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The soil sciences in India: Policy lessons for agricultural innovation

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Abstract

There is increasing demand for institutional reform in the agricultural sciences. This paper presents lessons from the content and directions in soil science research in India, to make a case for institutional reform in the agricultural sciences. It demonstrates how existing institutional and organizational contexts shape the research content of the soil sciences and its sub-disciplines. These contexts also shape the capacity of the soil sciences to understand and partner with other components of the wider natural resource management (NRM) innovation systems. The professional association has received little attention in the innovation systems literature, even within the nuanced, context specific and historically sensitive accounts of innovation. As a professional association, the Indian Society of Soil Sciences (ISSS) plays a limited role currently, with little engagement with the key professional and social issues that confront the soil sciences. The ISSS is presented here as a potential actor in the NRM innovation systems. The paper argues that with the involvement of the ISSS, the existing discipline-based, commodity oriented, linear and instrumentalist problem solving approach in the soil sciences can be reformed to a learning and partnership based innovation systems approach, enabling professional excellence, field level technology utilization, along with substantial policy and donor support.

Keywords: Institutional reform; Innovation system; Professional association; R&D policy; Soil sciences

1. Introduction

Institutional reform has in the 1990s become a catchword in the literature on agricultural research and extension organizations in India. Institutional reform is demanded to enable the transition of the existing research and extension organizations from their current linear and compartmentalized R&D organizations/mandates to dynamic components in evolving inter-dsciplinary non-linear innovation systems (Jha, 2001, 2002a,b; Rhoades, 1999; Sulaiman and Hall, 2002b; Hall et al., 2003a,b,c; Raina, 2003b). While organizations are relatively easy to establish or change, the institutions (norms or rules) that govern these are extremely difficult to change. The relative difficulty or unwillingness to reform the institutions is a feature that marks Indian agricultural research and extension (Lele and Goldsmith, 1989; Raina, 2003b). Despite several conferences/workshops, research papers and other esoteric research outputs, little institutional reform has occurred in public sector agri-

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cultural research or extension organizations that allow them to effectively cater to changing demands for agricultural innovation.[1] This paper presents lessons from the content and directions in soil science research in India, to make a case for institutional reform in the agricultural sciences. Using an analysis of the soil sciences publication patterns, the paper explores the institutions of science that shape the research context and determine the content of soil sciences research. It shows how these institutions/norms constrain the capacity of the soil sciences to address socially and ecologically relevant issues. The purpose of this paper is to highlight the role that R&D policy and professional associations must play in changing the institutions or norms that govern the organizations and contents of scientific research.

The organizations that spearheaded the green revolution in India in the 1960s, are the Indian Council of Agricultural Research (ICAR) under the central Ministry of Agriculture, the State Agricultural Universities (SAUs) and Departments of Agriculture or Agricultural Extension in their respective state governments in every State of the Indian Union. Scientific research in these organizations is highly institutionalized. There are rigid institutions or norms that dictate the disciplinary and sub-disciplinary formations, choice of research topics, outputs expected from and the evaluation of research, relationships between science and other stakeholders in the economy, and the role of science in agricultural policy-making. The indifference to the demands for institutional reform in agricultural R&D is largely because the scientists (in life sciences and social sciences) in these organizations are accustomed to the given organizational structures and the institutions/norms that govern them. There is a need for de-institutionalization of fields like the agricultural sciences, to enable critical self-reflection and corrective mechanisms/processes. Professional associations in science, unlike the organizations of R&D, have a central concern about furthering the interests of the profession, are not tied to any patron (state/private/civil/legal entity), and can legitimately reflect upon the status/evolution of the profession in order to strengthen its professional identity and future. There has been a proliferation of professional associations, their journals, and meetings/conferences in the agricultural sciences in India. These professional associations can now play a major role in institutional reform in the agricultural sciences. They can orient the agricultural sciences towards the dynamic role that science can play as one of the components in wider innovation systems.

The rationale for this analysis also stems from the way economic research on science policy as well as the trans-disciplinary field of 'science, technology, society' studies (STS) has more or less ignored agricultural science and innovation processes (see, Schrum, 2000), the key to better livelihoods in almost all developing countries. Moreover, there has been a steady erosion of the conviction among donor agencies that science can play a key role in poverty alleviation. The declining allocations to agricultural research since the late 1980s, is evidence enough. Little effort is made to facilitate scientific research as part of dynamic innovation systems, enabling its participation in and partnerships with other stakeholders in the system. There is a felt need to demonstrate that the content of science and its research results can change if research is conducted in a different manner as part of wider innovation systems.

Despite excellent research, the soil sciences, as a field of agricultural science now confront uncomfortable and complex questions from its ecological and social constituencies. Several consequences of the green revolution technologies and the ultimate impact of these consequences on the development goals of the nation pose difficult questions, often directed at policy, research and extension organizations. The soil sciences, straddling different disciplinary realms, scales, bio-physical and socio-economic contexts, have to contend with several of these questions. These include issues like soil salinity/alkalinity and other problem soils, soil and water quality/toxicity, declining crop productivity and soil fertility, loss of soil organic matter, impact of farm machinery, appropriate tillage practices and other cultivation methods, input subsidies and price/access factors, use and impact of new technologies like information technology or biotechnology, land use policy in general and agricultural policy in particular.

[1] The workshops/conferences include the (a) seminar on 'Institutional Change for Greater Agricultural Technology Impact', at the National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi, on 13–14 March 2001, (b) workshop on 'Agricultural Policy: Redesigning R&D to Achieve the Objectives,' sponsored by the National Academy of Agricultural Sciences, New Delhi, on 10–11 April 2002, and (c) session on 'Institutional reform in agriculture', at the Annual Conference of the Indian Society of Agricultural Economics, New Delhi, on 19–21 December 2002. Important papers/official documents that demand institutional reform are the *National Agriculture Policy* (Government of India, 2000), the *National Agricultural Technology Project*: *Main Document* (ICAR, 1998b), the NAAS policy paper (NAAS, 2002), Jha (2001, 2002b), Paroda and Mruthyunjaya (1999), Hall et al. (2000, 2003a,b,c), Mruthyunjaya (2002), Byerlee and Echeverria (2002), Sulaiman and Hall (2002a,b), Chandrashekara and Ganeshaiah (2003), and Raina (1999, 2003b).

There is an increasing demand especially over the past two decades, from scientists, policy-makers and other stakeholders, for resource-conserving technologies (RCTs). The main articulation is that soil quality has to be maintained for sustainable natural resource management and agricultural development. Yet, little has changed within the soil sciences in particular or the agricultural sciences in general to ensure sustainable development through RCTs or soil quality maintenance (See Doran, 2002; Karlen et al., 2001, 2003; Erickson and Ardon, 2003). This, we argue is largely due to the rigid institutions/norms that govern the content and conduct of the soil sciences.

The soil sciences can no longer sit back having "produced" a technology, and handed it over to the extension system to transfer it down to the farmers. The constraints that hamper effective soil science research begin with a policy misconception, leading to commodity oriented research organization and funding patterns. This is a discipline conducting excellent research, within several institutional constraints. But there are important internal problems within the soil sciences. These include an inability to work in a trans-disciplinary fashion with other disciplines, highly specialized compartmentalized sub-disciplines, and the conformity of research content and performance with the linear model of R&D. The soil sciences do not address any of these institutional constraints and the increasingly complex technological and social contexts. This paper argues that a discipline-based, instrumentalist problem solving approach in the soil sciences can be reformed to an issue-led partnership based innovation systems approach, enabling both professional excellence, field level technology utilization, as well as substantial policy and donor support. This would entail the professional association, the Indian Society of Soil Sciences (ISSS) playing a lead role, bringing in changes in research content as well as the organization of R&D and stakeholder partnerships in innovation. The ISSS has an important leadership role to play, in helping the soil sciences fulfil the demand for truly inter-disciplinary teamwork, systems research, partnership building with other stakeholders and learning in each context. There is now a legitimate demand for the ISSS to influence research policy in the Council and in the entire country.

This paper presents the case of soil science research in India in the post-green revolution period, to argue that the content and the conduct of hard scientific research as well as its results and impact on development are determined significantly by the institutions or rules and norms that govern agricultural research and extension. When a linear perspective of technology generation, diffusion and adoption remains the norm that governs the relationship between research and extension and between extension and farmers, there is little scope for the agricultural sciences to interact with or learn from a society or the ecosystem that is located way below science in the linear knowledge hierarchy.

In Section 2, we present a brief introduction to the institutions, the rules/norms that govern the agricultural sciences and its key mandates and organizational formats. Section 3 analyses how the compartmentalized and linear organization of the soil sciences are major determinants of the content and direction of research in the different sub-disciplines of the soil sciences. A bibliometric analysis of the soil sciences in India reveals that the reiterated accusation in Indian agricultural science, of repetitive and ritualistic fertilizer/manurial trials is justified. Section 4 highlights the role that the ISSS can play in the de-institutionalization of existing linear and compartmentalized norms of soil science. The introduction and institutionalisation of evolutionary innovation system norms to govern the soil sciences demands the active legitimisation by and involvement of its professional association, the ISSS. The concluding Section 5, deliberates the processes and capacities that can enable a pro-active soil science research community involved in a natural resources innovation system. Policy lessons from the above analysis are presented.

The analysis here suggests that the soil sciences must relocate from the organizational confines of research to a wider range of partners and system of innovations in agriculture. It is important for the soil sciences to see themselves as one of the key actors in a wide network of innovators, adapters and adopters, with crucial linkages with other actors and innovation processes. This can be facilitated through excellence in science, relevant partnerships and internal learning processes.

