The Use of Data and Information in Irrigation Water Management (Case Study: Colo Irrigation Area, Bengawan Solo River Basin)

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Abstract. In term of geography, water is a resource which is not favouring administrative boundaries. Water has its behaviour in flowing. However, we cannot confidently say that water flows following the laws of gravity. There is no guarantee that locations which are close to reservoir or water resource are not prone. Water scarcity when comparing the resource to demand for it is more relative than absolute. Irrigation water management is aimed to guarantee to make every agricultural land has access to water. In other hand, map is an important tool especially for portraying conditions of an area such as river basin. Map have played important roles in water management. This study aims to explore the use of data in decision making in irrigation water management practices. Colo irrigation area in Bengawan Solo river basin was chosen not only its vast coverage area but also because of its complexity in water management. It across two provinces and six municipalities. Content analysis was undertook to analyse two data sets: laws and regulation related to water management practice and the interview of policy actors. Elaborating the implementation of laws and regulations regarding to the use of data and information in irrigation water management, the comparison of the results also disclosed deviations among what it is regulated and what it is implemented. Quantitative and qualitative data that mostly used in practices cannot fully support to inform water conditions, physical and environmental conditions, social economic conditions in wider context. Spatial data is essential tools to represent comprehensive interconnected data and information in wider context. A profound understanding of stakeholder perspectives on the role of each data and information is essential for policy actors in the implementation of integration water resource management. Shared, comprehensive and interconnected data can promote common ground and collaboration potential.

Keywords: data, information, map, irrigation, water management

1. Introduction

Emerging water management challenges have pushed government to re-think about its policies and prioritizes, signalling a growing commitment to build a more integrated water resource management. The concept of Integrated Water Resource Management (IWRM) stems from the need to provide solutions to
water use conflicts, as demand is greater than supply [1]. IWRM aims to fulfil the water needs of a growing population, while also protecting and preserving the sustainability of water resources [2]. However, integrated water resource management is frequently linked with high complexity of water related issues and growing interconnected actors or stakeholders beside the uncertainty of water supply triggered by climate change. Nowadays, policy actors in water management are faced with large amount of data with various characteristics and complex interdependencies among them.

In practices, the specific unique condition, such as different physical and social-economic condition, are conditioning factors in water management. Every area and actor or stakeholder in water practices generally focuses on solution of their own problem instead of comprehensive solutions towards public and environmental benefits as sounded by the laws and regulations. In their decision-making process to utilize water, actors or stakeholders have different considerations [3]. Common practices show that actors formulate their considerations of their decisions by comparing available information from direct experience they have [4] instead of implementing the comprehensive analysis that need to be conducted in analysing data [5]. Some stakeholders need simple and structured information, some stakeholders need more detailed and more technical information [6] whereas others use intuition and their experience in water management. This filter process are particular ways in which policy actors regard data and information including their judgement of its importance from their point of view. Their point of view is likely influenced by their roles/functions, interests, belief [7], and available resources [8]. Thus, although the laws and regulations related to water management in Indonesia have pointed out that integration is one of the principles need to be applied in water management, their approaches differ considerably in term of broadness and focus [9].

In Indonesia, water is a common public resource which everyone has a right to have adequate access amount of water for domestic and agriculture use [10]. Water management has become a big issue since the notion of availability is asymmetric with the accessibility [11]. Even though water has its behaviours in flowing, but we cannot confidently say that water flows following the laws of gravity. Many phenomena show that water flows toward money especially in irrigation water management. With this background, water scarcity when comparing the resource to demand for it is more relative than absolute [12]. It will depend how water have been managed and utilized by the policy actors and the users itself. Many programmes have been implemented by various government to make sure every agriculture parcel land has an equal access to water. However, it has been found that water practices implemented tends to stand alone and sometimes makes worse the real condition so that sustainable development is difficult be achieved. There is an increasing trend among actors to focus on their self-interest issues rather than thinking altruistically for collective interest. Patchy and incremental actions such as large-scale exploitation of ground water, damming water flow in creeks to cope with temporary and specific area problem can be detrimental to other sectors, actors, or regions.

