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Boundary concepts for interdisciplinary analysis of irrigation water management in South Asia

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Abstract

This paper reviews the boundary concepts that have emerged in interdisciplinary irrigation studies in South Asia, particularly India. The focus is concepts that capture the hybridity of irrigation systems as complex systems, and cross the boundaries of the natural and social sciences. Concepts capturing the materialisation of rights, design-management relations and the social construction of technology, the notions of landesque capital and (the valuation of) ecosystem goods and services, and finally the broader issues of space-time relations and a cultural politics of water, are explored. The paper takes the analysis forward by suggesting starting points for more comprehensive interdisciplinary social theory on irrigation. On the side of formal theory a focus on a combination the emerging concept of hydrosocial cycle with structure-agency theorisation as morphogenesis is proposed; on the side of substantive theory three avenues for investigation of the materiality of the social process of irrigation are proposed in the commodity form, a materialist institutionalism and the embodiment of agency. The paper concludes by listing five further research activities.

Keywords:
interdisciplinarity, India, irrigation, boundary concepts, technology, landscapes

1 Introduction

The case for natural-social science interdisciplinarity in water resources management analysis is easily made. It derives from 1) the complexity or multidimensionality of water resources management as a concrete phenomenon, and 2) the perceived urgency and intractability of water resources management problems and conflicts urging decision makers to look for 'integrated', 'adaptive', or otherwise comprehensive approaches. The latter has led to an upsurge in water resources management studies and policy approaches that seek to capture, and cut through, the socio-material complexity of water systems dynamics, and the complexity of their contested and negotiated transformation. The relevance and need for this is as apparent in South Asia as it is elsewhere (see for instance Baviskar, 1995/2004; Joy et al., 2008; Ballabh, 2008; Shah, 2009).

The intellectual and institutional odds are still largely against practising science in interdisciplinary mode. Scientific disciplines continue to be staunchly defended territories, occupied by a diversity of academic tribes (Becher and Trowler, 2001); academic specialisation, no matter how useful for some purposes, makes 'integration', on any definition, a tall order (Pohl and Hirsch Hadorn, 2007); the organisational division of labour in government and administration means that ministries and sectors experience great difficulties to interact and collaborate effectively; research remains uncomfortably related to policy, expert and scientific knowledge separated from lay and local knowledge. Cutting through all this are different worldviews and political standpoints, within science as much as outside it (Lele and Norgaard, 2005). Nevertheless, the poignancy of contemporary natural resources management controversies is increasingly forcing inter- and transdisciplinary research – policy related research funding being an important instrument. Klein's (1996) seminal book on interdisciplinarity is titled Crossing Boundaries. There is no scarcity of boundaries to cross for those who attempt to develop 'integrated perspectives' on the complex system that water resources management is.[2] In US sustainability science the term 'boundary work' has been coined to refer to the concerted and systematic effort that boundary crossing involves – it is (hard) work (Cash et al., 2003). This work primarily focuses on the research-policy boundary, and what can and should be done to make that a more productive interface. The boundary work concept can, however, also be used in a broader sense, referring to the variety of boundaries that exists in natural resources management research and practice, and need to be 'managed'.

In Mollinga (2010a) I suggest that boundary work in inter- and transdisciplinary research on natural resources management has three components. Boundary concepts allow us to think, that is conceptually communicate about, the multidimensionality of the phenomena studied and addressed. Boundary objects are devices and methods that allow us to act in situations of incomplete knowledge, non-linearity, and divergent interests (the category includes models, frameworks and participatory processes for decision-making and planning, among other things). Boundary settings are the institutional arrangements within which these concepts, devices and methods can be fruitfully developed and effectively put to work.

This paper concentrates on the first of these three elements, the theoretical constructs required to think across the boundaries of the natural sciences and the social sciences, and leaves the acting and enabling of the second and third elements aside. By exploring the conceptual terrain at the interface of natural science and social science approaches to water resources management, I aim to contribute to a 'critical interdisciplinarity' (Klein, 1996) of water. The paper seeks ways to combine a socio-political perspective of water management policy, institutions and organisations with an interdisciplinary perspective on the politics of technology/infrastructure and landscapes (Mollinga, 2008).

Perhaps the major analytical boundary challenge is binarism as a form of analytical reductionism (Castree, 2002). At the heart of interdisciplinary analysis of water resources management lies the material-social binary. This binary is 'real' within the water resources domain as a division between disciplines and professions that are labelled 'technical' and 'social'. The division is institutional (as embodied in government and university departments, professional associations, and academic journals), cultural (as embodied in professional identities) and cognitive (by considering the material and social as distinct objects).

The fallacy of binarism is that the world is ontologically complex – structured, stratified and heterogeneous (Sayer, 1984). Irrigation systems provide an archetypical example. The networked system of dams, weirs, canals and other ouvrages d'art, structures both the physical landscape and institutional and economic life, at village, district and country

[2] On the emergence of the boundary vocabulary, see Gieryn (1983) and Star and Griesemer (1989). Mollinga (2010a) distinguishes three forms of complexity of natural resources management: ontological (heterogeneity in components and relations), societal (its contested nature) and analytical (difficult to understand). Ontological and analytical complexity constitute the case for interdisciplinarity; societal complexity for transdisciplinarity. Adjectives I use for these three complexities are hybrid, contested and complicated.

scale.[3] The collection of boundary concepts presented in the following four sections is informed by an understanding of sociology as a 'science of connections' or 'science of associations' (Latour, 2005). Social-ness exists in the act of creating and maintaining networks of heterogeneous objects and relationships. It is in that sense that human beings are the prime-movers in 'socially constructing' water resources management systems.

