantaged, etc.) depend upon technical and institutional arrangements. These include rehabilitation of existing canal irrigation system in terms of modifying the water delivery system, regular operation and maintenance of the created system, conjunctive use of surface and groundwater, careful design of cropping patterns, optimal allocation and appropriate scheduling of water, and greater enforcement (or changes, if needed) of the rules and regulations governing access to irrigation water by individual farmers (Chambers, 1988; Vaidyanathan, 1994). Until recently, the decision-making environment, and incentives facing farmers and irrigation officials were not dealt with sufficiently. It is, however, now recognised that these technical solutions are not sufficient, involvement of the farmers is key to improve management effectiveness. In India the impact of water users' associations in terms of implementing the equity based institutional arrangements are mixed. They are functioning effectively in some areas and have failed in others. The key reason for the successful water users' associations may be attributed to effective functioning of technical and institutional arrangements at the main canal system, below the outlet and at the community/farms levels (Chambers, 1992; Patil and Lele, 1996; Marothia *et al.*, 1989).

The use of the groundwater accounts for over half of the total irrigated area in India. The expansion of groundwater irrigation was largely due to improved drilling and lifting technologies, lower per unit cost of water pumped, massive rural electricity programme, liberal credit for exploring groundwater and subsidised supply of electricity. The productivity of irrigation in conjunction with chemical fertilisers and HYVs is much higher for groundwater as compared to canal irrigation, mainly due to less wastage of water and flexibility to adjust the timeliness and quantity of water distribution to the crops. Until recently the government's policies of supporting and promoting private groundwater development were widely acclaimed time and again. However, there is now a growing concern that the existing policies, if continued may lead to over-exploitation of groundwater particularly in arid, semi-arid and hardrock regions of peninsular India (Shah, 1993; Dhawan, 1995; Vaidyanathan, 1996). Further, under the private property rights regime, water markets have emerged in many parts of the country (Shah, 1993). The individual farmers are more concerned with their private gains and costs, while completely ignoring the social cost of over-exploitation of groundwater resource (Joshi and Tyagi, 1991; Dhawan, 1995; Vaidyanathan, 1996). At the aggregate level only 50 per cent of the total utilisable groundwater is currently used. It indicates that considerable potential exists for the expansion of groundwater based agriculture. At the micro level, however over-exploitation of groundwater has been observed in many areas (Dhawan, 1995). In some areas even drinking water has become a problem due to the excessive use of groundwater in irrigation (Ballabh and Singh, 1997).

Efficient, equitable and sustainable use of groundwater can be achieved through designing technical arrangements relating to spacing regulations, identification of aquifer, size of pumps, control on the overall rates of exploitation and supporting institutional arrangements which include rights to water, land tenure, users' relationship, financial incentives. The traditional property rights structure dominated by private property rights needs serious rethinking for judicious use of groundwater. Ownership of groundwater is tied with the ownership of land in India, and the landowners have the right to extract the groundwater beyond any time until it is available (Singh, 1991). The landowner can use the groundwater and market it to other potential users and locations. Property rights to groundwater are complicated due to the fugitive nature of aquifer, the size of aquifers, the seasonal and secular nature of aquifers and the capability of more than one user to tap the same aquifer. Groundwater is thus neither a true open access resource because the ability to extract groundwater is limited by well ownership, nor common property resource because it lacks an identifiable group of users having co-equal use rights (Ciriacy-Wantrup and Bishop, 1975; Veeman, 1978). Research and administrative efforts are urgently needed to carry out exploratory studies on several aspects of water rights systems and their adoptability in different agro-climatic regions. The ecological, economic and equity gains with water rights systems could be much more higher than the investment in institutionalising these (Saleth, 1994). Legislative structures, equally important, to manage groundwater through appropriate local organisations and approaches may also help to minimise environmental and equity problems in the long run (Moench, 1994). Current financial incentives provided for power, diesel oil and credit need to be critically analysed in addition to developing new technical and institutional arrangements (Shah, 1993; Dhawan, 1986, 1995; Vaidyanathan, 1996). For example, groundwater can be efficiently managed through drip and sprinkler irrigation technologies under common property regimes if supported by use rules for water users. These technologies are being adopted on a large scale by private landowners. It is important to expand the manufacturing capacities of sprinkler and drip irrigation systems to meet the growing demand as well as to keep the prices under check so that the full benefit of the financial incentives could be passed to the farmers. There is an urgent need to reorient the existing technical and institutional arrangements for sustainable use of groundwater.

Chemical Inputs Use, Environment and Health Concerns

Fertiliser has become an essential input for increasing agricultural production. However, its excessive use could cause serious spatial and temporal external effects. Researches relating to the optimum combinations of fertilisers for different soils, agro-climatic conditions, crop and crop rotations under irrigated and unirrigated conditions have provided meaningful recommendations. At the aggregate level fertiliser consumption is skewed for different crops and regions, and in large part it is much lower than the recommended levels (Mruthyunjaya and Kumar, 1989). However, there are a few areas where fertiliser consumption has exceeded the recommended doses in spite of soil test carried out by the farmers (Sah and Shah, 1992). On the other hand, without testing the soils fertility structure in terms of macro- and micro-nutrients, the farmers have been using less than recommended doses of available fertiliser in several parts of the country. The results of some studies have confirmed that not more than 50 per cent of nitrogen supplemented through fertilisers is used for crop growth, even with the best agronomic practices. The remaining is lost in the soil system and percolates and thus contaminates groundwater in the poor quality water zones (Katyal, 1989; Katyal *et al.*, 1985). Although the current level of fertiliser consumption does not establish the relationship between its use and the increase in the concentration of nitrate level in the groundwater, reports are emerging from some parts of the country regarding its adverse effects (Joshi and Singh, 1991). Eutrophication of lake and river water bodies, nitrate pollution of groundwater, increased emission of gaseous, nitrogen and metal toxicities are the major fertiliser related environmental damages (Katyal, 1989).

