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REVIEW

A review of the water resources management for the Brantas River basin: challenges in the transition to an integrated water resources management

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Abstract
This paper reviews an integrated approach involving the representative stakeholders in the development and management of water available in the Brantas River basin and provides new insights into the future water management practices toward the implementation of integrated water resources management. Overall process of governing the availability of water at the Brantas River basin level by sequencing updating master plan can have a significant achievement. The institutional arrangements support good water governance as a long-term process of the Brantas River basin development and management. Challenges of managing the optimum use of water resources in the Brantas River to fulfil the needs of various stakeholders related to technical issues, institutional frameworks, and regulatory instruments were construed as being rooted in the participation of stakeholders. This review may contribute to the incremental improvements in water management practices to gain better understanding of the future direction of water resources management at river basin level.

Keywords Brantas River basin · Stakeholders participation · Water management practice · Water resources infrastructure

1 Introduction

The Dutch East Indies government and Indonesian army had surrendered without offering resistance on land following Japanese invasion during the Second World War in 1942 (Reid, 1975). Most parts of Indonesia today were then briefly governed by the Japanese colonial rule that ended abruptly in 1945 whereas the Indonesian authorities have openly declared their independence by Soekarno—Hatta on behalf of Indonesian people (Abdullah, 2015; Heller, 2009; Vandenbosch, 1953). It is recognised as a consequence that Japan

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should pay the reparations to Indonesia for damage and suffering caused by military aggression during the war (McGregor, 2016). The Japan's grant aid in the form of its war reparation to Indonesia was implemented from April 1958 to April 1970. The Japanese government had undertaken the assignment to construct several civil engineering structures, including the water projects in Java, Borneo, and Sumatra. Therefore, it has to be noted that the history of coordinated development and management of water resources for Indonesia has been on the rise since 1958 with the first water resources development project in the Brantas River basin of East Java province.

The Brantas River that flows clockwise with Mount Arjuno and Mount Kelud as its centre stretches 320 km from its spring at Mount Arjuno to New Lengkong where it branches into two rivers of Surabaya River and Porong River (see Fig. 1). The Brantas River basin region has been one of the most productive and advanced food granaries in Indonesia (Aldrian et al., 2008) due to the effective use of water available in the basin has a significant impact on the growth of both agricultural and industrial sectors. Alternatives of regulated water flows at the areas downstream of the Brantas River basin are that the Surabaya River serves as the primary water supply to the Indonesia's second largest city of Surabaya and the Porong River essentially serves as a floodway, where both rivers flow into the Madura Strait of the southern Java Sea (Bhat et al., 2005). The Brantas River basin with its main tributaries of Lesti, Konto, Ngrowo, and Widas Rivers has an area of 11,800 km^2 comprising approximately 24.6% of East Java's land area. This basin receives an average annual rainfall of approximately 2,000 mm and has an average annual runoff of approximately 12 billion m^3 (Aldrian et al., 2008; Bhat, 2008). In fact, according to the Jasa Tirta 1 Public Corporation (known as the Perum Jasa Tirta 1 (PJT1) in Indonesia) reports, the only 25% or approximately 3 billion m^3 of the available water across the basin are manageable (Subijanto et al., 2013). The basin's population of nearly 15 million has increased

