INTEGRATED WATER RESOURCES MANAGEMENT: A PRACTICAL SOLUTION TO ADDRESS COMPLEXITY BY EMPLOYING THE NEXUS APPROACH

HANS SCHREIER, MATHEW KURIAN, REZA ARDAKANIAN

WORKING PAPER - No. 2

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About UNU-FLORES

BACKGROUND

The United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) was established in Dresden, Germany in 2012. The institute is supported by the Federal Ministry of Education and Research (BMBF) and the Ministry for Higher Education, Research and the Arts (SMWK) of the Free State of Saxony, Germany. As part of the United Nations University (UNU), the institute helps to build a bridge between the academic world and the United Nations. The UNU was founded in 1973 as an autonomous organ of the UN General Assembly. It encompasses 16 research and training institutes and programmes in 12 countries around the world. UNU as a whole aims to develop sustainable solutions for pressing global problems of human survival and development. Through a problem-oriented and interdisciplinary approach, UNU aims at teaching, applied research and education on a global scale.
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VISION

The Dresden-based institute of UNU-FLORES acts at the forefront of initiatives promoting a nexus approach to the sustainable management of water, soil and waste. UNU-FLORES acts as a think tank for the United Nations and its member states, in particular addressing the needs of developing and emerging countries. As a think tank, UNU-FLORES will be an internationally recognized hub and intellectual focal point promoting integrated management strategies. Additionally, UNU-FLORES will attract high-calibre students for postgraduate study and research programmes in cooperation with other research institutions. The institute will build the capacity of future leaders in the area of environmental resources management and develop innovative concepts for target- and region-specific knowledge transfer.

MISSION

UNU-FLORES develops strategies to resolve pressing challenges in the area of the sustainable use and integrated management of environmental resources such as soil, water and waste. Focusing on the needs of the UN and its member states, particularly the developing and emerging countries, UNU-FLORES engages in research, capacity development, advanced teaching and training as well as dissemination of knowledge. In line with UNU's general mission to promote sustainability, UNU-FLORES also considers impacts of global change on resources management.

THE NEXUS APPROACH

Advancing a nexus approach to the sustainable management of the environmental resources water, soil and waste is the main mission of UNU-FLORES. The nexus approach is based on the belief that vital environmental resources are strongly interconnected and require a integrated perspective to manage them sustainably. Such a nexus perspective must take into account different sectors and disciplines in both research and capacity development and strive for holistic management strategies.

RESEARCH AREAS

UNU-FLORES aims at a truly integrative and global perspective on resources management, considering interrelated resources in a comprehensive manner. This holds also true for impacts of global change and its nexus to green economy. In all of the following research areas of UNU-FLORES, the institute will cooperate closely with other universities and research institutions in both research and teaching:

- Water inventory and fluxes;
- Soil and land use management;
- Management and treatment of waste;
- Systems and flux analysis;
- Resources quality and quantity; and
- Global change assessment.

EDUCATION AND CAPACITY DEVELOPMENT

UNU-FLORES will engage in the following areas of postgraduate education, capacity development and trainings:

• UNU-FLORES has established a joint PhD programme with its partner the Technische Universität Dresden (TUD). The programmes will focus on each of the research areas of UNU-FLORES and will include course work according to a pre-defined scheme.

• Additional capacity development and training programmes will focus on the further education of professionals who are working in the area of environmental resources management.

A unique feature of all education activities will be the emphasis on the global dimension of the covered issues. One aspect of this global nature will be international exchange programmes for students and teachers as well as internships with other UNU and UN bodies.

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Summary

Integrated Watershed Resource Management (IWRM), while a popular concept, is difficult to implement successfully. Many authors have expressed concern that few IWRM projects have resulted in improvement in the way we manage water and few have solved the emerging water quantity and quality problems. The two main criticisms are: 1. Restructuring the many government agencies responsible for water and making them work in an integrated or collaborative manner is an unrealistic proposition, and 2. The issues are too complex to be solved in an integrated manner, because there is a disconnect between the land, water, governance, social and environmental factors and human behaviour. Moreover, these activities are mostly unpredictable. Few of the critical authors offer a viable alternative, because neither the traditional top-down sectoral approach nor the integrated multi-stakeholder approach has been successful in solving all the water problems. It is proposed that the IWRM be practiced within watersheds, because it is the only sensible way to address the complex land, water, human and environmental issues. However, a nexus approach is required that makes linkages between the top-down and bottom-up approach and that includes selective stakeholders to develop and implement IWRM plans. It is argued that the multi-stakeholder process needs to be streamlined to a more problem solving session with fewer and selective participants. This will speed up the process and allow more resources to be assigned to management actions. This also requires a commitment by the researchers and managers to monitoring the effectiveness of the implemented management over time. It is also advocated that the IWRM approach can only be successfully implemented at the micro- and meso-scale and not at the river basin scale.

