Climate Risks and Adaptation in the Indonesian Water Sector: A Rapid Assessment

Overseas Development Institute:

Sarah Opitz-Stapleton, Adriana Quevedo, Paul Sayers, Yue Cao and Maria Ratnaningsih

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Contents

List of boxes, tables and figures

Figures

Tables

Boxes

List of Acronyms

ADB	Asian Development Bank
Bappenas	Ministry of National Development Planning
BAU	Business-As-Usual
BMKG	Meteorology, Climatology, and Geophysical Agency
BNPB	National Disaster Management Agency
CCD	Comparative Climate Data
CMIP5	Coupled Model Intercomparison Project Phase 5
CORDEX	Coordinated Regional Downscaling Experiment
ENSO	El Nino Southern Oscillation
FAO	Food Agriculture Organisation of the United Nations
GMSL	Global mean sea level
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LCDI	Low Carbon Development Initiative
MoEF	Ministry of Environment and Forestry
MoPWPH	Ministry of Public Works and Public Housing
NICR	National Intelligence Council Report
PDO	Pacific Decadal Oscillation
RAN-API	Indonesia National Action Plan on Climate Change Adaptation
RCP	Representative Concentration Pathway
RPJMN	National Medium-Term Development Plan
RPJPN	National Long-Term Development Plan 2005-2025
RSPO	Roundtable on Sustainable Palm Oil
SD	Systems dynamic (model)
SEACLID	Southeast Asia Regional Downscaling
SLR	Sea level rise
SST	Sea surface temperatures
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

Executive Summary

Indonesia has some of the highest biodiversity and natural resource riches on the planet, which can be conserved and protected to assist the country in meeting its goals for a prosperous, low carbon and sustainable economy. How the country manages its water resources today and into the future will play a critical role in whether or not it is able to achieve socio-economic development targets. Increasing demand, pollution, deforestation and peatland drainage, and climate change present serious risks to Indonesia's water resources and require coherent, integrated management.

Water resources are unequally distributed across the country. Islands with higher population concentrations – Java, Sumatra and Sulawesi – have fewer water resources than some of the lesser populated islands like Kalimantan. Per capita reservoir water storage capacity remains lower than other Asian countries, and currently is unable to keep pace with population increases. The National Water Resource Council estimated 2018 water storage to amount to 68 m^3 per capita per year, well below the 1000 m^3 per capita per year threshold that the government considers necessary to provide an adequate buffer to drought and flooding. And access to piped water services is low. Current government estimates indicate that only 20% of households have piped services for domestic use; many rely on untreated groundwater or shallow surface water sources. This creates health risks and is placing a significant burden on groundwater, leading to land subsidence in major cities like Jakarta and contributing to cascading risks like increased flooding.

The total water demand for domestic, agricultural and industrial uses is growing, in part due to population growth and shifting economic activities. An ADB study (2016), estimated that urban water demand could increase 14% by 2030 through population increase alone.

Extensive rainfall deficits are common during certain types of El Niño events, and as a whole Indonesia's monsoons experience high multi-decadal variability. Precipitation variability, and the frequency, intensity, duration and spatial extent of rain extremes are likely to increase under climate change, including the potential for heavy rainfall and drought events in the same year. Warming ocean temperatures and ocean acidification will have impacts on coastal ecosystems, livelihoods and infrastructure. The combination of peatland drainage, groundwater extraction and sea level rise pose significant threats of flooding to coastal cities; some in Java and Sumatra are sinking on average 10-20 cm a year.

Climate change risks need to be mainstreamed into socio-economic, land use and spatial, and integrated water resource management planning from sub-provincial to national levels. Actions to build climate resilience can be phased to deliver benefits starting today – reducing the 'adaptation deficit' that gives rise to high losses in current climate-related disasters – and adjusted as contexts evolve and new information about climate change and hazards emerges. Such actions could include conducting a regular national climate risk assessment and requiring water infrastructure projects to consider a range of future climate and demand scenarios.

The Indonesian government recognises these challenges. Under the current five-year development plan, the RPJMN 2020-2024, the government is linking forest and water interdependencies and has set a target to maintain a minimum of 175.5 million ha of national areas with 'safe' water. It has also set a number of emission reduction targets under the Low Carbon Development Initiative to move toward a green economy, inclusive of plans for forest conservation. It is also working toward developing guidance and capacity building for provincial and sub-provincial governments on mainstreaming disaster and climate risk management into planning.