In other side, a map is a tool that can help to inform data spatially. According to Indonesia laws and regulations, several data have been listed to be used in water management practices. However, there remain doubts regarding the use of data especially spatial data (map) as a reference for water management practices in Indonesia. The type of data and their characteristics are fundamental aspects of integrated water resource management. If the synergizing of the data and information used in systemic resource, such as water resource, are not substantially fostered, the diversity approaches are likely to constraint the efforts toward integrated water resource management. Therefore, recognizing the condition of data used in water practices is the essential to reflect our pathway toward integration water resource management. The objective of the article is to explore the use of data in decision making in irrigation water management practices. To reach this objective, we elaborate the implementation of laws and regulation in irrigation practices by comparing what is written in formal documents and the practice implemented by the policy actors regarding to use of data and information.
2. Data and Methods

2.1 Case Study

We conducted our research in one of irrigation areas in Bengawan Solo River Basin named Colo Irrigation area. We chose the irrigation area as our example because of its high complexity due to diverse actors involved, various issues occurred which are the challenging factors of integrated water resource management. Over an area of about 166,189 ha and crossing two provinces and six municipalities, the Colo irrigation area is divided under three different level authorities: national authority for irrigation areas which is above 3000 Ha, province authority for irrigation area which is between 1000 – 3000 Ha, and municipal authority for irrigation area which is under 1000 Ha (Figure 1). The irrigation water supply is mainly supported by Colo water dam which use Wonogiri water dam as the water source. However, the use of groundwater instead of surface water for irrigation is found in some area of this irrigation area.

![Figure 1. Colo Irrigation Area, Bengawan Solo River Basin](image)

2.2 Data

To understand how Indonesia laws and regulations directs the use of data in water management practice, we conducted document analysis. The data for document analysis was gathered online from peraturan.go.id which all laws and regulated enacted in Indonesia are freely published online. Five keywords were used to our first search, that area water (“air”), irrigation (“irigasi”), river (“sungai”), conservation (“konservasi”), and “Bengawan Solo”. The search generated a total number 350 Items are removed if they only included incidental mention of water or focused on specific areas which is not in Bengawan Solo river basin. Only enacted policies that are still use in 2021 were extracted. This resulted in 199 relevant policies for analysis.

Interview methods used to obtain the implementation of laws and regulations regarding to the use of data and information in water practices by policy actors in water management. To study facts, the semi-structured interview model with open response questions was conducted. The topic was introduced by interviewer before they were set free to discuss the topics suggested in the questions in order to obtain as much information as possible. Three stakeholder groups identified as relevant to the implementation of water practices: the Bengawan Solo Water Authority (Balai Besar Wilayah Sungai/BBWS Bengawan Solo), government agencies in province and municipal level (represented by Department of Public Work,
Department of Agriculture, and Planning Department), the farmer association (represented by Perkumpulan Petani Pemakai Air/P3A). They are the stakeholders who are responsible for the pillars of water management: planning, operational, monitoring, and conservation. The interviews were performed from March to June of 2021. A set of five questions common to all respondents and some questions specific were considered (Table 1).

**Table 1. Structure of the interview scripts**

| Issue                                | Questions                                                                 |
|--------------------------------------|----------------------------------------------------------------------------|
| Respondents                          | Water Authority                                                                 |
|                                      | Provincial Government                                                   |
|                                      | Municipal Government                                                     |
| Bengawan Solo Water Authority        | The Farmer Association (P3A)                                              |
| Planning Agency                      | Dept. of Agriculture                                                     |
| Dept. of Public Work                 | Planning Agency                                                           |
| Dept. of Agriculture                 | Dept. of Public Work                                                      |

| The number of respondents            | 3   | 6   | 1   | 1   | 6   | 6   | 6   |

| The stakeholder job desk area        | What is your job desk area of this department that is related to water management practices |
|                                      | Consideration to water management practices is required. |

| The use of data and information      | Regarding to your job, which data are essential for supporting your decision? |
|                                      | • What are they? |
|                                      | • In which format? Are they spatial qualitative or quantitative data? |
|                                      | • Are they real time data? If not, what is your approach to ensure its accuracy? |
|                                      | • Do you need to do data analysis before you can use the data? |

| Understanding and communication      | Where do you get the data? |
|                                      | Do your institution produce your own data to produce the data needed? |
|                                      | How is the communication occurred to make sure the data coherence among different stakeholders? |

| Planning, Monitoring and evaluation  | What type of data gathered? |
|                                      | • The use of comprehensive data in water practice |
|                                      | • The use of one source data to direct water practice |
|                                      | • The use of individual knowledge/experiences in water practice |
|                                      | • The use of stakeholder agreements (consensus) instead of data in water allocation |
|                                      | • No data used |

| Relevance to the water practice decision (water allocation) | What type of data gathered? |
|                                                          | • The use of comprehensive data in water allocation |
|                                                          | • The use of one source data to direct water allocation |
|                                                          | • The use of individual knowledge/experiences in water allocation |
|                                                          | • The use of stakeholder agreements (consensus) instead of data in water allocation |
|                                                          | • No data used |
2.3 Content analysis

