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Data and Information for Integrated Water Resources Management (IWRM): Needs and Challenges

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Abstract: Perspectives on data and information sharing and management are varied amongst individuals, organizations and countries. It refers to different needs and challenges among them to collect and keep the data in sustainable ways and practices. The big challenges related to data and information in Integrated Water Resources Management (IWRM) is to acquire and compile data and information in a timely manner. These need to be discussed in order to better understand the needs of data and information to be packaged in the appropriate way for various stakeholders i.e. government, private sector, NGO, academia, public, etc. in order to overcome barriers in data and information sharing exercise. Challenges in differences of software and hardware matters of data and information management are also important to be discussed and streamlined in order to facilitate the implementation of IWRM in our countries and regions. Collaboration among agencies and all related stakeholders is very much needed to realize this aspiration. Collaborative Decision Making (CDM) is seen to be a suitable mechanism for data and information sharing and exchange among agencies, where data and information need to be obtained through consensus and consultation mechanism. CDM needs involvement of relevant stakeholders to work together as partners and make decisions collaboratively in aspects related to various issues in water resources management. CDM will also ensure a more informed and holistic decision-making in water resources management.

Key words: Data, information, challenges, information system, collaboration, decision making.

Introduction

Management of water resources is a sharing of responsibility among stakeholders that need involvement and participation from all related stakeholders, which is not only managed by government agencies alone but also needs involvement from private sectors, water users, universities, communities and Non Governmental Organizations (NGOs). If there were problems occurred including problems that are related to data and information availability, all related stakeholders should play their roles and take initiatives to solve the problems together. This is a big challenge because to make parties collaborate with each other and to share data and information is in reality very difficult.

Integrated Water Resources Management (IWRM) is a systematic process involving various disciplines of knowledge and levels of multi stakeholders. It is a process that promotes the coordinated development and management of water, land and related resources to maximize resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems, in line with Agenda 21 and concept of Sustainable Development, also in fulfilling the Millennium Development Goals (e.g. Decade of Education for Sustainable Development, UNESCO 2005-2014).

Issues on water resources management cannot be managed properly if there is not enough data and information on those issues. There is a need to provide data and information to facilitate decision making processes that are related to water resources management. The main action for water resources management includes the monitoring programmes and water resources planning and development.

Data and Information

In the exact sciences there is a clear distinction between data and information, where data is a measurement that can be disorganized and when the data becomes organized it becomes information. Data can be about reality, or fiction such as a fictional movie. Data is about numbers, characters, images or other outputs from devices to convert physical quantities into symbols, in a very broad sense. Such data are typically further processed by a human or inputted into a computer, stored and processed there, or transmitted (output) to another human or computer. Information is a description about data. The terms information and knowledge are frequently used for overlapping concepts and in interdisciplinary research a few independent specializations of these terms have been proposed.

The Need for Data and Information

One of the vital information required for good environmental management is the know-how of the latest development of environment related technology. Information and data related to environment including on water resources had been available for many decades, and some had been developed as a well established database which could be easily accessible. However the existing information system on environment in Malaysia focus on physical, biological, ecosystem, human health, social and economy data, including data on water quality and air quality of selected locations in Malaysia and some forms of wastes.

Integrated information system is very much needed and critical in water resources management and towards IWRM. There is lack of information system which could deliver data and information on water resources management issues and status, cause difficulties to identify and determine the best and appropriate methodology towards IWRM, and influence water resources management process in the country, policy and decision maker, scientist and wider community.

Systematic data and information need to be developed based on data received from various agencies. Such data and information perhaps is not suitable for some agencies, e.g. data that need correction or adjustment, conversion, digitizing, audition and competition. The problem related to data that is not suitable for direct use by agencies is usually the difference of format of the data and measurement unit or data standards, where agencies have to do further work to convert the data based on needs and purposes.