2. Soil sciences research in India—the institutional and organizational contexts

Among the agricultural sciences ranging from genetics and plant breeding to agricultural economics and rural sociology, the soil sciences conduct research on soils, soil-water, soil-plant and several other systems that interact with the soils. The soil sciences are recognized as a group of sub-disciplines drawing from different parent disciplines and applied to the study of soil systems, aligned to address the fundamental knowledge as well as practical policy measures and technologies necessary for agriculture, ecosystems and livelihoods. Ideally, the application of its research on land and water caters to diverse demands, and in different contexts conforms to a wide variety of norms pertaining to crop production, natural resource management, market structures and rural livelihoods. Knowledge about soils cuts across and is inclusive of different realms (bio-physical/socio-economic, scientific/bureaucratic), scales (eco-regional, state/district, farm/watershed), actors (farmers/policymakers/scientists/extensionists/engineers/input (fertilizer) industry), knowledge systems (traditional/ scientific, public/private, fundamental/applied, discipline-based/inter-disciplinary) and innovation approaches and perspectives (reductionist/integrative, singular perspectives/participatory, linear/systems). Yet, this dynamism of varieties of actors, their inter-sectoral and multi-disciplinary ferment is painfully absent in the conduct of and content of the soil sciences within agricultural research organizations.

2.1. Institutions governing innovation: scope for professional associations

The current scenario of complex technological and social problems confronting the soil sciences (as in its relevance to poverty reduction, or in the emerging field of 'soil quality' research), and the inadequate response these problems have evoked demands that scientists explore the institutional arrangements in agricultural research, instead of adhering to our inadequate 'technological' ship (see, Doran, 2002). Many analyses have been conducted on the need for institutional reform and norms that institutionalize a field of activity. But few have asked or analyzed how the existing institutions can be changed or de-institutionalized.

Few have explored appropriate agencies such as a professional association, and processes to re-institutionalize open and more flexible norms or institutions to govern a particular field of activity (Greenwood et al., 2002). Institutions can be created, as a set of incentives or rules for an organization, or they can evolve (informally) as part and parcel of patterns of action or culture. We must ask how these norms or rules governing scientific disciplines can be changed[2]. As routines or patterns of behaviour in a work culture or social context, institutions explain processes of decision-making, conduct and performance. Institutions offer a more 'proceduralist' account of an organization rather than a 'consequentialist' account (Elster, 1989). Thus institutional analysis enables a better understanding of the intra-organizational processes in the conduct of science (for instance the facilities or incentives for partnerships, or the flexibilities allowed in research design); the rules that shape the way research is conducted. In the context of agricultural research organizations, institutional analysis explains 'how' research and development occurs mediated through rules, norms, processes and practices in the organization (see Raina, 2003b). According to Hall et al. (2000, p. 86):

> Institutional arrangements of agricultural research are undoubtedly emerging as a key constraint in efforts to apply excellence in science to efforts to alleviate poverty. This perspective has received little attention over the last 40 years. As a result, not only are there growing crises in many agricultural research systems, but also there is very little comfort to be found in current policy treatments of this problem.

The rules or institutions of a professional association are different from those of a research organization, programme or discipline, and seem to offer opportunities for institutional reform.

In Indian agricultural sciences, the professional associations are established through voluntary action. The aim is to establish the identity of increasingly specialized groups of disciplines or areas of common interest and vocation. In all the professional associations in the agricultural sciences in India, the members are scientists employed in or retired from (largely public sector) agricultural research organizations. These associations are largely self supported. They carry out their functions through subscriptions/membership fee, voluntary contributions (time of officer bearers, finances from Divisions/Departments, etc.). They are also eligible for and do avail small grants for specific activities such as workshops/seminars, publication of monographs, books, journals, etc.[3]

The Indian Society of Soil Science (ISSS) was established in 1934. It now has 40 local chapters spread throughout India. The objectives of the ISSS, are to promote the science, disseminate knowledge about soils, influence decision-making about soil use, seek excellence in the science and its teaching, work with similar learned societies, and carry out activities to achieve the

[2] 'If organizations are the players and institutions the rules, then how are the rules changed?' (Edquist and Johnson, 1997, p. 57).

[3] These grants are generally availed from the National Academy of Agricultural Sciences (NAAS), the ICAR, the Indian National Science Academy (INSA), the Third World Academy of Sciences (TWAS), the International Union of Science Councils (ICSU), the Department of Science and Technology (DST), etc.

above objectives.[4] As is the practice in other professional associations of the agricultural sciences, the ISSS also publishes its own journal, bulletins, proceedings of national and international symposia, and other special publications, organizes an Annual Congress of Soil Sciences every year, and conducts or encourages activities (such as participation in scientific meetings/symposia, awards to best dissertations, etc.) to promote professional interest and personal recognition of its members. These activities are all located within the scientific realm involving only research organizations and scientific disciplines – note that the society has a stated objective to work with 'similar' learned societies. There are no questions asked about the way science is conducted, or ways to address policy issues that are of relevance to soils or any other natural resource.

If leveraged well, a professional association can recognize the need for and be concerned about changes in the way scientific research is conducted. A professional association can enable the integration of scientific research with other actors playing crucial roles in wider innovation systems. The case of the African Association of Biological Nitrogen Fixation (AABNF) is an example of attempts to shift scientific research in BNF from its technocentric obsession with N-fixation to larger innovation systems, acknowledging the presence and role of different organizations, complementing capacities and skills. It is now recognized that the BNF science community can no longer be "immune to larger social and environmental issues." They cannot expect "others to recognize and translate their research products into forms applicable to them." (AABNF, 2001, p. 9) The BNF research community therefore needs to recognize that BNF research must not be conducted for its own sake, but rather should be regarded in a broader innovation systems context (ibid).[5]

The innovation systems perspective[6] evident here makes equal demands from professional actors and society in general, to enable the nesting of BNF into system dynamics and land management goals. There are rules of the game or institutions of science that must change. These institutional changes will also include changes in the relationships among and capacities of crucial organizations of research funding, research conduct, extension and input delivery, legume marketing and processing, and policy-making. The professional association that addresses these institutional changes from within the discipline(s) and its norms makes a strong case for change.

Research in the soil sciences, when conceptualized in an innovation systems framework, ought to be endowed with continuous interactions among the soil sciences sub-disciplines and other forms and contents of agricultural knowledge. This entails diverse roles for science besides mere technology generation, and partnerships with other organizations in the system that are not scientific organizations or learned societies but organizations/individuals with different skills, information, funds, or other resources needed to 'nest technologies into larger understandings and applications of knowledge' in agricultural/rural development. Can de-institutionalization of the rigid, linear, commodity oriented and compartmentalized norms governing the soil sciences be facilitated? How can a re-institutionalization of evolutionary, non-linear, and flexible norms of natural resources innovation systems be facilitated? An analysis of the research content of the soil sciences – *what* do they address, *how* and *why* do they work on these problems, areas or sub-disciplines – can help us assess the scope for institutional reform in the soil sciences as part

[4] The objectives of the ISSS are (a) to cultivate and promote soil science and kindred branches of science; (b) to disseminate the knowledge of soil science and its applications, through meetings, discussions, and publications; (c) to promote judicious interactive use of soil, water and other natural resources, fertilizer and other inputs to maintain quality and resilience of soil for sustainable agriculture; (d) to foster high standards in the teaching and education of soil science; (e) to work in close association with learned societies and organizations having similar objectives; (f) to create public awareness about the importance of soil as a finite natural resource; (g) to carry out research and to perform all other acts, matters, and things that may assist in, or be conducive to, or be necessary for the fulfillment of objectives and purposes of the society. (http://www.isss-india.org).

[5] The 21st century paradigm for BNF impacts, according to the AABNF is: "Research in biological nitrogen fixation must be nested into larger understanding of system nitrogen dynamics and land management goals before the comparative benefits of N2-fixation may be realistically appraised and understood by society as a whole." (AABNF, 2001, p. 12).

[6] A number of studies have applied the innovation systems framework to the analyses of agricultural research and extension (Hall et al., 2000, 2001; Ekboir and Parellada, 2002; Clark, 2002; Sulaiman and Hall, 2002a,b; Biggs and Matsaert, 1999; Raina et al., 2004), proving that the conduct of successful science for agricultural innovation does not conform to a linear hierarchical organization of R&D. Contrary to the linear models of technology generation, transfer and adoption, the innovation systems approach views innovations as arising from and mediated through a range of actors, technologies and institutions. The innovation systems approach removes the hierarchy of the top-down linear model, and treats innovations as interactive processes that involve several mutually dependent actors and active learning processes. Innovation systems are marked by different combinations of technological and institutional innovations – no innovation has ever been successfully utilized in society without appropriate partnerships and institutional arrangements (Lundvall, 1992, 2004).

of evolving, socially responsive, cutting-edge science, and partnerships in wider natural resources innovation systems.

3. Research content

The publication patterns in the sub-disciplines of the soil sciences give us an institutional account of the way soil sciences research functions. We use publications as an output indicator of the content of research.[7] Each sub-discipline in soil sciences research in India has produced excellent research publications, and has made its own contributions to fundamental, strategic, applied and adaptive research. So the attempt here is not to evaluate or assess the research content, but to establish the relationship between research context (the organizational and institutional arrangements) and the content of research. We argue that several norms or institutions and organizational features are evident in the narrow sub-discipline-based research content, the inadequate collaborations among the soil science sub-disciplines and between disciplines, and the inability to look beyond instrumentalist agendas and research results, to seek and learn from other partners in the natural resource innovation system. In our discussion on de-institutionalization of the linear and compartmentalized R&D model and the research content legitimised by this model, we pay special attention (in Section 4) to the role that the professional soil sciences association (ISSS) plays now and can play in future.

3.1. Sub-disciplines: significance and roles

The productivity of research is one of the important questions addressed by bibliometrics. A bibliometric measurement of research effort assumes that research publications are the output of research and therefore can function as a proxy measure of research effort. The bibliometric measure does not give us any idea about how or how much of these research results are used by society. The central assumption, applicable to all agricultural sciences is that since agriculture is an 'applied science' all its research results are utilized or potentially utilizable by its clients (Thompson, 1995).