Another problem regarding the use of fertiliser is the imbalance of the three primary plant nutrients, namely, nitrogen, phosphorus and potassium. Imbalanced fertiliser use is bound to not only adversely affect the growth of agricultural production, but also permanently damage the physical and chemical structure of soil. In addition, the increased incidence of growing deficiencies in micro-nutrients concentrations in several parts of India has been observed. The balanced use of fertiliser depends on soil types, agro-climatic conditions, crop rotations, price and non-price parameters (see Government of India, 1997). In fragile ecosystems or hill agriculture where water induced soil erosion is prominent, fertiliser serves as a potential source of point and non-point externalities. Landowners, non-landowners and multiple resources like waterbodies suffer from primary and secondary damages. Technical arrangements relating to soil, water and crop management at the farm levels have to be evolved and policies should be designed to encourage the balanced use of fertiliser to avoid on-farm and off-farm damages. Extensive soil testing facilities, availability of appropriate fertilisers, integrated fertiliser management through the use of judicious mix of organic manure, bio-fertiliser, green manure and chemical fertilisers for minimising adverse environmental effects and the long-term fertiliser price policy require urgent attention. The current research on bio-fertiliser is not applied by the farmers on a wide spread scale. More research and extension efforts are required to make these technologies commercially viable.

Negative effects of pesticides are matters of concern in the intensive agriculture zones of India, where it is widely used and poorly regulated. The agricultural sector accounts for about two-thirds of the total pesticides consumption in India. The application of pesticides across regions and crop is uneven and more than 50 per cent of the total pesticides is used only in cotton. Rice comes second in turn. The pests are becoming resistant due to the increased use of pesticide. This has resulted in a secondary pest outbreak because these chemicals also kill the natural enemies of pests, like birds, spiders and worms (CSE, 1985). Nearly 70 per cent of all pesticides consumed by Indian farmers belong to banned or severely restricted categories in the developed countries (CSE, 1985). The pesticide residues in soil may create a variety of hazards. Soil micro-organisms which cause break down of cellulose, nitrification, turnover of organic matter and other biological materials may be adversely affected by pesticides (Kalra and Chawla, 1981).

The toxic effects of pesticides and herbicides in the form of food and water contamination and pollution may adversely affect human and animal health and eventually influence their overall productivity. The health hazards to agricultural workers exposed to pesticides varies from the acute to chronic poisoning (Mencher, 1991; Dasgupta, 1993). The Indian Council of Medical Research (1993) conducted an extensive study covering all the states of India to examine the status of contamination of a variety of items including maize, mustard, cotton and seasame seeds, milk, canned fruit products, poultry feeds, vegetables, etc., associated with pesticides residues. This study clearly indicates that the samples far exceeded the tolerance limits of pesticides residuals in the case of milk, canned fruit products, poultry feeds and vegetables. Invariable presence of DDT and HCH was also found in samples of maize, mustard, cotton and seasame seeds, although the residue levels in most of these items were negligible. The private benefits of pesticides use should, therefore, be evaluated against these social costs. It has been estimated that only 10 per cent of the total foodgrains production can be saved from increased pesticides use (CSE, 1985). Once the health hazards and other costs are imputed these benefits appear too meagre.

Pesticides externalities are inter-spatial and inter-temporal in nature. Externalities associated with the cotton bollworm in Andhra Pradesh, for example, arising from increased resistance to pesticides were caused by over-use. Pesticide-resistant strains have spread from coastal to inland areas and from cotton to other crops, thereby creating migration externalities. The quantity of pesticides applied today by the farmer will have significant effects in many crop seasons in future (Kishor, 1997). Pesticides externalities have also serious third party effects in terms of food contamination, reduction of export potentiality and health hazards. To internalise the pesticides externalities at the farm level, effective implementation of integrated pest management (IPM) is required. However, application of IPM goes beyond the individual ownership boundaries and it needs collective action. The involvement of the government or farmers' groups is required to use IPM as public good. There are good reasons for the involvement of government, non-government organisations or farmers' groups, including the lack of well defined property rights for common pool resources and high transaction costs when large number of farmers or users are involved (Antle, 1994). With such institutional arrangements the problem of 'free riders' can also be effectively solved in the pest management area. These institutional arrangements in turn can create incentives for research organisations and scientists to develop IPM technologies and for farmers to adopt these technologies. Inputs from large scale research institutions and government agencies are required for the farmers' education, extension work, crop insurance schemes to persuade the farmers to adopt components of IPM technologies.