Sometimes the data and information received is not as requested, not completed, not up-dated, not consistent, and not as specified. Other issues that are also important are timelines in providing data by various agencies, as well as data interpretation.

Good decision making needs data and information. There is a need to package data properly for decision making at various levels (international, regional, national, and local). Decision-making involves framing the issues, gathering information, drawing conclusions, and learning from feedback. Collaborative decision-making enables each of these steps, where the best thinking comes from the collective intelligence of the group as long as there is an underlying process and the process is apparent to all. Done well, participative decision-making is more likely to translate to successful action than top-down processes because it naturally develops commitment and alignment.

Types of Data and Information

Data is a basic unit of information. There are three types of data and information, i.e. primary, secondary and tertiary data. Primary data is obtained from site sampling and also through survey and interview. Secondary data is obtained from such agencies/institutions in the form of raw data that still need to be elaborated before they can easily be used or analyzed e.g. minutes of the meeting, list of committee member or projects number, etc. Tertiary data is normally obtained from library material such as books, journals, thesis, articles, brochures, annual reports, research reports and newspapers.

All data have their Meta data. The simplest definition of metadata is data about data, or more specifically information (data) about a particular content (data). Metadata is used to facilitate the understanding, use and management of data (Halsall, 1997). Secondary data were usually produced from the analysis of the primary data. Usually data will be analyzed directly from primary data. Most of the time, secondary and primary data could be interpreted to produce new theories and describe information findings.

Data and Information Challenges

Normally agencies or institutions work alone and have their own goals, perspectives and interests. Data should not be kept trapped in the documents only. There should be initiatives from agencies to extract the data to make it useable. There is also a challenge to use the data and information at many levels (international, regional, national, local and ground), where different people or

agency may need different kinds of data and information (e.g. data on water quality, water quantity, water demand, hydraulic and hydrology).

Availability of Data and Information

Data availability not only refers to the existence of data in the organization but also to the way of organizing data to be user friendly for various groups of users. Accessibility to data and information that are related to water resources management in the country must be packaged appropriately to easily know where to get the data and how to get them.

Everybody needs data and information in specific format, but that kind of data and information is apparently not available. It is difficult to choose the suitable data for each agency. It is also difficult to find the suitable agency that collect and keep the data. It is even more challenging to get data in suitable time and form. Therefore a team is needed (e.g. information technology officer) that understands the need of IWRM to locate the "trapped" data and extract the data to be useful for agencies and the public. At Local Level, such as Local Authority (LAs) and Land Offices, they also should have their own information technology officer.

Data Confidentiality among Institutions

In term of data and information confidentiality, there are some data and information that are considered confidential by some agencies/institutions or companies, such as information on land ownership, data on water quality or water supply if they are owned by such agencies. It happens because some agencies are not allowed to show their data to public or give their data to other parties without permission from the owner of that data (agencies who sponsored or paid for the collection of the data), normally for data that are owned by two or more parties (co-ownership) through partnership or joint effort. However, agencies still can request for that kind of data with permission from the owner of the data; otherwise the owner can decide to disclose information considered confidential and keep the data and information confidential if agencies that need the data cannot justify their purposes to get the data. There are also some data and information that can be made accessible to the public.

Quality of Data and Information

Data quality can be defined as the state of completeness, validity, consistency, timeliness, and accuracy that makes data appropriate for a specific use (Wikimedia Foundation Institute, 2007). Data quality is multidimensional and includes many factors beyond accuracy, such as resolution and precision, data completeness, data timeliness (currency), data synchronization, relevance, and appropriate data context. Data quality refers to the degree of excellence exhibited by the data in relation to the portrayal of the actual phenomena. The state of completeness, validity, consistency, timeliness and accuracy makes data appropriate for a specific use.

Ownership/Custodianship of Data and Information

The concept of ownership is often employed to find someone who will be responsible for the quality of the data (Scofield, 1998). "The owners" of the data must be responsible for its quality. This is often heard when information technology people wish to absolve themselves of responsibility for something, like data quality, for instance. In order to succeed in a data ownership role, there are some critical success factors including performance measures that must be simple to measure, easy to understand and relate cause and effect to enable the improvement of data quality.