To compare what is written in formal documents and the practice implemented by the policy actors regarding to use of data and information, we undertook two times coding. The first coding was conducted to legal documents, that is policies relevant to water management. The second was conducted to stakeholder interviews who is the actor of water management practices. The purpose of those two coding was to efficiently examine the characteristics of data and information used in irrigation water management practices. Each relevant policy and interview were individually reviewed and coded. By using NVivo software, coding was conducted manually because we believe human coders are more alert to any implied elements of arguments in their context.

3. Results and Discussion

3.1 The variety of data to promote integrated water resource management

Variety of data shows any data and information covered in Indonesian laws and regulations. Data and information used in water management listed in Indonesia’s laws and regulation are ranging from physical condition, technical data and information, social, economic, cultural condition, and policies. Detail characteristic of data and information directed by Indonesian laws and regulation for water management practices is explained in the following Table 2.

Table 2. The characteristic of data and information directed by Indonesian laws and regulation for water management practices

| Data                        | Information                                                                 |
|-----------------------------|-----------------------------------------------------------------------------|
| Physical Condition          | Hydrogeologist in national, provincial and municipal level                  |
|                             | Hydro-meteorologist in national, provincial and municipal level              |
|                             | Soil conditions                                                            |
|                             | Topography                                                                  |
|                             | Water tables                                                                |
|                             | Groundwater potencies                                                       |
|                             | Surface water potencies                                                     |
|                             | Infrastructure condition                                                    |
|                             | Critical area                                                               |
| Technical data and information | Water usage information                                                      |
|                             | Water Quantity                                                              |
|                             | Water Quality                                                               |
|                             | Groundwater utilization data                                                |
|                             | Groundwater license data                                                    |
|                             | Minimum maximum quantity water ratio in the river                           |
| Social, economic, cultural condition | Social-economic-cultural activities                                         |
|                             | Technology practices                                                        |
|                             | The number of populations                                                   |
|                             | Economic condition                                                          |
| Policies                    | Programme                                                                   |

Source: Document Analysis, 2021

Data coding was applied to determine further factors influencing variety of data. The listed variety of data is accordance with the list of factors needs to be considered in water management practices as it is shown in Figure 2. Based on Figure 2, it can be seen that influencing factors consist of data and information, technology, demands, special conditions, financial condition, environment, social conditions, physical conditions, and economics that each of those factors has more detailed influencing factors.
3.2 Data provision to promote integrated water resource management

Apart from covering the variety of data, Indonesian laws and regulations also mention the actors in charge of producing the data. Table 3 below shows the data and information producer directed by Indonesian laws and regulated for water management practices.
As can be seen from Table 3, the provision of the data is the responsible of various actors both government and non-government parties. The huge number of data producers requires made the data and information flow to be accessible to all actors as directed by laws and regulations suffers become challenging and crowded as presented in Figure 3. The other problem identified from its practice is the data produced can’t be directly used by policy actors as they need to convert the data so that it suits with their objectives and the other type of data they have. Because its difficulties, the common practices occurred is

### Table 3. Data and information producer directed by Indonesian laws and regulated for water management practices

| Data                        | Information                                                                 |
|-----------------------------|-----------------------------------------------------------------------------|
| Physical Condition          | Hydrogeologist in national, provincial and municipal level (national government, provincial/municipal government, water resource managers) |
|                             | Hydro-meteorologist in national, provincial and municipal level (national government, provincial/municipal government, water resource managers) |
|                             | Soil conditions (Municipal government)                                        |
|                             | Topography (Municipal government)                                             |
|                             | Groundwater potencies (Groundwater conservation center, Geologist center, The Mayor, The Governor) |
|                             | Surface water potencies (national government, provincial/municipal government, enterprise) |
|                             | Infrastructure condition (national government, provincial/municipal government) |
|                             | Critical area (Municipal government)                                          |
| Technical data and information | Water usage information (national government, provincial/municipal government, water resource managers, business actors) |
|                             | Water Quality (national government, provincial/municipal government)          |
|                             | Groundwater utilization data (The Mayor, The Governor)                       |
|                             | Groundwater license data (The Mayor, The Governor)                            |
|                             | Minimum maximum quantity water ratio in the river (Technical operational unit of Minister of Public Works) |
|                             | Irrigation area (farmer association, enterprise, individual)                  |
| Social, economic, cultural condition | Social-economic-cultural activities (national government, provincial/municipal government) |
|                             | Technology practices (national government, provincial/municipal government)   |
|                             | The number of populations (Municipal government)                              |
|                             | Economic conditions (Municipal government)                                    |
| Policies                    | Programme (national government, provincial/municipal government)             |

Source: Document Analysis, 2021
the policy actors do not involve the data as their basis in water practices which made little opportunities to conduct integrated comprehensive analysis as a reference of their decisions.