The manner in which the soil sciences have been classified into different sub-disciplines is an important indicator of the way the soil sciences address its R&D clients. We compare two classifications, the AGRIS (FAO)[8] and the ISSS classifications, to see how and why these classifications are different. The ISSS classification goes strictly by the basic disciplinary content of each paper, while the AGRIS classification adopts a more flexible boundary, placing articles that are of a more general nature or involve more than one sub-discipline in a sub-discipline called soil science (see Table 1).

The AGRIS database reports publications (journals, books, proceedings/reports) while the ISSS database reports summaries of papers accepted for the National Seminars organized by the ISSS, annually. The most evident differences between the two are (a) the absence of soil science, soil reclamation and conservation, and soil cultivation as sub-disciplines in the ISSS classification, (b) the parent discipline-based distinction between soil chemistry and soil physics in the ISSS classification (which are clubbed in the AGRIS database), and (c) the presence of soil technology and soil mineralogy as distinct sub-disciplines in the ISSS classification. The ISSS classification is one intended to help prospective authors (submitting papers to the association's Journal, the JISSS) in slotting their papers into suitable sub-disciplines. The classification in the AGRIS column above is a selection of seven sub-disciplines that fit into the soil science research area, from among a larger group of sub-disciplines in the research area of "natural resources" plus the sub-discipline of soil cultivation, which is part of a larger research field "plant production" in the AGRIS classification of research fields. This elimination of other natural resources sub-disciplines (say drainage, nature conservation and land resources, water resources and management, etc.) and addition of the soil based sub-discipline from the 'plant production'

[7] Despite the problems associated with a bibliometric measure and assessment of research effort, publications are important indicators of research content and changes in research direction overtime (see Trigo, 1987; Rajeswari, 1995).

[8] AGRIS (International Information System for the Agricultural Sciences and Technology) is an FAO database that collects information from different collection centres of the AGRIS network every year. Each collection centre (like the ICAR centre in New Delhi) provides information to the FAO–AGRIS database. Each centre prepares and reports the list of papers published from that specific region, be it in local journals of the region or in other national or international journals. The AGRIS database used in this paper has been collected from the AGRIS centre in the ICAR, New Delhi, and gives a list of Indian publications in the soil sciences, in Indian, other national or international journals, books, proceedings/reports. The AGRIS database from a collection centre of the network is, therefore, the most comprehensive database available to assess the output from a region. The Journal of the Indian Society of Soil Sciences (JISSS) uses the classification given in Table 1 above to organize its publications. This classification is decided by the Indian Society of Soil Sciences (ISSS) the professional association of soil scientists in the country ISSS.

Table 1
Comparison of soil sciences sub-disciplines and number of publications by AGRIS and ISSS classifications (1981–2001)[a]

SI. no.	AGRIS			ISSS		
	Sub-disciplines	No. of publications	Percentage of total	Sub-disciplines	No. of publications	Percentage of total
1	Soil science & management	902	31.0	Soil physics	578	12.9
2	Soil biology & biochemistry	578	19.9	Soil chemistry	713	16.0
3	Soil chemistry & soil physics	551	19.0	Soil biology & biochemistry	265	5.9
4	Soil fertility	423	14.6	Soil fertility	1960	43.9
5	Soil reclamation & conservation	216	7.4	Soil genesis, classification and cartography	337	7.5
6	Soil cultivation	82	2.8	Soil technology	557	12.5
7	Soil survey and mapping	74	2.5	Soil mineralogy	57	1.3
8	Soil classification & genesis	81	2.8	–	–	–
9	Total	2907	100.0		4467	100.0

Source: AGRIS database, various years, New Delhi. Abstracts & extended summaries of papers accepted for National seminar (various themes) from 1982 to 2002 by the Indian Society of Soil Science, Division of Soil Sciences Agricultural Chemistry, IARI, New Delhi.
[a] *Note*: AGRIS (International Information System for Agricultural Sciences and Technology) and ISSS (Indian Society of Soil Science).

research group, was done to make the AGRIS classification compatible with that of the ISSS.

The sub-discipline ‘soil science and management’ in the AGRIS database reveals a characteristic feature of Indian soil science research. There are several studies (902) that do not belong to any one parent discipline, address resource management questions, and do not therefore, conform to the rigid disciplinary classification (as used by the ISSS). About 35% of these ‘soil science and management’ publications are commodity or crop-based publications; the rest of these 902 are papers detailing features of different soil types, describing different management practices, in different states, etc. Most of these papers appear in journals that are not strictly soil science journals but deal with NRM, agronomy, plant production, water, resource policy, ecology, pollution or toxicology. A significant question for the ISSS and the professionalization strategies it promotes is whether it should encourage inter-disciplinary publications, or should stick to its parent discipline-based classification. More crucially, as international research trends move towards inter-disciplinarity, context specificities (technological and social), and resource management (in collaboration with social sciences), the Indian NRM R&D community will also address and perhaps lead this effort.

Another significant feature of the ISSS classification is the presence of ‘soil technology’ as a distinct sub-discipline. This mostly contains papers on soil reclamation and conservation, though it is widely acknowledged that all soil sciences (all eight sub-disciplines) produce technologies or knowledge that can be transformed into technologies. There are two possible explanations for this narrow view of soil technology.

First, in the conventional understanding of R&D, technology (embodied or disembodied) is an end product of research. Hence, by definition, all soil sciences sub-disciplines ought to produce technologies. But a separate sub-discipline ‘soil technology’ carrying technologies that solve resource problems becomes important in the light of the resource problems unleashed by a broad array of green revolution technologies (including soil fertility and fertilizers, soil chemistry, etc.). Thus ‘soil technology’ within the soil science community is perceived as the sub-discipline that produces technological solutions to handle second and third generation resource (soil) problems created by research in other disciplines/sub-disciplines of soil sciences.[9] Besides, it helps legitimise the linear hierarchy of science; the position within scientific research, that all natural resource problems can be solved with technologies and that the organizations or institutional arrangements that go with or herald these technologies and their adaptations do not count as much. Secondly, the dominant technological context of agricultural science in general – the irrigated terrains of the Indo-Gangetic Plains (IGP), seems to dictate the content of this sub-discipline, soil technology. The sub-discipline ‘soil technology’, is then

[9] ‘Soil technology’ was introduced in Indian soil sciences as a separate sub-discipline following the International Soil Science Congress held in India in 1982, when the International Society of Soil Sciences had included ‘soil technology’ as one of its commissions.

Table 2
Soil sciences publications in the first phase[a] (1975–84)

Sub-disciplines	No. of publications	Percentage share
Soil science	22	0.5
Soil biology	452	9.4
Soil chemistry& physics	914	19.0
Soil fertility & fertilizers	2246	46.6
Soil erosion & reclamation	139	2.9
Soil cultivations & cropping	853	17.7
Soil surveying & mapping	30	0.6
Soil classification & genesis	143	3.0
Soil resources & management	23	0.5
Total	4822	100.0

[a] See Table 1 (AGRIS data) for Soil Sciences publications in the second phase (1981–2001). *Source*: ICAR, 1987 (Indian National Agricultural Bibliography, Vol. 1, ICAR, New Delhi.

limited in scope (reclamation technologies) and scale (Indo-Gangetic Plains)! The policy significance of these classifications and the disciplinary modes of research they encourage should not be underestimated.

3.2. Content and context: institutional features of soil sciences research

Quantitatively soil science publications take us through two phases of soil science research – the first phase (1975–1984) with 4822 publications, and the second phase (1981–2001) with 2918 publications[10] (see Table 2). The focus on soil fertility and fertilizers (almost half the publications) here can be directly attributed to the aftermath of the green revolution, where there was a significant disciplinary convergence to the green revolution technology (HYV-chemical fertilizer/pesticide-irrigation) paradigm.

There is a clear relationship between the research content (output) and the institutional and organizational context of research. In the sub-disciplines (almost all the 4822 papers in the first phase and the 2900 papers in the second), there is very little evidence of partners/actors or of actor linkages in the innovation process.[11] There is not one paper from Indian soil sciences, that analyses or discusses the institutional arrangements that hinder partnership building with other stakeholders, effective research, utilization of research results in the field (adoption constraints at the farm level being part of agricultural economics), and the need for changes in the content of research or ways of working of research organizations. Since there is no demand from the public agricultural research organizations for the soil sciences to prove their understanding of local soil conditions or land management practices, there are few papers that discuss or explain the specific location or rationale for the experiment/project.

A lab-based perspective, which considers scientific knowledge as the exclusive source of innovations, is characteristic of all these soil science publications. While there are several general papers, there is a clear absence of inter-disciplinary research publications that transcend two or three parent disciplines. Institutionally, the soil sciences are not tuned to learning – in a truly interdisciplinary and self-reflective fashion – from each technological context (eco-region/social domain). Learning for a pro-active NRM innovation system is possible only in a context inhabited by a range of relevant partners (Hall et al., 2000, 2003a,b,c). Given that this learning is not reflected in its conduct of research or in research publications, status and relevance of the soil sciences are being increasingly undermined.

Publication patterns in the soil sciences reveal the institutions or norms governing the conduct of soil science research. While discussing some of these institutions, as formal and unwritten (hidden) norms or rules that shape the content and conduct of research, we bear in mind that (a) these are applicable to all divisions of agricultural science, and not limited to soil sciences alone, and (b) these features are poignant in the case of soil sciences research because innovations in natural resources as a rule are more complex, straddling socio-economic and bio-physical domains and demand both technological and institutional innovations.

3.2.1. Publication oriented research

During the first phase, the Agricultural Research Service (ARS) was a major factor that prompted a major increase in number of publications. The success of the new ARS (Initiated in 1976) into which professionals were appointed by the Agricultural Scientists Recruitment Board (ASRB), depended on an integrated system of evaluations and assessments.[12] It was assessments

[10] The slight overlap of 3 years between the two phases ensures that we do not lose any of the publications. The danger of duplication does exist for these 3 years though some attempt has been made to weed out papers repeated.

