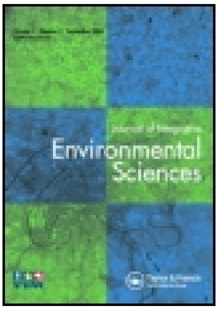

Journal of Integrative Environmental Sciences

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/nens20

The duality of integrated water management: science, policy or both?

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Version of record first published: 25 Feb 2009.

Journal of Integrative Environmental Sciences
Vol. 6, No. 1, March 2009, 51–67

The duality of integrated water management: science, policy or both?

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(*Received 20 February 2008; final version received 10 December 2008*)

Integrated water management (IWM) is the mainstream approach for addressing and accommodating issues in current water management. Despite many elaborations, its meaning, interpretation and implementation are still debated. In this study, the meaning of IWM within the domains of science and policy is assessed by exploring its conceptual scope. Moreover, the rationale of IWM in both domains is compared and the different approaches are subjected to a thorough consideration. Emphasis is given to describing how science has elaborated IWM in a conceptual way. It is shown that in science, IWM is foremost a collection of theories and approaches surrounding resource and ecosystem management. It is argued that difficulties in scientific IWM development are attributed to different research traditions and dominant paradigmatic underpinnings. Taking the case of Dutch water policy, the article shows that IWM is multi-objective and adaptive, being functional in driving changes in the management process. Differences between science and policy in framing IWM may complicate the input of scientific knowledge into the policy process. Further, advancement of IWM depends on clarifying the different roles of science and policy in the framing process and consideration of the practice and nature of science itself.

Keywords: integrated water management; meaning of integration; the Netherlands; Dutch water policy; water policy

1. Introduction

Water systems are of vital importance for human well-being, providing many benefits to society in terms of water-related resources and functions. Over time, the field of water management has rapidly evolved and modernised in response to the ever-increasing demands that are being made on finite water resources in many parts of the world (Baron et al. 2002). Over the last two decades, integration and integrated approaches have been increasingly presented as new and superior ways to consider the environment in policy- and decision-making. This development has established integrated water management (IWM) as the mainstream approach for management of water bodies. Its full spectrum refers to a range of management approaches that offer synthesis by analysing, solving and managing water-related issues through a coordinated approach (Biswas 2004; Gilman et al. 2004)[1].

The diversity of existing IWM approaches results from the societal and scientific context in which water management has to operate today. In comparison to the

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ISSN 1943-815X print/ISSN 1943-8168 online

DOI: 10.1080/15693430802689181
http://www.informaworld.com

1970s when the focus was on well-defined, local environmental problems, water policy these days has to address and accommodate issues that are more complex and less controllable, having a 'mosaic' nature that requires balancing a multitude of interests in and uses of the water system. These issues arise from a variety of human activities on a (supra) national scale and manifest themselves in a multitude of effects over long time periods, across diverse localities. Underlying this complexity are global developments in markets, technology, communication and information systems. Furthermore, socio-cultural developments have led to increased attention to water management and shifted perspectives of its main objectives. Liberalisation and individualisation of citizens, demands for responsibility and accountability by authorities concerning the environment and its management process, characterise a transition from 'government' to 'governance' that underlies water management development as well.

In search of understanding current environmental issues, scientific research has set the challenge to focus on the linkages between social, political, economic, biological, hydrological, chemical and geological systems (Lubchenco 1998). Thereby, it has moved away from individualistic, discipline-driven research to utility-focussed research that connects research activity across a number of boundaries. New modes of science, labeled Mode-2, post-academic and post-modern, have been recognised in which research is not solely decided within the academic domain alone, but in negotiation with other actors of various intellectual and social backgrounds (Van Kerkhoff 2005). The emergences of new practical and epistemic perspectives as well as new organisational forms are part of this. The role of science is no longer seen as steadily advancing the certainty of our knowledge and control of the natural world, but is replaced by a view that sees science as coping with many uncertainties in policy issues of risk and the environment (Gallopin et al. 2001).

The imperative of 'integration' in both water policy and water-related research has led IWM to become popularised as a political slogan and a fashionable umbrella term for directing research efforts. As such, it has stimulated a wide range of elaborations based on different perspectives. This has however resulted in a diversified meaning of IWM, and has led to ongoing discussions on its meaning, interpretation and implementation. In the scientific field, multiple authors have observed that clear consensus on the scope of the concept is lacking, arguing that IWM has been poorly articulated and elaborated in different competing definitions (Gilman et al. 2004). Strategic and conceptual, rather than operational and concrete use of IWM seems more common (Biswas 2004). The position of IWM as an 'inter-cultural' concept between policy and science (i.e. involving political goals as well as scientific understandings) may underlie difficulties and ambiguities in elaboration of the concept (Jeffrey and Gearey 2006). Different authors have elaborated on the interactions between these institutions (e.g. Cortner 2000; Hoppe 2005). In these studies, the troublesome nature of this relation is recognised, referring to existence of a 'boundary' between science and policy, which as such is not considered to be natural but created by social and political processes (Van Kerkhoff and Lebel 2006).