Figure 3. Actors in Data and Information Production (Source: Data Coding, 2021)

3.3 Data and information applied for irrigation water management

Based on the data types listed in the formal documents, we triangulated the data through interviews with three stakeholder groups who are responsible for the pillars of water management: planning, operational, monitoring, and conservation: the Bengawan Solo Water Authority (Balai Besar Sungai Besar/BBWS Bengawan Solo), government agencies in the province and municipal level (represented by the Department of Public Work, Department of Agriculture, and Planning Department), the farmer association (represented by the Association of Water-Using Farmers/P3A). The types of data used by stakeholders are divided into four: quantitative data, qualitative data, spatial data, and no data used as shown in Table 4.
Table 4. Type of Data and information used by policy actors in practices

| Type of Data                                                                 | Planning | Operational | Monitoring | Conservation |
|------------------------------------------------------------------------------|----------|-------------|------------|--------------|
| Hydrogeologist in national, provincial and municipal level (national government, provincial/municipal government, water resource managers) | V        | V           | V          | V            |
| Hydro-meteorologist in national, provincial and municipal level (national government, provincial/municipal government, water resource managers) | V        | V           | V          | V            |
| Soil conditions (Municipal government)                                        | V        | V           | V          | V            |
| Topography (Municipal government)                                             | V        | V           | V          | V            |
| Groundwater potencies (Groundwater conservation center, Geologist center, The Mayor, The Governor) | V        | V           | V          | V            |
| Surface water potencies (national government, provincial/municipal government, enterprise) | V        | V           | V          | V            |
| Infrastructure condition (national government, provincial/municipal government) | V        | V           | V          | V            |
| Critical area                                                                | V        | V           | V          | V            |
| Water usage information (national government, provincial/municipal government, water resource managers, business actors) | V        | V           | V          | V            |
| Water Quality (national government, provincial/municipal government)          | V        | V           | V          | V            |
| Groundwater utilization data (The Mayor, The Governor)                        | V        | V           | V          | V            |
| Groundwater license data (The Mayor, The Governor)                            | V        | V           | V          | V            |
| Minimum maximum quantity water ratio in the river (Technical operational unit of Minister of Public Works) | V        | V           | V          | V            |
| Irrigation area (farmer association, enterprise, individual)                  | V        | V           | V          | V            |
| Social-economic-cultural activities (national government, provincial/municipal government) | V        | V           | V          | V            |
| Technology practices (national government, provincial/municipal government)   | V        | V           | V          | V            |
| The number of populations (Municipal government)                              | V        | V           | V          | V            |
| Programme (national government, provincial/municipal government)              | V        | V           | V          | V            |

1: quantitative data; 2: qualitative data; 3: spatial data; 4: no data used
Source: Interview Analysis, 2021

Based on the results of the interviews listed in Table 4, it is seen that each type of data has not been used thoroughly on the four pillars of water management. Of four types of data gathered, spatial data is the data that is used at least in practices. The spatial data is only available on conservation pillar. Moreover, there are also many data requirements that are not available (no data used).
The concept of institutional fit expects that regulatory system should match with what is implemented in practice to address the local problems and conditions. However, the research found the discordance in the use of data between what is regulated in the laws and regulation and practices. The content analysis of formal legal documents revealed many factors need to be considered in water practices, where collected data and information is one of the factors (Figure 2). Regarding the information coded from the documents, they are many types of data need to be provided to support the decision regarding to water practices (Table 2). The listed data are the product of various government agencies which should be freely accessible by other stakeholders or policy actors (Figure 3). The qualitative elicitation of legal documents reveals accordance in implementing the integration principle. The type of listed data required, influencing factors needed to be considered in water practices, the targeted objectives shared focus - that is integrated comprehensive decision among actors, sectors and regions as a focus. Furthermore, the listed data implicitly shows the need of spatial data (map) informing water conditions, physical and environmental conditions, social economic conditions in wider context as reference to understand the causal effects of implemented water management.