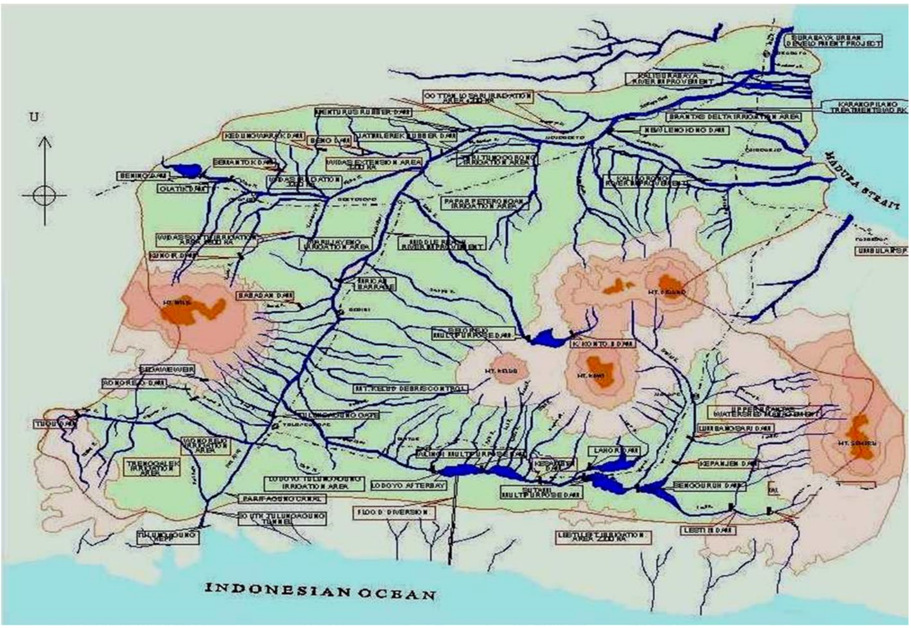

Fig. 1 Brantas River basin

by 53.4% over the past 30 years and represents 42.4% of the East Java's population with a density of 1249 per km^2 (Bhat et al., 2005).

There is in 1961 the first water resources infrastructure development in Indonesia for the Brantas River basin that the Niami Tunnel was constructed to drain excess water from seasonally inundated Ngrowo River basin from the Tulungagung area to Indian Ocean (Bhat et al., 2005). Many people using the lands around the Tulungagung city have been becoming more intensive farmers of the rice fields as the area has become flood-free along the year. Part of the Ngrowo River basin has been utilised by farmers as fertile land for agricultural purposes. The construction of the Niami Tunnel can benefit many people wanting to restore their agricultural lands traditionally occupied by seasonal and semi-permanent wetlands and has been highlighted as the first important scheme for the integrated water resources development at river basin level in Indonesia (Adeoti, 2010). Nevertheless, the emerging perspective seems to be that a wide plan of the river basin should provide the overarching framework for a basin, focusing firstly on the upstream and downstream issues of multi-sectoral water uses identified through the situation assessment (Fulazzaky et al., 2017; Munia et al. 2016). A transition of technocratic water resources management to an integrated water resources management is the result of the interplay of various factors at the landscape, regime and niche level (van der Voorn & Quist, 2018). An emerging vision of the integrated water resources management with an effective engagement of stakeholders plays an important role in the transition of the Brantas River basin water management. The importance of the external landscape factors can lead to awareness and urgency of integrated water resources management at the river basin level in decision-making processes. The transition of water resources management leading to an extension of the number of societal functions requires a more coordinated approach to water management (Kaweesa et al., 2020). As a final result of the most comprehensive basin-wide analysis for the sustainable development of water resources at the Brantas River basin level would consider cross-sectoral planning and cooperation in a basin-wide perspective. Figuring out the overall water resources infrastructure system must integrate to each other (Rasul, 2015).

The concept of the Brantas River basin development seems to be semantically very close its initial concept of integrated river basin planning and development that was stipulated for the Tennessee Valley development by the United States of America (Molle, 2009). The relevance of the integrated water resources management approach applied in the Brantas River basin to the Tennessee Valley Authority model is associated with several stages of water resources planning and the realignments of water allocations between the upstream and downstream of the basin by integrating the geographic units of district/municipality, which have not been included in the sustainable management and optimisation of water resources and infrastructures. Therefore, the Indonesian Ministry of Public Works suggested to the Japanese Government to perform a river basin-wide study in order to settle a plan of the water resources development (Hamilton, 1971). For the first time, the government of Indonesia was able to enhance the river basin development based on an integrated plan to undertake development sequentially in form of rational development master plan in a step-wise manner to only the Brantas River basin of East Java province. Therefore, the experience of the Brantas River basin development and management needs to be shared with other river basin authorities. The objectives of this study are: (1) to use secondary data as scientifically-based information on the water resources infrastructures to support a review of the previous and current water resources management practices and (2) to suggest challenges of future water resources management practices in the Brantas River basin of East Java province for gaining a new insight into the implementation of sustainable integrated water resources management.