1. Introduction

Water resources management has traditionally been done in a sectorial manner and with this fragmented approach it has not been possible to fully address the supply and demand problems for various water uses northe cumulative effects on water quality from different land use activities. To stem the deterioration of water resources the "Integrated Water Resources Management (IWRM)" approach has been promoted over the past 30 years, as a better and more effective alternative to the traditional sectoral and top-down approach. After thousands of publications on the topic of IWRM, evidence of successful IWRM approaches are still being questioned. Why do we have so many difficulties in finding an integrated management approach that can deal with water in a holistic and coordinated manner? Part of the answer to this question can be found in the definition of IWRM.

The IWRM approach has been defined by the Global Water Partnership (GWP-TAC, 2000) as: "A process which promotes the co-ordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."

IWRM has also been defined by Odendaal (2002) as: "The integrated and coordinated management of water and land resources as a means of balancing resource protection, while meeting social, ecological needs and promoting economic development."

These definitions clearly show the complexity of managing a resource that plays a key role in all aspects of life on earth. The main challenges that need to be overcome are:

1 Everybody has an opinion about how to manage water and its uses, but few have sufficient knowledge of the intricacies and dynamic processes involved.
2 Few good methods exist to deal with the complexity and uncertainty effectively.
3 Top-down decision-making is considered more efficient and is the preferred approach by organizations and governments but this approach falls short of addressing all interactions.

The objectives of this paper are to review the evidence on integrated water resources management to explore potential for adoption of a hybrid approach that can make the linkages between the top-down and bottom-up planning initiatives more effective. Another objective of this paper is to examine the literature on the subject of integrated management of environmental resources which argues that multi-stakeholder processes needs to be streamlined to ensure facilitated learning by doing and trial-and-error approaches. What does this mean from a scientific perspective, especially for researchers interested in effective project strategies and programme design, monitoring an evaluation?

Finally, another objective of this paper is to shed light on the issue of scale and its role in influencing the effect of spatial and temporal factors on environmental and social outcomes of integrated management of water resources. Can one conclude for instance that IWRM approaches can only be successfully implemented at the micro- and meso-scale and not at the river basin scale?

2. Why is IWRM so Difficult?

2.1 Scientific complexity

Water is a moving resource that undergoes many phase changes from rain, to snow, to ice, to evapotranspiration and back. At the same time, the rate of water movement and storage is in constant flux and only about 35 per cent of all precipitation that is deposited on the land surface of the earth ends up in the ocean annually (Dai and Trenberth, 2002). As water moves through the atmosphere, soil, plants and geology, it not only undergoes changes in the storage compartments but also inherits different chemistries; added to this are the contaminants from land use activities that are conveyed into the freshwater systems by direct surface runoff, soil and groundwater seepage, or via deposition of atmospheric contaminants.

Many processes are stochastic in nature and affect short- and long-term water storage sources in different ways. These processes are dynamic and change over spatial and temporal scale. We have great difficulties dealing with upstream to downstream impacts in river basins, accounting for groundwater release and recharge, determining cumulative effects, deciding how to reallocate water and re-use water without expensive treatment. We also remove water from the natural systems and release it back to nature in changed conditions, which further complicates assessment and management.

On top of the current demands for water and the pollution impacts, new problems are emerging that will affect supply and demand, as well as the water quality. These include increased climatic variability, land use intensification (both in the urban and agricultural environment), new water uses such as those associated with fracking, increased desalinization, water for snow-making, atmospheric changes, renewed interest in hydropower production (as an alternative to electricity generation that produces greenhouse gas emissions) and many others.

Most water management has been human centric and only recently have we started to address the topic of how to maintain water for environmental services (Postel and Richter, 2003). This will result in significant trade-offs and changes in the way we use and protect water resources. There is also a major need to pay more attention to the green water cycle (the rainfall that enters the soil and plants and is evapo-transpired back into the atmosphere). Currently, human activities are primarily focused on the blue water cycle (the portion of rainfall that ends up in rivers, lakes and groundwater). The difference is striking because up to 65 per cent of all precipitation moved through the green water cycle (Falkenmark and Rockstrom, 2006) and only one third moved through the blue water cycle. There is much to be gained by improving the management of green water (Wani et al., 2007; Figueres et al., 2011).

2.2 Governance and management complexity

In addition to the bio-physical complexity are the socio-economic issues, where we debate whether water should be a common good or a marketable commodity (Hochuli, 2004). What pricing structure should we use to account for water and pollution and how do we value environmental services in an economic context?