The second starting point is that 'putting and holding things together' in configurations that have some endurance, that is structures (Archer, 1995), involves such configurations having 'internal relations' and exhibiting 'emergent properties' (Sayer, 1984).[4] In the inventory of attempts at capturing emergence related to irrigation technical artefacts and to irrigation landscapes[5] in the following sections, the term institutions is used for what are conventionally called social dimensions, social factors or social aspects – formulations that treat the social as a distinct object. Social in this paper is reserved for the activity of making, reproducing and transforming the hybrid and complex sets of 'associations' and 'connections' in water resources management configurations. Interdisciplinary analysis attempts to move beyond analysis that is framed around the interaction of different components, to a framework that conceives of heterogeneous configurations of components as exhibiting emergence, and tries to capture these in 'boundary concepts', that is concepts that grasp the concrete as 'the concentration of many determinations' (Marx, 1973).

The following four sections give an overview of the different ways in which conceptual hybridisation has been attempted in the South Asian, particularly Indian, context, with a focus on irrigation.[6] Section 2 looks at how water rights and entitlements can be understood in an interdisciplinary way. It discusses the concept of hydraulic property, and, as an extension of that, how ecological relations are part of rights and entitlements concepts. Section 3 looks at interdisciplinary analysis of water use; it explores conceptualisations of design-management relations and the social construction of irrigation technology, producing management 'scripts'. Section 4 addresses the impacts of water use in developmental terms. Boundary concepts discussed are landesque capital and the value/valuation of ecosystem goods and services. Section 5 finally looks at interdisciplinary conceptualisations of the embeddedness of irrigation/water resources management processes, by discussing time & space relations in irrigation, and the 'cultural politics of water' perspective. Section 6 discusses how these boundary concepts can help to further develop interdisciplinary social theory on water, and identifies some formal and substantive theoretical avenues for that. The conclusion of the paper, section 7, outlines potential further research activities.

2 Water and rights: hydraulic property and ecological integrity

Hydraulic property

In his analysis of farmer managed irrigation systems in Thailand, Indonesia and the Indian Himalayas, Coward (1986a, 1986b, 1990) analyses the intimate relations between the social relations of water management and the technical infrastructure. His basic argument is that "(…) creation of irrigation facilities establishes among the creators property relations." (Coward, 1986b, 227) Naturally, "[n]one of this property can be sustained over time without frequent renewal through the investment of labour and capital." (ibid., 225) Therefore "the basis for [the] social action [of the community irrigation group] is the common relationship they have with regard to property objects which they have created." (ibid., 225) This means that the creation and upkeep of irrigation infrastructure go hand in hand with the (transformation of the) social relations through which that infrastructure is used: they co-evolve and are each other's expression as 'hydraulic property'.

Coward (1990) on property rights arrangements in farmer managed irrigation systems in the Kangra valley of Himachal Pradesh shows that the consolidation of land rights in the colonial period included a specification of the materials to be used for diversion weir construction and a description of the (proportional) division structures for water distribution. "The width of the openings created by the thelu [division structure, PPM] is measured in 'fingers' depending upon the area of land to be served by a given turnout. (…) the thelu is a simple but effective device by which the abstract water rights of individuals can be translated into calibrated water flows." (ibid., 83)The land cum water rights thus defined had to be reproduced through the contribution of labour to maintenance and repair. Coward also shows that distribution of rights

[3] Tanks as found in South India are an example of village-scale structuring (Shah, 2003); canal irrigation (Mollinga, 2003) and interlinked system tanks (Sharma and Selvaraj,1999) an example at district level; the interconnected Indus plain irrigation system of Pakistan an example at country level (Merrey,1983).

[4] See Sayer (1984) on the critical realist perspective underlying these formulations and the overall approach of this paper.

[5] 'Embodiment', a third instance of materiality, is not pursued in this paper, but see the discussion section below.

[6] Below, I preferentially make use of PhD research work of students I co-supervised, notably those who were part of the Ford Foundation supported Matching Technology and Institutions PhD programme at Wageningen University, the Netherlands. I thank Linden Vincent and Dik Roth for valuable comments on a draft of this paper.

and access in local irrigation systems are not necessarily equitable. "The lower zone people (...) reproduce their water rights in the Bharul network even though the costs to them are considerably higher than those incurred by the upper groups." (ibid., 84)

The concept of hydraulic property thus captures two theoretical ideas: 1) that water rights take on a material form in the characteristics of the infrastructure of the systems in and for which they exist, and 2) that the activity of infrastructure creation and upkeep is a process of property rights creation and upkeep. Though the initial formulation of the concept is partly India based, it has attracted little follow up work in South Asia, but much more so in Latin America (see f.i. Gerbrandy and Hoogendam, 1986).

Property rights and ecological integrity

The scope of the 'hydraulic property' concept can be broadened to the ecology or the landscape. In her study of the interaction of pond (small tank) and canal water management in a watershed in the Palakkad region of Kerala, Krishnan (2009) links the ecological characteristics of the landscape to the (land and) water rights that govern its use.[7] She documents how ecological relations were historically part of the definition of land and water rights in a way that achieved ecological sustainability. The land used to be owned by landlords (janmis) who rented it out to tenants through intermediaries (managers). Those cultivating land in the command area of a pond had a water right attached to it, involving access rights to the pond water, access to the upland forested area for forest products for their own use, while there were also arrangements for pond (tank) maintenance. The janmi undertook regular desilting of the pond, through the supervisor appointed by him. Day to day activities like cleaning run off channels in the catchment (necessary to fill the tank), and other regular tasks, were undertaken by permanent labourers who worked for the concerned tenant(s).