Ownership or Custodianship of data and information influences procedure or mechanism to get the data from other agencies. Some agencies need permission or agreement letters from the owner of the data before giving their data to others, some are perhaps free to obtain and some have to be obtained with some cost.

When establishing data ownership, we need to understand the process of establishing data ownership as well as the critical success factors of establishing data ownership. Pieterse (2005) explains the steps that need to be taken to establish data ownership in practice:

- Data owners should be informed by name of their responsibilities
- Work on the requirements of the data ownership role with data owners and determine if data responsibilities must be delegated
- Update job descriptions with data responsibilities
- Work on the data measurement metrics
- Access the current data maturity level per data owner
- Set data ownership objectives
- Set a time line for implementation of data ownership objectives.

Data Acquisition, Storage, Retrieval and Dissemination

Data acquisition (DAQ) is the process of automating data collection from analog and digital measurement sources such as sensors (Gale, 2007). Data acquisition uses a combination of PC-based measurement hardware and software to provide a flexible, user-defined measurement system. The measurement system has to meet a standard

criteria ensuring data accuracy. Limited storage for keeping data is one of the common issues faced by organizations. There is a need to establish an integrated information system as accessible information system with a role of data collection, storage, retrieval and dissemination about issues that are related to environment and water resources management. The needs of more storage in the hi-end hardware will increase the cost as well as maintenance. Otherwise data cannot be organized properly and cannot be retrieved. This problem will interrupt the dissemination of data information.

Data Sustainability

Data sustainability needs information sharing and exchange among agencies continuously and systematically. There are some kind of data and information sharing and exchange among agencies that are related to water resources management, but there is also some constraints in data and information sharing, that is, there is no specific mechanism to facilitate the data and information sharing among agencies. Data and information sharing and exchange among agencies can be done in forms of hard copy or soft copy, reviewing, suggestions and comments. Unfortunately, there are agencies that give their data to other agencies and also agencies that only receive data from other agencies if they do not have any data on water related issues to be shared among other agencies (Elfithri, 2006).

Trans-boundary Issuess

The success of information system development involving multi-organizations, depends heavily on effective knowledge sharing across boundaries. Attention to inter-organizational information systems has grown substantially in both theoretical and practical terms in recent years. Factors of globalization, rapid technology change, government reforms and the demands of knowledge work have created pressures for organizations to improve information sharing and integration capabilities across organizations (Pardo et al., 2006). Information system is a very important element that facilitates data integration and management in all scope of area. Environmental management needs information technology. Data integration in term of information sharing by having collaborative working groups is very important to let data and information cross the boundaries. But it is not as simple as that. It involves policies, protocol and a lot of factors.

There are several successful collaboration initiatives that had been made on information sharing and exchange in environmental issues such as the Asia Pacific Economy Cooperation (APEC) Virtual Center (VC) programme based in Osaka, Japan. The collaboration is focussed on information sharing about environmental technologies, including water related technology. As a regional partnership, APEC-VC provides information in order to support business on advanced environmental technologies and enhance the feasibility in environmental investment (APEC-VC Japan, 2007). APEC-VC for Malaysia is currently hosted by LESTARI, UKM and was re-established on December 2006 with the aspiration to be a Malaysian focal point on Environmental Technology Exchange. It is an information system using a web-based approach. The status is now in the phase of continuing information collection and conducting surveys among the multi stakeholders in Malaysia (Mokhtar and Faizul, 2007).

Development of Information System

The role of information system in managing environmental issues such as water related problems is vital. Previous study has shown that information system plays an important role in policy and decision making processes, monitoring and enforcement as well as developing cutting edge knowledge. There are many research initiatives conducted under fund from Ministry of Science, Technology and Innovation (MOSTI) of Malaysia on Geographic Information System (GIS) for management on natural resources and to help in decision making for social and economic requirements related to environmental management (MOSTI, 2007).