1 Introduction

This report is a rapid assessment of the Indonesian water sector and climate-related threats to the sector. It supports the Indonesia's Low Carbon Development Initiative (LCDI) and, presents an augmented focus on water building off the climate risks and adaptation chapter of the recently released *Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia* (Bappenas 2019a).

In October 2017, the Ministry of Planning of Indonesia (Bappenas) launched the LCDI process across government *'to identify development policies that maintain economic growth, alleviate poverty, and help meet sector-level development targets, while simultaneously helping Indonesia achieve its climate objectives, and preserve and improve the country's natural resources'* (Bappenas, 2019a). Specifically, the LCDI has: explored the extent to which climate change action is consistent with Indonesia's economic and social development objectives; helped the Indonesian Government to identify specific low carbon policies and required investments to deliver its objectives; brought together stakeholders to integrate climate action into policy, and; is helping communicate the outcomes of the analysis.

The findings of the LCDI report are reflected in the new RPJMN 2020-2024. The new five-year socio-economic development plan launches the process for systematic integration of low carbon development targets into broader economic and spatial planning. The RPJMN draws on a number of sector background studies that provide evidence on trends in emissions growth and intensity, deforestation rates and water security issues between 2000-2014. The plan notes that ongoing failures to protect natural resources, particularly forest and peatland cover in spite of a number of environmental regulations, are hindering economic development targets and contributing to longer term risks such as water and food insecurity, and increasing disaster risks (e.g. flooding-related). Such failure is also inhibiting efforts to meet the 29% emissions reduction target by 2030 that the Government of Indonesia pledged at the 2015 Conference of Parties in Paris.

The first round (2017-2019) of the LCDI process was limited in its ability to include an integrated analysis of climate risks and resilience, or a detailed examination of the water sector, within Systems Dynamic (SD) analysis used to support low carbon development. Stakeholders to the LCDI process indicated these as priorities for further elaboration. And such a water risk assessment and/or adequate discussion of risks is lacking in the RPJMN 2020-2024.

This Rapid Assessment provides an initial response to this request and considers issues of water security (supply, demand, sanitation, pollution, environmental needs and extremes) the interactions between climate change and population and economic development processes that drive water-related risks and their management. It draws on data recently released in the RPJMN 2020-2024, as well as recent amendments to the Water Law and some other environmental regulations, to examine near-term (e.g. the next ten years) challenges facing integrated water, forest, disaster and climate risk management in Indonesia.

2 Methodology

2.1 Information gathering

The Rapid Assessment uses available information from multiple sources, including:

- **Stakeholder consultations** - with Bappenas, RAN-API, BMKG, Deltares and ADB during the October 2018 and January 2019 country missions;
- **Review and discussion of the System Dynamics analysis** – working with the SD team to understand the existing approach to water and climate issues and the opportunities for further improvements.
- **Published literature** - including government and academic water studies, journal articles and grey literature.

The 2014 *RAN-API* (the National Action Plan for Climate Change), supporting sectoral assessments from 2010 and the various national communications to the UNFCCC, such as the 2017 *Third National Communication*, have broadly mapped some vulnerabilities and climate risks, but a detailed national climate risk assessment remains lacking. This detailed national climate risk assessment would likely be conducted under the mandate of the National Disaster Management Authority (BNPB) according to the *National Strategic Plan for Disaster Management 2015-2019*, which stipulates 'synchronization and harmonization between planning documents in the fields of disaster, environment and climate change' and disaster risk assessment (BNPB, 2015a). However, the RPJMN 2020-2024 highlights that targets set under the disaster plan 2015-2019 for conducting disaster risk assessments and building disaster maps are not yet complete (Bappenas, 2019b).

Nonetheless, several case studies at provincial, city and district level have been completed or are underway; and some climate change risks information may be gleaned from these. The majority of these studies were conducted through collaborative efforts between Indonesian ministries, predominantly Bappenas and MoEF, international funders (e.g. ADB, AusAID, DfID, DANIDA, GIZ, the Rockefeller Foundation and USAID or the World Bank) and NGOs (e.g. WRI, WWF Indonesia). On individual islands, a number of donor and NGO projects are either on-going or recently completed. However, these projects are rarely coordinated, sometimes leading to a duplication of effort and limited connection with national planning processes or the national Climate Change Task Force (Butler *et al*. 2016).