The Kerala government decided to implement a land reform and distribute the landlord owned land to the tillers, to achieve equitable access to land. Around the same time the vesting of privately owned forests with the government was implemented. The time lag between the promulgation of the forest act and its final implementation enabled landlords to dispose of the valuable trees, resulting in deforestation of the uplands. Landlords also made sure that they maintained access to the valuable valley lands by strategic registration of plots. When the uplands and lowlands were redistributed under the land reform process, only land rights were consciously redistributed. The government overlooked the water rights linked to land rights. Some land kept the water rights attached to it, other land did not. Many former tenants who obtained small plots of land remained without water rights.

In parallel a government irrigation system was constructed and implanted on the landscape without taking cognisance of the pond/tank systems already extant. The water supplied through the government canals to a significant extent ended up filling ponds/tanks, whose original function changed from capturing runoff and groundwater to capturing canal water. The public water provided by the government system was privatised the moment it entered the ponds/tanks, and became accessible only to those with water rights to the tank.

Notwithstanding the depressing outcome of this rights reform and development process[8], the theoretically interesting point is that ecological relations were part of the definition of the land and water rights. How rights are defined shapes the landscape, and the reproduction of certain landscapes assumes specific property rights arrangements.

3 The use of water: design-management relations and the social construction of technology

Design-management relations

Notwithstanding images and ideologies of western technical sciences being standardised and universal, irrigation engineering has a strongly regionally specific history. Technical concepts and approaches developed in, say, British, French and Dutch colonial engineering are quite distinct. Within these there are variations reflecting contexts of development – in British colonial engineering for instance for Egypt and India. When to this are added irrigation engineering traditions from other regions, like China, Japan, the USA and Europe, and local engineering knowledge of for

[7] I have unsuccessfully searched for other papers (on Indian irrigation) presenting a similar argument about ecological relations internalised into property rights arrangements. See Wade (1988) and Mosse (2003) for related arguments.

[8] Including the irony that ecological sustainability existed under a system with feudal characteristics, while ecological degradation ensued when land reform was implemented on welfarist principles driven by a communist party political agenda.

instance mountain and hill irrigation in the Andes and Himalayas, it is clear that there is a wide variety of cultures of engineering.

Apart from physical differences in terrain, rainfall and runoff regimes, available construction material and the like, the variation is due to a series of institutional factors. As shown in the previous section, designs materialise property rights. Within government owned and managed irrigation systems the variation lies in the state-irrigator relationship incorporated in technical design, that is the form of organisation for management and governance of the system materialised in technical design principles.

The significance and specificity of design-management relations has been innovatively explored by Horst (1996, 1998; also see Levine, 1980). The thrust of Horst's analysis is that different types of division/offtake structures (fixed, open/closed, gradually adjustable) associate with different forms and principles of operation and management (summarised in Horst 1998, 84, figure 9.1). Moreover, each of these offers different opportunities for manipulation, adding a second layer to the analysis: the discrepancy between on paper and real operation and management practices.

Bolding, Mollinga and van Straaten (1995) discuss how colonial governments have attempted to implement the rationing of irrigation supply in canal irrigation through varying combinations of technologies and institutions differently in the northern, western and southern parts of India. The case study of early 19th century efforts to introduce the so called 'block system' in present-day Maharashtra shows the two levels of analysis: the search for an appropriate combination of technical and institutional features, and the undermining of this in the realities of irrigation system use, allowing an analysis of the features and contradictions of colonial rule as well as the dynamics of peasant social differentiation in an emerging capitalist rural economy. An analysis of the contemporary relevance of division structures and canal design principles in farmer organisation in Haryana and Maharashtra is provided by Narain (2003). He shows how organisational concepts of local Water Users Associations as promoted under government Participatory Irrigation Management policies and programmes, do not fit with the technical reality of India's canal irrigation systems.

A second strand of analysis elaborating Horst's perspective is the detailed analysis of 'proportional division structures' in Nepalese farmer managed irrigation systems. These studies give rich empirical detail on how, in Parajuli's (1999) phrasing, agro-ecological and socio-cultural considerations of an area help determine infrastructure, and, vice versa, the operational and managerial implications of that. His study concludes that "[i]n irrigation systems distributing water by ad hoc adjustment type of division structures, water distribution is the primary objective. In (…) open-close type (…) water distribution and resource mobilization are equally important (…). In (…) fixed proportional type (…) resource mobilization is the local organizations' primary objective of irrigation management." (ibid., 207)

Social construction of technology

The inquiry into design-management relations as described above, pursued from a civil engineering starting point, could be more comprehensively theorised using the 'social construction of technology' perspective that became available in the 1980s.[9] From this perspective, Shah (2003) investigates the 'social designs' of tank irrigation[10] in Karnataka. Many tanks were built in pre-colonial times. She suggests that "the design principle of a labour intensive construction method of embankments carries the imprint of the historical era that rested on a rigidly built, hierarchical social order which exerted a considerable degree of control over labour." (ibid., 261) When this order changes, maintaining the infrastructure in a good state becomes difficult. In the present situation, with expanded market relations, decentralisation policies and a general loosening of social rigidities, rural elites find it increasingly difficult to mobilise labour for tasks like canal cleaning, sluice operation and field-to-field irrigation from lower caste labourers. They turn to the state for investment in maintenance and management (ibid., 262-263). "This push and pull – the push that rural elites are increasingly less inclined to invest in tank resources and the pull that traditional social arrangements to mobilise lower caste labour cannot be reproduced in their entirety – has created a crisis in terms of management of tank resources." (ibid., 263)