Another level of complexity is in the way we manage and govern water resources. There is a key disconnect between the way we regulate land use activities and water resources. Agriculture, urbanization, transport, mining, forestry and recreation are all governed and managed as separate entities and water is usually placed under the environmental portfolio. However, water monitoring, water allocations, infrastructure financing and water and health are usually the responsibilities of other ministries or departments. For example water quality monitoring is usually the responsibility of one ministry, while stream water or groundwater monitoring is done by a different ministry. This leads to such problems as water quality monitoring stations located in different places other than stream flow measuring stations. Water allocation is equally complex and distributed among different jurisdictions such as groundwater versus surface water allocations for drinking water, irrigation and mining. Water treatment is different for drinking water, wastewater and salt water and in many cases there is no communication or sharing of knowledge between the three.

Most laws that govern such activities have not changed much or have only evolved slowly over historic times. Most water laws are archaic and in the case of British Columbia have not changed since 1909. Our primary governance structure is in compartments and in the case of water resources there are too many overlapping jurisdictions and very little integration. We also prefer the top-down approach to decision-making because it is considered far more efficient than using a multi-stakeholder consultation process.

It is extremely difficult to separate the impacts of natural processes from those induced by land use activities and the cumulative effects of all these interactions pose a major scientific and governance challenge as shown in Figure 1. This is particularly problematic for setting up regulations, guidelines

and standards. All government agencies have regulations for individual contaminants but creating cumulative effects regulations is exceptionally challenging because some of the interactions between contaminants can be synergistic, additive or antagonistic (Dube et al., 2013).

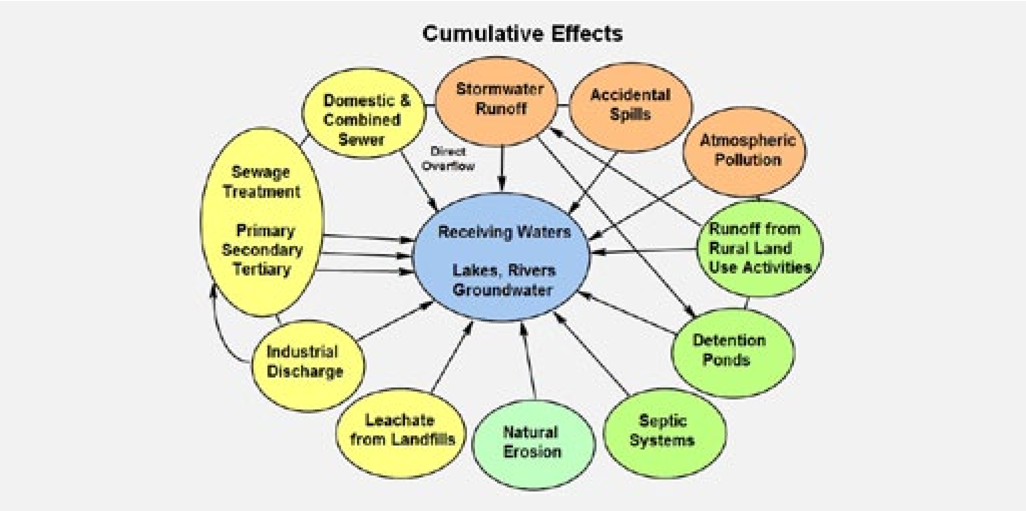

Figure 1 Cumulative effects on freshwater resources from multiple activities and sources

2.3 Emerging factors that add to the complexity

It is a formidable challenge to address the scientific and governance complexity. What makes this even more difficult is the emerging challenge of increased climatic variability. Recent extreme events clearly show that we can no longer rely on historic trends and experiences and traditional management practices are no longer capable of fully addressing the impacts of extreme floods, droughts, high temperatures and storm events. Intensity-duration–frequency graphs (IDF curves), which have traditionally been used to plan for 100-200 year flood events now require major re-adjustments because flooding risks have not only increased as a result of increased variability in precipitation, but we have also changed the surface conditions at the same time through land use intensification. This has altered the hydrological cycle to generate more surface runoff.

As a result we need to re-think the traditional water governance approaches. The main question is whether the IWRM framework is the most appropriate option to address the complexity and emerging problems, and if so, what are the advantages and shortcomings of such an approach.

3. Advantages of Using the IWRM Approach

One of the main reasons why the IWRM framework was introduced was to move from command and control to a more flexible and adaptive management approach, where water supplies, availability, infrastructure, demand, ecological factors, societal needs, conservation measures and environmental considerations were addressed in a holistic manner. This requires a more participatory and trans-disciplinary approach (Schneider, 2011). This suggests that scientific knowledge should not be independent of cultural, historic and environmental knowledge (Pahl-Wostl, 2002). These authors state that scientists should take part in a dialogue with society about uncertainties, values and beliefs (Pahl-Wostl, 2008). To address all these issues, the river basins, or watershed, were chosen as the natural units, which allows for the measurement of processes, helps integrate land use activities and facilitates the assessment of ecosystem health. This is also an effective way to encourage societal interactions between land use activities, water management and scientific assessment within a natural landscape unit that affects all residents.