Development of information system for IWRM should be prioritized on developing a database on technology, which is to be used or produced in Malaysia. Such technology could be tangible products, water quantity and quality methods, standards, guidelines, procedures, systems or programmes for water resources management with emphasis on avoiding or minimizing impact on water resources.

Feasibility Study

Feasibility study is very important to build information. Feasibility is all about exploring what we need including the type of data as well as information system specification. Usually, it involves data sampling at the site to get real time data using certain methodologies. Survey via questionnaire can be conducted to obtain fresh input. Some existing good example of this is the Malaysian Quality of Life Index (MQLI) Report by EPU (2004) that includes information on income and distribution, working life, transport and communications,

health, education, housing, environment (including water quality index), family life, social participation, public safety, culture and leisure.

The MQLI in Malaysia improved during the period 1990-2002 as reflected by the upward movement of the MQLI until 2004. All components of the MQLI recorded improvements in the number of participating agencies with the exception of public safety and environment. Water is monitored using the Water Quality Index (WQI), which appraises water quality on six parameters, namely, biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen, suspended solids, pH value and dissolved oxygen. The main sources of river water pollution were from the discharge of domestic sewage, manufacturing, pig farming, agricultural production and land clearing and earthworks (EPU, 2004).

Department of Environment (DOE) Malaysia issued the annual report that contains State of Environment Report including water quality monitoring, air and noise quality monitoring, schedule waste monitoring, etc. (DOE, 2005). In 1996, there were 909 river monitoring stations in Malaysia. From the data collected, based on the National Water Quality Index (Indeks Kualiti Air Negara – IKAN), 42 rivers were classified as clean, 61 as slightly polluted and 13 rivers remained polluted. However, the overall river quality was generally on a deteriorating trend. The major cause was silt due to soil erosion and organic pollutant from partially treated sewage and animal wastes. On the other hand, the marine environment quality in 1996 had improved compared to 1995. As in previous years, the main contaminants of the coastal waters in all States were oil and grease, total suspended solids (TSS).

Data Analysis

Data analysis is the act of transforming data with the aim of extracting useful information obtained from feasibilities studies. Depending on the type of data and the question, this might include application of statistical methods, curve fitting, selecting or discarding certain subsets based on specific criteria, or other techniques. In contrast to data mining, data analysis is usually more narrowly intended as not aiming to the discovery of unforeseen patterns hidden in the data, but to the verification or disproval of an existing model, or to the extraction of parameters necessary to adapt a theoretical model to reality.

Framework

Data analysis is a very important part to ensure the accuracy of the framework. The framework produced must involve the data structure and also data flow process to make the input and output of the information system clear. This is important to make sure all components needed are inside the framework before the development of the information system (technically) starts. Figure 1 shows the framework for data and information development.

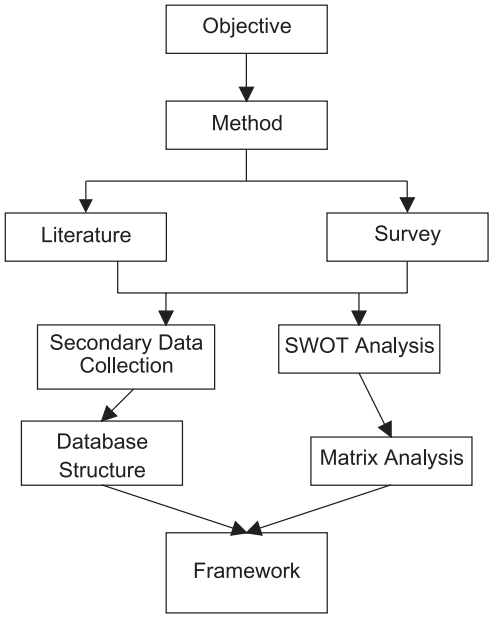

Figure 1: Framework for data and information development.