These observations mean that the technical features of water infrastructure must be understood as historical products, fitting a particular context, but being potentially inadequate in others. The historical literature on irrigation and flood control in India and South Asia profiles this statement with rich and fascinating accounts (see for instance Stone, 1984,

[9] The seminal paper is Pinch and Bijker (1984). This SCOT literature, particularly inductive being Winner's (1985) title question 'Do artefacts have politics?' was very influential. Earlier work along this line focused on the 'code' of technology in Indonesian colonial irrigation technology (Ter Hofstede and van Santbrink, 1979). For further application see for instance Ertsen (2010), and Bolding (2004) for 'technography' as a methodology for 'following the artefacts'.

[10] Tanks are small, multipurpose reservoirs, created by, in South India, blocking valleys with earthen dams, to capture and store monsoon rainfall. Many tanks in Karnataka are individual tanks; many tanks in Tamil Nadu come in 'cascades'.

Gilmartin, 1995, Weil 2006). The broader theme is the role of water resources development and technology in colonisation and nation building.

The social constructivist analysis of technology and technological systems (cf. Hughes 1987) can also be reversed. With particular societal objectives and forms of organisation in mind, efforts can be made to consciously design technological systems in such a way that they fit these objectives and forms. A perspective of design and planning as self-conscious social construction has been developed for irrigation in certain parts of the world, notably Latin America and Africa. The relative absence of participatory approaches to irrigation design and planning in India can perhaps be explained by the hierarchical and prescriptive style of government irrigation intervention on one side, and the glorification, that is, not being in need of innovation, of 'traditional' irrigation by civil society organisations on the other side. An innovative effort at redesigning the Sardar Sarovar dam, part of the Narmada project, and its downstream irrigated area is Paranjape and Joy (1997). It is telling that the proposal did not spark anyone's imagination (see Mollinga. 2010a).

The upshot of the discussion above is that the designs of irrigation infrastructure carry, in social constructivist language, management 'scripts', or put differently, have 'social requirements for use'. Technology is not neutral; its contextuality can be revealed through careful observation and analysis of irrigation designs and water management practices, and by documenting the life histories of artefacts.

4 Water, landscapes and livelihoods: landesque capital and the value of ecosystem goods and services

Landesque capital: cultural and engineered landscapes

Amartya Sen has been given the credit of first using the term 'landesque capital', in a conceptual combine with 'labouresque capital' (Sen. 1968, Håkansson and Widgren, 2007, Widgren, 2007). The term refers to human alterations to the landscape designed to yield long-term gains in productivity, and is mostly used in analyses of agricultural intensification, particularly in smallholder subsistence agriculture. The building of irrigation systems, and water infrastructure generally, is one form of creating landesque capital.[11] Apart from agricultural productivity, the term has also been used in relation to the symbolic (identity) dimensions of landscapes. Harrower (2008, 505) for ancient irrigation in Southwest Arabia suggests that "[i]rrigation structures not only served as landesque capital (…) improvement that established economic investments in landscape infrastructure, but more importantly (…) irrigation structures and tombs served as symbolic landesque capital investments that proclaimed people-land relations." Greider and Garkovich (1994) speak of 'landscapes as definitions of ourselves'. Landscapes are as relational as technology, and as contested (Strang, 2001).

The richness of these perspectives is still to be appropriated fully in South Asian water and irrigation studies. Closest to it comes the historical literature of irrigation, floods and landscapes (Ludden, 1978; D'Souza, 2006).

Ecosystem goods and services: value and valuation

The new millennium saw the global consolidation of the 'ecosystem goods and services' concept through the Millennium Ecosystem Assessment (MEA, 2005). The notion of 'ecosystem goods and services' is a boundary concept because the globally shared typology distinguishing between supporting, provisioning, regulating, and cultural ecosystem services allows ecologists, economists, sociologists, and other disciplines to have a common language on the usefulness of ecosystems to human society (Slootweg and Mollinga, 2009). In India, the epistemic community most closely associated with the analysis of the valuation of ecosystem goods and services is the Indian Society for Ecological Economics. The literature on (agricultural) water from this perspective is still very small (Puttaswamaiah and Raju, 2009; Kerr 2002). In the international sphere, the interdisciplinary analysis of wetlands has contributed much to the development of the perspective – a field scarcely developed in India (Narayanan and Venot, 2009). However, an 'ecosystem goods and services' notion is implicit in much debate on local irrigation systems, as these usually have multiple uses and users (Agarwal and Narain, 1997). It would seem relevant to explore more fully the value and valuation of water, and its commensuration, beyond the existing economistic thematics of water pricing and payment/markets for ecosystem services (Espeland and Stevens, 1998).