The main objective of this study is to give an academic overview of the scientific rationales behind IWM and explore its fundamental scientific conceptual scope in relation to its strategic scope in a national policy setting. In doing this, we take that IWM approaches are determined by the level of (non-) interaction between the institutions of science and policy. The degree and direction of these interactions may differ, resulting in different strategic approaches in terms of scientific support and goal setting. We will not go into elaborating how these relations are shaped specifically, which other authors have done in detail (Hoppe 2005), but take science-policy interactions into account as an explanatory factor for the development of IWM.

The scientific development of IWM is confronted with its policy development in the Netherlands as an example of national level implementation. The Dutch setting is chosen as IWM has been the adopted approach in water policy in the Netherlands for two decades. Also, the Netherlands has an leading international reputation in water management. Pragmatically, the Dutch case is suitable because documentation on policies was readily available to the researchers. The next two sections address how IWM is understood in the scientific and Dutch policy domain, respectively. The scientific elaboration of IWM is discussed in the context of international peer-reviewed research; the policy domain is elaborated by means of Dutch water policy developments during the last 40 years. In the discussion section, possible differences in meaning between and within both domains are discussed. This makes it possible to see whether and how mutual dependency exists between the policy and scientific domain. The article finalises with shortly stating the main findings.

2. IWM in fundamental science

A scan of scientific publications reveals that it is only recently that the concept of IWM has established as a research topic (Figure 1b). Before the 1990s, publications

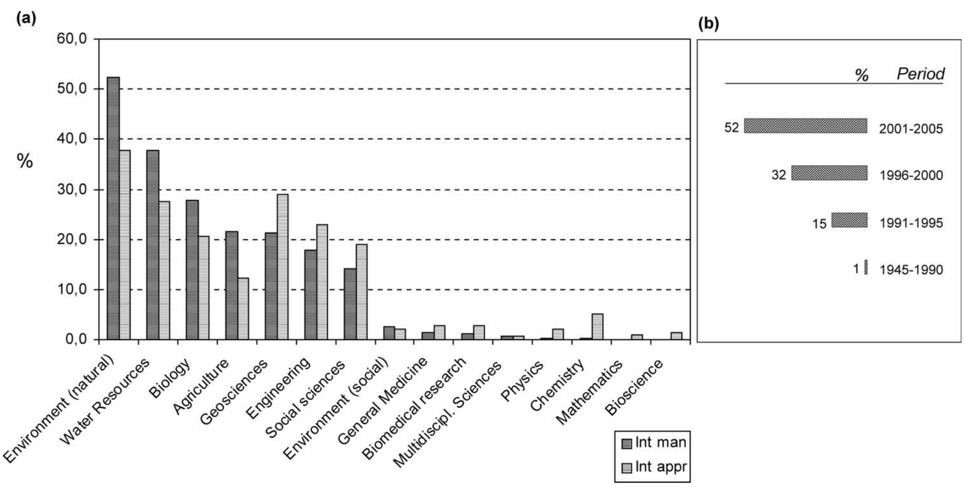

Figure 1. (a) Percentage distribution of publications between fields of science for the terms 'integrated management' and 'integrated approach'. Publications were categorised based on ISI subject categories, which were subsequently generalised to fields of science. Only subject categories that contained a minimum of 1% of all publications were included. Classes of science fields are derived and adapted from (Glänzel and Schubert 2003). (b) Appearance of integrated management and approaches and their conjugations in scientific literature. Per category, cumulative percentage over all years is 100%. Data were derived from a general search in ISI Web of Science (http://portal.isiknowledge.com) in the Web of science databases SCI-EXPANDED, SSCI, A&HCI. Searches performed in publication titles for 'integrated management' and 'integrated approach in relation to the term water, as well as the term river (total $N = 2751$). Online analysis tool was used to generate data.

on the topic have been scarce within the international scientific literature database. Since 1990, the interest in IWM and integrated approaches has been increasing. It should be noted that this claim relates to formal scientific publications (ISI database) only. Semi-scientific (national) publications from research institutes or governmental organisations have not been considered.