2 Methodological approach of secondary data analysis

The sources of secondary data evaluated with respect to a multi-criteria analysis of water management strategies were collected from the PJT1 and the Large River Basin Office (LRBO) Brantas. The secondary data include the annual reports and publication archives of hydrological and water quality data, locations and years of construction, and purposes of water infrastructure development. With a combination of these two data sources, this review would be able to determine which factors lead to some of the persistent challenges of managing the available water resources at the Brantas River basin level. All water-related data have been processed by a computer system of specialised processing programme for storing data in an Excel database and simulated to gain a meaningful use of assessing the achievements of each water resources development master plan phase. For instance, the use of the No Pollution (NOPOLU) programme could be useful to develop the scenarios of controlling the Brantas River pollution. Application of the NOPOLU programme together with the water quality evaluation system could help predict the status and suitability of the Brantas River water to different uses (Fulazzaky, 2009, 2010). An entropic difference among the water infrastructures is away from the investment value of every water asset having the different initial capital costs of small and large water infrastructures. The importance of chronologically combining the benefits of water management services together with different units of quantifying and measuring the achievements of social-economic development can improve the identification of the water management progresses. A brief review of the water-related data collection has been performed by the PJT1 to describe the application of data for each master plan in chronological listing of significant floods, droughts, and other water-related events across the Brantas River basin. A data processing system by computer-assisted quantitative data analysis using combination of machines, people, and logical processes was carried by the PJT1 Data Centre, where one set of the data inputs can produce one defined set of the outputs as the valuable information. Simple dynamic databases in Excel using list, figure, and table managed by the PJT1 Data Centre were used as the data inputs in a logical sequence of information.

3 Four phases of the water resources development master planning

A comprehensive water resources development and management plan of the Brantas River basin has been an essential issue for sustainability of water management. The guiding principles of water management for the Brantas River have been a pioneer adopting the ordinary concept of one river, one plan, and one integrated management (Subijanto et al., 2013). A master plan comprises a series of subsidiary plans which include many step-wise strategies to develop and manage the Brantas River basin, saying the government's bureaucratic plan seems like a never-ending process to accomplish the tasks (Grigg, 2010). The master plans of the Brantas River basin have been designed to present four consecutive planning periods of strategic plan that draw together all initiatives proposed by stakeholders require an accurate and reliable information quantifying the flood flow behaviours, irrigated areas, domestic and industrial water demands, as well as the water pollution and river basin degradation. This supports effective land-use planning and sustainable water management for the purpose of implementing the master plans (Sheikh & Rao, 2007; Smith et al., 2016). These four master and strategic plans should be communicated to all administrative districts/municipalities along the Brantas River and its main tributaries and must be aware in all spheres of the water resources development and management. All the master plans have been issued to cover critical or emerging water issues into the short- and long-term goals based on the dialogue and inputs from public participation and concerned stakeholders. The master plan phase-1 outlined long-term roadmap to achieve a truly sustainable development was accomplished in 1961 and has strongly emphasised flood control aspect of building the dams because of the occurrence of flooding events in the Brantas River basin as the major constraint to economic development before 1961 (Duvail & Hamerlynck, 2007). After the goals of the master plan phase-1 has been achieved almost completely only in ten to twelve years, the master plan phase-2 was completed in 1973, focusing on food sustainability as the government emphasised on the development of irrigated agriculture (Subijanto et al., 2013), while the sustainable intensification of agriculture by use of the water resource infrastructures with various facilities in all districts/municipalities of the Brantas River basin has contributed substantially to the tremendous increases in food production (Matson et al., 1997). The master plan phase-3 was completed and issued in 1985 to focus on water supply for the needs of domestic, commercial, and industrial uses. The planning of strategies for the master plan phase-4 was completed in 1998 to focus on the issues for the improvement of water quality and the rehabilitation of aquatic ecosystem to gain the sustainable and rational utilisation, protection, conservation, and management of water resources based on the community needs and priorities within framework of the national economic development policy (Snellen & Schrevel, 2004). Each master plan included a degree of public opinion was set up according to the needs of various parties in the water management practices and the rationale for an integrated water resources management.

A comprehensive national water policy guiding the sustainable development of water resources and water sector strategies has led to the project realisation process of the construction of 8 large dams, 6 barrages, and 3 rubber dams along the Brantas River for the period of 1970 to 2000. These water infrastructures serve the needs of all water users within the Brantas River basin and prevent the detrimental effect of floods (see Table 1). The total investment of the infrastructure projects over the period of 1970 to 2000 was estimated to reach USD 7.38 billion, of which the share of investment funds provided by the government differs from the year to year depending on the government committing financial support to a project (Subijanto et al., 2013). In spite of the relative time and costs required to develop the water resource infrastructures were relatively easy to calculate owing to the governments can manage the infrastructure investments relatively easily, the social benefit of a water infrastructure investment is much more difficult to quantify. The participation of stakeholders by giving credibility and accountability to the management process of water infrastructures may help predict the social benefit of water (Hargrove & Heyman, 2020). The use of water served many different purposes of balancing social, economic and environmental sustainability requires better arrangement of coordinating and integrating multistakeholder interest along the Brantas River (Kusters et al., 2018). The fact that the monetary and non-monetary benefits to different groups of stakeholders generated by the water infrastructure assets for the purposes of water resources management have been increasing steadily income per capita in almost every district/municipality in the Brantas River basin. Table 2 shows the benefits due to extending the water and electricity infrastructures, comparing the state inside Brantas River basin between 1960 and 1990 (Subijanto et al., 2013). It has been estimated that approximately 60,000 hectares of medium and deep flooded areas of 50-year return period flood have been fully preventing danger from inundation since 1978. The annual average hydroelectric power generation has increased from 170 million kWh generated by two hydropower plants in 1960 to 910