3.1 The river basin as a natural unit ideal for understanding processes

Quantitative measurements and analysis of processes can readily be examined in a river basin. It is a good way to facilitate science based decision-making. River basins or watersheds are natural units that allow us to account for water cycling and water use in a quantitative manner. It is ideal to determine mass-balances, monitor changes over time and examine changes from the head waters all the way downstream. It facilitates the creation of models that simplify complexity and help us understand key processes within the system. Processes like entry, absorption, detention and release can readily be assessed both spatially and over time, and this allows us to examine cause and affect relationships. It links human activity with natural responses and facilitates the measurements of the interactions between human activities and the natural environment.

3.2 The river basin as an integration tool

The basin unit serves as an integration tool that links all human activity with natural responses. It is a platform where human activities, climate, water, sediments, ecology, nutrients and contaminants can be examined in an interdisciplinary way using a system-based approach. Local stakeholders can play an active role by presenting data and local knowledge that is often unavailable when problems are assessed by experts. It also allows us to determine the cumulative effect from all activities and natural processes.

3.3 The river basin facilitates the assessment of ecosystem health

Ecosystem health can readily be identified by measuring abundance, vigour, change and diversity of plants and aquatic organisms. The impact of land use activities on the health of the aquatic system can readily be monitored and identified.

3.4 A framework for understanding complex systems and accounting for actions

The scientific knowledge gained by quantifying processes, determining change, modelling and developing scenarios helps us to understand complex systems.

It also provides a basis for monitoring the effectiveness of management over time and provides a measure of accountability.

3.5 Stakeholder involvement and decision-making processes

Bringing all stakeholders together at the table provides the opportunity to understand all issues in a comprehensive manner. Local stakeholders bring local knowledge and can make a major contribution in data generation, monitoring and rehabilitation efforts. This provides a platform where local issues are considered and trade-offs can be negotiated. The main challenge is how to arrive at consensus and how to set priorities. Having all stakeholders involved helps in building a bridge between top-down and bottom-up approaches to decision-making (Warner, 2007).

The IWRM approach has been discussed and applied globally for the past 30 years and the history has been well described (GWP-TAC, 2000, 2004; Biswas, 2004; Mizanur and Varis, 2005; Molle, 2006; Pahl-Wostl, 2008; UNW-DPAC, 2010; UNDESA, 2005; Hassing et al.,2009). It has evolved from a sectoral approach to cooperation and then evolved into integrated water resources management. Over the past few years emphasis has been placed on goal oriented IWRM and capacity building (WVLC, 2010).While there has been considerable success particularly in the developed world (Hidalgo and Pena, 2009; Najjar and Collier, 2011; Lenton and Muller, 2011), success in the emerging world has been mixedas discussed below.

4. Critique and Problems with IWRM

Over the past 10 years hundreds of authors have stated that there is little evidence that the IWRM approach has been very effective (Braga, 2001; van der Zwaag 2005; Merrey, 2006; Medema et al., 2008; Biswas, 2008; Jeffrey and Gearey, 2006; Moss, 2009; Biswas, 2013). The claim is that few watershed studies have achieved significant improvement in the way we manage, rehabilitate, conserve and re-allocate water resources. There seems to be an idealistic belief that the problem solving capacity of IWRM is far better than traditional approaches (Jeffrey and Gearey, 2006; Medema et al., 2008; Biswas, 2013).

The main problem in all water resource management endeavours is how to change the public view that the most convenient way to deal with the impacts of contaminant in water is "the best solution for pollution is dilution". Moreover, the only time the human water footprint is given consideration is during extreme events. Reducing part of the human water footprint, protecting water sources, treating effluents and rehabilitating degraded sites is considered inconvenient, time consuming and far more costly than diluting the impacts or minimizing water use. Similarly, water is considered a common good by many people and should be freely available. Our economic system does not value water and has great difficulties accounting for the services nature provides to recycle and purify water. Neither the traditional approach nor the IWRM approach has been very effective in changing these attitudes but claims have been made that IWRM is a better approach.

4.1 The multi-stakeholder process

The main critique of IWRM is that while the multi-stakeholder participatory approach is laudable, experience has shown that reaching consensus is a very difficult and time consuming process. The resulting outcome is usually in the form of trade-offs and compromises that are often insufficient to address the fundamental causes of the problem. Without good leadership and forward looking stakeholders, the process is tedious and consumes excessive amount of time and resources. The result of the multi-stakeholder process is to arrive at an integrated watershed management plan and only when the plan is completed do the people comprehend what the short- and long-term financial and resource commitments are. If financial support is not assured at the beginning of the process, only a portion of the comprehensive plan will be implemented. At that stage, the main issue is determining responsibility for the different tasks and how the different departments and stakeholders can effectively collaborate.