Different scientific disciplines are involved in research on IWM. Figure 1a shows how existing publications on 'integrated management' and 'integrated approaches' are distributed amongst major scientific fields. As a research topic, IWM seems bound to specific scientific fields. Elaborations on integrative approaches in water management are predominantly made in the environmental and natural sciences. About 95% of all publications in the used dataset are indexed in the ISI SCI-EXPANDED database, which is restricted to publications of the natural sciences. The remaining publications are listed in the Social Sciences and Arts & Humanities indexes. On the basis of the journal publications, it can thus be derived that the scientific contribution of social, economic, legal and management fields to IWM is (unexpectedly) small. A negating argument may however be that the social sciences tend to publish more in books in stead of journals. Also, the IWM terminology may be less common to the social disciplines. The data in the table do not imply that knowledge of the social sciences is not used in elaborations of IWM. The disciplines themselves may make limited scientific contributions to the concept as such, but social knowledge may be nonetheless applied through elaborations of the environmental sciences, which generally have a broad, multidisciplinary scientific scope.

The dominance of natural sciences in elaborations of water management is also pointed out by Lant (1998) who presented the topical focus of 341 submissions to the Water Resources Bulletin (currently known as the Journal of the American Water Resources Association) in the period 1995–1997. Over three-quarters of the submissions were from the physical sciences, primarily focussing on water quality, hydrology and engineering. A similar result was found in an analysis of Dutch research on IWM. Within an advisory report on knowledge innovation for water management (De Wilt et al. 2000) an analysis was made of the knowledge infrastructure on IWM in the Netherlands. It showed that over 80% of the studies on integrated management performed at universities focussed on the physical system and its different aspects. The remaining studies focussed on its management and administration. Up to now, research on social aspects within the explicit context of IWM has been strongly focussed on the studying of political and decision-making processes (Endter-Wada et al. 1998). However, increasing attention is given to social aspects like the role of citizens and public attitudes in water management (e.g. Tunstall et al. 2000).

Figure 1a shows that research on integrated management is primarily rooted in the 'environment' field of science. This field includes disciplines such as environmental science and (conservation) ecology. The second most number of publications is in the field of 'water resources', covering applied disciplines such as hydrology and hydraulic engineering, as well as management disciplines. Overseeing literature, the disciplines of ecology and environmental science cover the largest part of contributions to water management concepts. Further analysis and discussion in this section on scientific elaborations of IWM will therefore primarily concern these disciplines, as within these disciplines alone, available literature is extensive.

2.1. Key concepts

When considering the rationale behind water management, one cannot ignore the embedded core values that motivate water management; it may be undertaken to meet human needs, the needs of ecosystems, or some combination of the two. Taking a human-nature dualistic stance, this reveals two basic positions that can be used to distinguish the rationale behind different concepts of integration. The first takes the human needs as a basis, emphasising resource use, waste production and pollution of the resource and the setting of development priorities. The second takes the needs of the natural system as a basis, emphasising ecosystem structure and processes that determine the availability and quality of water resources (Endter-Wada et al. 1998). These perspectives coincide with basic value systems (also referred to as 'world-views', or 'ethical approaches'; Grumbine 1994; Hull et al. 2003).

The human viewpoint takes that goods and services of ecosystems (tangible or intangible, short- and long-term) are needed by society and are appropriable to man. It includes the assumption that ecological systems are resilient to resource use. The natural viewpoint considers maintenance of ecological health or integrity as the principle goal (Vugteveen et al. 2006), and generally assumes that human influences are detrimental to ecological systems. All other aspects, including man's use are of secondary consideration.

The aforementioned perspectives have been used to structure Table 1, which presents a list of key concepts and covers the current understanding of IWM in scientific literature. Although a detailed review of the literature on all water management approaches is beyond the scope of this article, the table provides a concise overview of the diversity and characteristics of existing concepts.

It is argued here that the two viewpoints underlie two major lines of research and conceptual development regarding IWM. In this article, these lines of research will be referred to by the generic terms resource management (human system perspective) and ecosystem management (natural system perspective).

Resource management approaches generally focus on water planning and development, in which the different needs and requirements of society (often economic) towards the environment are central. Its conceptualisations are strongly associated with a school of thought that adheres to concepts of sustained yield, reflecting an economic, utilitarian belief that human consumption is the focus of management; the purpose of resource management should therefore be to provide a continuous supply of market-oriented goods (Cortner and Moote 1994). This traditional belief has its roots in the progressive era of industrialisation (first half of the 20th century), and places emphasis on human welfare and comfort. The people-centered approach of resource management explains the broad number of elaborations in the context of developing countries, where it is often linked with a sustainable development agenda and used as an umbrella concept to frame applied technological approaches on hydraulic engineering and technologies for monitoring and remediation, irrigation and drainage. The focus of elaborations thereby lies on incorporating multiple aspects of natural resource use into a system of sustainable management to meet explicit production goals (e.g. of farmers) and other uses (e.g. profitability, risk reduction). As expressed in the Integrated Water Resources Management (IWRM) concept, such goals can be pursued through cross-sectoral planning and involvement of all stakeholders across different management levels (Jønch-Clausen and Fugl 2001). Broader community goals as considered in the Integrated Natural Resources Management (INRM) concept, like food security and

Table 1. Key concepts in literature with relevant aspects.