Table 1 Water resources infrastructures in the Brantas River basin

Infrastructure	Location	Year	Purpose
Large dam:			
Selorejo	Konto River	1970	Irrigation, hydropower, flood control, recreation
Sutami	Brantas River	1972	Water supply for domestic and industrial uses, irrigation, hydropower, flood control, recreation
Lahor	Lahor River	1975	Water supply for domestic and industrial uses, irrigation, flood control
Wlingi	Brantas River	1978	Irrigation, hydropower, flood control, recreation
Lodoyo	Brantas River	1983	Hydropower
Bening	Widas River	1984	Irrigation, hydropower, flood control, recreation
Sengguruh	Lesti River	1988	Sediment control, hydropower
Wonorejo	Bodeng Song River	2000	Water supply for domestic use, hydropower, flood control
Barrage:			
New Lengkong	Porong River	1974	Water supply for domestic and industrial uses, irrigation
Gunungsari	Surabaya River	1981	Irrigation
Jagir, rehabilitation	Wonokromo River	1981	Water supply for domestic use
Tulungagung gate	Ngrowo River	1986	Water supply for domestic use, hydropower, flood control
Wonokromo	Mas River	1990	Flood control
Mrican	Brantas River	1992	Irrigation
Rubber dam:			
Gubeng	Mas River	1990	Water supply for domestic use
Jatimlerek	Brantas River	1993	Irrigation
Menturus	Brantas River	1993	Irrigation

Table 2 Compelling benefits of water management in the Brantas River basin

Water management services	Unit	By year			
		1960	1990	2000	2010
Operation and maintenance of reservoir	Number of dam	0	7	8	8
Water supply for:					
Domestic uses	Million cubic meter	73	125	204	315
Industrial uses	Million cubic meter	50	115	144	181
Hydropower generation	Million kWh/year	170	910	1024	1315
Water quality monitoring along Brantas River	Sampling location	0	51	51	51
Rice cropping intensity	Tme/year	0.8	1.8	2.2	2.2
Areas inundated by flood waters	Hectares	60,000	0	0	0

million kWh generated by eight hydropower plants in 1990. An investment in the water resource infrastructures can boost the economic growth and the networks of land and water uses to provide better services to people for all urban and rural communities, together with a secured water supply to meet the needs of public, domestic, commercial, irrigational, and industrial purposes in all districts/municipalities of the Brantas River basin (Vasanthavigar et al., 2012). As can be seen in Table 2 that cropping intensity has increased to more than twice from 0.8 time per year in 1960 to 1.8 time per year in 1990.