4.2 Scale issues

Political boundaries rarely match watershed boundaries and as a result it is difficult to extrapolate data that is collected within political boundaries and apply it to watershed units. This is particularly true for population, economic, land use and climate data.

Applying IWRM at large river basin scales is particularly problematic because different jurisdictions have different regulations particularly in international trans-boundary watersheds. This not only makes data integration difficult but also creates political and legal problems. More importantly, processes change over special scales. For example soil eroding in head water systems directly enters streams, while lowland systems primarily re-mobilize and transport accumulated sediments that have been deposited in the riverbed over time. The downstream impact of a problem that originates in a head water basin is often not evident for long periods of time and the distance between impact and response is often too large to make the connection. A good example of this is the case of hydropower dams that collect sediments above the dam. The sediments absorb most of the available phosphorus, which deprives the downstream location of this much needed essential nutrient to maintain aquatic biota. Only after 10-15 years was it discovered that phosphorus deficiencies a great distance below the dam were responsible for fish decline (Schindler et al., 2010).

The extreme variability within large river basins is a particularly difficult problem to reconcile. For example a sub-watershed within the Fraser River Basin in British Columbia is considered the driest sub-watershed in Canada, while another sub-watershed in the same basin is considered one of the wettest places in the

country. How these two extreme sub-systems interact and how this influences the overall flow regime of the river basin is difficult to reconcile.

Giordano (2012) suggests that the IWRM approach should be ignored when trying to solve river basin issues, because trans-boundary conflicts cannot be resolved in an efficient manner. Also water rights should be ignored and water should be priced and reallocated to higher value uses. It is unlikely that we can ignore all the legal issues and allow economics to determine how water is used, because this will only create new conflicts and does not easily address the topic of maintaining fully functioning environmental services.

One of the main criticisms is that developing a standardized approach that works at all scales and in all watersheds is impossible. This is true, because extrapolating from one large watershed to another is very difficult given that topography, climate, geology and land use are always different between watersheds. As a result each IWRM programme is different and evaluation methods need to be changed depending on the type of issues and concerns. This leads to delays and efficiencies in establishing different regulations and jurisdictions.

4.3 Problems with inter-sectoral linkages

Jeffrey and Gearey (2006) argue that substantial changes in the way we manage resources is risky because the transitional costs are unknown and require extensive transformations across several sectors. They further suggest that this risk does not decrease with multiple observation, perception and interpretation. It appears that institutional reforms in planning the management of complex resources is not only a formidable task, but is particularly problematic when trying to integrate inter-sectorial departments and jurisdictions and setting appropriate budgets.

Some people have proposed the idea that governments should manage water as part of one super agency that deals with all aspects of water management. As mentioned by Biswas (2008, 2013), this is likely an impossible task because so many institutions and jurisdictions are involved. As an example it has been shown that up to 20 different federal agencies are responsible for managing some aspects of water resources management in Canada alone (Morin and Cantin, 2009). This type of complex jurisdictional division is common in all countries. Aligning and integrating these agencies with local authorities is clearly an impossible task that would take enormous time and resources. As mentioned by Jeffrey and Gearey (2006) and Biswas (2013), integrated management of only one resource is not possible because of the interconnections with other resources and human activities. Applying all these jurisdictions to all watersheds is clearly a difficult and unrealistic proposition (Moss, 2004).

Many scientific studies have made the linkages between land use activities and water impacts (e.g. Berka et al., 2002) but solving problems effectively can only be done when land use professionals, government agencies, researchers and managers work together and have the willingness to collaborate.

4.4 Top-down vs. bottom-up approach

Top-down decision-making is far easier than bottom-up approaches because the former is much more suited to rapid response and efficiency of process. Government agencies have real problems accepting a distributed decision-making approach because it is much more time consuming to reach consensus and making decisions with multiple actors and agencies is much more cumbersome. Government agencies are unenthusiastic about downloading the data collection process, the monitoring programme and decision-making process to local stakeholders because this dilutes their authority. Also, each community in the basin has different priority issues that often ignore the issues that are of primary concern for the overall management of the basins.

There is a real need to move from too much centralization to a more distributed model in order to reduce risks and to build more resilience into watershed management.

Data is power and data collected by community volunteers and stakeholders is often questioned by government agencies as to the objective manner in which it was collected, whether quality control was in place and if the analysis was done in a reproducible manner.

Distributed activities and shared decision-making is complex and governments have difficulties accepting such an approach, because it is considered inefficient, more time consuming and difficult to determine accountability for the various activities.