Well co-ordinated interdisciplinary research should be initiated to classify the existing agricultural technologies according to potential externalities problems in different agro-ecosystems to fill existing gaps in knowledge. Such research efforts will help in quantifying the relationship between agricultural production and human health risk. The existing research and extension systems are required to be restructured and research priorities and productivity need to be based on broader set of criteria. For example, development of pest resistant varieties and use of bio-pesticides would be beneficial in the long run to sustain natural resources base, even if it is less profitable in the short term. Strict regulation to monitor the quality of pesticides and use, imposition of appropriate economic and non-economic sanctions are also needed to be evolved and enforced. Increasing cases of rejection of consignments of food items meant for exports by the importing countries force us to adhere to the standards laid down regarding sanitary and phytosanitary measures.[9] This is a complex issue and needs correction at different levels. To identify the exportable items prone to pesticides a technical group may be set up to suggest on regular basis adjustments in technical and institutional arrangements at farm, research organisations and quality control levels.

III

RESOURCE CONSERVATION TECHNOLOGIES

While irrigation induced bio-chemical technologies remained confined to a few pockets, nearly 65 per cent of the cultivated area continued to be rainfed contributing 40 per cent of the total agricultural production. Low and erratic rainfall, heterogeneity and fragility are the basic attributes of the natural resource base in dryland areas. The repeated attempts to improve dryland agriculture through bio-chemical HYVs package suited to irrigated conditions could not make a visible impact in the rainfed areas due to the harshness of environment and the location specificity (Jodha, 1986). These efforts have shown considerable yield gaps between experiment stations and farm levels due to various bio-physical and socio-economic constraints. To overcome various constraints in dryland agriculture resource management and conservation technologies have been evolved and initiated in the early seventies (Jodha, 1986). The new varieties performed very well and absorbed growth promoting inputs under assured soil moisture situations or rainwater management (Jodha, 1986).

A large part of the rainfed areas in the country acutely suffers from soil erosion. The main reason for soil erosion is poor land cover and the continuous extension of cultivation to marginal land (or poor quality lands) in terms of shallow layers of top soils and low organic matters. Several agro-climatic regions under dryland areas are experiencing pronounced rainwater run-off that causes soil erosion. The farm level damages associated with soil erosion include the loss of productive soils, reduced crop productivity as well as temporal and spatial externalities. Spatial and temporal damages arise because the soil has both qualitative and quantitative characteristics. These damages generally extend to the entire area which may have complex integration with agricultural land, forest resources and forest lands, common grazing and wastelands and common water bodies. Furthermore, about 95 million hectares of degraded lands are spread in rainfed areas of the country. These degraded lands are managed and controlled under different property rights regimes in diverse agro-climatic settings in India. Traditionally, to enhance dryland productivity, domestic ponds or multipurpose tanks for life saving irrigation, fish culture, planting trees for food, fodder, small timber and grass cultivation for livestock farming and other development activities have been initiated and managed under different property regimes. Most of the degraded lands are community lands and are owned collectively by the village community or the local panchayats and are managed traditionally under common property regimes. Community wastelands have been subject to encroachment, privatisation and government appropriation due to ineffective institutional arrangements or absence or the breakdown of a collective management and local authority system, whose very purpose was to introduce and enforce a set of working rules of behaviour among villagers or resource users with respect to community lands utilisation. In this process community lands managed under common property regime have degraded into open access and created spatio-temporal externalities in terms of scarcity of fuel, fodder and small timber requirements for the rural poor (Marothia, 1989a; Marothia and Nandi, 1994; Kalla, 1996).

In dryland areas of the country the problem of soil moisture stress is serious. The development of techniques for dryland agriculture remained a neglected area until the early seventies. To increase land productivity of these areas, capital expenditure for improving soil moisture environment through bunding, terracing and shaping fields, creation of drainage facilities apart from *in situ* rain water management have so far been initiated. Diversification of economic activities by creating assets in non-credit activities such as animal husbandry, fisheries, agro-forestry, tree plantation programmes, has also been introduced in the regions where soil moisture stress is a permanent problem. These activities become components of the drought-prone area programme, the desert development programme, the integrated land use planning, and other rural development programmes. These programmes were developed on-farm, and non-farm private, common and state lands

(Chopra and Kadekodi, 1991; Marothia, 1992, 1993, 1997; Singh, 1994; Chopra, 1996).

The agro-climatic regional planning (ACRP) approach was initiated in the mid-eighties to reduce regional imbalances in agricultural growth between irrigated and dryland areas through evolving location-specific resource conserving technologies. The resource conservation technologies are more location specific than resource intensive technologies. The ACRP approach reduces the location specificities of resource conservation technologies to a great extent at least in the simpler homogeneous agro-climatic regions. Water harvesting, tank irrigation, and farm ponds are a few examples. The advantage of the ACRP approach is that it overcomes the danger of over-generalisation and lack of focus on problems and prospects that are specific to agro-climatic, demographic, economic, ecological and sociological conditions. Such a decentralisation also made possible to designing institutional arrangements and establishing linkages between different types of property rights structures, much simpler as the physical and technical attributes of the region and socio-economic cultural characteristics of resource users were more or less homogeneous (Alagh, 1990; Bhuyan and Marothia, 1990). This approach has yielded positive outcomes in terms of the efficiency, equity and sustainability of the technological package adopted in different agro-climatic settings supported by well designed institutional arrangements (Bhuyan and Marothia, 1990; Marothia, 1996 a).