4 Institutional development in the Brantas River basin

A sustainable development and management of the river basin requires the basin to be considered as a whole, with multiple interactions of water-ecosystem-economy regarding the upstream, midstream, and downstream areas of the basin coordinated appropriately (Cheng et al., 2014). The development of water infrastructures in the Brantas River basin has been started since 1960s as an integral part of the national development planning scheme (Arriënsa & de Montalvo, 2013; Millington, 2000; Subijanto et al., 2013). The evolution of water management institutions has been reported in the previous studies for the Missouri River and Red River basins (Hearne, 2007; Hearne & Prato, 2016). This study revealed that the forms of organisation to have been developed to carry on the various procedures and meet the various responsibilities of the institution for the development and management of water resources have been the four types of public water agencies established. Firstly, the Brantas River Basin Executing Agency (BRBEA), most known as the Brantas Project (BP), as the central government institution to the fulfilment of tasks for sustainable development of water resources in the Brantas River basin has been established since 1961 with a mandate to address the interrelated issues of the environmental and economic importance of floods and droughts within the basin and thus has been the large part of the investments to improve the water services under the national water policy programmes (Hart et al., 2001). Because of the central government has a role as the main investor in the country's water resource infrastructure development during the authoritarian years of Suharto's New Order era (1965–1998), the role model of provincial and district/municipal agencies seeks to ensure that the Brantas River water resources must be protected, managed, and controlled by regulating and supporting the delivery of effective water supply. Secondly, in spite of the PT Indra Karya (Persero) as one of the state-owned companies has been established in Jakarta since 1972 as a continuation of the Perusahaan Negara Indra Karya, such a consultant company has been practically reestablished in 1981 in Malang City due to the needs of many project consultants by various institutions to which the BP transferred 500 employees (Fujimoto, 2011). Thirdly, the PT Brantas Abipraya (Persero) as one of the state construction companies with its core business in the watering field projects (dam, irrigation, etc.) was founded in 1981 due to the needs of accelerating the development of water resources infrastructures to which the BP transferred 519 employees. Fourthly, the PJT1 to which the BP transferred 439 employees was established by the Government Regulation (PP) No. 5/1990 with its core business of managing the major water resources of the Brantas River to provide the needs of water supply for domestic, industrial, and agricultural purposes, as well as the water flow for the electric power generations (Subijanto et al., 2013). The PP No. 5/1990 was then replaced by the PP No. 93/1999 to allow the PJT1 to extend its core business of the company's corporate responsibility and to get a jurisdiction for managing water resources in the Bengawan Solo River (Bhat et al., 2005). The PP No. 93/1999 was then replaced by the PP No. 46/2010 to comply with the Water Resources Law No. 7/2004 and the PP No. 42/2008 on Water Resources Management (Fulazzaky, 2014). The establishment of these four public water agencies in compliance with cross-cultural communication of stakeholder participation might have been considered the goals to implement an integrated water resources management approach which promotes the coordinated development and management of water resources in the Brantas River basin to maximise an equitable share of the resultant economic and social welfare without compromising the sustainability of vital ecosystems (van der Voorn, 2008).

Since 2007 the BRBEA has been renamed to the LRBO Brantas as one of the central government institutions and has a long experience in the field of handling strategic importance of the Brantas River basin. According to the ministerial regulation No. 11a/PRT/M/2006 issued by the Minister of Public Works and Housing (Fulazzaky, 2014), the LRBO Brantas has a strategic role in the development of water infrastructure but not required to operate and maintain the water infrastructures themselves (Zhang & Chen, 2013). The PJT1 has a role to manage the availability of water resources and operating the water infrastructures in the Brantas River basin. The benefits of water management services by the PJT1 as compiled in Table 2 have been increasing over five decades while the causes are well understood due to a new standard of water management practices. The manageable water sources, most efficient way to increase supply of the Brantas River water is by managing the operation of 8 dams effectively, insure safety of these dams, and making every water serve more purposes, more efficiently. Table 2 shows that the water supplies of 73, 125, 204 and 315 million m^3 for the domestic uses and those of 50, 115, 144 and 181 million m^3 for the industrial uses have been recorded for the years of 1960, 1990, 2000 and 2010, respectively, due to more effective water network management addressing by the PJT1 has been made to increase an efficiency of water use in the Brantas River basin during the last two decades.

5 Challenges of managing the available water resources

This paper provides an overview of the previous and current water-related issues, management strategies, and institutional developments to address challenges of water resources management in the Brantas River basin. Healthy terrestrial and freshwater ecosystems play a key role in achieving of sustainable water resources development and management and are vital to sustain quantity and quality of the water available within the Brantas River basin, on which both nature and people rely (Fulazzaky, 2009). The influence of climate change on the future water resources management consisting of a chain of the consecutive actions must consider the projections of rainfall and temperature (Doroszkiewicz et al., 2019). A water resource management of the Brantas River basin underlies the most basic type of strategic planning and development control challenges as a consequence of the rapid population growth (Fulazzaky, 2014; Fulazzaky & Gany, 2009; Goes et al., 2016). It is expected that economic growth rate and productivity gains should increase over time as the extraction and share of the water and natural resources in the Brantas River basin shall continue to increase and remain elevated for the years to come; therefore, this must consider different aspects of determining the feasibility of water-use efficiency measures. More efficient water management of the Brantas River basin has been based on the establishment of the PJT1 and the accompanying growth of agricultural and industrial activities with the same quantity of water (Horne, 2013). Development of the proper water infrastructures plays a vital role in facilitating the economic growth in all administrative districts/municipalities of the Brantas River basin where such growth can lead to environmental pollution.