Ecosystem goods and services (EGS) is both a richer and a poorer concept than the Marxist categories of goods/commodities having use value and exchange value. The plurality of goods and services identified by the EGS

[11] See Cosgrove and Petts (1990), Earle and Doyel (2008), Lansing (1991) and Trawick (2008).

category is a plurality of meanings of water (cf. Strang, 2004), and a plurality of interest groups. EGS is, however, also primarily a descriptive concept that lists and maps – without much analytical 'punch'. The use/exchange value pair has a lot of such 'punch' (through the labour theory of value), but theorises away materiality of commodities by focusing upon exchange value. Neoclassical and neo-institutional economics tend to be totally agnostic about the material specificities of commodities, as became dramatically clear in neoliberal economists' advocacy of 'tradeable water rights' and 'water markets' in the early 1990s (cf. Rosegrant and Binswanger, 1994).

5 Irrigation and society: space-time relations and a cultural politics of water

The broader the canvas, the more tentative the conceptualisations of the multidimensionality of irrigation are. Geography and political ecology inspired perspectives are making significant contributions to a broader based interdisciplinary analysis of irrigation.

Space-time relations

An early and one of the most perceptive accounts of the connection between the physical characteristics of irrigation systems and the social processes that take place in them is VanderMeer's (1971) historical analysis of water thievery in Taiwanese rice irrigation. In his explanation of types and frequency of thievery, the spatial organisation of the canals and the land play an important role. Very few analyses of Indian irrigation address the complexity of spatial relations with such nuance, even when the 'head-tail' problematic of unequal water distribution along canals has been a central theme in Indian, and global, irrigation management studies since the 1980s (Chambers, 1988).

The 'head-tail' problematic is usually stated in the apparently straightforward terms of locational advantage: farmers with land on the upstream 'head' of the canal have better access to water than those further down at the 'tail' of the canal. Head-enders thus have better options for productive farming, and thus become rich farmers, while those with land on the downstream end of the canal remain or become poor farmers. Mollinga's (2003) analysis of the spatial form of the social differentiation in the Tungabhadra Left Bank Canal irrigation system in Karnataka State, India shows that locational advantage is not a 'given'. When analysis is done, over a period of time, of whose land is located where in the canal system, and how the canal system itself is partly remodelled in the process of emerging head-tail patterns, the dynamic nature of locational advantage can be shown. In this particular case that dynamism involved land acquisition by (experienced) migrant rice farmers from a neighbouring state, patterned by government crop zoning (called localisation) and strategic settlement (on canal-road crossings), and the institutional mechanisms of loans, indebtedness, lease agreements, and land registration. Responses to emerging inequalities in access were both physical and institutional (including a lift irrigation boom in the 1990s and forms of political and administrative lobbying and corruption).

The construction of irrigation canals creates linkages between individuals, settlements and communities by organising them in a complexly bifurcated and queued sequence for access to water. Once constructed, there are inflexibilities that provide strategic advantage to some and disadvantage to others. A spatial pattern of social differentiation is thus configured. However, the implanted canal system grid of the social processes of irrigated agriculture is not immutable. Over time, the grid is partly remodelled and spatially reorganised through a variety of means and mechanisms. The process also has an important time dimension. The introduction of canal irrigation has induced a move away from the monsoon-derived overlapping two cropping seasons to two sequential irrigation seasons, allowing intensification of land use. The combined rhythms of the weather (rainfall and temperature) and crop cycles define the periods in the year when water distribution conflicts peak, and thus structure irrigation management interactions in time (cf. Carlstein, 1982).

A cultural politics of water

Political ecology has been strongly interested in transcending the society-ecology binary, critiquing and complementing political economy perspectives exclusively focused on access and distribution. In India, a political ecology of agricultural water approach is still largely to be developed (Mollinga 2010b). The closest to it is Baviskar's 'cultural politics' approach to natural resources management, which aims to combine political economy and the epistemological variant of political ecology (Baviskar, 2003; Mollinga, 2010b). It emphasises that "[s]truggles over water are simultaneously struggles for power over symbolic representations and material resources." (Baviskar, 2007, 1) The perspective aims at "incorporation of ecological specificity into the cultural politics of water" (ibid., 7; emphasis in original) and wants to "emphasize the distinctive bio-physical properties of water which shape its modes of appropriation" (ibid., 5). Along the same lines of the epistemological varieties of political ecology Mehta (2005) has analysed the social construction of concepts of scarcity and droughts. The importance of this perspective lies in the fact that it allows analysis of local knowledges and

cosmologies, as well as policy and other public discourses, within a single framework, enriching the understanding of human agency and the meaning of landscapes in water resources management. When combined with a more 'materialist' understanding of irrigation, political ecology perspectives can make a significant contribution to interdisciplinary irrigation studies – as is discussed in the next section.

6 Discussion: towards interdisciplinary social theory on water

In critical realism's stratified ontology of structures, mechanisms and events, the previous four sections have mapped different structures and some associated mechanisms as their emergent properties. The structures are:

- The structure of property rights and entitlements;
- The structure of techno-institutional arrangements for everyday water use, management and governance;
- The structure of water resource based livelihoods;
- The social structure in general.

For all of these structures some mechanisms were identified. The objective was to show the materiality of the social process of water management, particularly that related to technology/infrastructure and ecology/landscape. There is thus no claim to comprehensive mapping, the more so because materiality as embodiment of agency, and as water as substance, were left aside. The purpose is conceptual. The four sections together suggest that boundary concepts that allow us to think across the boundaries of the natural and social sciences can and have come into existence for irrigation/water resources management.