The watershed approach, which is similar to the ACRP approach in principle, was introduced in the eighties in different dryland areas of the country with the technical supervision and scientific backup of Indian Council of Agricultural Research, State Agricultural Universities and International Crops Research Institute for the Semi-Arid Tropics of India (ICRISAT) and implemented by the state departments of agriculture. The main objectives of the watershed approach were to optimise land use patterns, to conserve the soils and water resources through controlling erosion to manage the land and biological resources so as to control land degradation, to recycle run-off water to boost up the production of food and non-food crops, fuel, fodder and timber and to improve the conditions of the resource users as well as village communities. To achieve these objectives, the basic condition is to regard watershed as a unit of integrated land use management. The basic problem in effective implementation of watershed management is that its functional area typically consists of land owned and cultivated by individual farmers largely under private property regimes and to some extent under community lands, from which villagers get fuel, fodder, small timber, which are operated either under common property regime or have resulted into open access due to decay of institutional arrangements. Collective action by resource users is required to adopt the technical components with well designed institutional structures relating to decision-making arrangements and patterns of interactions. The combined effects of these have implications on outcomes of the programme in terms of efficiency, equity and sustainability. Research has shown that the watershed programmes had tremendous impact where technological components were governed through institutional arrangements and managed through resource users' committees. Several experiments of watershed management initiated by government and non-government organisations as well as user groups have shown wide adoptability and replicability in different agro-climatic zones if the technological components were governed through flexible institutional arrangements under well designed property rights structure enforced by resource users with active participation (Rajagopalan, 1991; Chopra and Kadekodi, 1991; Singh, 1994; Vaidyanathan, 1994;

Marothia, 1996 a; Chopra, 1996).

In several parts of India tanks have been used as resource conservation technology for irrigation and domestic activities since centuries. Irrigation tanks in India before Independence were managed and controlled under private property regimes. After Independence ownership rights in private tanks have been abolished and vested with State Governments but the tanks are used by village communities as common pool resources for irrigation and in some cases for aquaculture and domestic activity. These common pool resources degenerated into open access due to poor management, non-contribution of labour or capital resources by users, absence of well defined structures of rights and duties with respect to water rules, regulations and acts and the breakdown of village panchayats authority system to protect the water users' rights. In several dryland areas of the country this traditional technology has been promoted for water harvesting through rainwater management. Irrigation tanks have been constructed by the state department of agriculture or soil and water conservation or irrigation department, and have been handed over to the village panchayats for their management to provide supplementary irrigation at the critical crop growth stages. In some cases these tanks were hooked with the canal irrigation system for water refilling (Marothia, 1992). These tanks are degenerating due to weak technical and institutional arrangements and the non-existence of resource users' authority (Marothia, 1992; Singh, 1994; Palanisami and Ramasamy, 1997).

IV

ISSUES FOR THE FUTURE

Environmental issues are at the forefront of the debate over the sustainability of Indian agriculture without depleting the natural resource base. These concerns include land degradation, water pollution, farm workers' safety, food contamination from chemicals, and climatic changes. Increased attention to the effects of agricultural production on health and environmental issues makes it clear that external effects can play a very vital role in the future development of technologies, level of production, input use, distribution and marketing patterns, farm product and input pricing, incentives, institutional arrangements and property rights structures. Environmentalists are lobbying for alterations in the current technologies and policies. They suggest that though present technologies encourage higher production of commodities, they lead to increased degradation of natural resources and environment. They further recommend to revert entirely to traditional agriculture but ignore the fact of food security. These issues need further probing.

Research evidences in India provide mixed evidences about the declining productivity of some crops in intensive agriculture zones either due to the saturation of genetic potentialities of crop varieties under cultivation, mono-crop or continuous crop rotations or other constraints, price parities between crops or crop groups and non-price parameters, damages due to fertilisers and pesticides, land degradation, groundwater exploitation, efficiency and application of integrated pest management, bio-fertilisers and bio-pesticides, replicability of resource conservation technologies, and comparative advantages of different management regimes in terms of efficiency, equity and sustainability. Research organisations have been making continuous efforts to reorient the agricultural technologies to minimise the resource degradation process. Internalising these external effects through technological and institutional arrangements gives producers and resource users the opportunity to adjust inputs, output, technology, working rules and feed back to researchers, user groups and policy makers. For technological solutions research priorities will have to be based on a broader set of criteria. Further, incentives have to be modified at the national and local levels to convince farmers through extension workers that environmental-friendly technologies would be beneficial in the long run, even if they are less profitable in the short run. Incentive-compatible institutional arrangements and the establishment of property rights can solve common property problems associated with pest resistance and other crop damages. Institutional arrangements can create incentives for both public and private sector researchers to develop pest management and other technologies that are safer for humans and the environment. Government and non-government organisations, user groups or coalitions of farmers can be involved to use such technologies by adopting community based management systems which in turn can reduce the transaction costs. To achieve this, reorientation of financial and fiscal interventions in favour of collective management to promote resource conservation technologies and augmentation of investment in farmers' education and multi-media for creating awareness for environmental friendly technologies are necessary.