5.1 Challenges of water resources management practices

The Brantas River basin has been one of the most productive and advanced food granaries in Indonesia due to its ample water resources provided by dam, tropical climate, and fertile soil (Fujimoto, 2013). A good knowledge, technology, and economic resource can help manage the availability of water resources much more efficiently and effectively in the future than today (Cosgrove & Loucks, 2015). An important role of the PJT1 in the water resource infrastructures management limited to the operation and maintenance of eight dams (see Table 1) is expected to focus on the most important tasks of controlling an effective water allocation and this can lead to better water resources management practices in the future. A challenge of the future water resources management must predict the influence of climate change on the projections of air temperatures and rainfall precipitation recorded at certain stations in the mountainous and hilly regions upstream of the Brantas River. A Backcasting-Adaptive Management approach has been proposed as an adaptation strategy of the long-term water resources management planning designed to face future uncertainties of climate change and complexity of the social-ecological systems without compromising short-term water resources management goals (van der Voorn et al., 2012, 2017). The conceptual and methodological base of the sustainable integrated water resources management requires taking into account the complexity of water uses and water users within the Brantas River basin and must give an attention to uncertainties of climate change by considering the principles of adaptive water management (Pahl-Wostl et al., 2007).

Even though the trend analysis of climatic variables based on the data of monitoring 5 stations indicates a significant warming trend in the upper part of the Brantas River basin, the amount of recorded rainfall at 29 stations did not show any significant decreasing trend in most region of the upper Brantas River basin for the period from 1984–2006 (Khare & Pingale, 2012). Application of the sediments dredged mainly from the Sengguruh Dam located at the upper part of the Brantas River for the agricultural lands and coastal nourishment may take into account every possible technical factor to be considered as the long-term management strategy of maintaining all reservoirs within this basin (De Vincenzo et al., 2019). The development of model to calculate a total sediment delivered from the mountainous and hilly areas to the reservoirs can be suggested to properly manage eight large dams of the Brantas River system (Ezz-Aldeen et al., 2018). Optimal operation of large water distribution system can be maintained by flushing or dredging sediments from the dams to ensure the provision of sustainable water resource management and services (Chang et al., 2003). The development of a proper model for managing the amount of water released from eight dams along the Brantas River can simulate a leakage in the water supply networks (Covelli et al., 2015, 2016a). The effectiveness of the mathematical models developed based on the physical models of operating the existing dams to predict the leakage of water will be able to reduce the water losses in water distribution systems (Covelli et al., 2016b). A long-term interest of the water management and financial support in the Brantas River basin focused on emerging markets and developing economies would consider to take into account of the concept of water paying water (Alaerts, 2019).

5.2 Challenges of water quality management

Current challenges of water management in the Brantas River basin are settled over the ideas of maintaining good water quality for domestic, industrial and agricultural purposes, conserving land most sensitive to agricultural activities, and performing optimal water resources allocation among the various water use sectors based on a fair, effective, and sustainable principles. The potential strategy for enhancing a synergy between agriculture and industry leading to polluted water could be due to the various upstream land use activities and industrial effluents are the major contributors of downstream water pollution and are associated with the causes of conflict over water within the Brantas River basin. For better understanding of the water quality information, 51 sampling locations have been selected since 1986 for the approval and set up of the programme for monitoring the quality of surface water along the Brantas River, as shown in Fig. 2. The level of water quality degradation has been assessed in term of the water quality index to possibly recommend to the local authorities. It needs to envisage certain priorities in handling the problems of water pollution by launching the programme of forest and land rehabilitation in many areas upstream of the Brantas River basin and by implementing the typical measures of reducing the Brantas River water pollution generated from industrial and domestic wastewaters (Fulazzaky, 2009). By maintaining a healthy ecosystem in the Brantas River basin representing a desired endpoint of environmental management has the lots of species diversity and is less likely to be seriously damaged by human interactions, natural disasters, and climate changes.

The demographic processes of population growth and urbanisation within the Brantas River basin causing the nitrogen and phosphorus sewage inputs to the river are the drivers that create a great pressure on the availability of water resources (Suwarno et al., 2014). As the growing population demands more and more natural resources for its own