Concept	References	Aspects	Position HV	Position NV
Co-management	Carlsson and Berkes (2005)	Deliberation Joint learning Negotiation Governance	++	–
INRM	Gottret and White (2001); Merrey et al. (2005)	Poverty reduction Food security Environmental sustainability Sustainable livelihoods	++	±
IWRM	Jønch-Clausen and Fugl (2001)	Coordination Economic efficiency Social equity Environmental sustainability	++	±
IEM	Margerum (1999)	Stakeholder collaboration Public involvement	++	+
Interactive water management	Van Ast (1999)	Interactive dialogue watersystem and society Active participation Adaptive approach to ecosystem processes	+	+
IRBM	Jaspers (2003); Gilman et al. (2004)	Coordination stakeholder interests Maximise (long-term) social and economic goals Maintenance native biodiversity	+	+
Adaptive water management	Hunt (2000)	Flexible management responses Learning cycle Monitoring ecosystem responses	+	++
Ecologically sustainable water management	Richter et al. (2003)	Ecological integrity Maintaining intergenerational human needs	+	++
Ecosystem management	Grumbine (1994); Sparks (1995)	Ecological integrity Maintaining viable populations and ecological processes Accomodation human uses	±	++
Adaptive environmental assessment and management	Grayson et al. (1994)	System dynamics Fundamental variability	–	++

+ and – symbols indicate (degree of) emphasis on either perspective (HV/NV – human-/natural viewpoint).

environmental quality (Gottret and White 2001), might be best pursued through a livelihoods approach set at the heart of the concept, as Merrey et al. (2005) argue. This latter approach takes improvement of livelihoods and stresses the empowerment of (poor) people, reduction of poverty and promotion of economic growth as basic objectives. In general, the development of resource management increasingly shows acceptance of participatory approaches instead of expert-based approaches. Stakeholder involvement in planning and consideration of local knowledge are examples of current focal issues in resource management approaches. For example, Carlsson and Berkes (2005) consider empowerment of local users to be especially important for solving current resource management problems and therefore propose the use of the concept of co-management, an approach that centralises partnerships and power-sharing arrangements.

In contrast to resource management, the conceptualisations of ecosystem management reflect a natural viewpoint. Thereby, the focus is on preserving and protecting the health and/or integrity (see Vugteveen et al. 2006 for notes on these concepts) of the natural system, stressing ecological function and balance. Human use of resources (or ecosystem services) is allowed within the limits of ecological carrying capacity (environmental sustainability). This school of thought is associated with ecological concepts and ecocentric beliefs (see below) and has become increasingly dominant in water-related science with the advent of the environmental movement, when the language and logic of especially ecology began to empower the management agenda (Cortner and Moote 1994; Hull et al. 2003). As defined in the ecosystem management concept, management should integrate scientific knowledge on ecological relationships within a societal (values) framework to protect ecological integrity over the long-term (Grumbine 1994). Thereby, the preservation of ecological integrity is considered necessary to maintain so-called ecosystem services. The latter represents the natural end of resource use and refers to a wide range of conditions and processes through which natural ecosystems (and the species that are part of them), help sustain and fulfill human life (Daily et al. 1997). A concept such as ecologically sustainable water management (Richter et al. 2003) focusses specifically on how to sustain and protect these benefits. Given the complexity of ecosystems, the procedural approach to attain ecosystem management goals should be adaptive (Hunt 2000). In a conceptual sense, adaptive management recognises that our knowledge of ecosystems is incomplete and management should be used as an ongoing process to gain further understanding of our impact on complex systems. This is done by viewing projects as a sequence of experimental designs and using the results of each experiment in a learning process to improve subsequent designs (Grayson et al. 1994). Hunt (2000) extends this concept by claiming that managers should adjust their actions not only in response to ecological conditions but to social and economic conditions as well.

The concepts of resource and ecosystem management reflect two major schools of thought on water management based primarily on a distinction between their different viewpoints on human use of the natural system. Though purposefully set apart in the text above for characterising the existing diversity in approaching water management, the table shows that most concepts do not adhere strictly to either one perspective. In the current scientific arena, there is general consensus that best management practices cannot be solely based on optimising consumptive uses (Cortner and Moote 1994). Furthermore, increased scientific understandings of human-ecological relationships concerning human welfare and sustainability of ecological systems have made it imperative to rethink the ways of managing water resources in accordance with ecological stewardship and social equity. For example, though Gilman et al. (2004) take a natural system perspective by contending that maintenance of native biodiversity should be a prerequisite in Integrated River Basin Management (IRBM) (and not a mere stakeholder interest), they also explicitly state that this should serve to realise human use goals.