Systematic efforts have to be directed to incorporate the social costs of environmental damages and human risk in the studies of the returns to scale to agricultural technologies/research. Such studies will be able to provide an answer to a fundamental question that if such costs are included in the assessments of agricultural technologies, would it still be concluded that the returns to agricultural technologies will be high? Detailed interdisciplinary long-term case studies are needed to assess the potential health and environmental impacts of the major agricultural production systems. For such studies reliable information will be needed on the physical relation between agricultural production activities, health and environment, and values that resource users and consumers attach to physical changes associated with agricultural production activities. Such studies may help to relate the agricultural techniques to the larger issues of health and environment. Ensuring the participation of farmer groups in identification, prioritisation and improved feed back mechanism of environmental, health and agricultural technologies issues is very vital. To carry out such research, the strengths and weaknesses of the agricultural universities and the research institutions of the Indian Council of Agricultural Research have to be evaluated and the capacity of these organisations in terms of infrastructure and technical expertise may be enhanced accordingly.

The most important questions related to environmental problem associated with agriculture technologies are, who manages or controls land, water and other resources over time, who benefits from that management or control or patterns of utilisation and who pays for the current utilisation patterns of land, water and other resources. Such questions can only be dealt within the conceptual framework of institutional economics.[10] The key elements of such framework includes physical and technological attributes of resource and technology, characteristics of resource users or community, decision-making arrangements; patterns of interactions; and outcomes in terms of efficiency, equity and sustainability. Each set of attributes relates to the others. Few researchers have used this framework in the Indian context to analyse the above questions of resource management. However, larger efforts are needed to undertake the institutional research in the organisations that are dealing with natural resource problems to increase the understanding for policy formulation.

NOTES

1. For an excellent interpretation of this issue, see Dantwala (1996).

2. Swaminathan (1977), Rahim and Singh (1978), Shah (1982) made early attempts to address the issue of environmental degradation. In recent years this issue has drawn more attention. See Joshi and Agnihotri (1985), Singh (1987), Marothia (1992, 1993), Nadkarni (1993), Chopra (1993), Vaidyanathan (1994).

3. The role of institutional arrangements and authority systems in managing natural resources have been analysed in recent years. See Marothia (1992, 1993, 1996 a, 1996 b, 1997), Singh (1994), Chopra and Kadekodi (1991), Singh and Ballabh (1996), Chopra (1996).

4. Jodha (1986) categorised agricultural research and technologies into two groups: crop or seed centred and resource centred technologies. See also Chopra (1993).

5. For example, highly subsidised canal irrigation and cheap or free electricity supply in a few states may have serious long-term effects on soil and water resource base.

6. Bromley (1991) used property rules, liability rules and inalienable entitlements for interpretations of complex nature of externalities in interdependence situations and the society's role in using inalienable rule in cases of irreversible loss of a particular resource. This framework of entitlements has also been used to understand multi-party externalities in the Indian context (Marothia, 1995).

7. Abrol (1985) in Tungabhadra irrigation project and Ukai Right Bank Canal of Gujarat, Mishra (1986) in Tawa irrigation project, Joshi and Jha (1989) in Sharda Sahayak Command Area, and Agnihotri *et al.* (1985) in vulnerable sections of the Rajasthan Canal Project observed adverse effects of irrigation system with respect to these attributes.

8. These observations have been made by Agnihotri *et al.* (1985) for Rajasthan canals, Chaudhary *et al.* (1983) for Mahi Right Bank Canal Catchment, Ahmad and Singh (1987) and Ahmad (1988) for Saryu and Gandak Canal Command Areas respectively.

9. For example, pesticides residue present in seasame has been a major constraint in promoting its exports to the major importing countries (see Government of India, 1997).

10. See Marothia (1989 b) and Marothia and Phillips (1985) for review of alternative perspectives for natural resource management.

REFERENCES

Abrol, I.P. (1985), "Salinity and Food Production in the Indian Sub-Continent", International Conference on Food and Water, Texas University, College Station, Texas, May 26-30.

Agnihotri, A.K.; P.K. Joshi and O.P. Singh (1985), "Environmental Impacts of Canal Irrigation in Arid Region: Problems and Remedies", *International Seminar on Environmental Impact Assessment of Water Resources Projects*, University of Roorkee, Roorkee, India, December 12-14, pp. 133-143.

Ahmad, Afroz (1988), "Environmental Impact Assessment of the Gandak Canal Irrigation Project and Guidelines for Its Management", *International Journal of Environmental Studies*, Vol. 30, pp.137-149.

Ahmad, Afroz and P.P.Singh (1986), "Assessment of Environmental Impacts of Sharda Sahayak Canal Irrigation Project of Uttar Pradesh, India", *International Journal of Environmental Studies*, Vol. 28, pp. 1123-1130.

Ahmad, Afroz and P.P. Singh (1987), "Environmental Impact Analysis of the Saryu Canal Irrigation Project and Guidelines for Its Management", *Journal of Environmental Management*, Vol. 24, No. 4, pp. 297-313.

Alagh, Y.K. (1990), "Agro-Climatic Planning and Regional Development", *Indian Journal of Agricultural Economics*, Vol. 45, No. 3, July-September, pp. 214-222.

Antle, John M. (1994), "Health, Environment and Agricultural Research", in J.R. Anderson (Ed.) (1994), *Agricultural Technology: Policy Issues for International Community*, CAB International, Wallingford, Oxon, U.K., pp. 517-531.