Integrating Data and Information

Many challenges remain in monitoring water quality and taking steps to improve water quality. To better address water quality problem in the future, more and better water quality data and information on the condition of waters and watersheds will be needed. This will require a greater collaboration among the federal agencies that participate in monitoring and managing water resources so that results can be provided in a common format (US EPA, 2003). Data in a common format will be more much useful for developing or improving indicators and can also more easily be made available to public. In addition, the relevant federal agencies should work with the states to design and implement cost-efficient water quality monitoring programmes whose data will be useful not only to the state water quality programme, but also to water quality characterisations.

State resources often are limited for such key activities as characterising waters, identifying sources of watershed stress, and monitoring the effect of implementing of pollution control. Therefore it is critical to encourage the

development, dissemination, and use of cost-effective monitoring and assessment tools, such as biological methods for water quality assessment and a new framework for design and data collection in water quality monitoring programmes.

The data on water related issues will be used to prioritize those issues in which further risk assessment needs to be carried out. It is probable that the data on water and all of the non-confidential data and information in the database will be made publicly available. There is the need to establish the integrated information system. Integrating data and information need collaboration among agencies to collect the data and to be shared among each other. Toward this, integration, involvement and participation from all related stakeholders in the planning and decision making processes is very much needed.

Collaboration through CDM

The best way to do collaboration among agencies is through consensus and consultation that will bring agencies towards Collaborative Decision Making (CDM). Agencies have to believe in this CDM concept, agree and accept it. CDM is needed to choose relevant data that is needed by relevant agencies or stakeholders. This mechanism is needed to collaborate among each other including sharing and exchanging of knowledge, experiences, data and information.

The participation and involvement of related stakeholders in water resources management, including the relevant federal and state agencies, private sectors, Non Governmental Organisations (NGOs), universities, public and local authorities are needed to incorporate their data and information into decision making process in the CDM mechanism (Mokhtar and Elfithri, 2005).

CDM is needed in order to improve the existing water management system, where the agencies and other related bodies have to sit together to discuss about the settlement of the issues together. CDM is a suitable and appropriate way within framework of IWRM and IRBM where CDM is needed as enabling environment towards IWRM. Mechanism of CDM allows and provides institutional frameworks; at the same time CDM can also become a tool for management instruments (Figure 2).

Definition of Collaborative Decision Making (CDM) is a joint effort among government agencies, private sectors, NGOs, the public, universities and other relevant stakeholders aimed at improving the present management system through increased information exchange among the various parties in the community and improved decision support tools (Elfithri et al., 2002, 2004; Mokhtar et al., 2004a). CDM offers an opportunity for more proactive and collaborative approaches to resolving environmental problems and it can be used in water resources management related issues. In turn, this will require the participation and involvement from stakeholders within a larger context of shared understanding. Particular attention is paid to the issues that emerge as a result of multiple stakeholder involvement within environmental problem situations.

The general objectives of CDM are to develop and implement procedures and technology that will continue to sustain collaborative management with consideration to the problem statement and to develop procedures and