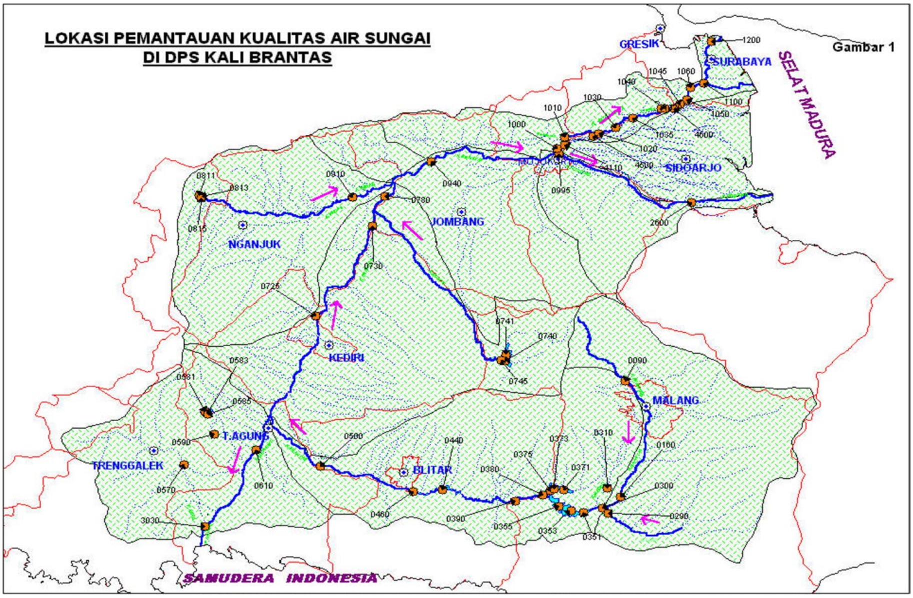

Fig. 2 Sampling locations of water quality monitoring along the Brantas river

application, the competition for fertile land and the use of the limited quantity of water available increases. The most intense human-nature interactions and conflicts occur in many cities such as Surabaya, Malang, and Kediri, while densely populated urban areas have been particularly deprived of greenery and are subjected to environmental degradation within the Brantas River basin (Jim, 2008). A holistic approach of the urban resilience established as a nature-based solution needs to consider a wide range of ecosystem disturbances to develop the environmental and ecological benefits of urban sprawl (Vargas-Hernández & Zdunek-Wielgołaska, 2020). This is not unthinkable to unravel the effect of different water management practices when taking into account the different people values and cultural systems, the different development priorities and needs, as well as the different levels of participation in conserving the natural resources (Berkes, 2007). One major component of the environmental degradations is the depletion of resources of fresh water for the Brantas River basin. It has a very rational way of looking at the assumptions that a broadly close relation could be among water resources, public health, social stability, economic growth, and ecosystem degradation in the environment (Hassan et al., 2015; Zhou et al., 2015). Multitarget backcasting scenarios of combining the strengths of multicriteria analysis, nexus approach and backcasting may be considered as the pathways suited to account for the multidimensional aspects of goal conflicts within the Brantas River basin (van der Voorn et al., 2020). Robust optimization of water quality management in the Brantas River basin is a participating multisectors that require more interdisciplinary professionals and engagements from water quality and environmental pollution practitioners. This may benefit from the advances of the multi-stakeholder network of water management practices (Zhou et al., 2019).

5.3 Change in the paradigm of water resources management

Political will and commitment of the regulators at the national, provincial and district/municipal levels to implementing the laws, adequate funding, and enforcement play a crucial role in all issues of water management practices (Kideghesho et al., 2013). Uncertainty assessment of the previous and current water management practices from different sources within the Brantas River basin has a potential to lower the accuracy of mapping outputs and reduce their reliability for the future water resources management (Wang et al., 2018). The efficient and effective regulators are needed to administer and enforce the regulations and are important to allocate the water available for covering multisector demands within the Brantas River basin. For creating an opportunity to perform the multiple concurrent actions, a paradigm shift in the water management away from the entrenched supply-side focused toward a comprehensive demand-side management should be established based on the master plans (Brandes & Kriwoken, 2006). Socio-economic development of the country as a complex problem has traditionally been seen as the first form of the infrastructure development (Milenkovic et al., 2014) and has led to a shift in the paradigm of water resources management in Indonesia (de Sherbinin et al., 2007). In spite of the availability of water resources in the Brantas River basin has always been acknowledged for its role in the economic development (Subijanto et al., 2013), many discussions of the international forum have called for water of its complementarity with the human right to be regarded as a social and public good (Carrozza & Fantini, 2016). However, regardless of where the responsibility of management is placed, the social and environmental costs associated with the water management practices must be met to ensure the sustainability of services. Role of the government in the new era of decentralisation politics after 1998 may change from statutory provider to enabler of the efficient infrastructure investment (Fulazzaky, 2014).