[11] This is the case even in sub-disciplines like 'soil reclamation and conservation,' and in the more recent 'soil quality' research, which are issues known for their collective/community-wide perspectives and implications across ecological and economic systems.

[12] A system of Five Yearly Assessments (FYAs), with a "peer review system" and a "point system" of assessment was introduced for personnel evaluation. In the point system, "maximum weightage was given to scientific achievements as evidenced through publications, reports,

based exclusively on publications and reports that led to an increase in publishing. But when the ARS assessments, based on the Five Yearly Reports were discontinued in 1986, the incentive for publication was lost.

Proof of impact or even presence of NRM innovations in the field is not a requirement for assessment/ promotion. The relative reduction in publications oriented research in the post-1986 phase is not because the pressure or incentives for publication has been replaced by other incentives. On the contrary, it reveals an overall lack of stringent evaluation in the agricultural sciences, which has been detrimental to the professional interests and expert authority commanded by the agricultural science community (Raina, 2003b; Raina, 1999; 2003b).

3.2.2. Team work

During the first phase (Table 2 above), assessments of individual scientific merit and merit based promotions caused a complete breakdown of team work. Scientists had serious reservations about the objective assessments within the Five Yearly Assessment (FYA) system, the expertise of peers, and the quality of work of the FYA committees.[13]

Evaluation in the ARS had resulted in proliferation of individual scientist centred projects rather than problem oriented or multi-disciplinary projects (Acharya, 1986, p. 58). Since the research project file (RPF) reporting procedure did not define specific personnel responsibilities in each project, this has led to a further problem of sharing credit and facilities. Teamwork is thus the casualty of the ARS, and it significantly reduced the innovation potential of the soil sciences. Applied soil science research where inter-disciplinary teamwork is a necessity, is also subject to these personnel policies of the Council. Moreover, the Council till date does not have an assessment procedure/method to assess inter-disciplinary research or provide incentives for the same.

3.2.3. Scientific excellence and strategic research

Another casualty of the publications based assessment was long-term strategic research where (publishable) results are not ensured within a period of 5 years. The allegations of repetitive and ritualistic applied and adaptive research in the Council (ICAR, 1988; World Bank, 1990) were all fully justified. The evaluation requirements of the ARS ensured that scientists worked on short-term publication oriented projects, which were mere repetitions of the same experiment in different crops/locations.

Within the practicing scientific community, fertilizer/manurial trials are acknowledged as the most result assured experiments in the short-term, because the expected research output is a fertilizer dosage for a particular crop and season. Given that local innovation potential is not the prime goal (but publications are) these manurial trials are the most replicable, amenable to blanket recommendations of dosage across location, and the given research design can be repeated on any location/eco-region without change.

3.2.4. Location-specificity

India is marked as the country with the highest number of general publications in soil sciences (Arvanitis and Chatelin, 1988). These publications are papers not specific to any location or any one parent discipline but are 'general.' Location-specificity demands interdisciplinarity and teamwork with a range of local partners. Both are unfortunately features that are discouraged by the patrons of soil science research, the ICAR with its policies and the ISSS with its rigid parent-discipline-based classifications. This is of significance, especially, when the leading soil scientists in the country recognize that the demand for location-specific research and application of systems concepts to studies in soil sciences, are increasing in the current context (Raina, 2003c).

3.2.5. Impact

In the recent impact assessment scenario, it is the trend to ask a soil scientist how her/his research has reduced poverty or increased yields. These are almost obligatory in the social sciences, in agricultural eco-

etc." (Randhawa, 1987, p. 132). The practice of maintaining a RPF, with entries of duties assigned, performed, and problems or constraints faced in the assignment, was commenced. ICAR Institutes do till date, maintain Research Project Files, to keep a record of each project proposal (RPF-I) annual progress of the project (RPF-II) and final project report (RPF-III). But these RPFs do not help in personnel evaluation or evaluation of projects because the RPF format does not define goals/expected results, plan of action or procedures, time schedules, and specific work assigned to each individual in the project. Neither the Head of the Division nor the Project Leader can make a meaningful assessment of individual scientists contribution to or performance in the project using the RPF information. Thus, promotions or increments are awarded based solely on publications and the Annual Assessment Reports and the FYAs. But assessment of merit loses meaning when almost all the scientists in the Council are granted promotions. This in turn, frustrates the real meritorious work. About 90% of the scientists who underwent assessments in 1985 were either given promotions or increments. (Randhawa, 1987, p. 133).

[13] While a good majority of the scientists in the Council believe that publications are a sure way to 'obtaining rewards', only 41% of the scientists believe that the FYA is objective. Peer review is a bureaucratic formality; 62% of the scientists do not consider the 'peers' to be eminent scientists in their fields. Only 27% believe that the FYA committee carefully studies the work they are to assess (Bala Ravi and Bandyopadhyay, 1988, pp. 140–141).

Table 3
Different types of soil sciences publications (1981–2001)

Sub-disciplines	Journals	Proceedings	Reports	Books	Total
Soil science & management	868	15	18	1	902
Soil biology & biochemistry	522	38	11	7	578
Soil chemistry & physics	481	52	13	5	551
Soil fertility	371	28	18	6	423
Soil reclamations & conservation.	152	28	27	9	216
Soil cultivation	67	12	3	0	82
Soil survey & mapping	44	21	8	1	74
Soil classification & genesis	74	1	6	0	81
Total	2579	195	104	29	2907
Percentage (%)	88.7	6.7	3.6	1.0	100.0

Source: AGRIS database, various years, New Delhi.

nomics in particular, mainly to legitimise more funding for the agricultural sciences (Raina, 2003a). The questions of 'impact' of soil sciences, addressed to individual soil scientists or sub-disciplines or research institutes is meaningless in a context where the rules/norms of the Council do not encourage inter-disciplinary collaborations, team work, or partnerships with non-research actors. Inter-disciplinarity and partnerships to enable better natural resources innovations exist in statements in vision documents or planning and priority setting papers.

Without appropriate mechanisms for the soil sciences to partner and collaborate with non-research actors in the innovation system, it is meaningless to ask soil scientists to prove impacts. Changes in personnel policy (recruitment pattern, incentives, assessment practices), in non-linear and non-hierarchical working arrangements with other stakeholders (extension, input industry, farmers, local administration, etc.), in research administration, in the content and practice of science (eco-regional or trans-disciplinary concepts and designs in research projects) etc. have been recommended time and again, but are not implemented. The soil sciences need appropriate partners, collaborators in each location, to plan and design and conduct research, as well as for the uptake and adaptation of these research results. It is then the entire partnership that can answer the question of nature and extent of impact.

3.2.6. *Interdisciplinarity*

Interdisciplinary research is being introduced in the Council without any of the institutional changes (incentives or even primary information networks to identify complementing partners or innovations relationships) necessary for inter-disciplinary research. The practice in interdisciplinary projects, with each discipline walking away with a share of the research funds and reporting back at the end of the project period or for a mid-term review with discipline-specific research result, does not provide opportunities for interactions among disciplines, learning or modifications in research. (see, Jeffrey, 2003, and Dr. Katyal's key-note address, in Raina, 2003c).

As a professional association, with significant autonomy from the Council that employs these scientific services, the ISSS can demand institutional changes. These reforms, including rules of assessment/recruitment processes, administrative reforms, etc., can be made to enable effective partnerships with other stakeholders, credit sharing and collaborations with other disciplines, and new and changing roles for science and scientists.

3.3. *Institutional analysis of sub-disciplines and their publication patterns*

Having discussed the institutional and organizational constraints to effective soil sciences innovations, we must now explore briefly, the publication patterns (Table 3) to see how the institutions or norms of the linear R&D model and commodity orientation influence the research outputs of sub-disciplines. This analysis focuses on the publication patterns as in the AGRIS database. We shall first explore the nature of publications and then move on to the sub-discipline-wise analysis.

During 1981–2001, journal papers account for 89 % of the publications, followed by proceedings (7%), reports (4%) and books (1%) (Table 3). Among different types of publications, scientists themselves consider research papers in journals as the most academically relevant output, because proceedings and reports they feel are targeted for internal consumption, for funding agencies or policymakers.[14] Thus in terms of scientific

[14] Note that agricultural scientists in India see themselves as the primary clients of their own research (World Bank, 1990).

Table 4
Soil Sciences publication in Journals (1981–2001)

Sub-disciplines	Years								
	1981–85	1986–94	1995–96	1997–98	1999–02	Total	Indian	Foreign	Total
Soil science	741	11	2	4	110	868	777	91	868
Soil biology & biochemistry	13	264	104	77	64	522	108	414	522
Soil chemistry & physics	3	179	105	76	118	481	233	248	481
Soil fertility	42	125	57	27	120	371	269	102	371
Soil reclamations & conservation.	47	55	18	27	5	152	72	80	152
Soil cultivation	2	41	12	10	2	67	24	43	67
Soil survey & mapping	24	7	0	4	9	44	29	15	44
Soil classification & genesis	4	27	22	6	15	74	46	28	74
Total	876	709	320	231	443	2579	1558	1021	2579
Percentage (%)	34.0	27.5	12.4	9.0	17.2	100.0	60.4	39.6	100

Source: AGRIS database, 2002, ICAR, New Delhi.

productivity, the soil sciences in India are rated high with an average of 122 journal publications in an year (1981–2001). But among the 373 journals covered in the AGRIS database (from the New Delhi centre), over 50 in which a good proportion of the papers with Indian first authors are found, are not refereed journals. Of these 10 are either bulletins or newsletters. These bulletins may influence policy-making or decision makers in input industry or input marketing. Overall, 60.4% of Indian soil sciences publications (journals, books, reports, proceedings) are published in Indian sources while 39.6% are in foreign sources/publications. Among the journal publications the number of papers in foreign (internationally refereed) journals has increased from only 15% in 1975–84 to almost 40% in1981–2001 (Table 4).