2.2 Language of risk

Bappenas and the Ministry of Environment and Forestry (MoEF) use the IPCC definitions of hazard, vulnerability, exposure, impact and risk – these conventions are adopted here (Box 1). The IPCC definitions themselves were developed from terminology used by multiple communities of practice, including: natural hazards and disaster risk management, climate adaptation, health, conflict and development.

It is important to clarify, for the purposes of this assessment that risk is not the same as a hazard, impact or disaster. *Climate-related risk is a description of potential outcomes if a climate-related hazard were to occur given underlying vulnerability, exposure and capacity conditions, not the hazard event itself*. Disasters, catastrophes and impacts are all actual outcomes; they are the things that happened when a hazard occurred because of the underlying vulnerabilities of an exposed society or system. The relationships between terms are visualised in Box 1.

Box 1: Definitions

Hazard – The potential occurrence of a natural or human-induced physical event or trend with the potential to cause harm…usually refers to climate-related physical events or trends…

Exposure – The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.

Vulnerability – The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Risk - The potential for consequences often represented as a function of the probability of occurrence of hazardous events or trends (within a specified timeframe) and the consequences should these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.

Impacts – The effects on natural and human systems – lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure – that occur through the interaction a hazard occurring and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes.

(Source: adapted from IPCC 2014a)

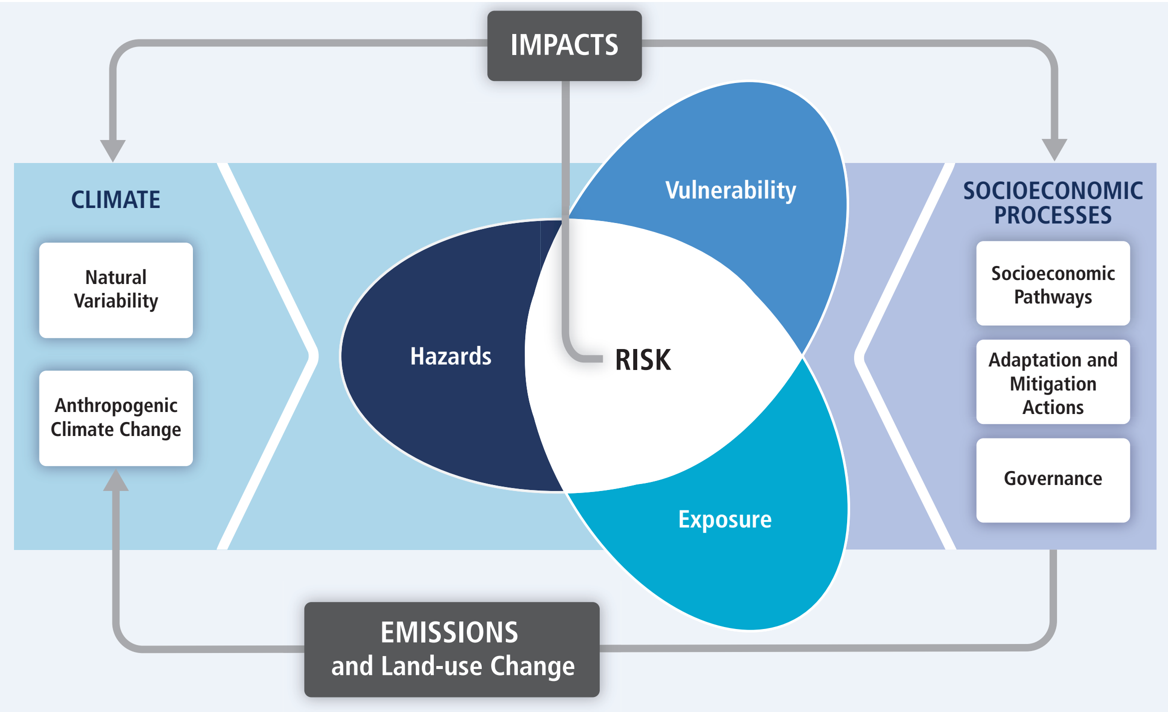


Figure 1: Relationship between climate risk, impacts, vulnerability and exposure. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. IPCC, 2014b: SPM.1.

