The Information Strategy Model

a framework for developing a monitoring strategy for national policy making and SDG6 reporting

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VIEWPOINT

The Information Strategy Model: a framework for developing a monitoring strategy for national policy making and SDG6 reporting

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ABSTRACT

Representatives from 14 countries worldwide worked together on improving their monitoring and ultimately their water management to reach the Sustainable Development Goal (SDG) 6 goals by 2030, thereby testing the Information Strategy Model (ISM). This model is developed to support identifying the need for information for water management. In a workshop setting, participants were instructed and subsequently developed the ISM for their own situation. The results show that the ISM fulfils its task of structuring the development and improvement of a monitoring network, but can be enhanced by adding detailed information for specific elements and needs explanation and assistance to be of use.

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Sustainable Development Goal 6; national water monitoring and assessment; Information Strategy Model; sustainable water management; information needs

Introduction

In its 2030 Agenda, the United Nations General Assembly (UNGA) set out to:

> end poverty and hunger [. . .] protect the planet from degradation [. . .] ensure that all human beings can enjoy prosperous and fulfilling lives [. . .] in harmony with nature [. . .] foster peaceful, just and inclusive societies which are free from fear and violence. (UNGA, 2015)

To achieve this, following up on the Millennium Development Goals, a framework of 17 Sustainable Development Goals (SDGs) has been set up, for the period 2015–30. These goals are accompanied by 169 global targets, relating to development outcomes and means of implementation. Agenda 2030 recognizes that social and economic development depends on the sustainable management of our planet's natural resources. The increased attention on water in the global political agenda, more specifically water scarcity and water pollution as well as safe drinking water and sanitation, are reflected in SDG 6's mission statement: 'Ensure availability and sustainable management of water and sanitation for all.'

Global key success indicators have been defined to track progress towards the SDGs at the global level, and countries are requested to report on the national situation using the indicators. SDG indicators are defined 'to be as useful as possible for as many countries as

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possible'. However, they are not exhaustive and other indicators for national policy- and decision-making processes are important to consider, therefore countries should not focus solely on the SDG indicators (UN-Water, 2017a).

From the data as collected in 2017 on the SDG 6 indicators, UN-Water concluded that there is a lack of information in many countries and expressed the need to localize and adapt the global SDG 6 targets to the country context (UN-Water, 2018): 'National governments must decide how to incorporate SDG 6 targets into national planning processes, policies and strategies, and set their own targets, taking into account local circumstances.' Further to this, 'effective water resources management needs more and better data' and 'less than half of Member States have comparable data available on progress made towards SDG 6 targets' (UN-Water, 2018, p. 23). The report also concludes that 'Sustainable management of water and sanitation underpins wider efforts to end poverty, advance sustainable development and sustain peace and stability', and that achieving SDG 6 is essential for progress on all other SDGs, and vice versa (p. 23). Additionally, from the Global Workshop for Integrated Monitoring of SDG 6 on Water and Sanitation held on 21–23 November 2017 in The Hague, the Netherlands, there was, among others, a call to 'assist countries in developing and operating national information systems' as well as support to improve monitoring methodologies and data collection procedures (p. 26).

In many countries, large amounts of data are collected by water management organizations to support the evaluation and development of water management and water policy. The data collection is often criticized by policymakers for not being useful. This is called the 'data-rich-but-information-poor' syndrome: a situation in which data are collected without a clear view of what information is to be produced out of them. It generally follows from a situation where information expectations are insufficiently evaluated, while, on the other hand, the expectations of information users may be higher than the monitoring system is capable of providing (Timmerman et al., 2010c; Ward et al., 1986). In many other countries, the availability of data is inadequate to support water management, especially when it comes to water quality data (UN-Water, 2016). In both situations, there is a need for careful consideration of the information needed to ensure that useful information is collected at the least cost.

With this in mind, the Dutch Ministry of Infrastructure and Water Management set out to support countries to improve their national monitoring and the collection of data and information at the national level. The goal was to enable countries to improve their water management and ultimately reach the SDG 6 goals by 2030, focusing on SDG 6.3 for water quality and SDG 6.4 for water-use efficiency, meanwhile keeping in mind that design of a monitoring network asks for a structured approach (Behmel et al., 2016; Strobl & Robillard, 2008; Timmerman et al., 2000).

To support a structured approach, the authors built a framework. This started by looking at the experiences from a pilot programme that was initiated in 1997 to test the *Guidelines on Monitoring and Assessment of Transboundary Rivers* (Adriaanse et al., 1997), a document developed under the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE, 1992). The guidelines describe the respective steps in designing and executing monitoring networks, and the subsequent data storage, data handling and reporting (Timmerman et al., 1997). The pilot programme led to an improved version of

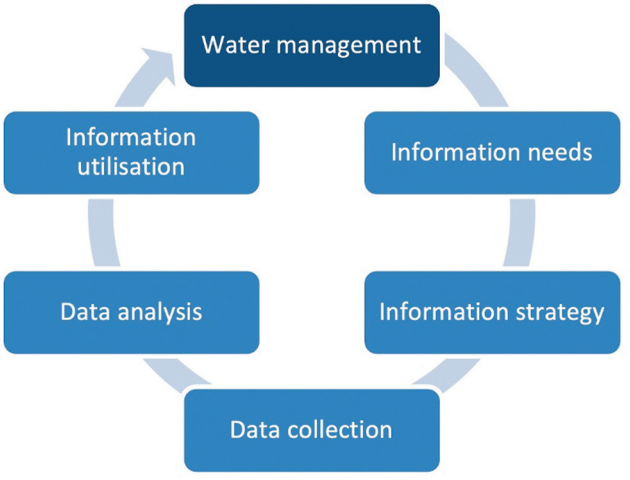

Figure 1. The information cycle.
Source: Timmerman et al. (2000).

the guidelines in 2000 (UNECE-TFMA, 2000) and the *Strategies for Monitoring and Assessment* that were published in 2006 (UNECE, 2006). Both documents build upon the so-called information cycle (Figure 1).