3.3.1. Fixation power – looking inwards

Fixation power is a ratio of the number of studies published in a country in a particular discipline or area, which are authored by scientists of that country. An indicator used commonly is the affiliation of the first author. For the year 1983 in the field of tropical soil sciences, compared to the fixation power of France (92.4%) or Brazil (77.5%) or any of the other countries that house the scientific publishing industry like the UK (55.8%), Holland (75.8%), or even the USA (68.1%), India has a fixation power of 34.9% (Arvanitis and Chatelin, 1988).[15] Given the number of internationally refereed publications and foreign authors publishing papers on Indian soil problems/any soil research programme, India has traditionally been one of the few countries with a low fixation power.

The AGRIS database here (1981–2000) reveals a relatively high fixation power of 94% with a first author count (see Table 5). It shows a significant increase in the Indian authorship of papers on soil sciences in India. This high figure is because the AGRIS database, unlike the database used by Arvanitis and Chatelin (1988) includes several journals (170 of the 373) that are not listed in the Journal Citation Reports (JCR) of the ISI, or Science Citation Index. Let us recall here that even the JISSS, the official journal of the ISSS, is not included in the list of Impact Factor Journals prepared based on the JCR. JISSS has a share of over 62% of the soil sciences papers published in Indian Journals. Note also that 92% of these papers in the JISSS that are included in the AGRIS database, belong to three sub-disciplines – soil science and management, soil physics–chemistry and soil fertility. This high fixation power brings us back to our previous point about the evaluation processes within the Indian agricultural research system, the demand for number of publications, the replicability of the soil fertility and related fertilizer/chemical trials, the proliferation of network-refereed or non-refereed journals that do not figure in the JCR. Quality of research is an issue of concern here.

3.3.2. Excellence in research and relevant partners in context

Soil biology, soil science and management, and soil fertility represent sub-disciplines with very high fixation power (more than 95%) with maximum number of papers by Indian authors and affiliation. The high fixation power for soil biology is very significant in this period, because unlike the other two, most of the papers

[15] France, Brazil and Holland have large numbers of French, Portuguese and Dutch journals to which much of the Anglo-Saxon scholars do not make contributions.

Table 5
Fixation power for publications in various sub-disciplines from AGRIS database (1981–2001)

Sub-disciplines	Indian authored papers in journals (no.) (1)	Total papers published in Journals (no.) (2)	Fixation power[a] (%) (1)/(2) × 100
Soil science & management	846	868	97
Soil biology & soil biochemistry	503	522	96
Soil chemistry & physics	432	481	90
Soil fertility	355	371	96
Soil reclamation & conservation.	131	152	86
Soil cultivation	57	67	85
Soil survey and mapping	39	44	89
Soil classification & genesis	59	74	80
Total	2422	2579	94

[a] Fixation power (%): no. of Indian authored papers/total no. of papers in journals (Indian + foreign) in 1981–2001) × 100.

in this sub-discipline are published in foreign internationally peer-refereed journals, indicating the excellence of scientific research in this sub-discipline. While high fixation power for 'soil science' and 'soil fertility' is more due to in-house journals published mostly from various ICAR Institutes and SAU's, the fixation power in soil biology and biochemistry is a matter of pride to Indian soil sciences in terms of quality of journals and excellence in science (as acknowledged by the rigorous international refereeing).[16] In the entire publication profile (journals, books, reports, proceedings), soil science and management and soil fertility stand out as disciplines that are published predominantly in Indian sources, while sub-disciplines like soil biology and biochemistry, soil chemistry and physics, soil cultivation, and soil reclamation and conservation are largely seen in foreign publications. Fig. 1 presents the total number of Indian and foreign publications by sub-disciplines. About 58.9% of the total soil sciences publications from Indian organizations (most of them authored by Indians) are published in Indian sources, and 41.1% are published in international sources. The international sources where Indian soil sciences publications appear are often refereed publications, and therefore are considered relatively good quality research outputs.

A question often aired in soil sciences circles is whether excellence in research will be compromised by increased effort at building partnerships, technology articulation and development networks, markets, farmers and other actors? The case of soil biology where the internationally refereed publications exceed the national local source publications by four times, gives us some lessons. In soil biology, with papers in international journals being almost four times the number of papers in Indian journals, there is obviously an emphasis on excellence in science. The dominance of internationally refereed soil biology publications with first author affiliation in South Indian States is a finding that merits attention. Researchers observe the apparent uptake of soil biology technologies (such as BNF, or Rhizobium technologies) in the South Indian States, (see Rao et al., 2004). The significant presence and interest in soil biology in the South is evident in this regional profile. It is also clear from the available case analyses of successful soil biology or soil microbiology innovations, that besides excellence in research (marked by a striking record of internationally refereed publications) this sub-discipline in South India has also built crucial local partnerships and linkages. In other words, soil biology and biochemistry is one sub-discipline of the soil sciences which proves that crucial partnerships with relevant stakeholders is a significant requirement for the active learning experience

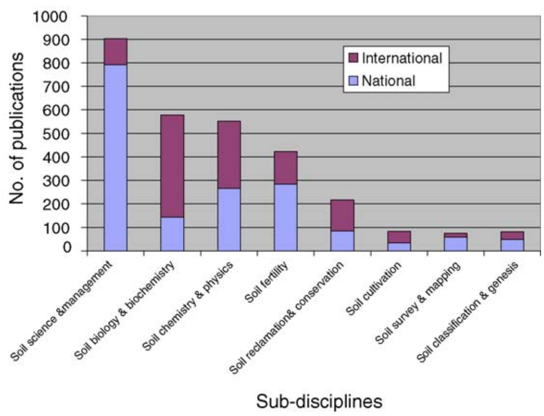

Fig. 1. Soil Sciences sub-disciplines in National and International publications (1981–2001).

[16] This paper has discarded a sub-section on refereeing processes followed in the Indian journals (in-house journals from ICAR and SAUs).

for researchers, excellent research and the social utilization of research results – the scientific public goods. But the case of soil biology and biochemistry seems to be the exception than the rule among soil sciences sub-disciplines.

3.3.3. Dominant production imperatives and national interests

A more detailed look at these sub-discipline publishing patterns by type of publication reveals that journals and proceedings (of conferences/workshops) with the Indian share accounting for 60.4% and 60.2% of the total, seem to be more Indian than international publications. But reports (especially technical and programme based) as well as books with the Indian share accounting for only 26% and 22% of the total, seem to be predominantly foreign publications (Table 6).

Consistent international pressure or donor demand for work on soil reclamation and conservation is evident in the significant number of foreign publications over Indian ones in all four types of publications (Table 6). The relative lack of interest from the international collaborators/donor community in the sub-disciplines soil survey and mapping as well as soil classification and genesis is also evident from the proceedings, reports, and books published in these sub-disciplines. This is striking when compared to the number of conference/seminar proceedings, reports and books published abroad or authored by/with foreign authors in other sub-disciplines. Soil classification and genesis stands out as the single sub-discipline that is sustained by an internal national imperative for information about soils/land as well as a fundamental scientific quest. The publication pattern here is a contrast to that of soil fertility, chemistry, physics, biology and biochemistry.

Three sub-disciplines, soil science, soil chemistry and physics and soil fertility account for almost 82% of the Indian journal publications in soil sciences (Table 6). This may be interpreted as a dominant feature of Indian soil science – three of the most popular sub-disciplines that contribute yield-enhancing technologies in convergence with the green revolution paradigm and the commodity orientation in agricultural science in general. The other reason is that in the journal database, AGRIS draws from a heavy aggregation of soil science publications during the period 1981–85. The late 1970s and early 1980s let us recall were a phase of peer review based assessment of agricultural scientists under the ARS. This accounts for over 34% of the total publications being reported during the 4-year period 1981–85. Overall, the decade 1986–96 stands out as an important phase in the soil sciences, reporting a significant (40%) share of the total publications. This decade also witnessed the growth of the sub-discipline of soil biology and biochemistry in its own right, though the sub-discipline was one of the first well established ones in the history of Indian agricultural science (Rangaswami et al., 1971).

3.4. Lessons from publication patterns

The analysis of the publication patterns by sub-disciplines confirms the dominant irrigated commodity production oriented norms that govern the choice of problem, research content and outputs of the soil sciences. In a country where land management during drought conditions is a regular and critical livelihood concern, there is little research in the soil sciences devoted to understanding or helping the management of drought prone soils (estimated by the Central Water Commission as 5.12 Mha. spread over 74 dis-

Table 6
Share of Indian and foreign publications by the type of publication

Sub-disciplines	Journals		Proceedings		Reports		Books	
	Indian	Foreign	Indian	Foreign	Indian	Foreign	Indian	Foreign
Soil science & management	777	91	11	4	4	14	1	0
Soil biology & biochemistry	108	414	27	11	5	6	3	4
Soil chemistry & physics	233	248	27	25	5	9	2	3
Soil fertility	269	102	13	15	0	18	1	5
Soil reclamation & conservation.	72	80	12	16	1	26	0	9
Soil cultivation	24	43	9	3	1	2	0	0
Soil survey & mapping	29	15	21	0	8	1	0	1
Soil classification & genesis	46	28	1	0	2	4	0	0
Total	1558	1021	121	74	26	80	7	22
Percentage (%)	60.4	39.6	62.1	37.9	24.5	75.5	24.1	75.9

Source: AGRIS database, various years.

tricts). A minimal 2% of soil science publications have to do with drought; there is a serious lack of interest in issue-based research, and a predominant concern about maintaining the professional, scientific discipline (sub-discipline) identity. In a system designed to publications based rewards and incentives, the governing principles of science are not those of innovation and meaningful changes in livelihoods/ecosystems, but those of instrumental knowledge or technology generation.