3 Water Sector Priorities and Vulnerabilities

Water governance, land-use and pollution management, and supply and demand are all socio-political, cultural, economic processes and factors that give rise to Indonesia's contextual water vulnerability. This contextual vulnerability, and exposure to various climate hazards gives rise to a variety of climate-related risks that could impact Indonesia's water security and contribute to secondary risks such as flooding, drought and poor water quality.

Stakeholder consultations and the literature review indicate that the following issues are of greatest priority for water management in Indonesia (Table 1) and subsequently contribute to much of its contextual water vulnerability[1] or the hazards to which it is exposed. The remainder of chapter 3 explores the priority areas of Table 1.

Table 1: Water sector priorities for Indonesia that contribute to water vulnerability and exposure

Priority area	Situational Overview
Water Governance	Decentralisation of water governance between national, provincial and local governments is challenging water management, including clear mandates for action, financial and technical capacities, and monitoring and evaluation [Chapter 3.1].
Supply and Demand Management	Estimates of surface and groundwater supply vary greatly between studies. Many Indonesians still lack improved water supplies and resort to private borewells and water sources, contributing to land subsidence, particularly in coastal areas [Chapter 3.2].
Pollution	Lack of appropriate sanitation and sewage coverage, as well control of industrial effluent and agricultural runoff lead to widespread pollution of surface and groundwater supplies [Chapter 3.3].
Land-use Change	Peatland drainage, urbanisation and industrialisation are altering water-related ecosystem services and river flows [Chapter 3.4].
Hydroclimatological Hazards	Shifts in precipitation trends and extremes that contribute to flood and drought; sea level rise; higher water temperatures; coastal flooding [Chapter 4]

Multiple water studies related to supply, demand, quality and shifts in potential water balances have similarly been conducted throughout Indonesia (see for example - Nugroho et al. 2013; Nastiti et al. 2017; Suwarno et al. 2013). The majority of these are watershed studies, frequently limited to a single basin or to a few of the larger basins with greater data availability. Extrapolating the watershed-scale studies to provincial or national-scale implications is challenging.

A countrywide assessment was conducted by ADB (2016) to support the development of the RPJMN 2015-2019 and tie that to the *Masterplan for the Acceleration and Expansion of Indonesia Economic Development 2011-2025* (MP3EI). We continue to draw heavily on the ADB water assessment, augmented by water-related information in the new RPJMN, as the water sector background study for the RPJMN 2020-24 is not publicly available at the time of update to this report (April-May 2020).

[1] Contextual vulnerability (Starting-point vulnerability): A present inability to cope with external pressures or changes, such as changing climate conditions. Contextual vulnerability is a characteristic of social and ecological systems generated by multiple factors and processes (IPCC 2014a).

3.1 Water Resource Governance

Water governance can loosely be defined as the set of rules, practices, processes, structures and instruments through which decisions for the management of water resources and services are taken and implemented, and decision makers (governmental and non-governmental at different levels of influence) are held accountable (OECD 2015; van der Kerk et al. 2013).

Within Indonesia, both formal (government-led) and informal (non-government) water governance is strongly shaped by the political reform process that led to a transfer of authority from the national government to the lower administrative levels. From the different layers of local government, (province, regions, districts and cities), the transfer of authority between central and local governments follows three patterns of arrangements for role sharing for water resource management: Decentralisation, Deconcentration and Coadministration[2]. Local customary water practices are overlaid on top of the formal water governance structures. The country is divided into 131 river basins (*wilayah sungai*), where each ethnic group has its own customary land and water use governance practices (*adat*). Table 2 shows water governance arrangements according to river basin management, irrigation system management, and water supply and sanitation functions of surface water governance.

Table 2: Current arrangements for role sharing for water resources management (Source: ADB 2016: 10)

Affairs Distribution	Approach	Central	Province	District or City	PJT
River Basin Management					
Trans state	Coadministration	✔			✔
Trans province	Coadministration	✔			✔
National strategic	Coadministration	✔	✔	✔	✔
Trans district	Decentralization		✔		
Within district	Decentralization			✔	
Irrigation System Management					
Area >3,000 ha	Coadministration		✔	✔	
Area: 1,000–3,000 ha	Decentralization		✔		
	Coadministration			✔	
Area <1,000 ha	Decentralization			✔	
Water Supply and Sanitation					
	Decentralization		✔	✔	
Coordination	Deconcentration		✔		

ha = hectare, PJT = Perum Jasa Tirta (state-owned enterprise Jasa Tirta).