For the purpose of improving national monitoring networks, the need for a more value-based framework was recognized. Such a framework should describe the rationale for why the information is needed. The framework chosen was the Business Model Canvas as developed by Osterwalder and Pigneur (2010) (Figure 2). The Business Model Canvas is a framework that helps to develop the logic of a business and it has been widely tested. The authors considered that this model, in a modified form, could also work for the business of monitoring.

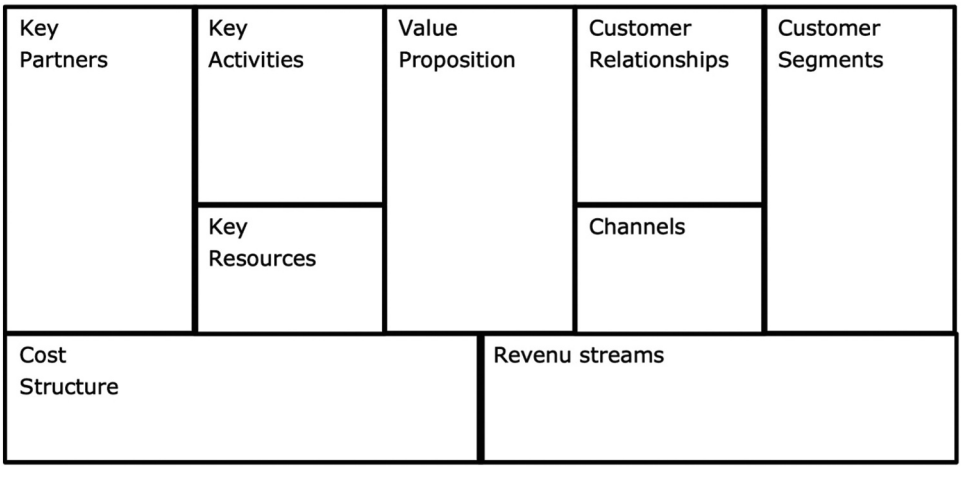

Figure 2. Business Model Canvas.
Source: Osterwalder and Pigneur (2010).

A new framework was created by integrating the information cycle and the Business Model Canvas, accounting for SDG 6 and related water monitoring. The new framework is called the Information Strategy Model (ISM). The ISM was tested during a workshop in May 2019 in Delft, the Netherlands, with representatives of 14 countries worldwide: Chile, Colombia, Egypt, Ethiopia, Indonesia, Jordan, Kenya, Myanmar, the Netherlands, Peru, Poland, Tajikistan, Uganda and Vietnam. During this workshop the country representatives were challenged to take a first step in developing a value-based monitoring system using the ISM. The information cycle and the Business Model Canvas will be shortly described as well as the targets and indicators under SDG 6.3 and 6.4.

The information cycle

The information cycle is a process model describing the sequential steps in the development and implementation of an information system (Figure 1). The context for the information system is the water management process; information is required to support decision-making and the output from the information system feeds into this decision-making. Going from information required to information obtained, the following steps are distinguished (Timmerman et al., 2000):

- Information users in cooperation with information producers decide upon the characteristics of the information needed (information needs).
- Information producers decide upon the best way (i.e., strategy) to collect information.
- The data are subsequently collected.
- The collected data are analysed and the results interpreted relative to the information needs.
- The resulting information is presented and transferred to the water management process where it is utilized.

The Business Model Canvas

The Business Model Canvas shows the logic of how a company intends to make money, described through nine basic building blocks (Osterwalder & Pigneur, 2010):

- Customer Segments: defines the different groups of people or organizations an enterprise aims to reach and serve.
- Value Propositions: describes the bundle of products and services that create value for a specific Customer Segment.
- Channels: describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition.
- Customer Relationships: describes the types of relationships a company establishes with specific Customer Segments.
- Revenue Streams: represents the cash a company generates from each Customer Segment.
- Key Resources: describes the most important assets required to make a business model work.

- Key Activities: describes the most important things a company must do to make its business model work.
- Key Partnerships: describes the network of suppliers and partners that make the business model work.
- Cost Structure: describes all costs incurred to operate a business model.

Figure 2 shows the nine building blocks within the overall framework. By filling in all the blocks, the business model of a company becomes clear and can be improved. There is no order in the different blocks: the model gives an overview and shows the linkages between the blocks.

SDG 6

The goal of SDG 6 is to ensure the availability and sustainable management of water and sanitation for all by 2030. The target of SDG 6.3 is to improve water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally by 2030. For this target, two indicators are developed:

- Proportion of wastewater safely treated: defined as the percentage of wastewater generated by households and economic activities that is safely treated.
- Proportion of bodies of water with good ambient water quality: defined as the percentage of water bodies in a country with good ambient water quality.