Ballabh, Vishwa and Katar Singh (1997), "Competing Demands for Water in Sabarmati Basin: Present and Potential Conflicts", Paper presented in a Seminar on Managing Water Scarcity, Indo-Dutch Programme in Alternative Development, Amsterdam, October 13-17.

Bhuyan, B. and D.K. Marothia (1990), "Agro-Climatic Zonal Planning and Agricultural Development: A Sub-Regional View", *Indian Journal of Agricultural Economics*, Vol. 45, No. 3, July-September, pp. 284-291.

Bromley (1991), *Environment and Economy: Property Rights and Public Policy*, Basil Blackwell Ltd., Oxford, U.K.

Centre for Science and Environment (CSE) (1985), *The State of India's Environment 1984-85, The Second Citizens' Report*, New Delhi.

Chambers, Robert (1988), *Managing Canal Irrigation*, Oxford and IBH Publishing Co. Ptd., New Delhi.

Chaudhary, R.K.; K.M. Mathur and B.S. Kalra (1983), "Ancillary Resources and Infrastructure - A Case Study of the Mahi Right Bank Canal Command Area, Gujarat", Research Bulletin No.42, Water Technology Centre, Indian Agricultural Research Institute, New Delhi, pp. 260-287.

Chopra, Kanchan (1993), "Sustainability of Agriculture", *Indian Journal of Agricultural Economics*, Vol. 48, No. 3, July-September, pp. 527-535.

Chopra, Kanchan (1996), "The Management of Degraded Lands: Issues and an Analysis of Technologies and Institutional Solutions", *Indian Journal of Agricultural Economics*, Vol. 51, Nos. 1 and 2, January-June, pp.238-248.

Chopra, K. and G.K. Kadekodi (1991), "Participatory Institutions: The Context of Common and Private Property Resource", *Environmental and Resource Economics*, Vol. 1, pp. 353-372.

Ciriacy-Wantrup, S.V. and R.C. Bishop (1975), "Common Property as a Concept in Natural Resources Policy", *Natural Resources Journal*, Vol. 15, No. 4, October, pp. 713-728.

Commons, J.R. (1950), *The Economics of Collective Action*, Macmillan Company, New York.

Dantwala, M.L. (1996), "My Academic Dialogues: Agricultural Price Policy and the Green Revolution", *Indian Journal of Agricultural Economics*, Vol. 51, Nos. 1 and 2, January-June, pp. 51-59.

Dasgupta, R. (1993), "Bitten by the Economics of Plenty", *The Economic Times*, December 5.

Datta, K.K. and P.K. Joshi (1993), "Problems and Prospects of Co-operation in Managing Degraded Lands: Case of Saline and Water-Logged Soils", *Economic and Political Weekly*, Vol. 28, Nos. 12 and 13, March 20-27, pp. A-16-A-24.

Dhawan, B.D. (1986), "Irrigation and Water Management: Perception of Problems and Their Resolution", *Indian Journal of Agricultural Economics*, Vol. 41, No. 3, July-September, pp. 279-281.

Dhawan, B.D. (1995), *Groundwater Depletion, Land Degradation and Irrigated Agriculture in India*, Commonwealth Publishers, New Delhi.

Gangwar, A.C. and W.H. van den Toorn (1987), "The Economics of Adverse Groundwater Conditions in Haryana State", *Indian Journal of Agricultural Economics*, Vol. 42, No. 2, April-June, pp. 160-172.

Gibbs, C.J.N. and D.W. Bromley (1989), "Institutional Arrangements for Management of Rural Resources: Common Property Regimes", in F. Berkes (Ed.)(1989), *Common Property Resource: Ecology and Community-Based Sustainable Development*, Belhaven Press, London.

Government of India (1997), *Report on Price Policy for Kharif Crops of 1997-98 Season*, Commission for Agricultural Costs and Prices (CACP), Ministry of Agriculture, New Delhi, March.

Gulati, Ashok (1989), "Structure of Effective Incentives in Indian Agriculture - Some Policy Implications", *Economic and Political Weekly*, Vol. 24, No. 39, September 30, pp. A-124-A-132.

Gulati, Ashok; Mark Svendsen and Nandini Roy Choudhary (1995), "Capital Costs of Major and Medium Irrigation Schemes in India", in M. Svendsen and A. Gulati (Eds.)(1995), *Strategic Changes in Indian Irrigation*, Macmillan India Ltd., Delhi.

Indian Council of Medical Research (1993), *Surveillance of Food Contaminants in India*, Muyar Printers, New Delhi.

Jodha, N.S. (1986), "Research and Technology for Dryland Farming in India: Some Issues for the Future Strategy", *Indian Journal of Agricultural Economics*, Vol. 41, No. 3, July-September, pp. 234-247.

Joshi, P.K. (1997), "Farmers' Investments and Government Interventions in Salt Affected and Waterlogged Soils", in J.M. Kerr, D.K. Marothia, C. Ramasamy, Katar Singh and W.R. Bentley (Eds.) (1997), *Natural Resource Economics: Theory and Application in India*, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Joshi, P.K. and A.K. Agnihotri (1982), "Impact of Input Subsidy on Income and Equity under Land Reclamation", *Indian Journal of Agricultural Economics*, Vol. 37, No. 4, October-December, pp. 252-260.