The adoption of fertilizers and the incremental yield due to fertilizers are cited often as the proof of impact of soil chemistry. It is worth noting here, the widespread institutional support to the fertilizer industry, infrastructure (roads, markets, transport, credit, etc.), price policies and subsidies, soil testing facilities, extension skills (demonstration plots, messages, field visits, trainings, etc.) and significant private sector presence (involving significant numbers of local input dealers, special schemes, services, linked markets – other inputs/chemicals, product processing facilities, etc.) in the agricultural chemistry innovation system; these non-technological factors account for the impact of soil chemistry often indicated by the increase in use of fertilizers or a particular compound/mixture. Though the Council's own reviews and others have commented on how ritualistic and repetitive these manurial/fertilizer trials are, the adaptation and adoption of these chemicals/fertilizer technologies by the farmers shows how other actors/agencies and their interests lead to successful innovations. Innovations do not flow from science alone (Biggs, 1990). Soil chemistry with repetitive and ritualistic research and a record number of publications in journals (not refereed at all or refereed in-house/within closed networks), is one sub-discipline that makes it clear that several other actors or components have a crucial role to play in innovations, that these actors and linkages can be fostered by State/policy interventions, and these decisions/processes need not draw from technology or excellence in scientific research.

Compared to the policy induced innovation system around soil chemistry, the direct impact of soil physics on productivity enhancement is considered pretty negligible; if anything this sub-discipline is of little significance to the productionist agricultural science regime, especially one organized in a rigid linear hierarchy of knowledge, without any relevant systems understanding, or linkages to other components of the agricultural innovation system. The soil physicists in the country have tried to orient this sub-discipline known for its study of long-term trends and changes in the structure and physical properties of soils; making attempts to rename this sub-discipline to suit the commodity production norms. The All India Coordinated Research Project (AICRP) on soil physics was renamed "AICRP on Soil Physical Constraints and Their Amelioration for Sustainable Crop Production"; the acronym for this AICRP being limited to SCP – emphasizing the commodity production imperatives of soil physics. The ICAR in 2001, closed down this SCP or the AICRP in soil physics, despite some excellent research results being produced by the soil physicists (see IISS, 2002). Soil physics is now considered a troublemaker; always pointing out degradation of physical properties of soil, which invariably means that the degradation of that land has been going on for some time (interview with soil physicists, December 2001). This is not the kind of research finding that the ICAR, focusing on productivity enhancement research and rules or ways of working (institutions) that do not facilitate learning from technological contexts, would like to see.

Compared to soil chemistry and physics, soil biology and biochemistry is a sub-discipline that has shown a significant increase in publications over these two decades (1980–2000), as well as impacts in terms of debates on soil quality and health/fertility, organic farming, and crucial topical areas such as soil biodiversity. Though the legitimisation used in soil biology is also that of commodity production, this sub-discipline is second only to soil classification and genesis, in its quest for fundamental soil processes which may or may not have production/productivity implications but several other major land management or agricultural policy implications. Overall, it may be argued that the desire to prove scientific excellence through internationally refereed publications is strong in a relatively young sub-discipline like soil biology and biochemistry. Compared to the other sub-disciplines soil biology does not seem to rely excessively on its own parent discipline-based in-house professional associations or journals.

The soil sciences publications also seem to conform to one particular design or format. Most of the papers provide an introduction about the results from a similar experiment/previous research result and almost 90% of the results/findings say whether this particular paper conforms to or differs from the previous experiments/findings. The papers read like a monologue of the soil sciences talking to the soil sciences. In applied research, as in the agricultural sciences in general, there is a need to specify and rationalize the choice of context or problem in the introduction to a paper, and to analytically lay out the conclusions and its implications for further research in the soil sciences (or other disciplines), research policy, agricultural policy, stakeholder interventions, market incentives, land management practices, research methodology, etc. But for this, the institutions and organizations of science must enhance the ability of the sub-disciplines to interact with and learn from each other, and build relevant partnerships with stakeholders to work towards innovation oriented (not publication oriented) research. There is then no need to legitimise soil sciences research relying exclusively on their commodity production contributions.

3.5. *The norms of commodity production*

The overwhelming commodity orientation in agricultural research is evident from the funding and organization of natural resources research in general. The allocation of the government grants in ICAR (1980–81 to 2000–2001) shows that commodity oriented research accounts for more than 70% of research allocations. The allocations made by the Central Government to the 'soil and water conservation' account of the ICAR has declined from 1.58% (1980–81) to 1.22 % (1990–91) and less than 1% after 1997–98 (*ICAR*, *Budget Books*, various years). Even with this steady erosion of the meager allocations made for soil and water conservation research, we notice that allocations to this division grow at a slower rate compared to the growth rate of allocations to other divisions (Rajeswari, 1995; Sangar, 2002, and estimated from *ICAR Budget Books*, various years). But this in itself is not cause for alarm because the NRM division is much larger than soil and water conservation. What is more alarming however, is the gradual reduction in the resources available for research in the institutes under the NRM division of the ICAR (Table 7). This is evident from a decline in the ratio of non-plan to plan expenditure, from 1:1.16 (1993–94) or even 1:1.19 (1994–94) to 1: 0.35 (2000–2001). Increasing plan schemes (from other programmes or bilateral agreements/loans for research resources (say like the National Agricultural Technology Project (NATP)), ought to increase the plan resources expended directly on research costs. Since Table 2 does not reveal extra budgetary resources it is not clear whether the institutes under the NRM division in the Council utilize external sources of funding for research expenses, while the Council mainly supports the research infrastructure of the NRM Institutes (i.e., non-plan expenditure on overheads, salaries for personnel, etc.). What is evident here, is an overload of non-recurring/non-plan expenses in the NRM Institutes. *Given the load of overheads and other committed expenditure like salaries,* the Council has limited resources available for regular research and little for building linkages with other actors in the NRM innovation system. This overload of non-recurring expenses is incurred in maintaining a huge administrative labour force. Even when enough research resources are available, the administrative impediments often undermine the ability of scientists to utilize these research resources productively. The elaborate administrative requirements and general lethargic administration of research are major impediments that most agricultural scientists feel can be done away with.

In the agricultural sciences the 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). The magnitude of agricultural output is the evidence of successful science. The processes of production and consequences of these production processes are addressed as predominantly technological problems that can be solved using largely technological solutions. There is recognition within the scientific community that the impact of agricultural production on the environment and human health, as well as the corresponding impact of the environment say, climate change, pedological changes, resource degradation or depletion on agricultural production, should be considered carefully in research and development policies. But within the formal commodity oriented decision-making processes of the ICAR and the SAUs, these issues are marginal. The competence to enhance commodity production is seen as distinct from and more crucial than (at times opposed to) the competence to address natural resource problems. Programmes like the recently concluded NATP (ICAR-NATP, 1998) and many scientists, do agree that agricultural production knowledge is embedded in production systems knowledge and ecological-cum-socio-political knowledge. Meanwhile, there is increasing disillusionment with the way agricultural research is organized and conducted, particularly in view of the evidence of declining crop productivity growth rates, increasing ecological disruptions, inability to meet new market and policy demands (ICAR, 1998a,b; Ministry of Agriculture, 2000; Raina and Abrol, 2002) and the apparent inability of agricultural research organizations to reverse these trends.

Internationally, within the soil sciences, these production oriented and sustainability oriented concerns evoke two main strands of research: (1) further intensification of production-oriented (yield-enhancing/management) research, and (2) better understanding of and technologies for management of soil processes including interactions with other systems (plant, human, minerals, microbial and other soil and water components, etc.). While the former uses conventional discipline-based

Table 7
Research expenditure of institutes under the Natural Resources Management division[a] of ICAR (1995–2001) (in Rs. Lakhs)

Sl. no.	Institutes	1993–1994		1994–1995		1995–1996		1996–1997		1997–1998		1998–1999		1999–2000		2000–2001	
		Non-plan	Plan	Non-plan	Plan	Non-plan	Plan	Non-plan	Plan	Non-plan	Plan	Non-plan	Plan	Non-plan	Plan	Non-plan	Plan
1	CARI, Portblair[b]	113	235	115	225	144	239.78	165	85	209	95	290.5	–[b]				
2	CAZRI, Rajasthan	500	127.1	460	95	530	130	600	120	786	120	1063	170	1139	170	1169	125
3	CRIDA, Hyderabad	165	114.5	169	88	200	150	220	120	310	110	371	165	354	121	499	126
4	CSSRI, Karnal[c]	225	85	220	110	268	84	300	80	366	103	462	130	545	111	587	138
5	CS&WCR&TI, Dehradun	362	260	340	200	377	210	530	120	687	120	932	220	918	216	964	203
6	NBSS&LUP, Nagpur	25.5	140	28	246	39	134	30	280	67	153	80	160	93	163	172	135
7	IISS, Bhopal	255	266	255	230	290	304	340	130	500	158	967	330	1184	300	790	346
8	ICAR Research Complex,N-E hill, Barapani	429	240	475	250	530	225	545	220	859	220	938	475	1013	400	1226	337
9	ICAR Research complex,Goa												140	83	100	110	79
10	ICAR Research Complex, East. region														100		14
11	NRC for Agroforestry, Jhansi	22	86.48	22	48.7	25	67	30	120	61	120	80.5	205	97	206	108	108
12	NRC for Weed Science, Jabalpur	21	80.17	20	120	23	108.07	21	100	60	98	93	150	101.5	168	105	102
13	WTC for Eastern region, Bhubneshwar	13.5	99.4	12.5	115	15.5	119	17	187	28	115	66	130	68.5	174	79	200
14	PD of Water management research, Patna[d]	10	368.62	9	361	12	187	7	92	20	265	57	200	72.5	147	100	100
15	PD of Cropping systems research, Merrut	54	460	49	517	58	380.33	57	81	68	199	179.5	139	181.5	268	224	83
	Total	2195	2562.27	2174.5	2605.7	2511.5	2338.18	2862	1735	4021	1876	5579.5	2614	5850	2644	6133	2096
	Ratio: non-plan:plan	1	1.167	1	1.198	1	0.931	1	0.606	1	0.467	1	0.469	1	0.452	1	0.342

Source: compiled from Annual Reports of ICAR institutes (various years).
[a] Called Soil, Agronomy and Agro-forestry Science Division till 1997–1998.
[b] After 1998–1999 CARI, Port Blair has been shifted to Horticultural Division.
[c] Plan expenditure for CSSRI is inclusive of provisions towards use of saline water project.(1995–1996).
[d] Project Directorate (PD) for Water management research, Rahuri shifted to Patna in 1995–1996.

research methodologies, the latter is a quest built on inter-disciplinary research methods, incorporating social and environmental interests (Keeney, 2000). The emerging area of research on 'soil quality' is part of the latter response (Karlen et al., 2001, 2003; Herrick, 2000). These two responses to agricultural production policies and practices that are ecologically and economically unsustainable have since the 1980s, led to considerable soul searching and rethinking of research strategies in Indian soil science research (See ISSS Symposia years 1982–2002, and some of the NAAS workshops since the 1990s). In the research institutes under the NRM division of the ICAR and in SAUs, research on residue management, organic agriculture, biological nitrogen fixation, zero tillage, soil amendments, reclamation measures, and much of pedology-based land characterizations, etc. are projects that had their origin in this milieu. Yet in much of soil science research, even in the latter group that addresses system-wide problems and seeks integrative or location specific solutions/strategies, the insurmountable problem seems to be the inability to balance the environmental quality and production imperatives, and the continuing yield enhancement legitimisation of R&D (Doran, 2002).