The target of SDG 6.4 is to substantially increase water-use efficiency across all sectors and to ensure sustainable withdrawals and the supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity by 2030. For this target, the following two indicators are developed:

- Change in water-use efficiency over time: defined as the output from a given economic activity per volume of net water withdrawn by the economic activity.
- Level of water stress: freshwater withdrawal as a proportion of available freshwater resources, defined as the ratio between total freshwater withdrawn by all economic activities and total renewable freshwater resources, after taking into account environmental water requirements.

For more information on SDG 6 and the related indicators, see UN-Water (2017b).

Objectives and method of the study

This study focuses on testing the ISM as a framework to support countries in developing and improving their national monitoring and collection of data and information. The framework was tested by representatives from 14 countries during a workshop setting in

which the ISM was applied for each country. Discussions at the end of the workshop and interviews after the workshop are used to draw conclusions on the applicability of the ISM. This paper describes the ISM and the way it was tested.

The ISM

The ISM (Figure 3) transforms the nine building blocks of the Business Model Canvas by implementing the insights from the information cycle to these building blocks. In this section, we will describe the respective building blocks including the ideas behind those blocks. The first seven blocks focus on designing the information strategy; the last two focus on how to implement that strategy. The block 'Problem definition' should be filled first, as the other blocks are related to it. The numbers show a logical order to fill in the block, but apart from block 1, this is not necessary. And it is recommended to reiterate the model after first filling in all blocks.

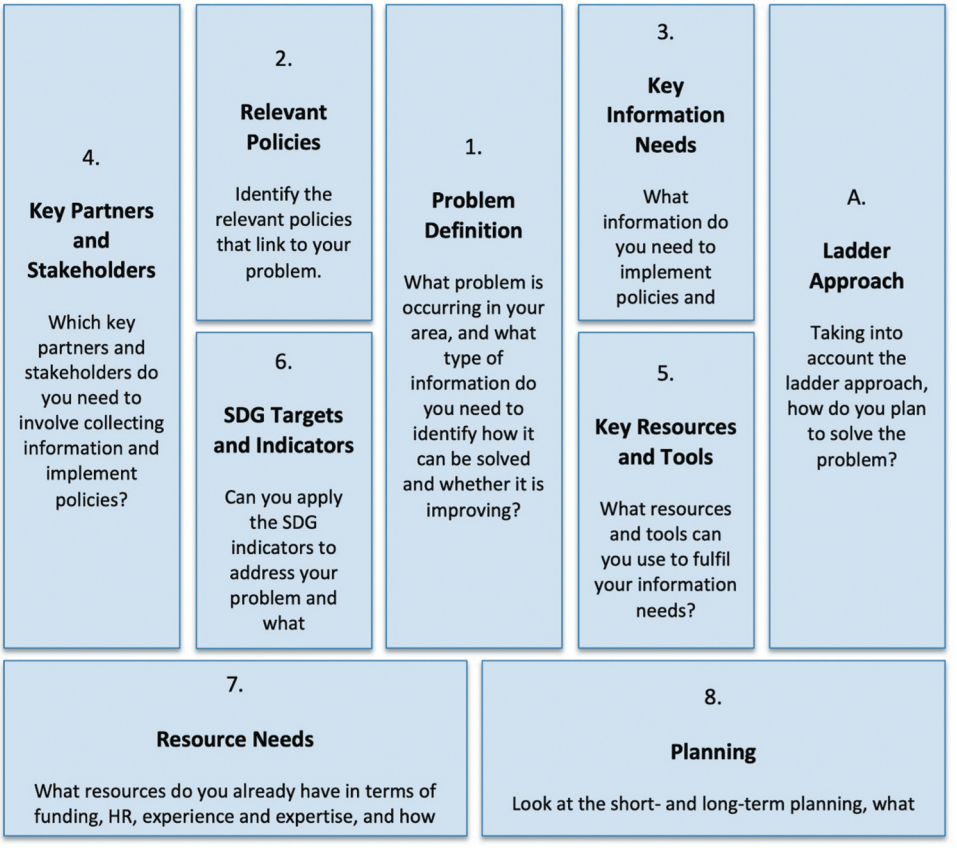

Figure 3. The Information Strategy Model (ISM).

Problem definition

The problem definition is the heart of the ISM. At the basis of the problem definition lie the policies that describe the goals and objectives for water management. Decision-makers in general know the reasoning behind the objectives, and this reasoning needs to be translated into information objectives (Timmerman et al., 2010b). A proper problem definition is therefore imperative. However, water management problems tend to be vague and loosely specified. For instance, the problem as stated may be that there is too little water in summer. The information needed resulting from this problem could be precipitation, evaporation, river discharge, water abstraction volumes, etc. By better specifying the problem, it becomes clearer what information would be needed (Timmerman et al., 2000). For instance, the problem can be rephrased as 'water availability for irrigation is limited in summer'. The problem definition should therefore be specified as precisely as possible to enable the development of a monitoring system.