Indonesia's national water laws have recently been amended through the passage of *Act No 17/ 2019 on Water Resources*. This act replaces the *Water Resources Law No 7 of 2004*, which had been deemed unconstitutional in 2015 and was temporarily superseded by the 1974 Water law in the interim (ADB 2016).

[2] The transfer of authority between central and local governments is based on three patterns and defined as: (i) Decentralisation – The transfer of power by the government to the autonomous region government to regulate and administer the affair of the government in the system of Indonesia, (ii) Deconcentration – The delegation of government authority by the government to the governor as representative of the government and/or the vertical institutions in a particular region, and (iii) Coadministration – The assignment from a higher-level to a lower-level government to carry out a specific task or assignment with funding and other resources. This can be from the central government to the province (or lower), from provincial governments to the district, city, village, or from the district or city governments to the village.

The 2019 water law specifies that all water resources within Indonesia are to be controlled by the State and administered by the government as a public good, in keeping with Article 33 of the 1945 Constitution. In reaffirming the State's role in controlling and managing water as a public good, the 2019 law is meant to alleviate some of the nation's challenges in providing clean drinking water to all, which are claimed by some to have been exacerbated by provisions in the 2004 water law allowing for privatisation and commercialisation of water resources (GWP, 2018). The law now sets 9 priorities for how the state is to ensure provision of water to the public ahead of commercial interests (Assegaf et al. 2019; Muryanti and Sasongko 2019):

- Absolute priority is to be given to ensuring that each person is provided with enough water for basic daily needs, specified as a minimum of 60 litres/day.
- The second priority is to ensure sufficient water (not specified) for public irrigation systems, including smallholder systems.
- The third highest priority is to ensure sufficient water for functioning public drinking water supply systems.
- The eighth and ninth, and therefore lowest priorities under the law, centre around providing water to state, regional or district-owned business enterprises, followed by water to private business entities. Provision of water to these two commercial categories is to be on a basis that all other higher priorities have been first fulfilled.

Two other national laws - *Law No. 32 on Regional Government* and *Law No. 33 on Fiscal Balance between the Center and the Region* – interact with the new water resource law to split water resource management planning and fiscal responsibility between the State, provincial and district/ city governments. The national government is to retain the right for setting and levying water delivery fees on inter-provincial rivers or rivers deemed of national strategic interest, and laying out the standards and procedures to guide subnational water management. The subnational governments are responsible for drawing up management plans; these plans are now required to include considerations of watershed ecosystem health and capacity, biodiversity regulations and climate change. The plans may be developed as standalone plans or integrated into socioeconomic development plans. Local governments also have the mandate to provide local water services and control the local water utilities (PDAMs). Although the 2019 Water Law requires local governments to incorporate 'considerations of climate change' into their decisions but there is little guidance within supporting explanation of how to do this within the regulations.

Several other national ministries are involved in water management, including quality monitoring and management. National-level government bodies set quality targets for individual rivers and local governments may make more stringent regulations. The Ministry of Environment and Forestry (MoEF) is charged with management plans and water quality control for all water resources falling within nature reserves, forests and coastal areas through two other pieces of legislation. The Ministry of Energy and Mineral Resources is charged with administering deep groundwater sources. Meanwhile, the Ministry of Public Works has oversight of dams and reservoirs, rivers and lakes, and shallow groundwater basins. The RPJMN 2020-24 notes, 'the synchronization of planning and implementation is also complicated by the large number of planning documents issued by various agencies, both at the national, provincial and district / city levels, and there is no single sectoral planning document reference. For example, there are Regional Action Plan (RAD) documents, the *Water Supply System Development Master Plan* (RISPAM), individual District / City Sanitation Strategy (SSK), and Policy and Strategic (Jakstra) for water and sanitation sector planning' (Bappenas 2019b: 138).