There have been significant attempts at an integration of commodity oriented research with natural resources research (Goldsworthy and De Vries, 1994), at combining (and modifying) scientific soil science knowledge with traditional/indigenous knowledge of soils (Talawar and Rhoades, 1998; Blaikie et al., 1997), at delineating resource management domains within which commodity production and management objectives can be addressed (Craswell et al., 1998). The authors have highlighted the need for systems perspectives, appropriate linkages between actors, the social capital built through and necessary for natural resource innovations, choice of the right policy tools, and changing the partial/reductionist professional perceptions of scientists (Goldsworthy and De Vries, 1994; Douthwaite, 2002; Biggs and Smith, 1998; Chambers, 1989; Rhoades, 1999). NRM literature also presents several active innovation clusters in biological nitrogen fixation (AABNF, 2001; Raina et al., 2004), land management and systems research for rural livelihoods (Mortimore et al., 2000), organic farming (Lampkin, 1992; Lampkin and Padel, 1994), ecological agriculture (Altieri, 1987; Altieri et al., 1998), land care programmes and their ethical implications (Uphoff et al., 1998; SEA News, Several years, 1990; Pannell, 2000, and some crop-based innovation clusters where resource management is integrated as one of the components, as in the Systems of Rice Intensification (SRI) (Stoop et al., 2002). These soil science research problems, with strong inter-disciplinary contents and collaboration of several relevant partners (extension organizations, banks/other service organizations, community based or micro-finance groups) are absent in Indian soil sciences projects and publications. Little has been done to translate any of these lessons from successful NRM innovation clusters into the organization and conduct of soil sciences research or agricultural research overall, in the public research organizations.

Unlike the innovation clusters above, there seems to be an inadequacy within organized mainstream soil sciences research, to engage effectively with other (non-research) components of the soil/land management innovation system. If contextualized within a wider innovation system, the soil sciences can become a strategic knowledge alliance to understand natural resource systems and manage them to meet the diverse demands of the new millennium. In the commodity oriented, linear R&D model, the soil sciences are reduced to research tactics for augmenting intensive yield enhancement practices.

4. Institutional constraints: the role of the professional association

The social sciences now have ample evidence to prove that technology alone is insufficient to make any impact on yield or poverty reduction (even in a relatively less complex technology like crop varieties) (Biggs and Smith, 1998; Hall et al., 2001). Technology can make an impact on poverty reduction or ecological sustainability or sustained yield enhancement, only when there are appropriate partnerships and other institutional arrangements that encourage scientists to confront complex problems and contexts, build and sustain self-reflective evaluation cultures, and recognize/change the different cultures of science in different organizations (Hall et al., 2000; Biggs and Smith, 1998; Ekboir, 2003; Raina, 2003a; Hall et al., 2003a,b,c in *Agricultural Systems*). The partners in an innovation system also go through continuous evolutionary cycles of learning and innovation, maintaining a continuous interaction with diverse research and non-research actors (Lundvall, 1992, 2004). Scientific research as well as all other actors are seen to take on shifting roles, as technology or information producers, information users and get involved in a need based exchange of knowledge (Hall et al., 2004). This in effect demands an institutional context that supports interactions and knowledge flows between actors. (Hall et al., 2000, 2004; Raina et al., 2004).

An important question that all the agricultural sciences and the soil sciences in particular need to ponder over is whether technology generation for commodity production is the exclusive justification for the agricultural sciences. An interrogation of this sort is essential for the hard sciences see why they are unwilling or unable to face the complex ecological and social contexts of technology generation and utilization.

First and foremost, there are the organizational – including funding, management and evaluation of research – constraints that the hard sciences like the soil sciences have learnt to live with. Secondly, functioning within these constraints, especially within a linear model of R&D, leaves little scope for these sciences to interact with, be accountable to, or learn from other actors or components of the natural resources innovation system. A third and important adaptive response that the soil sciences have made to function within these organizational constraints and uni-dimensional (publications based) evaluations, is the proliferation of in-house journals from Departments or Research Institutes, refereed by familiar colleagues in the same discipline/sub-discipline. The attraction is ease of publication. A further disadvantage is the increasingly narrow and specialized contents of these journals and the papers that effectively hinder any inter-disciplinary questions/analyses. None of the papers contain or reflect any concern expressed in conversation, about other disciplines or components of the soil/natural resource innovation system. Why and how should scientists address complex technological contexts and problems if as a matter of policy, their research Councils and patron States impose such institutional constraints?

Agricultural research and extension, the exclusive preserve of the public sector till the 1980s, was not subject to institutional reform concerns till recently. The soil sciences can and must enable institutional reform. First of all, the recent private investments in agricultural biotechnology as well as the criticisms about public sector science and its impacts on soil and water degradation have evinced some concern from public sector R&D. For one, the ICAR and the SAUs whose scientific mainstay was plant breeding (research output measured in numbers of varieties released), now find themselves marginalized in the new millennium with a plethora of new actors and organizations addressing a wide range of S&T issues from rural livelihoods to international trade and climate change. A second and crucial imperative was the increasing criticism about a general decline in Indian science and a need for rigour and relevance instead of the repetitive and ritualistic agricultural sciences (Balaram, 2002; Arunachalam, 2002; ICAR, 1988, World Bank, 1990).

Thirdly, Indian agricultural research, especially research on natural resource management (NRM) including the soil sciences, has been asked to respond to several agro-economic, political and scientific crises (Raina and Sangar, 2002; Mortimore et al., 2000). Fourthly, there are lessons from the way the international agricultural research centres (IARCs) under the Consultative Group on International Agricultural Research (CGIAR) are attempting to respond to various concerns and technological opportunities including poverty reduction, ecological degradation, and agricultural biotechnology (Hall et al., 2004; World Bank, 2004). While some of these responses have been organizational like converting an irrigation management institute (with a narrow focus) to an institute for water resources management (wider mandate with a more integrated perspective); there have been several important institutional changes too. Some IARCs have established new protocols or norms for partnerships – across research organizations, other development organizations, different sectors (besides agriculture, and the public sector), rules for negotiating property rights, commercialisation, legal issues and assured access to technology for small farmers, incentives and norms for re-orienting research incorporating equity, gender, ecological security and other social concerns. These are beginning to usher in a new culture of science in these CG centres, many of which have been subject to severe fund cuts (Hall et al., 2002, 2004; Douthwaite, 2002).

Finally, the soil sciences have an active professional association, the Indian Society of Soil Sciences (ISSS) established in 1934. The ISSS is now part of the International Council of Scientific Unions (ICSU). The soil sciences professional association offers scientists a forum for debate, discussions, expression of frustration, generation of new collaborations, meeting and learning about organizational contexts and problems (different from their own). An overview of the ISSS (Section 2 above) reveals several important contributions that it can make towards institutional reform in the soil sciences.

Professional associations are important in the transformation of highly institutionalized fields. Firstly, by giving its members an identity, consistent space to interact, and a common understanding of conduct and modes of behaviour, a professional association enables the “intra-professional agreement over boundaries, membership and behaviour” (Greenwood et al., 2002, p. 62). The ISSS, has its own journal, the JISSS, and has an active interest in promoting the professional identity as well as impact of the soil sciences in society. The strong parent-discipline-based classification of the soil sciences into sub-disciplines, the clubbing together of all the not-directly-production-enhancing sub-disciplines, the overall commodity production legitimisation (even in recent research areas like 'soil quality' which seek an environmental/democratic legitimisation) and the inclusion of a separate sub-discipline (soil technology) reveal the boundaries and behavioural norms that this professional association reinforces among its members.

Secondly, the professional association is also a forum for interactions with other stakeholders. By representing themselves to others through the association, the members get to rethink and negotiate their practices, 'to seek acceptance or openly contest the legitimacy of the projected identity and role of the association' (op cit). The analysis of sub-disciplines reveals that the ISSS always conforms to the productionist philosophy and unquestioningly accepts the commodity oriented norms of the country's agricultural policy and R&D policy, despite strong research results from within the soil sciences that show how the productionist philosophy and intensive production practices lead to major ecological degradation and imbalances. The ISSS, like the ICAR (see ICAR, 1998) knows that these soil and water degradation processes ultimately will lead to declining productivity and declining profits for the farmer (who has to invest more and more to maintain production levels), but the need to conform is important to the association. Since the ISSS has stated objectives to promote excellence in soil sciences, judicious use of soil and water resources, and increase public awareness of soils, this is an appropriate forum for the soil sciences to interact with other stakeholders – non-scientific actors in particular.