Among these boundary concepts, some are neatly articulated as concise and precise concepts, like 'hydraulic property' and 'landesque capital'; some are more metaphorical in nature, like the management 'scripts' of socially constructed technology; some are descriptively valid but lack social 'punch', like 'ecosystem goods and services', though this is perhaps compensated by the force of the concept of 'value'; and some are indications of areas of inquiry that need further conceptual articulation specific to water resources situations, like 'space-time relations' and 'cultural politics/political ecology'. The conceptual boundary work is work in progress, but sufficient evidence exists, at least in the view of this author, that the multidimensionality of irrigation/water resources management and the ontological complexity of its internal relations, can be fruitfully captured, and understanding of it moved forward, by adopting an interdisciplinary perspective.

The general theoretical reasoning that water resources management is 'multidimensional' was developed in the 1990s by understanding the concept of water control as a central boundary concept, positing internal relations between the technical/physical, organisational/managerial, and socio-economic/political dimensions of irrigation management (Bolding, Mollinga and van Straaten, 1995; Mollinga, 2003). The 'water control' concept is a generic statement about the ontological complexity of irrigation systems, which have been described by several authors as hybrid 'sociotechnical systems' (Vincent, 1997). The articulation of water control as a 'loose concept' (Löwy, 1992) identified a conceptual space in which the human metabolic engagement with nature in the form of irrigated agriculture can be studied in an interdisciplinary way, by unraveling the hybrid connections that water management involves. The boundary concepts discussed in the previous sections can be read as specifications (but by no means derivations) of this general theoretical idea. With this conceptual space now being well populated, an effort at subsequent general, and more precise, theorisation may be in order.

The structures and their emergent properties as identified in the previous four sections can be regarded as a non-reductionist dissection of the 'concentration of many determinations' that water resources management is. All mechanisms/emergent properties identified derive from hybrid structures, against reductionism, which involves positing ontologically singular structures.[12]

This image of dissected determinations begs the question of their 'concentration', that is, how they fit together. For the concrete situations discussed above, the fit is relatively easily suggested. Property rights and entitlement arrangements are one of the structuring forces of water use, management and governance practices (by shaping access and control), while the practices in their turn shape the resource based livelihoods they support, which shape and are shaped by the broader societal structure and dynamics they are part of. This is neither a time sequence, nor a hierarchy of causality – all this shaping happens simultaneously. However, the possibility to identify related but nevertheless distinct 'determinations' suggests that, indeed, reality is structured and stratified as critical realist philosophy would have it.

[12] My understanding of reductionism originates from Rose (1987). Reductionism is at least of two kinds: 'true' specialisation, as for example in hydraulics exclusively theorising the mechanics of physical water flow, and 'imperial' forms of reductionism that impose a single metric or frame on plurality and diversity, like reducing value to price.

The increasing complexity, ontologically as well as societally, of natural/water resources management in combination with the increased scientific legitimacy of notions of complexity and emergence (cf. Scheffer, 2009; Trosper, 2005) seems to induce new theorisations of the 'concentration of determinations'. In the rest of this section I sketch some of the research avenues that seem to me particularly promising for 'substantiating' the water control concept. The first of these sketches focuses on formal theory, the second on substantive theory.

Formal theory: the hydrosocial cycle and morphogenesis

Within the field of geography, a political ecology perspective on water resources is engaged in developing the concept of the 'hydrosocial cycle' – as an interdisciplinary counterpoint to the physically reductionist renderings of the hydrological cycle that are found in hydrological textbooks (Linton, 2008). "In a sustained attempt to transcend the modernist nature-society binaries, hydro-social research envisions the circulation of water as a combined physical and social process, as a hybridized socio-natural flow that fuses together nature and society in inseparable manners" (Swyngedouw, 2009, 56).

This perspective potentially brings together several theoretical components that allow a formal social theory of water resources in the sense of Latour's sociology of connections or associations. Human intervention in the physical cycle of water behaviour is about rearranging flow, availability and quality of water in time and space. These rearrangements are consolidated in technologies (e.g. storage reservoirs), landscapes (e.g. polders), and a variety of institutional arrangements for water use, management and governance, made, reproduced and transformed by different categories of human actors, embodying various forms and dimensions of human agency, thus constituting different 'logics of structuration' (Kontopoulos, 1993).[13]

The link with formal social theory about structure-agency dynamics seems relatively straightforward – at least at this level of abstraction. Archer's (1995) morphogenetic approach to structural elaboration (the change of structures through episodes of the deployment of human agency, requiring time, that is, in cycles) strongly resonates with the hydrosocial cycle perspective. Archer's approach is not explicitly interdisciplinary in the sense of this paper, but her approach applies as much to hybrid structures and their emergent properties as it does to social structures as conventionally understood. Her critique of Giddens' (1984) approach as conflating structure and agency in the understanding of change, that is, her argument for analytical dualism (Archer 1995, chapter 6), allows a much easier incorporation of the material dimension than Giddens' approach does.[14]

Formal theoretical resources for thinking through the time and space dimensions of morphogenesis for water resources management, and implicit in that issues of (multiple) scale(s), can be found in recent work on the politics of space (Jessop, Brenner and Jones 2008), and older work on time-geography (Carlstein, 1982). Both provide typologies as heuristics for exploring structured diversity. Jessop, Brenner and Jones (2008) distinguish four key spatial dimensions of social relations: territory, place, scale and network. Carlstein (1982) considers that "[h]uman time is a resource, since all activities necessarily require it as input and since we have limited capacity to act in relation to time." (p.27) This gives three types of time-space constraints: capacity constraints, coupling constraints, and regulatory/authority constraints (ibid., 260).