However, the elicitation from interview findings shows the opposite. In practices, there is discordance regarding the use of data by related policy actors in managing irrigation water. The track record of using the listed data has been limited. Data and information as references in water management has been patchy and piecemeal due to the lack of spatial data. The type of data used, influencing factors, and objectives forming unshared foci among policy actors highlighting the limited understanding among actors regarding to water condition in wider context the importance of wider objectives – sustainability and equality water accessibilities.

In practices, the absence of spatial data as reference in water management practices has led to difficulties to mediate environmental condition and economic productivity, which both are objectives and considering factors in water management practices. Although the laws and regulations have set that environmental condition as one influencing factors in water management, the laws and regulations also set economic and community welfare as other influencing water. Without understanding the condition of water in wider context led difficulties to decide which one need to be the winner. As long as the detrimental conditions cannot be detected, the economic productivity and community rights can be a threat of sustainable condition. It is essential to have spatial data as regulated in the laws and regulations that can inform the wider context of water condition to promote integrated water management system.

4. Conclusion

Integrated water resource management is very valuable for finding shared solutions to common good issues such as irrigation water. However, the realization is a challenge. The research found that it requires comprehensive data that substantially fosters communication and deliberation among policy actors. Elaborating the implementation of laws and regulations regarding to the use of data and information in irrigation water management, the comparison of the results also disclosed deviations among what it is regulated and what it is implemented. Quantitative and qualitative data that mostly used in practices cannot fully support to inform water conditions, physical and environmental conditions, social economic conditions in wider context. A notable number of influencing factors were identified. However, the diverse actors consider a broad range of issues to be important in their water practices. The conflict of interest among factors cannot be mediated when the data and information are still patchy and piecemeal. Spatial data is essential tools to represent comprehensive interconnected data and information in wider context. A profound understanding of stakeholder perspectives on the role of each data and information is essential for policy actors in the implementation of integration water resource management. Shared, comprehensive and interconnected data can promote common ground and collaboration potential.
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6. References

[1] Garcia L E, 2008 Integrated water resources management: a ‘small’ step for conceptualists, a giant step for practitioners Int. J. Water Resour. Dev. 24, 1 p. 23–36.
[2] Ben-Daoud M et al., 2021 Integrated water resources management: An indicator framework for water management system assessment in the R’Dom Sub-basin, Morocco Environ. Challenges 3 p. 100062.
[3] Basu M DasGupta R Hashimoto S and Hoshino S, 2021 A multi-actor and bottom-up perspective on attaining rural water security: qualitative evidence from India Environ. Dev. Sustain. 23, 2 p. 1461–1484.
[4] Skrydstrup J Madsen H M Löwe R Gregersen I B Pedersen A N and Arnbjerg-Nielsen K, 2020 Incorporating objectives of stakeholders in strategic planning of urban water management Urban Water J. 17, 2 p. 87–99.
[5] Baccar M Bergez J-E Couture S Sekhar M Ruiz L and Leenhardt D, 2021 Building Climate Change Adaptation Scenarios with Stakeholders for Water Management: A Hybrid Approach Adapted to the South Indian Water Crisis Sustainability 13, 15 p. 8459.
[6] Delozier J L and Burbach M E, 2021 Boundary spanning: Its role in trust development between stakeholders in integrated water resource management Curr. Res. Environ. Sustain. 3 p. 100027.
[7] Nabiafjadi S Sharifzadeh M and Ahmadvand M, 2021 Social network analysis for identifying actors engaged in water governance: An endorheic basin case in the Middle East J. Environ. Manage. 288 p. 112376.
[8] Hermans L M Naber A C and Enserink B, 2012 An approach to design long-term monitoring and evaluation frameworks in multi-actor systems—A case in water management Eval. Program Plann. 35, 4 p. 427–438.
[9] Nagata K et al., 2021 Practicality of integrated water resources management (IWRM) in different contexts Int. J. Water Resour. Dev. p. 1–23.
[10] Malisie A F Prihandrijanti M and Otterpohl R, 2007 The potential of nutrient reuse from a source-separated domestic wastewater system in Indonesia—case study: ecological sanitation pilot plant in Surabaya Water Sci. Technol. 56, 5 p. 141–148.
[11] Kobayashi K Ari I R D Escobar I C and Schaefer A, 2014 Community based water management and social capital IWA Publishing.
[12] Shaw W D, 2021 Water resource economics and policy: an introduction Edward Elgar Publishing.