Relevant policies

Policies lay down the consensus among policymakers on the norms and values attached to a problem situation by describing a series of policy objectives for different themes. The policy objectives together help to reach the overall aim (Timmerman et al., 2010b). The policies include the rules, intent and instruments with which governments manage human uses of water, control water pollution and meet environmental water needs, among others. Policies include the legal and regulatory framework, and the planning and the implementation practices around water management (The CEO Water Mandate, 2010). As such, policies help define what the problem is, and they provide directions for solutions. Identifying the relevant policies consequently also helps in defining the problem.

Moreover, an important flaw in many reports is that, although generally rich in statistical data, they are of limited use in the state-of-water assessment and in the policymaking process. The analytical part of the assessments has to be improved to make the assessments more relevant in the policymaking process (EEA, 2011). To this end, an inventory of the relevant policies is needed.

Key information needs

The purpose of monitoring is to help policy- and decision-makers at all levels of government to identify challenges and opportunities, set priorities for more effective and efficient implementation and communicate progress, or lack thereof (and therefore associated requirements), to ensure accountability and generate political, public and private sector support for further investments (UN-Water, 2017a).

A translation from the problem definition into information needs is consequently needed, entailing deliberation about different values and discovering the reasoning behind the policy objectives (Timmerman et al., 2010a). Different types of information, such as social, economic and ecological information, information about the implementation of measures, and information about the degree to which the policy objectives are reached to enable recognition of change (Timmerman et al., 2011), are

needed for proper water management. General information to be collected includes (Timmerman, 2014):

- Baseline information: this is largely geo-hydrological information on the catchment area (area size, area delineation, hydrological and meteorological information, etc.) and socio-economic information (demographic data, economic activities, land use, etc.). Much of this information is available in most countries, also taking into account open data and remote sensing, although sometimes incomplete and/or outdated.
- Information about the use and problems: this is information about activities that influence the water system (drivers) and the effects of the activities on the water system, and vice versa (pressures). This information is often available, but fragmented and incomplete. Information on the pressures can partly be derived from information about the drivers.
- The status of the water system: this is information about the water quality and quantity and is usually collected through monitoring networks. In many countries, such networks are only partial present or absent and data availability is limited.
- Policy options: this is information about the possible policy options, their implementation and the effects these may have on the water system (responses). The abovementioned information is necessary to determine the effectivity and efficiency of policy options. Decision support systems can be helpful to make projections about the effectivity of measures.

Formulating the specific objectives of the information system is the most important and most difficult step (MacDonald, 1994). And the use of monitoring information in decision-making is often diffuse and indirect (Hermans et al., 2013). Attempts should be made to explicitly provide the link between the policies and problem definition, and the information needs. Preferably, this is done in close collaboration with the key partners and stakeholders (Timmerman et al., 2010c). The Driving force–Pressure–State–Impact–Response (DPSIR) framework largely covers for the abovementioned information elements and is useful to explain the cause–effect relationships and distinguishing between the different aspects of water management issues (Timmerman et al., 2011).

Key partners and stakeholders

Monitoring is also a process of collaborative problem-solving through the generation and use of knowledge, and by corrective action based on shared decision-making involving all stakeholders. It is important that the information coming from the monitoring system supports stakeholder's capacity for analysis and problem-solving, and that it builds commitment to implementing any recommended corrective actions (Hilhorst & Guijt, 2006). Stakeholders include the relevant decision-makers and others responsible for water management, but also the people who are directly or indirectly affected by or otherwise involved in the problem as defined. Mapping of stakeholders and stakeholder networks help to identify the people who need to be involved in developing the information strategy (McNicholl et al., 2017; Schiffer & Hauck, 2010). Identifying the key stakeholders thus relates to the relevant policies and the problem definition.

Monitoring also builds on a range of information sources. The partners that can provide relevant information should therefore also be identified. These include statistical institutes, geographical or geological institutes, environmental protection agencies, hydro-meteorological institutes, research institutes and agencies responsible for monitoring. Depending on the information needs as identified, the relevant partners can be sought.

Key resources and tools

Looking at the information needs, specific resources and tools may be needed. For instance, if areal mapping is needed, remote sensing, an airplane or a drone could be needed. For water quality purposes, sensors and laboratory facilities may be needed. Moreover, analytical tools and resources are needed to process the information coming from the monitoring network. Also, personnel are needed who can operate the various facilities. The level of capacities and expertise of the personnel needs to be specified. And funding is needed to develop and maintain the information system (e.g., Graveline et al., 2010; Harmancioglu et al., 1998; Pellerin et al., 2019; Strobl & Robillard, 2008). This block therefore focuses on inventorying what resources and tools would be needed to fulfil the information needs irrespective of if these are readily available.

SDG targets and indicators

The SDG targets are defined broadly, and the problem definition may well fit within one or more of the targets. If this is the case, a comparison can be made between the respective SDG indicators and the key information needs as identified. This comparison will help to determine which SDG indicators can be used to fulfil the key information needs and what information would be needed additionally. In this way, the information strategy will both provide information for tackling the problem as well as provide information for reporting under SDG 6.

Ladder approach

The ladder approach as used in the global indicator methodologies is largely on improving the information available to populate the indicators.