A second formal theoretical thematic is the concepts of change (and power) to be adopted. In the Marxist tradition the dynamics of change are often conceived as 'dialectics' (cf. Swyngedouw, 1999). Other critical perspectives would use the terminology of 'technologies of rule' (Lansing, 1991) for the concentrations (in the plural) of determinations at different levels and in different domains. Such perspectives would take the critical realist notion of society as an 'open system' further than most Marxist theory might. The way forward, I would suggest, is concrete research on mechanisms/emergent properties/logics of structuration in water management transformation processes: events are easily described, structures are easily labelled, unravelling the mechanisms/emergent properties/logics of structuration is hard empirical and analytical work.

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[13] Kontopoulos (1993) is a fascinating though somewhat impenetrable mapping of the mechanisms/emergent properties associated with different types of social structure. The appendix of the book lists and describes 40 'logics of structuration' divided in micro-, meso- and macrologics. The 'material dimension' does not play a role in Kontopoulos' approach. 'Logic of structuration' is an attractive phrase as it avoids the association with linear determinism that many have with 'mechanisms', as well as the opacity, if not magical ring, of the notion of 'emergence' that many find uncomfortable.

[14] Archer's approach distinguishes three types of emergent properties: structural, cultural and agential. Commenting on Giddens (1984), she notes a 'parting of ways' with "[s]tructuration theory, whose proponents (…) elide these three since material resources are confined to a 'virtual existence' until instantiated by agency drawing upon interpretative schemes." (Archer, 1995, 175) This type of elision explains much 'oversocialisation'. Archer's perspective that "(…) structural emergent properties (…), irreducible to people and relatively enduring, as with all incidences of emergence, are specifically defined as those internal and necessary relationships which entail material resources, whether physical or human, and which generate causal powers proper to the relation itself." (ibid., 177) allows, if not calls for, an interdisciplinarity as explored in this paper.

Towards substantive theory: thinking materiality

Substantive theorisation of irrigation/water resources management situations deploying formal conceptual constructs as sketched above, is necessarily contextual, that is, time and space, and thereby 'social formation', specific. This is where Wittfogel (1957) went wrong. The intuition that irrigation and state formation are strongly linked is sound, as subsequent historical work has amply shown, but Wittfogel's singular substantive theorisation of 'hydraulic societies' and 'oriental despotism' was easily undermined. Comparative analysis of structured diversity seems a safer way forward in the accumulation of knowledge (Mollinga and Gondalekhar, forthcoming).

In terms of substantive theory I (therefore) confine myself to listing what I consider prospective concrete thematics for advancing theorisation of the materiality of social change in water resources management. I want to suggest that rethinking of the commodity form, a materialist instutionalism, and the embodiment of agency are useful entry points for advancing 'hybrid' social theory on water. Given the era in which this paper is written the necessary setting of such exploration is, in this author's view, the process of (neoliberal) capitalist globalisation (Brenner, Peck and Theodore, 2010; Conca, 2006; Moore, 2010).[15]

Commodities: the social life of things

Perhaps the most characterising and emotive controversy in contemporary water disputations is whether water should be considered as an 'economic good' or as a 'social good'. The former is strongly associated with the 1990s neoliberal development paradigm of market fundamentalism; the latter is the core strategic essentialism of much of the critical constituency of alternative water politics. The Marxist binary mapping onto this is that of the exchange value and use value of commodities, with exchange value taking on 'a life of its own' under capitalism. Most Marxist theory has focused on the exchange value dynamics, at the detriment of the use value component. 'Social good' perspectives on water can be understood as giving primacy to the use value dimension, and the plurality and diversity associated with that, wanting to keep the exchange value dimension at bay.

I want to suggest that richer conceptualisation of water as a commodity, and other commodities implicated in its use, can help to avoid the 'oversocialisation' that stands in the way of capturing hybridity.

Appadurai's attempt to develop "a new perspective on the circulation of commodities in social life" (1986, 3) understands "the creation of value [as] a politically mediated process" (ibid., 6). It is an effort "to restore the cultural dimension to societies that are too often represented simply as economies writ large, and to restore the calculative dimension to societies that are too often simply portrayed as solidarity writ small." (ibid., 12). He proposes that "the commodity situation in the social life of any 'thing' be defined as the situation in which its exchangeability (past, present, or future) for some other thing is its socially relevant feature." (ibid., 13) Whether and how things move in and out of commodity status is a matter of social (including cultural) regulation, that is, it can be done in structurally different ways in different 'regimes of value' (ibid.:15). The 'commodity-hood' of a thing can be regarded as an emergent property, constituted by the qualities of the thing itself and the configuration of which it is part. As Appadurai observes, the "formal truth" that things have no meaning other than that humans endow them with "does not illuminate the concrete, historical circulation of things. For that we have to follow the things themselves, for their meanings are inscribed in their forms, their uses, their trajectories." (ibid., 5).

It is difficult to imagine a water resources management process of some scale that does not have an 'exchange' dimension to it, as securing of the capture, distribution and use of water require socially organised investments of labour and materials (cf. the discussion of hydraulic property and landesque capital above, while the circular flow and bulky nature of water make it an 'uncooperative' commodity (Bakker, 2003)). This means that rather than 'commodification yes or no?', the question has to be, in 'modern' and 'traditional', 'state/corporate' and 'community' water resources management alike, one of forms and patterns of commodification, differentiated by phase or compartment of the circulation process, type of water use, and a variety of contextual factors. In this way the economic vs. social good simplification can be transcended and more refined theorisations of water resources management, and concomitant logics of accumulation, in global(ising) capitalism facilitated.