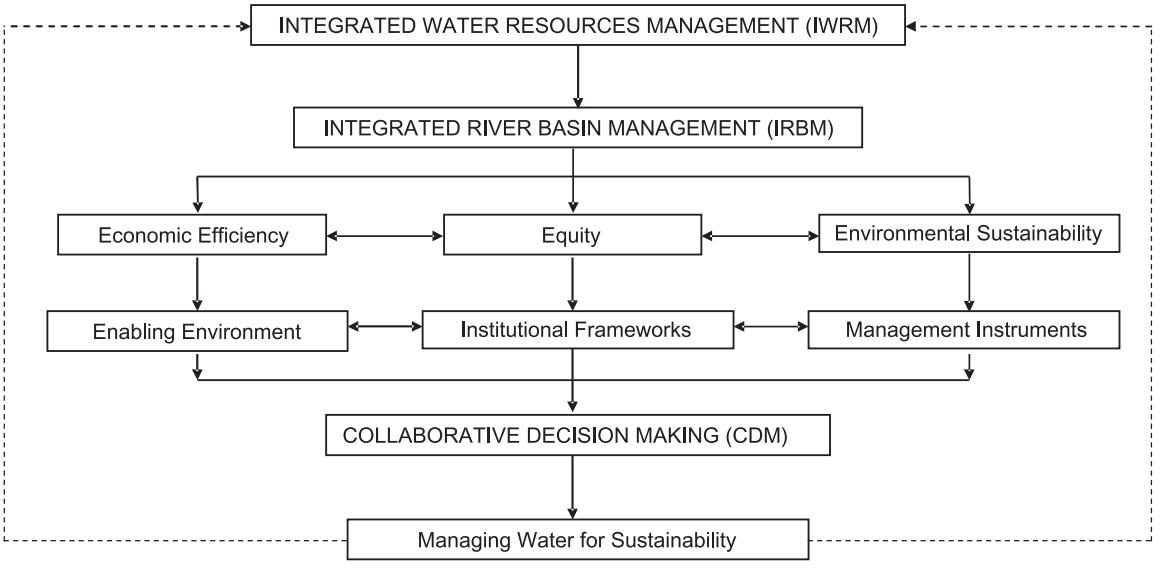

Figure 2: Framework of IWRM and IRBM that showed the importance of CDM (Source: Elfithri 2006).

technology that will be needed to integrate into the water resources management (CDR Associated, 2002).

Definition of CDM in terms of data and information sharing and exchange is a collaboration process in decision making in a way forward to generate an integrated information system among multi stakeholders to be easily used and obtained by relevant stakeholders, through data and information sharing and exchange. The importance of CDM in term of data and information sharing is to identify the collaboration level among stakeholders that are related to water resources management and identify the need of CDM among agencies. Without collaboration among agencies through CDM, the status of availability of data and information is only based on estimation from backgrounds or types of such agency, that specific agencies will have specific kind of data and information.

Effective CDM requires stakeholders associated with environmental problems to develop solutions co-operatively as opposed to acting as advocates purely in their own interest. Participation in decision making encourages stakeholders to buy into outcomes and see them implemented. Since good decision making depends on the availability of sound supporting information, the need for carefully managed participation applies equally to gathering information and developing the systems for managing it as it does to the decision making itself (Allen and Kilvington, 1999). However, the involvement of people in this way is all too often neglected, especially within information technology enabled projects.

CDM provides individuals and organizations the opportunities to better listen, to develop a more honest approach, and to demonstrate follow-through or modify commitments. In doing so, trust is developed, and individuals and organizations more easily work together to develop new approaches or creative ideas. CDM provides a forum for discussion that permits diverse points of view to be aired which leads to issues being defined in terms of joint problem solving (Bauer and Randolph, 1998). Achieving trust among participants with diverse interests occurs when the parties are capable of looking beyond their positions. An open dialogue can demonstrate that opposing parties may actually share interests, values and concerns. Thus, collaborative processes can lead to a shared vision of the future, resolve conflicts, and result in creative solutions.

CDM will lead the agencies and communities to better prepare and manage information required for making decisions about sustainable resource use, predictability over the outcomes, and better solutions by bringing a diversity of knowledge and expertise. Given the complexity and different social perceptions surrounding many resource management issues, the challenge facing science is to develop understanding, knowledge, forum and learning environment to better inform and support more sustainable decision-making processes. Not only will the CDM efforts improve efficiency in water resources management, it will also promote better allocation of resources.

CDM is important to combine the idea, data and information from all agencies within the local context. By knowing the status or availability of the data, we can better plan and better prepare the management of water resources to reduce unwelcome surprises related to water resources management. With the collaboration among agencies, the CDM will build involvement of agencies into commitment to making decision or collaborate together.