Joshi P.K. and A.K. Agnihotri (1984), "An Assessment of the Adverse Effects of Canal Irrigation in India", *Indian Journal of Agricultural Economics*, Vol. 39, No. 3, July-September, pp. 528-536.

Joshi, P.K. and D. Jha (1989), *A Study on Farm Level Impact of Soil Degradation in Sharda Sahayak Irrigation Project, Uttar Pradesh, India*, Central Soil Salinity Research Institute, Karnal and International Food Policy Research Institute, Washington, D.C., U.S.A. (mimeo.).

Joshi, P.K.; O.P. Singh; K.V.G.K. Rao and K.N. Singh (1987), "Sub-Surface Drainage for Salinity Control: An Economic Analysis", *Indian Journal of Agricultural Economics*, Vol. 42, No. 2, April-June, pp. 198-206.

Joshi P.K. and N.T. Singh (1991), *Environmental Issues in Relation to Incentive and Resource Allocation in Indian Agriculture*, Central Soil Salinity Research Institute, Karnal (Haryana).

Joshi, P.K. and N.K. Tyagi (1991), "Sustainability of Existing Farming System in Punjab and Haryana - Some Issues on Groundwater Use", *Indian Journal of Agricultural Economics*, Vol. 46, No. 3, July-September, pp.412-421.

Kalla, Jagdeesh C. (1996), *Mission Report on Socio-Economic Analysis of Common Lands in the Aravallis of Haryana*, Aravalli Project, Haryana Forest Department, Gurgaon, Haryana.

Kalra, R.L. and I. Chawla (1981), "Monitoring of Pesticide Residues in the Indian Environment", in B. Vasantharaj David (Ed.)(1981), *Indian Pesticide Industry,* Vishvas Publication, Bombay.

Katyal, J.C. (1989), "Fertiliser Use and Impact on Environment", FAI Seminar on Fertiliser, Agriculture and National Economy", The Fertiliser Association of India, New Delhi, December 4-6, pp.VI/2.1-2.8.

Katyal, J.C.; Bijay Singh; V.K. Sharma and E.T. Craswell (1985), "Efficiency of Some Modified Urea Fertiliser for Wetland Rice Grown on a Permeable Soil", *Fertiliser Research,* Vol. 8, No. 2, pp. 137-146.

Kishor, N.M. (1997), "Pesticide Externalities in Coastal Andhra Pradesh", in J.M. Kerr, D.K. Marothia, C. Ramasamy, Katar Singh and W.R. Bentley (Eds.) (1997), *Natural Resource Economics: Theory and Application in India,* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Marothia, D.K. (1989 a), "Socio-Economic Rationales of Waste Land Afforestation", *Journal of Tropical Forestry,* Vol. 5, No. 4, pp.343-350.

Marothia, D.K. (1989 b), "Resource Ownership and Human Interactions: A Theoretical Exposition", *Annals of Arid Zone,* Vol. 28, Nos. 3 and 4, pp. 165-180.

Marothia, D.K. (1992), "Village Irrigation Tanks: Institutional Design for Sustainable Resource Use", *Agricultural Situation in India,* Vol. 47, No. 6, September, pp. 479-487.

Marothia, D.K. (1993), "Property Regimes and Institutional Arrangements: Concepts and Their Relevance in Managing the Village Commons", *Indian Journal of Agricultural Economics,* Vol. 48, No. 3, July-September, pp.557-565.

Marothia, D.K. (1995), "Urban Lake Pollution: Issues of Property Rights and Institutional Arrangements", Paper presented at Beijer Research Seminar organised by the Beijer Institute, The International Institute of Ecological Economics, The Royal Swedish Academy of Sciences, Stockholm, Sweden, held at Kota Kinabalu, Malaysia, May 16-19.

Marothia, D.K. (1996 a), "Designing Institutions for Self Governing System of Common Pool Resources", Agro-Climatic Regional Planning Unit of Planning Commission (ARPU), Government of India, Technical Paper No. 25 ACRPU, Ahmedabad.

Marothia, D.K. (1996 b), "Co-operative Management of Non-Timber Forest Products: Issues of Property Rights and Institutional Structures", in R. Rajagopalan (Ed.)(1996), *Rediscovering Cooperation: Strategies for the Models of Tomorrow,* Vol. 2, Institute of Rural Management, Anand.

Marothia, D.K. (1997), "Institutional Arrangements in Common Fish Ponds", in J.M. Kerr, D.K. Marothia, C. Ramasamy, Katar Singh and W.R. Bentley (Eds.) (1996), *Natural Resource Economics: Theory and Application in India,* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Marothia, D.K.; A.P. Mukherjee and S.K. Sharma (1989), "Canal Irrigation System: Socio-Economic and Management Issues", *Indian Journal of Agricultural Economics,* Vol. 44, No. 3, July-September, p. 300.

Marothia, D.K. and D. Nandi (1994), "Degraded Lands, Agroforestry and Energy Needs: Issues and Development Strategies", in Punjab Singh, P.S. Pathak and M.M. Roy (Eds.)(1994), *Agroforestry Systems for Sustainable Land Use,* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Marothia, D.K. and W.E. Phillips (1985), "Analysis of Natural Resource Problems Using a Synthesis of Neoclassical and Institutional Economics", *Asian Journal of Economics and Social Studies,* Vol. 4, No. 4, pp. 263-281.