> The concept of progressive monitoring was developed to enable as many countries as possible to engage in SDG 6 monitoring, starting at a relatively simple and inexpensive level and becoming progressively more ambitious over time, as country capacity and resource availability improve. (UN-Water, 2017a, p. 27)

At a more generic level, the ladder approach starts from the question: Do I have enough information to act? If yes, then there is no need to collect further information (Figure 4). This is founded in the fact that in a data-poor environment one should only focus on the information needed to mitigate the most pressing problems. Getting a more balanced view of the situation based on a set of indicators is further up the ladder. The ladder approach determines the extent of the information strategy and therewith the effort needed to implement it.

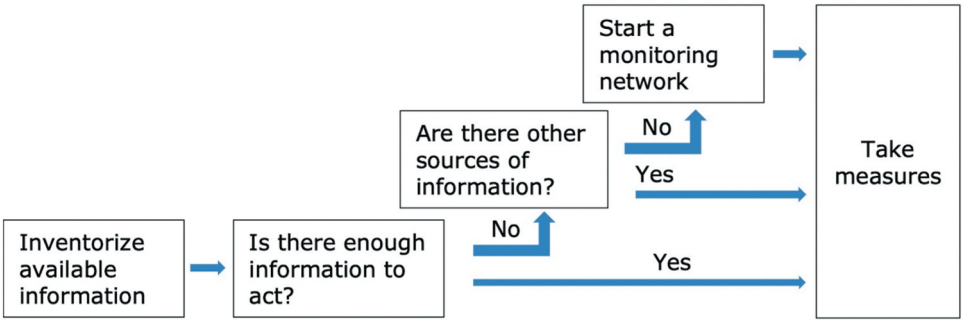

Figure 4. The ladder approach.

Resource needs

Now it is time to start developing the information strategy. The inventory of key resources and tools gives an overview of what is needed to implement the information strategy, while through the ladder approach limitations are set to what will actually be implemented. Looking at the already available resources and tools, now it is time to identify what is actually needed and also what is additionally needed. This includes, among others, funding, personnel with the relevant competencies, housing, and technical facilities such as apparatus, computers, software, etc.

Planning

Subsequently, planning needs to be made on how to implement the information strategy as designed: what needs to be done when? This includes looking at interdependencies of activities and putting them on a timeline.

Testing the ISM

A workshop setting

For the purpose of supporting the countries in improving their monitoring networks as well as to test the ISM, a workshop was organized. The goal was to enable the participating countries to improve their water management and ultimately reach the SDG 6 goals by 2030 by improving the collection of data and information at the national level with the use of the ISM. At the same time the ISM was tested for its suitability to increase the capacity of countries to further develop and improve their water quality and quantity information networks to better support their water management. The focus was on water quality and availability, specifically on SDG targets 6.3.1 (Proportion of wastewater safely treated), 6.3.2 (Proportion of bodies of water with good ambient water quality) and 6.4.2 (Level of water stress: freshwater withdrawal as a proportion of available freshwater resources) for both surface water and groundwater.

The workshop setting enabled us to provide all participants with the same information about the ISM. Any difference in between countries could as a result not be attributed to a difference in instructions.

The information network to be developed through the ISM includes monitoring networks as well as the regular collection of other types of information (see below). To this end, the workshop focused on presenting approaches, tools and methods for determining information needs for monitoring. The ISM was subsequently tested through hands-on sessions to apply the ISM in the countries' situations.

The ISM deals with the different types of information as mentioned above and how they contribute to improved water management. An important issue is collecting status information, often an important bottleneck in countries' information system. The ISM provides guidance on how to develop an information system, even under limited availability of resources. Finally, the ISM deals with developing policy options.

Set-up of the testing of the ISM

Representatives from 14 countries worldwide participated in testing the ISM. The participants were asked to bring one case study of a water management challenge including supporting information about their challenge, such as a historical overview of the case, maps of the area in question and an overview of available datasets. Each country was asked to send two participants, one from the policy side and the other from the technical side, to ensure the consideration of both sides when working on the challenge.

During a three-day workshop, introductions to the subsequent elements of the ISM were interspersed with working sessions in which the participants worked in groups to fill in that respective element of the ISM for their own country. The group work allowed the participants to discuss the issues and compare them with the situation in other countries. Several masterclasses were given on methods and methodologies to collect data, allowing the participants to discover the possibilities that open data and new methods and technologies bring.

Results from testing the ISM

The outcomes for each individual element of the ISM are discussed below by providing the general experiences of the countries.

Problem definition

Each country presented its own situation and the problems it faces. A range of issues was mentioned here, including agricultural water use in relation to water efficiency and water quality, and water pollution from various sources, including industry and mining. Next to that, limited water resources and water scarcity and related water allocation and over-abstraction and pollution of groundwater were mentioned. Finally, urban water supply

and land subsidence were mentioned as well as a generic need for improving the information situation. In general, the participants provided a short but comprehensive explanation of the problem situation.

Relevant policies

Under the relevant policies, generally mentioned were the national water policies, plans and acts and sometimes more general policies or acts are mentioned like the environmental act, or more specific the groundwater policy. Also, the constitution is mentioned several times and even wider policies and acts such as interinstitutional agreements and Agenda 2030. Other policies and acts are also mentioned, such as agricultural or economic policies, water-use policies and wastewater discharge regulations. Sometimes, shortcomings of policies are mentioned, such as a policy that does not come with resources to implement them. It should be noted that in general policies directly related to water are considered relevant. To a lesser extent, agricultural and economic aspects of water management are included. By including adjacent policies into the structure, the necessary integrated approach to water management was shown. Identifying the relevant policies enabled the participants to make the description of the problem definition more specific.