The way the relation between society and the natural system is conceptualised (in terms of resource use) is strongly guided by its underlying system perspective, which relates to how systems are thought of in terms of connectedness, i.e. the linkages among the components as well as the context of the entire system. This 'systems thinking' has changed over time and has come to include holistic viewpoints, which add that complex systems show emergent properties that can only be understood within the context of the larger whole, arising from the interactions and relationships among the parts (Holling 2001). Thereby, the 'hard' system (based on physical laws) is a subsystem of the human constructed system definition, and the so-called 'soft' system (Checkland 2000) arises from the images and interpretations of reality by members of the system.

The concepts in Table 1 take different system perspectives. Ecosystem management approaches are clearly associated with the eco-centric paradigm. This paradigm is apparent within the field of ecology, where ecosystems are considered the major structural and functional units. This paradigm has been a primary driver for scientific activity in water management, offering a broader, synthetic approach to deal with complex societal issues than the 'traditional' reductionist, analytical approaches.

Though concepts such as adaptive water management and IRBM clearly emphasise the conditions in the 'hard' system as the basis for management action, they take more to the holo-centric paradigm than the eco-centric paradigm because they recognise the plurality of stakeholder interest (including the interest of the natural system) to define management actions. This is also true for INRM and IWRM. Co-management is a typical example of a concept that fully takes to the holo-centric paradigm. It emphasises the 'soft system', arising from contextual relevance, participation in planning and decision making, responsive and reflexive practice. The holo-centric paradigm has evoked new styles of approaching water management that centralise the consideration of the contributions and perspectives of all users, planners, sciences and policy-makers, and the promotion of communication between different public and private stakeholder groups as well as the wider public (Jeffrey and Gearey 2006). Participatory procedures, defining management as an outcome of 'dialogues' between all participants, are main elements in this management approach. An example of such a concept is interactive water management (Van Ast 1999). In this concept, the water policy agencies are in a continuous interactive dialogue, both with the water system and the societal system. In a sense, this comes down to combining the concepts of adaptive management and co-management. Similar notions are also articulated in the concept of Integrated Environmental Management (IEM). Margerum (1999) uses the term to refer to a whole array of integrated management concepts, including IWRM and IRBM, arguing that it is the most inclusive term. Like Van Ast (1999), Margerum (1999) also emphasises the role of interaction and coordination (by stakeholder collaboration and public participation), suggesting that interaction is not just an important part of IEM, but the key operational component for achieving integration.

Overseeing scientific developments, the theoretical framework that supports IWM is broad and fully in development. One-sided ecosystem or resource management perspectives are abandoned and more expression is given to the need to include 'soft' relations within the holo-centric paradigm, defining management in the context of social networks. Interdisciplinary disciplines such as conservation biology and ecological economics play an important role in synthesising natural and social knowledge within management perspectives. Worth mentioning is the current rise of disciplines such as 'civic science' (Cortner 2000; Plummer 2006) and 'public ecology' (Robertson and Hull 2001). The connotations 'civic' and 'public' indicate that such disciplines seek to bring science closer to society by integrating policy and scientific dimensions.

The general observation is that no scientific consensus exists on the conceptual rationale behind IWM. Conceptual definitions are not unambiguous and leave ample space for interpretation (and therefore misunderstanding). Multiple authors have observed that the range of opinions on IWM is wide, leading to critical discussions in the scientific community on the meaning and scope of these concepts (Biswas 2004; Gilman et al. 2004). For example, in a critical paper, Biswas (2004) asserted that the IWRM concept as defined by the global water partnership is currently unusable and not implemental in operational terms as most basic social, economic and environmental goals are implicit in its definition. Overseeing available literature on integrated management concepts, papers generally provide reasoning for integrated approaches and include general conceptual discussions on how to practice integrated management, sometimes including narrative case studies. However, it was found that the category of empirical research that gives context and order to theories in IWM, allowing case studies to be analysed and compared rather than presented anecdotally, is generally lacking. These observations have been made earlier by Margerum and Born (1995) in relation to IEM but apply generally to IWM as well.

3. Development of IWM in Dutch policy setting

After the previous section has shown the scientific scope of IWM to be diversified, this section will look into the framing of IWM in a national policy setting, in this case Dutch water management. The purpose of the section is to show how (thinking on) IWM has developed, indicating the elements of integration that have come to be included in the strategy over time.

We have limited the selection of policy documents to key documents with formal status in order to keep the overview tractable as well as informative. Extended historical overviews of development of water management have been addressed by other authors (e.g. Disco 2002; Van der Brugge et al. 2005).