Mencher, J.P. (1991), "Agricultural Labour and Pesticides in Rice Regions of India: Some Health Considerations", *Economic and Political Weekly,* Vol. 26, No. 39, September 28.

Mishra, Anupam (1986), "The Tawa Dam: An Irrigation Project that has Reduced Farm Production", in E. Goldsmith and N. Hildyard (Eds.)(1986), *The Social and Environmental Effects of Large Dams,* Wodebridge Ecological Centre, Cornell, U.S.A..

Moench, Marcus (1994), "Approaches to Ground Water Management to Control or Enable?", *Economic and Political Weekly,* Vol. 29, No.39, September 24, pp. A-135-A-146.

Mruthyunjaya and P. Kumar (1989), "Crop Economics and Cropping Pattern Changes", *Economic and Political Weekly,* Vol. 24, Nos. 51 and 52, pp. A-159-A-166.

Nadkarni, M.V. (1993), "Sustainable Development: Concept and Issues with Special Reference to Agriculture", *Indian Journal of Agricultural Economics,* Vol. 48, No. 3, July-September, pp. 516-526.

Palanisami, K. and C. Ramasamy (1997), "Conjunctive Use of Tank and Well Irrigation", in J.M. Kerr, D.K. Marothia, C. Ramasamy, Katar Singh and W.R. Bentley (Eds.) (1997), *Natural Resource Economics: Theory and Application in India,* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Patil, R.K. and S.N. Lele (1996), "Irrigation Co-operatives in Maharashtra: Experiences and Lessons", in Katar Singh and Vishwa Ballabh (Eds.)(1996), *Cooperative Management of Natural Resources,* Sage Publications India Pvt. Ltd., New Delhi.

Rahim, K.M.B. and Katar Singh (1978), "Some Special Characteristics of Agricultural Development Projects and Their Implications for Project Formulation and Evaluation", *Indian Journal of Agricultural Economics,* Vol. 33, No. 4, October-December, pp.185-191.

Rai, D. (1983), "Environmental Impact from Development Activity", *Bhagirath,* Vol. 30, No. 3, pp. 115-122.

Rajagopalan, V. (1991), "Integrated Watershed Development in India: Some Problems and Perspectives", *Indian Journal of Agricultural Economics,* Vol. 46, No. 3, July-September, pp. 241-250.

Ramalingaswami, V. (1984), "Human Ecology and Health", *Mazingira,* July, pp. 40-42.

Sah, D.C. and Amita Shah (1992), "Efficiency of Fertiliser Use: Demand for Soil Testing Services in Gujarat", *Indian Journal of Agricultural Economics,* Vol. 47, No. 3, July-September, pp. 459-467.

Saleth, R.M. (1994), "Towards a New Water Institution: Economics, Law, and Policy", *Economic and Political Weekly,* Vol. 29, No. 39, September 24, pp. A-147-A-155.

Shah, S.L. (1982), "Ecological Degradation and Future of Agriculture in the Himalayas", *Indian Journal of Agricultural Economics,* Vol. 37, No. 1, January-March, pp.1-22.

Shah, Tushaar (1993), *Ground Water Markets and Irrigation Development: Political Economy and Practical Policy,* Oxford University Press, Bombay.

Shah, Tushaar and Vishwa Ballabh (1986), "Ownership/Use Rights and Community Involvement in Wastelands Development: Experience from Gujarat", Paper presented at the Workshop on Fodder Production - An Alternative for Marginal and Wastelands Development, May 15-16, National Dairy Development Board, Anand.

Singh, C. (1991), *Water Rights and Principles of Water Resources Management,* Water Project Series, Indian Law Institute, N.M. Tripathi, Bombay.

Singh, I.J. (1987), "Rapporteur's Report: Impact of Agricultural Development on Ecology and Environment", *Indian Journal of Agricultural Economics,* Vol. 42, No. 4, October-December, pp.531-533.

Singh, Katar (1994), *Managing Common Pool Resources: Principles and Case Studies,* Oxford University Press, Delhi.

Singh, Katar and Vishwa Ballabh (Eds.) (1996), *Cooperative Management of Natural Resources,* Sage Publications India Pvt. Ltd., New Delhi.

Swaminathan, M.S. (1971), "Indian Agriculture at the Crossroads", *Indian Journal of Agricultural Economics,* Vol. 32, No. 4, October-December, pp. 1-34.

Tyagi, N.K.; P.K. Joshi and M. Svendsen (1995), "Cost Effectiveness of Salinity Mitigating Measures", in M. Svendsen and A. Gulati (Eds.)(1995), *Strategic Changes in Indian Irrigation,* Macmillan India Ltd., Delhi.

Vaidyanathan, A. (1994), "Agrarian Relations in the Context of New Agriculture Technology: An Issues Paper", *Indian Journal of Agricultural Economics,* Vol. 49, No. 3, July-September, pp. 317-329.

Vaidyanathan, A. (1996), "Depletion of Groundwater: Some Issues", *Indian Journal of Agricultural Economics,* Vol. 51, Nos. 1 and 2, January-June, pp. 184-192.

Veeman, T. (1978), "Water Policy and Water Institutions in Northern India: The Case of Groundwater Rights", *Natural Resources Journal,* Vol. 18, No. 3, pp. 569-587.