4.5 Modelling challenges

Models help us understand processes and rates of change and allow us to determine which of the processes are most sensitive to change. Many people assume that the model output allows the prediction of future trends, but this is not the case. Models are a simplification of reality, yet they help us to understand how the system works better. Few comprehensive IWRM modelling programmes have been successful because of the complexity of such ecosystems. Too many assumptions need to be made in simple models, while complex models become highly data intensive and do not necessarily improve the outcome. Many authors have suggested that insufficient attention has been given to ecosystems modelling in IWRM and that most models only deal with portions of the process like hydrology, nutrient cycling (Brown et al., 1999), contaminants or sediment budget calculations (Horowitz and Walling, 2005). Additionally, they are rarely capable of making the link to biota and land use dynamics.

4.6. Mismatch between research and management

Probably the greatest criticism is the mismatch between research and management in IWRM. Researchers provide the evaluation framework and process understanding, but these are not well linked to management, because

researchers rarely participate in management or the monitoring of the effectiveness of management. Due to its complexity, the scientific framework is fuzzy, and according to van der Zaag (2005) and Biswas (2013), is not conducive to effective implementation. This is particularly problematic because human actions are highly unpredictable and these can lead to unexpected ecosystem responses (Geldorf, 1997; Smil, 2008).

Policy and management requires long-term commitment for understanding processes, monitoring and evaluating management success. Non-point sources of pollution (NPS) are particularly difficult to account for and to regulate. Developing an equitable legal framework for NPS is particularly challenging. To allow the monitoring of the effectiveness of management requires long-term funding commitments from government agencies and this is rarely a priority because it is assumed that best management practices (BMP) are taking care of the problem.

4.7. Emerging issues not well addressed in IWRM

Climate change and air pollution are given insufficient attention in most IWRM projects. The contribution from these external forces cannot be controlled from actions within the watershed. The only action that can be taken is to build resilience into the watershed system that can mitigate their impact. Hence the IWRM approach is not well-suited to deal with these trans-national and global issues.

Another external water resource issue (Hoekstra, 2011) suggests that the river basin approach is no longer sufficient because it does not address global trade, efficiency and equity issues. Local water users need to consider the virtual water concept. When a country or river basin becomes water scarce one of the main options is to allocate the remaining water for domestic and industrial use strategically and import water intensive food to save water (Hoekstra and Chapagain, 2008; Schreier and Wood, 2013). Producing food is one of the most water intensive activities, and in cases of water scarcity, a key strategy is to import food to save water. The global trade issues and the associated water issues need to be given much more attention. In this context a clear distinction needs to be made between green and blue water use.

5. The Nexus Approach and the Way Forward

If there is not enough freshwater available in a watershed we have only four different options: 1. Import more water by inter-basin transfer or virtual water imports, 2. Make more water available by desalination (in those cases where there is access to the ocean), 3. Increase the efficient reuse of water and 4. Water conservation. To solve these issues neither the sectoral way of managing water nor the IWRM approach has been very successful. Water scarcity is increasing in many places, water quality is in decline and increased climate variability is resulting in major shifts in the way water is supplied, stored, changed and released. This is affecting all physical, chemical and biological processes within watersheds and when we add the social, economic and regulatory processes to it, we end up with a formidable amount of complexity. What is disappointing is that most papers that criticize the IWRM approach offer relatively few alternatives and most think that reorganizing regulatory agencies is an unrealistic proposition. However, it is suggested that that the nexus approach offers several opportunities to simplify and improve aspects of IWRM management an issue that we discuss in the ensuing discussion.

5.1. IWRM in watershed – the problem of scale

IWRM framework is an appropriate way to proceed because it uses a landscape unit that is best suited for measuring processes and impacts in a quantitative manner. It provides a good linkage between human activities, land use and water, and the people residing within the watershed who have a vested interest in having access to reliable supplies, while also maintaining environmental quality. However, in order to be effective, IWRM should primarily be done in watersheds of small to medium size (Schreier and Brown, 2002), and according to Ballweber (2006), it works when it is feasible to address the scientific, social and motivation issues.

Applying this concept on a large international basis appears too daunting. At that scale it is difficult to show how individual management in sub-watersheds can improve the overall system operation (Kennedy et al., 2009). Bringing multi-stakeholders to the table at the river basin scale and arriving at a consensus in a timely manner is unrealistic and can only address high level concerns without being able to make a contribution to management at the watershed scale.

5.2. Multi-stakeholder processes and co-management

The process of including all actors that have a stake in managing water resources is laudable but is unrealistic, because these processes take enormous time and resources. Success is very much dependent on leadership and on the willingness of the actors to be objective and willing to compromise (Loux, 2011). In the end too much compromise often does not solve the key problem, and the management plans that have been derived through a multi-stakeholder process are often too ambitious and require unrealistic amounts of financial resources. The alternative is to involve only the key stakeholders that are responsible for the cause of the water problem and the management and enforcement of it. This needs to include the different land resource users such as agricultural, mining, forestry, urban and energy professionals.