Key information needs

A wide range of information needs was mentioned. Actual need for (additional) information was expressed about water quality, groundwater, information on households and municipal levels, water abstraction and use per sector, hydrological information and climate information, land use, drought frequency and impact, investment plans, demographic information, early warning information, emission data from industries, and information on water allocations. Further to that, a need for methodologies, tools, scenarios and models was expressed. Also, the need for actualization of information, quality standards and extension of the monitoring network were mentioned as needs to improve the information base. In general, the information needs were closely related to the problem definition, as intended in the ISM.

Key partners and stakeholders

Some countries separated between partners and stakeholders, but most made a general list. Among the key partners and stakeholders, ministries of Environment, Agriculture, Water, Finance, Natural Resources, Planning and Public Works are mentioned several times. Also, ministries of Health, Housing, Planning, Transportation and Information are listed as key partners and stakeholders, stressing the need for an integrated approach. Meteorological, geological, statistics and agricultural institutes and general research institutes and academia are also included multiple times. Additionally, national organizations are mentioned representing, among others, farmers, nature, media and tourism as well as local governments and communities, non-governmental organizations (NGOs), (international) river basin organizations, water service providers, water utilities and water users' associations as well as international organizations such as the World

Bank and different United Nations agencies. Some countries specifically mentioned politicians and parliament. Companies were included by a few countries only, and one country mentioned religious leaders. The partners and stakeholders could in general be connected to the problem definition.

Key resources and tools

Looking at the key resources and tools needed to improve the information situation, geographical information system (GIS), modelling techniques and general data management tools were mentioned by almost all countries. Remote sensing and citizen science were also included many times. Inputs from other sources including emission registrations were also considered important resources. Several countries listed development or improvement of the national monitoring system. Capacity development, finally, was mentioned by some countries. The tools and resources as presented during the workshop were in general considered relevant for improving the monitoring and were related to the key information needs.

SDG targets and indicators

Looking at the SDG targets and indicators, some countries underlined the relevance of the indicators for their water management. Much of the attention went into the information that was missing to fill in the indicators. This ranged from agricultural information (e.g., irrigated area, crop type, yield and water-use efficiency) and temporal and spatial disaggregation to general water quality data and standards. For one country, the SDG 6.3 water quality indicator did not provide the specific information needed for national water management. In general, the SDG 6 indicators consequently cover much of the issues as defined. However, not all countries had sufficient data to fill in the indicators.

Ladder approach

Half the countries did not fill in this item of the ISM. Presumably they could not find stepwise approaches towards improving the information situation. The countries that did fill in the ladder approach provided steps that could fill in their information needs relative to their problem definition or steps to reduce the problem, including capacity-building and law enforcement. One country mentioned the use of scenarios to identify priorities. Overall, this element was apparently not clear enough for all countries to give a targeted response.

Resource needs

A range of resource needs was mentioned here, including technical and financial resources, long-term planning, flexible legislation, awareness, political commitment and consistency in policies, and knowledge, experience and capacity-building, especially on the resources and tools, as mentioned in the introduction. Where for some

countries the focus was on building up a monitoring network, for others the focus was on improving the network. Depending on the situation, other priorities were mentioned.

Planning

In the short term, planning focused on consolidating what was available, including capacity-building, improvement of methods and awareness-raising. In the longer run, the countries expressed their need to expand the monitoring to other topics related to the problem. Some countries also mentioned improving the water management, basically along the same lines as for the short and long terms.

Discussion

The ISM was developed to support countries in improving their monitoring networks relative to the SDG 6 monitoring that they had been working on earlier. The workshop was designed to test the ISM model as a basis for capacity-building around monitoring. The participants showed high appreciation of the ISM as well as the workshop. The data availability in most of the participating countries is limited and related to that; many participants had limited experience in developing and running monitoring networks. The ISM provided them with an opportunity to work in a structured way on their own practical case situation and the opportunity to compare and discuss with other countries. The ISM was appreciated in supporting a structured approach and was well understood, but not all elements were easily filled. Nevertheless, several countries indicated afterwards that they had used the ISM model to further improve the monitoring in their respective countries after returning to their country. Also, participants with more experience in developing monitoring networks indicated that the ISM provided a good structure to reflect on the choices they made in developing their networks.

The problem definition was rather straightforward for all countries as were the relevant policies. Relating the key information needs to the problem definition was well understood. Nevertheless, the countries stayed close to the water domain in specifying the information needs, largely leaving out information on sources of the problems and on measures as taken.

Many countries indicated where they needed improvements, such as in methodologies, but also in capacity development. Regarding the key partners and stakeholders, the countries identified a wide range of organizations to be involved that were related to the problem definition. Farmer organizations were involved as both source of problems and as being affected by the problems. NGOs were also generally considered as stakeholders. In identifying the key resources and tools, the countries related this to their key information needs and mentioned many of the methods and tools that had been presented during the workshop. They also indicated that several of these methods and tools were already applied in their countries.

Regarding the SDG indicators, the countries identified those indicators as largely relevant in their problem situation. Nevertheless, they also indicated some information that was not included in the SDG indicators, such as specific agricultural information,

and that there was a need for spatial and temporal disaggregation to make the information applicable to the water management situation. The ISM thus enabled looking beyond the SDG indicators.