Future Challenges

Broad public participation in decision making processes is one of the fundamental conditions in water resources management. This presupposes access to information on environmental issues, and access to participation in the decision making process. For this reason it is important to develop indicators for measuring involvement and people's opportunities to take part in societal decision making processes and also to measure performance.

To suggest these indicators, one needs to have information about the status of water and other related resources. The development of indicators is an ongoing challenge, and will need inputs and agreement from various stakeholders. There are many challenges to the development and implementation of indicators, where identifying the issue is important. The definition and application of indicators must be clear, transparent and easily understood (Mokhtar et al., 2004b).

There is a need to develop suitable indicators for such data and information including the availability of the existing data, quality of the data and usefulness of the data. Data and information should be shared among agencies, therefore we need to know the percentage of data in a common database or information system that is being used by various agencies. Currently such information is not available and the quality of the data is unknown. Usefulness of this data is to indicate the extent of data and information sharing among agencies.

Methodology and quality of data among agencies have to be standardized. Therefore percentage of data from other agencies that can be used by a particular agency without any modification has to be obtained. This

information is available from agencies and quality of the data can be verified. The usefulness of the data is to indicate the level of standardized data and methodology among agencies.

Data and information exchange and dissemination should be part and parcel of CDM. Existence of regular mechanisms for exchange and dissemination of information is currently not available and the quality of the data is unknown. Usefulness of the data is to indicate the data exchange and dissemination as part and parcel of CDM.

There is also the need for appropriate and suitable management instrument or tools, such as development of Geographical Information Systems (GIS) Database, Global Positioning System (GPS) Data Conversion, the development of a GIS database to be used by the water quality modelling DSS and other sectors of the study, Water Quality Decision Support Systems (DSS), development of water quality modelling Application System and application of the development of a water quality modelling DSS.

Challenges in Research and Development regarding data and information for IWRM is much challenging where the IWRM study and development of IWRM Tool Box are still in progress (some countries had but need to be further improved and scrutinized). Properly planned research on IWRM and its appropriate application play an important role in the resolution of water problems, and while the diversity of circumstances within the regions calls for specific programmes in most countries, there is also scope for the co-ordination of efforts. There is a need to review and evaluate the work carried out so far and to outline areas in which further research should be undertaken. IWRM studies and projects generate and provide a lot of data and information related to water resources management. Data and information resulted from these research projects should be shared and disseminated in a proper way to make it useful for others. GWP IWRM ToolBox is already accepted and utilized internationally. Country IWRM ToolBox should be more enhanced, widely used and acknowledged, and contain much more data and information.

Conclusions

River and water resources need to be managed in an integrated and holistic manner to safeguard the water resources, land and the other physical and biological resources, for now and the future. Initiatives between agencies to cooperate and collaborate are needed, where data and information sharing and exchanging can be enhanced. It is hoped that the initiatives towards practical implementation of IWRM in countries and regions will result in a variety of approaches for effective water resources management. The CDM efforts among agencies and other relevant stakeholders that are related to water resources management are pertinent to be applied at various scales. This calls for better coordination and cooperation among related agencies involved in water resources and environmental management.

This would include an evaluation component so that necessary adjustments can be made as the process progresses and to improve subsequent efforts. Any evaluation should be based on what have been identified as the goals and objectives of CDM including in data and information sharing. Care must be taken in choosing the variables and indicators by which the CDM will measure success so that the selection does not undermine the intent of the collaborative effort.

Parties that are related to water resources management in this region should establish or strengthen mechanisms for consultations/dialogues and sharing of data and information among them in a way to achieve the IWRM goals. This collaborative effort will undoubtedly assist in the effective implementation of IWRM.

If the concepts of CDM for IWRM are applied in river basins then hopefully this will help resolve some problems that are related to water resources management, including in data and information sharing.

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