The key water issues in a watershed could be identified in a rapid reconnaissance survey by the main stakeholders before a management plan is developed and implemented. Involving local stakeholders is critical because they can make a major contribution by providing local knowledge. However, the choice of stakeholder participation needs to be done selectively to improve the efficiency

of the process. Selecting issues in a strategic manner rather than trying to address all issues will speed up the process and will likely result in more rapid management responses. Volunteers can be engaged effectively in the management as long as some financial incentives are available on a long-term basis.

5.3 Interdisciplinary perspective

The collaboration between disciplines is critical but not every professional is prepared or suited to collaborate. This requires new learning and understanding the scientific culture of other professionals (Molle, 2009). Trans-disciplinary collaboration is a more realistic proposition because few professionals have sufficient knowledge to cover the wide range of topics that are relevant to understanding the complex processes involved in managing water. There are significant initiatives under way to train young professionals to think more holistically and the next generation of environmental engineers will be better prepared to help implement aspects of IWRM. An example of how a successful cooperative can be achieved in the construction of dams within a watershed framework was discussed by Khagran (2004).

5.4 Improved transitions between research and management

Researchers are very good at studying processes and trying to understand how a watershed functions. However, few are involved in applied research that is focused on studying the effectiveness of the implemented management practices. One good example is the construction of wetlands in urban environments to retain storm water and reduce the contaminant loads. Many are built with the assumption that they work and few are actually monitored over time to see how effective they are in reducing the contaminant load. This requires funding resources beyond those allocated for the construction of wetlands and also needs to consider adaptive management practices. Another way to link research with management is to produce annual water and nutrient budgets for land activities and within the watershed (Schindler et al., 2006). Sediment budgets can also provide the link between erosion and sediment transport.

5.5 Linking components of IWRM with adaptive management (AM)

Adaptive management (AM) is another framework that has been promoted as a viable alternative in the way we manage resources (Holling, 1978; Walters, 1986; Gunderson and Holling, 2001). The argument is that we will never understand all the complexities of how natural systems work and management interventions need to be revised on a continual basis as our knowledge improves. There are many challenges associated with this approach and Jeffrey and Gearey (2006), Walters (1997), McLain and Lee (1996) suggested that AM is equally unrealistic as is IWRM. However, it is the only logical way to pursue, because we will never fully understand, model and predict how watersheds will respond to all the different water demands and contaminant inputs from land use activities (Lankford et al., 2007). What needs to be done is use the best current knowledge and initiate management changes that we think are most appropriate (Habron, 2003). One of the key missing linkages is to monitor the effectiveness of the introduced new management to determine how successful the interventions are and how they improve the functions of the water cycle system over time. It is inevitable that adjustments need to be made over time in order to fine-tune management. IWRM promotes best management practices (BMP) but these should be renamed "beneficial management practices" because there are no win-win situations, and for every intervention, there are trade-offs and unexpected threshold responses, which we only observe after some time.

Adaptive management requires long-term commitments from all stakeholders and the research community needs to spend much more time working collaboratively with the water managers to show how the interventions are improving water resources. If improvements are small and inconsistent, researchers need to help by providing a revised understanding on how the system works and responds. This is not going to be an easy task because government agencies like simple solutions to fix the problem and then move on to other issues.

5.6 Incentives and enabling legislations and policies

To improve, IWRM requires a more flexible institutional framework that includes interactions between central and local governments, the private sector and the public (Carter et al., 2005). Without incentives for local stakeholders they are not keen to collaborate. In North America the central governments have downloaded many responsibilities to municipalities without providing sufficient financial resources. Municipalities usually do not have sufficient in-house expertise to deal with the complex water problems and unless they have sufficient financial resources, cannot access external professionals to help address the water problems in an expedited manner.

The other problem is that central governments are unwilling or reluctant to give up control over monitoring, data generation and decision-making. Collaborative monitoring programmes are likely the only way to create the necessary information that allows us to determine trends and changes in vital water processes. The sticking points are quality control, timeliness and consistent long-term observations. This can be resolved by supporting community groups to be partners in monitoring and data generating. A good example of a successful initiative is the invertebrate monitoring programme by Environment Canada (Cabin Approach) where community groups were trained to do an annual survey in late summer, collect and classify the organisms and incorporate the data into the national database. The collected specimens are then submitted to the experts within the government institution to maintain quality control. Some of these community-government collaborations have been supported in climate and water quality monitoring and with the advances in technologies, such approaches are now also possible for hydrometric monitoring. To speed up these types of collaborations requires new enabling policies. Similarly, efforts to rehabilitate streams and enhance buffer zones would greatly benefit if policies would be in place to promote these types of collaborations. Such efforts would greatly enhance transparency and make data readily available to the public.