3.1. Key policy documents

Table 2 gives an overview of key policy documents and their primary elements of integration that have contributed to the transition of traditional water management to IWM in the Netherlands. These elements can be attributed to three main aspects, i.e. (i) the physical water system, (ii) societal interests and (iii) control and administration. As shown in the table, IWM development in the Netherlands is captured by six main policy documents. This main strategic framework has been shaped over time by different preparatory documents and given direction by documents that elaborated on focal aspects of water policy.

Overlooking the table it can be seen that different elements of integration have been emphasised or added in policy documents over time. Hereby, attention seems to have shifted from a focus on systemic aspects to control and administration. The transition from technical and quantity-oriented sectoral water management to IWM began with the appearance of the First Policy Document on Water Management (1968), which recognised the need for a more coherent water policy, but specified this mainly from a water quantity perspective focussed on balancing the interests of public water supply and agricultural use.

Table 2. Key policy plans in the development of water management and their primary elements of integration.

			System									Interests			Control and administration						
Year	Main policy documents	Preparatory and/or partial	System analytic approach	Quality/ quantity	Vertical connectivity	Longitudinal connectivity	Water system - ecological	(Region-oriented) Catchment	Ecosystem functioning	Short–term, Long–term planning	Environment, society, economy	User functions	Nature value of water systems	Consideration of social values in	Integration across policy domains	Vertically integrated management	Water as structuring spatial	Participation stakeholders	Coherence of measeures	Integration among assessment	Integration legislative instruments
1968	First policy document Water management[a]																				
1975		Indicative long-range programme water I, II, III[b]																			
1984	Second policy document water management[c]																				
1985		Dealing with water[d]																			
1989	Third policy document water management[e] INCLUDING:																				
1993	Evaluation of third policy document water management[f]																				
1997		Room for the river[g]																			
1998	Fourth policy document water management[h]																				
2000		Water framework directive[i]																			
2000		Dealing with water differently[j]																			
2000	Fifth policy document Spatial planning[k]																				
2003		National administrative agreement water[l]																			
2004		Policy document Space[m]																			
2004		Integration waterlegislation[n]																			

[a]Rijkswaterstaat 1968; [b]VROM 1975–1985; [c]V&W 1985a; [d]V&W 1985b; [e]V&W 1989; [f]RIZA & RIKZ 1993; [g]V&W and VROM 1997; [h]V&W 1998; [i]European Commission 2000; [j]V&W 2000; [k]VROM 2000; [l]National Administrative Agreement 2003; [m]VROMs 2004; [n]V&W 2004.

Different shadings are used to indicate the developments pertaining to the system, interests and control and administration. European WFD is included because its policies are obligatory for Dutch water policy.

The approach in the next Policy Document on Water Management, in 1985, differed significantly from the first and was a response to the growing environmental concern in the 1970s (embodied by The Club of Rome report 'Limits to growth', which prompted thinking about the negative impacts of humans on natural systems). Also, it was a response to an unusually hot summer in 1976, in which not only the quantity but also the quality of available freshwater had dramatically deteriorated (Disco 2002). The Second Policy Document gave attention to the coherence between surface and ground water, as well as its quantity and (physico-chemical) quality, and introduced a system analytic approach to water policy. One could say that turning into the 1980s, the awareness of the need for integration was rising, having its main focus on the integration of quantity and quality management. The publication of the policy memorandum 'Dealing with water' (V&W 1985) is generally seen as the turning point in Dutch water management thinking as it defined the basic strategic principles of IWM (Van Ast 1999). In this memorandum, ecological aspects were added to the system analytic approach. This resulted in the adoption of the so-called 'water systems approach' basis for an integrated water policy. As defined in the memorandum, the approach embeds the physical system as the basis for managing the water system, thereby aiming at an integrated consideration of water-related societal functions in accordance with the potentials of the system by means of a fitted technical and legal infrastructure.

As can be seen in Table 2, the memorandum put forth an approach that incorporated aspects of the physical system, societal interest and administrative aspects. Following the strategic elaboration in 'Dealing with water', IWM was established as a policy in the Third Policy Document on Water Management (1989). Here, IWM was defined as 'a form of coherent policy and management by the different governmental bodies with strategic tasks and management tasks in the area of water management from the perspective of the water system approach'. With regard to policy, the water system approach referred to internal functional coherences (relations between quantity- and quality aspects of surface and groundwater) as well as external functional coherences (relation between water management and other policy domains like spatial planning). The Third Policy Document elaborated on the performance of IWM in terms of objectives expressed as 'target images'. The policy document defined these target images mainly in terms of physical–chemical standards for water quality and elaborated on the necessity for horizontal harmonisation (i.e. between policy areas) and vertical harmonisation (i.e. between tiers of governmental bodies) in administrative control. Explicit in this policy document, the physical object of management changed from single parts of the water system (main bodies of surface water) to include the whole water system as a unit, including relations to groundwater and banks. Demarcation of management objects was no longer based on functional criteria (i.e. relating societal uses) and restricted to mere physical aspects of the water system, but shifted to include ecological criteria extending to physical, chemical and biological aspects of the system. The establishment of the water system approach further meant that the separate tracks within overall water management of demand-oriented water quantity management on the one hand and effect-oriented water quality management on the other were combined into supply-oriented and source-oriented management of quantity and quality altogether. The supplementary evaluation document (RIZA & RIKZ 1993) to the Third Policy Document extended and refined the set target images and, similarly as the Third Policy Document, in essence related to IWM in terms of being a policy objective.