Some countries did not fill the element ladder approach, possibly because it was not fully understood. Resource needs in general focused on technical and financial resources and capacity-building. Interestingly, also political commitment and consistency in policies were mentioned by several countries. The latter underlines the importance of an enabling environment for monitoring, without which the sustainability of monitoring networks is weak.

The element 'planning', finally, was quite detailed for many of the countries and only schematically developed. The ladder approach seemed to show some overlap with this element, which may be another reason why the ladder approach was not filled by some countries.

In general, the responses in the filled-in ISMs showed clear consistency between the different elements within one country relative to its problem definition. In many cases the responses did not focus on data and information solely but often included water management measures to be implemented or improved. Especially the elements key information needs, key resources and tools, resource needs, and planning included water management measures.

Reporting on the SDG indicators is based on national data. As many rivers and groundwaters are shared among different countries, water management problems often have a transboundary dimension. It was recognized that data on SDG 6 indicators should therefore also be available at the basin level. Exchange of data and information is needed to tackle the relevant problems at the basin level.

All participating countries were able to fill in the ISM to a similar level. This shows that the ISM with the instructions given during the workshop provided the countries with sufficient input. The ISM thus provides a solid and useable framework.

This study describes a framework, the ISM, and its application by 14 countries. The results are country specific and the study was not intended to provide 'standard responses' to the ISM blocks. The study thus only provides a qualitative appreciation of the ISM. The responses from the participants during and after testing the ISM showed that it provides a model that is easily understood and has a high value in structuring the necessary information needed to develop and improve national monitoring. The ISM thus fulfils its purpose.

Conclusions

From the analysis of the responses, the responses of the participants and the interviews, it becomes clear that the ISM provides a suitable framework to structure the development and improvement of a monitoring network, not only in countries with limited experience in monitoring but also in those with more extensive monitoring networks. The ISM, starting with the problem definition, enables a clear focus on the elements of the monitoring network that need attention and improvement. By making the explicit link between the information and the policy problem and related policies, the resulting information is more likely be relevant for policymaking. The ISM is, as a result, useful for both policy and technical people. From the policy-oriented responses, it becomes

clear that it is difficult to distinguish between information and its purpose. On the other hand, there is a tendency to focus on generic indicators, without considering their purpose. The ISM helps to improve this situation.

The ISM can be improved. Further detailing of the individual elements of the model is needed, especially on the element ladder approach. Furthermore, the workshop setting has shown that facilitation of the use of the ISM is needed. Targeted, facilitated workshops focused on filling the ISM will be useful to support countries in developing and improving their national monitoring systems.

The results of this study are based on a one-time event, although the ISM was in this event tested for 14 different countries. The conclusions of this study therefore have a limited reach. Nevertheless, the results have led to the conclusion that applying the ISM can substantially support countries in improving their water management information base, also by linking it to their policies. Its use is therefore recommended when countries are working on improving their monitoring networks.

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References

Adriaanse, M., Timmerman, J. G., Ottens, J. J., van Oirschot, M. C. M., Breukel, R. M. A., Van De Guchte, C., & Mulder, W. H. (1997). *Guidelines for water quality monitoring and assessment of transboundary rivers.* RIZA report nr. 96.034. RIZA, Institute for Inland Water Management and Waste Water Treatment.

Behmel, S., Damour, M., Ludwig, R., & Rodriguez, M. J. (2016). Water quality monitoring strategies— A review and future perspectives. *Science of the Total Environment*, *571*, 1312–1329. https://doi.org/10.1016/j.scitotenv.2016.06.235

EEA. (2011). *Europe's environment. An assessment of assessments*. https://www.eea.europa.eu/publications/europes-environment-aoa

Graveline, N., Maton, L., Rinaudo, J.-D., Lückge, H., Interwies, E., Rouillard, J., Strosser, P., Palkaniete, K., & Taverne, D. (2010). An operational perspective on potential uses and constraints of emerging tools for monitoring water quality. *TrAC Trends in Analytical Chemistry*, *29*(5), 378–384. https://doi.org/10.1016/j.trac.2010.02.006

Harmancioglu, N. B., Ozkul, S. D., & Alpaslan, M. N. (1998). Water quality monitoring and network design. In N. B. Harmancioglu, V. P. Singh, & M. N. Alpaslan (Eds.), *Environmental data management* (pp. 61–106). Springer Netherlands. https://doi.org/10.1007/978-94-015-9056-3_4

Hermans, L. M., Slinger, J. H., & Cunningham, S. W. (2013). The use of monitoring information in policy-oriented learning: Insights from two cases in coastal management. *Environmental Science & Policy*, *29*, 24–36.