While the top-down decision-making process is more efficient, it often fails to address local concerns. What is needed is a hybrid system that requires a more flexible approach of governance that promotes more joint decision-making and supports management actions at the local level. There is an urgent need to decentralize many activities because this can increase innovations, improve efficiency and will make watersheds more resilient in case of unusual climatic events.

5.7 Streamlining the IWRM approach

The IWRM approach would work much better if government agencies would be more flexible and consider improved inter-institutional mechanisms to facilitate more decentralization. Rather than trying to address all the issues and interactions in a multi-stakeholder process, why not follow a stepwise approach that deals first with the key issues and activities that have the greatest impacts and identify those that are relatively easy to resolve. This involves fewer stakeholders but requires government agencies to be willing to download some of the responsibilities to local authorities and stakeholders and provide economic incentives so that they can accomplish the tasks of improving water management.

A good start is the focus on the "Water-Energy-Food Security Nexus" proposed by SEI (2011). The focus is on the inter-relationships between these three key resources and this is critical because more than 3 billion people will move into major cities (centralization) over the next 35 years, putting enormous pressure on water, energy and food resources. Can we develop new institutional mechanisms and policies that show how stakeholders work together in a pro-active way to reduce the demand for, and the impact on water using a nexus approach (Kurian and Ardakanian, 2013; Kurian and McCarney, 2010)? These are major governance and policy challenges because at the scientific level such interactions are already taking place. However, what is missing is to improve the link between science and policies and the willingness of policymakers to consider scientific findings as a basis for decision-making. This is a particular challenge in Canada where increased economic growth and international trade of resources is the main policy driver.

Since every watershed is different we will never be able to arrive at a standardized method but we can expedite the process by improved cooperation between different government agencies and those responsible for the impacts. This of course requires selective restructuring of government agencies, innovative policies and a long-term financial commitment.

5.8 A role for data visualization

Communicating science to policymakers and the public is a major challenge and the academic community has not done a very good job in translating science in a way that the public understands. The best example is the public controversy over climate change. A much greater effort is needed to show the public the advantages and difficulties of managing water, based on our understanding

of current scientific knowledge. Data needs to be transparent and readily available and in a form that takes advantage of the digital tools that are used in other professions. Making the information available in a digital and interactive map format is one of the first steps and knowledge translation can be further enhanced by using video and scenario development tools that show decision makers different options and trade-offs.

6. Conclusions

What is needed is a willingness by all stakeholders and the public to accept that managing water is one of the most complex challenges and there are no simple solutions to address all the water problems in an integrated manner. Using the watershed as a basic unit is clearly the only sensible approach to make the link between science, management and policies. It does not address all the problems but it goes a long way in being able to examine the interactions between human activities and the environment. However, going beyond the micro and meso-scale is unrealistic, because at the river basin scale, the social, policy, international and global issues and perceptions are too complex and only specific water issues can be addressed in an expedited manner at that scale.

A major change is needed in the governance structure and it is not proposed to restructure all the many government agencies responsible for managing water, but to facilitate cooperation within watersheds. There is no standardized method or recipe that can be applied to all watersheds because the conditions and issues differ from watershed to watershed. However, a concerted effort is needed to form new organizations such as watershed councils that can bridge the gap between top-down and bottom-up decision-making. This requires a more flexible approach to governance and a rearrangement of financial incentives that not only cover the assessment of water problems, but also cover monitoring of management that is put in place in order to show how the system responds. The adaptive management approach also needs to be supported financially, because our knowledge on how complex systems interact is always incomplete and needs continuous updating and modifications.

It is essential that we simplify the IWRM process by not trying to address all the water problems and interconnections at the same time but by prioritizing the issues. Focusing on key interactions between water, energy and food security is of key importance because global changes such as urbanization, demographic and climate change are likely to intensive the demand for food and energy production that require the most amount of water and these activities also have the greatest environmental impact.

It is important to point out in this context that adapting to the effects of global changes are more likely to be successful when attention is paid to environmental sustainability and impacts on poverty. Attention to issues of environmental sustainability and poverty reduction are likely to be aided by a nexus approach that focusses on management of environmental resources such as water, soil and waste that lie at the heart of discussions on water, food and energy in the context of global changes currently underway.

To improve IWRM is more of a governance and policy challenge because scientists are making progress working in trans-disciplinary projects and can easily be persuaded to work on assessments of the effectiveness of water management initiatives, provided economic incentives are in place. A major effort is needed to improve communication between science and governance and to make use of the new digital mapping and graphic tools to make data transparent and communicate scientific findings to the public in a more effective way.

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