[15] This resembles Bakker's (2007), Swyngedouw's (1999) and Kaika and Swyngedouw's (2000) political economy/political ecology approaches to urban water use. However, I am much less certain about the 'right' theory of capitalism than particularly (Kaika and) Swyngedouw seem to be. More important in the context of this paper is that these approaches, while taking a hydrosocial starting point explicitly, tend towards 'oversocialisation' in their concrete analysis, treating the material dimension in much less depth than approaches like those discussed above.

Materialist institutionalism

A 'materialist institutionalism' as proposed here involves an analysis of institutional arrangements and forms of organisation that takes into account the material mediations of water's circulation. Sections two to five above provide several concrete starting points for 'materialist institutionalist' analysis. The hydraulic property concept (and its extension to ecology/landscape) neatly captures the materialisation of rights. The emergent properties of property rights arrangements can, of course, be seen in the way power is exerted in water allocation and distribution. It is clear that technological structure and spatial extent/organisation recursively structure management and governance regimes, but how exactly remains to be theorised more precisely (cf. Wade, 1995). The emergent properties of 'locational advantage' and 'queuing' in canal irrigation point in the direction of a (to be developed) typology of 'system characteristics' of canal infrastructure. The connection between water resources development and nation building suggests the need for an interdisciplinary analysis of institutions as technologies of rule (Lansing, 1991).

To link a 'materialist institutionalist' analysis of irrigation/agricultural water management with the process of commodification discussed above, it seems useful to me to explore something in between Loftus' (2009, 964 ff.) "production of everyday environments" with "the waterscape as an accumulation strategy" and Swyngedouw's (2007) analysis of the reconstructing of the complete hydraulic landscape in Franco's fascist Spain as part of a socio-environmental and socio-spatial project of nation building and capitalist accumulation.

The embodiment of agency[16]

The fact that the human body is about 65-70% water is an evocative beginning of a discussion on the embodiment of agency in water resources management. However, perhaps more significant is that human beings have a direct material experience of water through their senses that is meaningful, remarkably consistent over time, and which shapes our engagements with and views about water (Strang, 2004, 2005). The strong cultural values (and taboos) attached to water have a lot to do with the multifarious personal encounters with water that are part of human life. Water is part of us in many senses.

A second form of embodiment of agency in water resources management is that use, management and governance are work: labour processes performed by persons, sexed humans, with physical bodies. These persons and their bodies are gendered and of a certain age. This affects water needs as well as capacity to perform water work, individually and collectively. The body is the repository of specific water resources management knowledge, skill and experience. Dramatic examples of this can be observed in some forms of spate irrigation, where the diverting of flash floods may require dangerous acts of management in fast flowing streams; or for drinking water supply in water scarce areas where force and agility are needed to carry water safely over large distances. The performance of water work also has bodily effects, for example health effects of headloading and working in paddy fields. Social power is thus partly bodily defined.

[16] This section is strongly shaped by discussions with Frances Cleaver, whose generous contribution to this framing I gratefully acknowledge. The usual disclaimers apply.

7 Conclusion: what next?

I started this paper by stating that the case for interdisciplinarity is easily made on the grounds of complexity. With the advent of the wide interest in complexity as a scientific puzzle, the disciplinary-interdisciplinary dichotomy has become somewhat of a caricature. More relevant seems to be distinguishing the different ways in which complexity can be approached and addressed. These differences are more 'paradigmatic' than having much to do with disciplines, which are, according to Lele and Norgaard (2005) better seen as 'academic administrative artefacts'. They argue that "the structure of scientific knowledge and the differences in epistemologies, theories, and methods among scientists have little to do with what have historically been called disciplines", and their advice for collaborative efforts at interdisciplinarity is to "forget disciplines; think scientific communities. (ibid., 972) It is for this reason that this paper has devoted considerable attention to the ontological premises that I find useful for interdisciplinary analysis of water resources management.

I conclude with listing five research activities that could lift the idiosyncratic focus on irrigation and South Asia of this paper to a more generic approach to the analysis of hybrid and contested water resources management.

1) A geographically, historically and sub-sectorally broad-based review of each of the boundary concepts identified in sections two to five, and potential additional ones, and the structures and mechanisms they seek to capture, to systematically consolidate existing conceptual framings of the diverse 'determinations' operating in water resources management situations.
2) To deploy the existing collection of boundary concepts in single, intensive case studies, to explore the complexity of internal relations in water resources management situations, and to develop theoretical capacity to capture the 'concentration' part of the determinations.
3) Subsequently and in parallel, undertake systematic comparative analysis of the structurally diverse dynamics of water resources management situations. [17]
4) Develop the formal theoretical base of an interdisciplinary political sociology of water resources (cf. Mollinga, 2008) by elaborating the formal theorisation of structure-agency dynamics and water circulation (with a suggested focus on the concepts of hydrosocial cycle and morphogenesis).
5) Develop substantive theorisation of the materiality of social change in water resource management by elaborating the suggested water-specific rethinking of the commodity form, of different varieties of materialist institutionalism, and of the embodiment of agency.

[17] Cf. Strang (2005, 92) who argues that in ethnographic analysis there is "a need for anthropological theory to recall its comparative foundations." She further states that "[i]t (...) seems remiss – and indeed irrational – to ignore [the] accumulated evidence [of numerous water related ethnographies from around the world] and cling to the political safety of culturally specific ethnography." (ibid., 93)

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