The establishment of four water-related agencies associated with financing, planning, constructing, operating and maintaining services of water could be an attempt to speed the transferability of water management from traditional demand-driven supply into an integrated water resources management covering the whole Brantas River basin (Thomas & Durham, 2003). There is due to the administrative rules have been travelling from the centralisation toward decentralisation. Therefore, setting up a project for the water management practices needs be reoriented from a single-purpose focus to a multisector river basin approach to promote an integrated water resource management and from supremacy instruction to people aspiration to avoid any conflict of interest between the personal interest and public interest in dealing with the projects of water infrastructure. This may pose a serious challenge to the main issues facing the water resources development and management in the future because of all aspects of the water resources management practices have been defined according to the new approach of integrated water resources management as mandated by the Water Resources Law No. 7/2004, even though the Constitutional Court has annulled the Water Resources Law No. 7/2004 and reinstated the Authoritarian Water Law No. 11/1974 by the year 2015. As a consequence, the new water law of Law No. 17/2019 on Water Resources has been promulgated on 16 October 2019 to guarantee the sustainable water management practices of taking into account the emerging technical and regulatory issues.

5.4 Emerging technical and regulatory issues

Several emerging technical and regulatory issues in the Brantas River basin such as deforestation and degradation of the upper watershed, lack of sufficient available water resources to meet the water needs within the basin, degradation of water quality in certain parts of the basin, areas of flood hazard in some parts of districts within the basin, threatened and endangered species living in and along the river, as well as deterioration and degradation of the infrastructure assets posing the liability risks can be identified as critical to the water management practices (Fulazzaky, 2014; Fulazzaky & Gany, 2009). The emerging technical issues must be considered as a future challenge in the context of discussions regarding the responsibility-sharing agreement between the river basin authority and the political authority within the Brantas River basin. Consequently, adopting agile work practices are perspectives and the starting point for any adoption of new water engineering practices guided by an updated master plan that must be regulated as the legal instrument to be implemented by every municipal/district within the Brantas River basin. The accepted approach of integrated water resources management based on stakeholder involvement in the planning and decision-making process facing the problems of water conflicts associated with a multitude of roles and statuses related to the responsibilities of central, provincial and district/municipal governments may be a challenge to the environmental sustainability and economic prosperity of water management (Fulazzaky, 2014; Thomas & Durham, 2003). A new standard for the water management practices can become more environmentally sustainable by developing and integrating practices that reduce the environmental impacts of forest and land occupations, water supply operations, water and wastewater treatments, riverbank protection, as well as operation and maintenance of the infrastructure assets.

A water fund of the innovative financing mechanisms employed by the downstream water users of water supply companies, industries, and agricultural lands within the basin to promote the upstream land conservation is recognised as a financial mechanism to fund the forest and land conservation measures in the mountainous and hilly regions of Batu, Malang, Blitar, and Kediri upstream of the Brantas River basin as part of the financial schemes for the future water resources management (Lin et al., 2010; Munawir & Vermeulen, 2007). Do some stakeholders require financial support to fully participate to ensuring that stakeholder participation practices for effective cross-sectoral collaboration and sustainable water management in the river basin (Shively & Thompson, 2016; Silveira et al., 2016). There is a need to adopt and implement the mechanisms of upstream–downstream interactions resulting from distributive bargaining processes based on the investigated competitive interactions between the participants to having a win–win solution. A willing community capable of active and constructive responding can do better to improve the coordination, cooperation, communication, and consistency of government. The community efforts toward sustaining the catchment's environmental, economic, and social values can help ensure the financial sustainability of many river basin organisations (Booth et al., 2001; Straton et al., 2011). Coordination among the related institutions across the Brantas River basin would be one of the future challenges in handling the emerging technical issues. Even though water is the link among most dynamic processes on the lands within a river basin (Nepal et al., 2014), decentralised resource management in the Brantas River basin is the smart approach that does not require national guidelines and allows for adaptive and flexible decision-making in response to the seasonal and annual variations.

6 Conclusions

This paper discussed an overview of the previous and current water-related issues, management strategies, and water management practices for the Brantas River basin as an insight of the future water resource management to support sustainable development in Indonesia. The most apparent measure toward resolving the water-related issues by implementing an integrated approach of the water management services has been important to not only provide an immediate economic benefit of increasing water supply, electricity, and rice production but also the future social and economic gains for people who live and work in the Brantas River basin. A typical behavioural model of stakeholders participation helps the river basin authority to gain a general acceptance of the water management practices explored on the basis of four consecutive applications of the master plans. Picking the right water management to deal with growing number of water-related issues and stakeholders participation depends on the accurate justification of the previous and current water conditions and the scheme of setting up the appropriate water management institutions. A new approach of integrated, adaptive and ecosystem-based water management supported by a number of the policy instruments need to be shifted from the traditional water management of demand-driven supply to an integrated water resources management. Challenges of the integrated water resources management in the Brantas River basin related to technical issues, institutional frameworks, and statutory instruments are highlighted to contribute to the future directions of the water management practices.

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