Hilhorst, T., & Guijt, I. (2006). *Participatory monitoring and evaluation: A process to support governance and empowerment at the local level*. A guidance paper. KIT and World Bank (TF055592). http://www.bibalex.org/Search4Dev/files/282315/114599.pdf

MacDonald, L. H. (1994, May–June). Developing a monitoring project. *Journal of Soil and Water Conservation*, *10*(2), 221–227. https://www.jswconline.org/content/49/3/221

McNicholl, D., McRobie, A., & Cruickshank, H. (2017). Characteristics of stakeholder networks supporting local government performance improvements in rural water supply: Cases from Ghana, Malawi, and Bolivia. *Water Alternatives*, *10*(2), 541–561. https://www.water-alternatives.org/index.php/alldoc/articles/vol10/v10issue2/369-a10-2-19/file

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: A handbook for visionaries, game changers, and challengers*. Wiley.Com. https://www.wiley.com/en-us/Business+Model+Generation%3A+A+Handbook+for+Visionaries%2C+Game+Changers%2C+and+Challengers-p-9780470876411

Pellerin, B. A., Stauffer, B. A., Young, D. A., Sullivan, D. J., Bricker, S. B., Walbridge, M. R., Clyde, G. A., & Shaw, D. M. (2019). Emerging tools for continuous nutrient monitoring networks: Sensors advancing science and water resources protection. *JAWRA Journal of the American Water Resources Association*, *52*(4), 993–1008. https://doi.org/10.1111/1752-1688.12386

Schiffer, E., & Hauck, J. (2010). Net-map: Collecting social network data and facilitating network learning through participatory influence network mapping. *Field Methods*, *22*(3), 231–249. https://doi.org/10.1177/1525822X10374798

Strobl, R. O., & Robillard, P. D. (2008). Network design for water quality monitoring of surface freshwaters: A review. *Journal of Environmental Management*, *87*(4), 639–648. https://doi.org/10.1016/j.jenvman.2007.03.001

The CEO Water Mandate. (2010). *Guide to responsible business engagement with water policy*. https://ceowatermandate.org/files/Guide_Responsible_Business_Engagement_Water_Policy.pdf

Timmerman, J. G. (2014). *Information needs for water management*. CRC Press. https://www.crcpress.com/Information-Needs-for-Water-Management/Timmerman/p/book/9781466594746

Timmerman, J. G., Adriaanse, M., Breukel, R. M. A., van Oirschot, M. C. M., & Ottens, J. J. (1997). Guidelines for water quality monitoring and assessment of transboundary rivers. *European Water Pollution Control*, *7*(5), 21–30. https://www.researchgate.net/publication/262002399_Guidelines_for_Water_Quality_Monitoring_and_Assessment_of_Transboundary_Rivers

Timmerman, J. G., Beinat, E., Termeer, C. J. A. M., & Cofino, W. P. (2010a). A methodology to bridge the water information gap. *Water Science and Technology*, *62*(10), 2419–2426. https://doi.org/10.2166/wst.2010.513

Timmerman, J. G., Beinat, E., Termeer, C. J. A. M., & Cofino, W. P. (2010b). Specifying information needs for Dutch national policy evaluation. *Journal of Environmental Monitoring*, *12*(10), 1907–1917. http://dx.doi.org/10.1039/c0em00135j

Timmerman, J. G., Beinat, E., Termeer, C. J. A. M., & Cofino, W. P. (2011). Developing transboundary river basin monitoring programmes using the DPSIR indicator framework. *Journal of Environmental Monitoring*, *13*(10), 2808–2818. https://doi.org/10.1039/c1em10092k

Timmerman, J. G., Beinat, E., Termeer, K., & Cofino, W. (2010c). Analyzing the data-rich-but -information-poor syndrome in Dutch water management in historical perspective. *Environmental Management*, *45*(5), 1231–1242. https://doi.org/10.1007/s00267-010-9459-5

Timmerman, J. G., Ottens, J. J., & Ward, R. C. (2000). The information cycle as a framework for defining information goals for water-quality monitoring. *Environmental Management*, *25*(3), 229–239. https://doi.org/10.1007/s002679910018

UNECE. (1992). *Convention on the protection and use of transboundary water courses and international lakes*. https://unece.org/DAM/env/water/pdf/watercon.pdf

UNECE. (2006). *Strategies for monitoring and assessment*. https://unece.org/DAM/env/water/publications/assessment/StrategiesM_A.pdf

UNECE-TFMA. (2000). *Guidelines on monitoring and assessment of transboundary rivers*. RIZA. http://www.unece.org/fileadmin/DAM/env/water/publications/documents/guidelinestransrivers2000.pdf

UNGA. (2015). *Transforming our world: The 2030 Agenda for sustainable development* (Resolution A/70/L.1). United Nations General Assembly. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

UN-Water. (2016). *Towards a Worldwide Assessment of Freshwater Quality* (Policy and Analytical Briefs).

UN-Water. (2017a). *Integrated monitoring guide for sustainable development goal 6 on water and sanitation*. Good practices for country monitoring systems. https://www.unwater.org/publications/good-practices-sdg-6-monitoring/

UN-Water. (2017b). *Integrated monitoring guide for sustainable development goal 6 on water and sanitation*. Targets and global indicators. https://www.unwater.org/app/uploads/2017/10/G2_Targets-and-global-indicators_Version-2017-07-14.pdf

UN-Water. (2018). *Sustainable development goal 6*. Synthesis Report 2018 on Water and Sanitation (p. 199). https://www.unwater.org/publication_categories/sdg-6-synthesis-report-2018-on-water-and-sanitation/

Ward, R. C., Loftis, J. C., & McBride, G. B. (1986). The 'data-rich but information-poor' syndrome in water quality monitoring. *Environmental Management*, *10*(3), 291–297. https://doi.org/10.1007/BF01867251