Thirdly and most important is the role that a professional association plays "in monitoring compliance with normatively and coercively sanctioned expectations" (op cit). Though such associations have often been labelled as conservative, reactionary forces that do not permit progressive reforms, the professional association being a torchbearer for the identity and aspirations of its members, does become a platform for blending conservatism with reform recognizing how the external world perceives them and the area of expertise they represent. The ISSS, in its refusal to contradict the ICAR Head Quarters when it wound up the national soil physics Co-ordinated Research Project, did conform to the norms and legitimisation of commodity production, immediate results seeking, myopic research vision, and compartmentalized thinking, which are all antithetical to the scientific and social commitment of the soil sciences. But in its vigorous debates about organic farming, soil quality, and problem soils, the changing roles of and expectations from soil chemistry and soil biology, in its encouragement of pedology and soil genesis and classification, in its (limited) engagement with a few important NGOs involved in constructive soil and water research and development, the ISSS does seek reform. While expectations from the ISSS are growing among the soil sciences community, it must also be recognized that institutional reform in the sciences is not created in a day, rashly, but gradually grown upon older institutions or norms, replacing or pushing back these old norms as the new institutional practices take over (op cit).

4.1. Professional association as an actor in the NRM innovation system

The professional association is a crucial and relevant actor in an innovation system. Yet, little attention has been paid to this actor, even within the nuanced, context specific and historically sensitive accounts of innovation in the innovation systems literature. The agricultural science community being a privileged community has not yet been subject to the careful anthropologist's examination of roles and relationships that rural households have. Even innovation systems literature tends to treat scientists as a homogenous entity, despite the existence of several forums (professional associations, local science popularisation networks, etc.) in which scientists belong and participate actively. The case of soil sciences research in India reveals some of these nuances, where scientists as part of their public sector organizations do take several institutional and organizational constraints in their stride, thought they can press for debates or analyses of these constraints and their impact on research content within their professional association. There is a felt need, though not expressed openly, within the soil sciences community that some of these institutional and organizational constraints must be addressed and that too by their professional association. The innovationsystems literature points to us the relevance of these institutional and cultural contexts; learning about and for innovations is an essentially interactive process. Scientists in these public sector organizations are constantly learning with a flow of information, perspectives and analyses to and from their organizational contexts and their professional and social contexts. It is this learning and rich experience within the soil sciences professional association that can initiate the institutional reforms towards a successful and dynamic NRM innovation system.

The professional association as a forum for discussing and resolving intra-disciplinary boundaries and behavioural patterns, as well as the platform for interaction with other stakeholders, presents the lead for each institutionally entrenched discipline like the soil sciences, to break out of this institutional quagmire.

Professional associations can play a major role in de-institutionalization and re-institutionalization, building sufficient flexibilities into the re-institutionalization processes so that the current status of a repetitive and ritualistic soil sciences, constrained by the commodity production norms of agricultural sciences, is never repeated. Already several members of the ISSS are conscious that research programmes and funds marked for improving soil quality, or understanding soil systems, say in coastal ecosystems or other specific regions, advanced research in soil processes and flora/fauna for organic agriculture, soil certification for trade/product quality assessments, etc. are moving to research foundations/organizations outside the public sector NARS. The professional association, the ISSS, can form a platform for the soil sciences to interact with and collaborate with these new actors in natural resource innovations.

The professional association as a torch bearer of institutional reform can also bank on the trust and professional commitment of the scientists. In the history of Indian agricultural research and extension, attempts at reform have been limited to some organizational changes and have often been considered a job outside the world of science, to be accomplished by some external review team or the bureaucracy (Raina, 1999, 2003b). It is also perceived as a one off event, a rare one that has to be made as bearable as possible (Jha, 2002a,b). Therefore, as a painful change often thrust upon science and technology diffusion organizations, by an external or hierarchically superior agency, there is always this fear, that institutional reform might be dictated by a bureaucratic review team with little knowledge about scientific research and innovation processes.

Yet, there is an apparent reluctance amongst the agricultural R&D community to engage with the issue of institutional reform. The larger body of scientists and extension officers in these formal organizations do not perceive that institutional reform has to do not only with administrative or organizational changes but also directly with the content and the conduct of hard science. The professional association, the ISSS can demonstrate that knowledge production and use is a highly context specific affair. Through an analysis of the research content, the professional association can prove the need for changing partnerships, new rules of research conduct and assessment, alternative ways of learning from/about different technological contexts, etc. It can enable institutional reforms from within, with the active involvement of and debates among the scientists and the key stakeholders.

Further, as an evolving forum of knowledge and knowledge based interests (say, as in the sustenance of a new sub-discipline like soil biology or an issue demanding rigorous research like organic farming or soil quality), the professional association can press for reforms not as a one off event to be tolerated or manipulated, but as a continuous and on-going process of change that will enable research and extension to confront their internal weaknesses and interact with as well as effectively learn from their social and ecological constituencies.

The professional association can demand lessons from case studies of positive natural resource innovation systems. These lessons can then set the de-institutionalization processes in motion, within new partnerships and formulations of specific innovation programmes and projects. The professional association can take on institutional reform in a phased manner, beginning with selected innovation clusters built in/around arid zones research, coastal ecosystems, saline soils, mountain agriculture, or BNF. None of these issues can be addressed within the norms of the linear R&D organizations and overriding commodity production imperatives. Livelihood concerns (assured through better overall incomes and not merely through increased production), farm and household sustainability over time, explanations of meso-micro level ecosystem interactions in (induced by) these systems, etc. become crucial when projects are designed for the sustainability of these systems.

The credibility and the future of the soil sciences in the public sector are at stake. The ISSS can and must enable institutional reforms in the soil sciences, moving them from the current instrumentalist technology generation agenda to a pro-active learning and innovation agenda. In this regard we highlight a few specific lessons from this paper, as action points that are relevant for the ISSS. The ISSS should

- actively explore and initiate active partnerships wherever possible with other scientific and non-scientific actors,
- encourage debates and discussions on the institutional contexts and organization of soil sciences research,
- take up case studies of successful NRM innovation, and devise strategies to identify and manage the institutions or rules that govern the relationships (with other stakeholders/partners) and processes of soil sciences research in these NRM innovation systems,
- demand of each research project an account of how the institutional and organizational contexts influence the project, and encourage scientists to innovate ways of overcoming these constraints to enable NRM innovation,
- actively highlight systems perspectives revealing that the utilization of technology or knowledge in society

(innovation) is a result of several institutional as well as technological changes,

- break the hierarchy of science and help scientists understand research as a social process of learning in an innovation system, and
- engage itself as an active 'public relations officer' for the soil sciences in the NRM innovation system.

These action points that emerge from our analysis of the institutional constraints that are evident in soil sciences research content and the potential role of its professional association can play, do conform with the accepted principles of an innovation systems framework (see Lundvall, 1992). But these points of action are not a blue print for the ISSS. The idea is to see how the ISSS can help the soil sciences gain their rightful place in the scientific profession and serve the purpose of enabling NRM innovations in India. It is a paradox that this learning and re-institutionalization demands a self-reflection and an evaluation culture that only a professional association can provide.

5. Conclusions and policy implications

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 the existing institutional inertia, to face the complexities of resource degradation and agricultural policy.

Institutionally, both research policy in the country and organization of research in the ICAR and the SAUs are geared for commodity research. They assess soil sciences research using the main criterion of yield enhancement. There is limited capacity for effective stakeholder interactions in innovation. Applied research (with the same research design) in different crop or agro-ecological permutations and combinations seems to be the safe norm that does not demand active stakeholder involvement or wider systems understanding. Besides the neglect of critical areas of fundamental knowledge and local (indigenous) knowledge, this has resulted in an increasing inability to address complex technological contexts.

A major policy implication emerging from this paper concerns an innovation policy that allows for constant interactions/collaborations between the social sciences and the soil sciences. Concerned agricultural sciences informed by and in close interaction with the social sciences, must now lead this debate about the relationship between innovation processes and research policy

As a community of practicing innovators in the agriculture sector, the soil science community must now actively orient its research effort to involve relevant stakeholders, alter project plans/research designs to different agro-ecological and stakeholder specifications, and explicitly include social scientists and policy-makers in their innovation systems. In a rapidly changing economic, ecological, political and organizational context, the soil science community must now be prepared to face these complexities of agricultural innovation and more importantly, help agricultural research policy-making. That these jobs (systems understanding, local knowledge/actor linkages, research planning/evaluation, and policy-making) can no longer be the exclusive domain of the social sciences (economics) is obvious. Institutional reform and further evolution of the body of knowledge of the soil sciences demands the active collaboration of soil scientists and social scientists, among other relevant actors.

In agricultural research policy and practice, an integration using systems perspectives and concepts, of the commodity oriented research with natural resource based research, is warranted (Goldsworthy and De Vries, 1994). The soil science community must now be prepared to lead the agricultural sciences through an ecological and social re-orientation, addressing all other key concerns in the knowledge about, utilization and conservation of natural resources. This demands a deeper and more critical understanding of the rules, norms and values that govern the agricultural sciences, and the soil sciences in particular. Otherwise it is unlikely that we will have innovation systems that can constantly review and reform the way 'research programmes are conceived, who participates in the programmes, how the programmes are conducted, transformed, reformulated, adapted, analyzed, lessons documented and deliberated, and development ensured' (Hall et al., 2003a,b,c). The task at hand now, is to make the institutional questions about research organizations more explicit and acceptable. Along with increasing recognition of the way the R&D processes (and the institutional arrangements that shape it) affect the success of the technical solutions it produces (Engel, 1997; Hall et al., 2000), there is a demand for policies that can promote broad-based research partnerships as well as excellence in science in a non-hierarchical system that would create the conditions for institutional learning. (ISNAR, 2003; Hall et al., 2003a,b,c). Agricultural research policy efforts must now focus on providing ample space and voice to professional associations like the ISSS, to address these questions and exert pressure from within the research organizations (using scientists who are members of the ISSS) to encourage institutional reform.

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