Internationally, since publication of the Brundtland report (Our Common Future) in 1987, sustainability thinking had started entering environmental policies. With the appearance of the Fourth Policy Document in 1998, IWM was no longer perceived as a policy objective but as a process for planning sustainable measures. Extending the water systems approach, the Policy Document emphasised the catchment approach, referring to region-oriented management that fits with the natural (hydrological) dynamics and boundaries of the water system. The catchment approach meant a strategic shift. Although management of the water system was first directed at specific uses and basically guided by economic growth, policy now established the recognition that use of the system needed harmonisation of functions within the boundaries of the systems ecological and hydrological resilience. This latter view was a departure from the traditional approach to land and water management ('heightening dikes') and had consequences for future spatial planning considerations in the river system. The new approach was prompted by the near floods of 1993 and 1995, an awareness that was further raised by the high water discharges of 1998 (Van Stokkom et al. 2005). As a consequence, the policy guideline 'Room for the river' (1997) formalised water as a 'structuring principle'. This policy plan proposed the application of measures for conservation of the winter bedding of the major rivers and the compensation for quantitative changes in the size of the riverbed by creating new room for the river elsewhere. As such it was part of the broader policy to conserve the existing capacity of the rivers to carry water and fitted the call for region-oriented policies, as close interaction between spatial planning and environmental policies is required. Importantly for Dutch water policy, the European Water Framework Directive (European Commission 2000) has added an overarching legislative-administrative dimension to the catchment approach, defining the hydro-geographic catchment as the basic functional unit area for harmonising member states' water policies through so called 'River Basin Management Plans'.

At the turn of the millennium, the integration of water with land use and spatial planning has become more explicit and a prominent theme in the policy making process ('room for water'). The Fifth Policy Document on Spatial Planning (2001) headed forth on the policy direction that the Fourth Policy Document had taken, adopting and elaborating 'water as a structuring principle' and the region-oriented catchment approach. The policy document 'Space' (VROM 2004) extended the policy intentions of the Fifth Policy Document on spatial planning and presented a vision for the 'integrated spatial development' of the Netherlands, based on considering different space-demanding functions in relation to social, economic and ecological spatial values. The appearance of this policy document clearly confirmed the political emphasis on spatial harmonisation based on interactive policy strategies. The above-described direction in water management has triggered the call for an institutional and legal infrastructure that is fitted to support the current policy objectives (including EU Water Framework Directive requirements). This is exemplified by current developments of integrating existing Dutch water legislation concerning water quality, water quantity and infrastructural works into a single legislative framework (V&W 2004).

Summarising, the development of integrated approaches in water management in the Netherlands has focussed on the following elements; the water system (surface and groundwater), water quality and quantity, water policy and adjoining domains such as spatial planning, the societal system and different interests, as well as regional/national harmonisation. Within this development, the step to the 'water systems approach' implied adoption of the holistic eco-centric paradigm. Consequent definition of management in terms of 'serving societal functions of water systems' indicates adherence to a resource management perspective. The internationally anticipated change of future hydrological conditions (climate change) has prompted policy to focus on the spatial eco-hydrological requirements of the whole biophysical water system (catchment), necessitating regional and (inter)national harmonisation in planning.

4. Discussion

Following the above analysis, the meaning of IWM at the scientific level is not associated with a single theoretical construct but with a collection of theories and approaches, which can be linked with two major schools of thought, i.e. resource management and ecosystem management. Though initially associated with system thinking and ecological functionality, integration efforts tend to be more and more aimed at including 'soft' relations, defining management in the context of social governance networks. Its practice needs learning and participation by all interests groups (Pahl-Wostl et al. 2008).

In contrast to the scientific level, IWM at a policy level was found to be foremost associated with a planning process that is multi-objective and adaptive to the political agenda, instead of being a fixed procedural framework with set principles. Different orientations towards integration over time seem related to (sudden) shifts in political focus, or political urgency (Table 2). This has been called the effect of so-called 'shock events' (Wiering and Driessen 2001). For example, the earlier mentioned drought in 1976 (Disco 2002) triggered political attention to water quality issues, next to the traditional attention for water quantity. Also the severe flooding events in 1993 and 1995 in the Netherlands drove the water management agenda to its current focus on spatial planning in relation to quantity management, and established a general political awareness about the issue of climate change. Currently, water quality is prominent in the agenda as well because of implementation of the EU WFD. IWM at the policy level thus serves as a dynamic and functional concept for rationalising the political changes in the management process.

Comparing the rational framing of IWM in science and Dutch policy, it shows that some basic understandings are shared, primarily concerning (ecological) systems theory. The rational framing of water management in policy made a significant change in the 1980s with the recognition of the eco-centric water systems approach and the catchment approach in policy documents (see Table 2). Making functional use of these systemic understandings, policy-makers were able to formulate coordinated, synthetic management objectives. Although systems thinking is a paradigmatic frame for policy as well as science, substantive understandings of system theory (i.e. what are system boundaries, what are the essential systems functions, etc.) are still evolving and debated at the scientific level (e.g. Holling 2001). Overseeing the current conceptualisations of IWM, it is apparent that the theoretical development has shifted its focus from natural system dynamics to include social dynamics, human perspectives and values. Central to this reasoning is the need to consider humans as part of ecosystems and linking ecological and social systems. Governance issues receive increasing attention, exemplified by such approaches as co-management. At the policy level in the Netherlands, the importance of involving stakeholders and creating an open policy process has been acknowledged, but is still very much a 'learning process' according to Witter et al. (2006).

Next to holding rational claims, IWM is undeniably value-laden as it involves how we as a society deal with the natural resource of water. The analysis at the scientific level brought forward that resource management and ecosystem management hold different embedded values towards the position of humans in relation to nature. The attachment of normative, ethical claims to IWM at the scientific level, does raise interesting questions about the value perspectives ('worldviews') in the scientific community and how science should relate to policy. Traditionally, scientific culture is characterised by adherence to objective, value-free science, preference for technical solutions and advancement of scientific rationality as preferred logic (Cortner 2000). This however complicates inclusion of non-quantifiable information and non-expert opinions, moving beyond technical questions, and integrating larger questions of values (e.g. ecological integrity, equity), aspects which all lay in the domain of social science.

Together, the above notions bring forward some important research issues to consider in the further advancement of IWM. This article was able to show that IWM is framed differently in science and policy but importantly, the different roles of science and policy in the framing process of IWM need further consideration. This needs a more specific definition of science and policy than taken in this article, taking into account the full institutional arena with different actors. Questions need to be directed on how to connect the sciences to policy in the pursuit of IWM, for example through civic science (Cortner 2000; Plummer 2006). More specifically, research issues involve how knowledge should be transferred between science and policy domains as well how knowledge utilisation needs to be shaped in the policy process (Hoppe 2005). Other suggestions relate to considering the practice and nature of science itself.

Exploring the literature base on IWM showed that the environmental and natural science disciplines are the main contributors to IWM concept development, especially (system) ecology. But although the importance of social dynamics is recognised from a systems perspective, it will need social science to understand and assess these dynamics. Importantly, social sciences need to be increasingly involved and challenged to contribute to IWM strategies, for example through social analysis approaches (Endter-Wada et al. 1998). As such, the social sciences can contribute to elaboration of the rising holo-centric paradigm in which water systems are regarded as the product of eco-social dynamics. Interdisciplinary collaboration between natural and social scientists can help to further develop IWM in the light of this paradigm.

5. Summarising conclusions

When contrasting IWM elaboration in both science and policy, it becomes apparent that IWM has a different standing in both domains; i.e. being a comprehensive systemic understanding for linking research in science *versus* being an adaptive approach for unifying policy objectives at the policy level. This corresponds with differences in culture between science and policy whereby the rational–analytical model dominates science and policy is driven by a bargaining-conflict containment mode (Cullen et al. 1999). At the scientific level, IWM is mainly elaborated in terms of system thinking and ecological functionality, but shifting to inclusion of social dynamic relations. At the policy level, IWM is foremost functional for framing multiple objectives and driving changes in the management process. Altogether, differences within science in dealing with the value-laden character of IWM may complicate development of the IWM knowledge base. Also difference between science and policy in framing IWM may complicate the input of scientific knowledge into the policy process. Further, advancement of IWM depends on consideration of the practice and nature of science itself and greater involvement of social scientific disciplines.

Acknowledgements

This study has been financed by the Interdepartmental Institute Science & Society of the Radboud University Nijmegen (grant W&S 2004-04).

Note

1. Note that the abbreviation IWM will be used throughout the article as a general denominator to refer to a range of approaches and strategies that have been labelled 'integrated management' and discussed in literature within the context of water systems.

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