Other governance-related issues contributing to water scarcity and water sector vulnerability in Indonesia include an under-investment in piped or improved water supplies by local governments; roughly 71% of local government areas did not provide the investment needed to meet the *National Water Resources Management Policy* that set targets to the Millennium Development Goals by 2015 (Ehrhardt et al. 2010; ADB 2012). Providing piped water is often not a local government priority particularly where households are able to pump local groundwater supplies, or where the local government and its associated service providers are not publicly accountable (Ehrhardt et al. 2010). The financial situation of many of the local government-operated water supply companies deteriorated, along with piped coverage for urban residents. Between 2000 and 2010, piped coverage in urban areas declined from 39% of the population to 31% and ~70% of the water supply companies became indebted with loans in arrears to the Ministry of Finance (ADB 2012). Additionally, while water quality regulations set forth by the Ministry of Environment and Forest and Ministry of Health are strong on paper, financing issues also directly impact their ability to enforce pollution regulations at the national and sub-national levels as do the coordination challenges that have arisen due to decentralisation (ADB 2012; Bedner 2010).

Another challenge is related to actual monitoring of supplies and water quality; there is little sharing of data and information between various government institutions, and with and between private water companies or community water enterprises due to no clear policy framework mandating sharing (van der Kerk et al. 2013). Existing datasets are unreliable due to monitoring and reporting differences between various water authorities (ADB, 2012). Some streamflow and pollution monitoring exists on individual river basins as the result of academic or internationally-funded studies, for example the Java Water Resources Strategic Study (Deltares et al. 2012), but longitudinal maintenance of monitoring in individual studies cannot be guaranteed. Monitoring of water supply and quality are noted challenges and priority areas under the RPJMN 2020-2024. Poor monitoring and communication of actual physical supplies along with their quality inhibits demand-side planning and management, and may contribute to maladaptation under a changing climate. The discrepancies in supplies are noted in chapter 3.2.1. Localised water scarcity for domestic and industrial use is also influenced by additional factors, including demand versus supply, land-use change and pollution; these topics are explored further in chapter 3.2.

Given the recent adoption of the new water law and required clarification about how some of its provisions might be enacted, local water resource management plans and annual water allocation plans still may not be easily integrated across different provinces and districts, and co-management is more difficult. The poor coordination of water governance activities across the government jurisdictional levels contributes to Indonesia's water sector vulnerability and is acknowledged as a serious issue within the RPJMN 2020-24.

3.2 Water Supply and Demand Management

3.2.1 Supply

Indonesia has significant ground and surface water supplies, but these are not shared equally by all the provinces and there is considerable annual and decadal precipitation variability, due to natural climate processes like the El Niño Southern Oscillation or the Pacific Decadal Oscillation (see chapter 4.1 for more information on climate). Tracking of natural variations in supply through space and time are critical for Indonesian efforts at building water security in the face of changing demands, land-use change and climate change.

Good water governance for balancing supplies with demands and environmental needs (e.g. peatland or streamflows for aquatic life) ideally draws from long observational records of ground and surface water sources. Indonesia's historical and current water governance issues discussed previously mean, however, that estimates of surface and groundwater supplies across Eco-regions vary widely in official studies by government and academic researchers due to limited historical data and lack of uniform monitoring methods – see Table 3. The lack of consistent, long-term observational data for both surface and groundwater sources also presents a challenge for assessing water-climate risks within the context of rapidly shifting water demand and land-use change for agriculture, industry and urbanisation.

Table 3: Estimates of Indonesian surface and groundwater availability according to different studies.

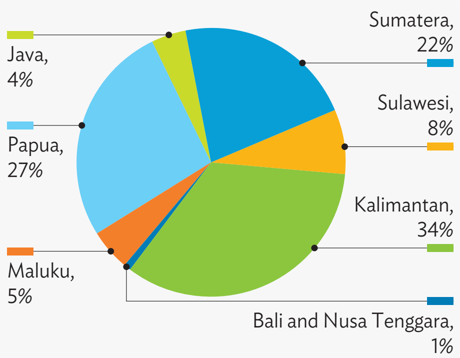
Source/Data	FAO AQUASTAT (2014)	FAO (2003)	Radhika et al. (2017)	Hatmoko et al. (2010)	ADB (2016)
Surface water (10^9 m^3/year)	1,973	2,793	2,780	3,900	3,900*
Groundwater (10^9 m^3/year)	457.4	455			520†

* Uses Hatmoko et al. (2010) figures.
† Uses government sources dating from 2001 and 2008.

There are approximately 8,000 watersheds. A 2010 Water Resources Research Agency study estimated *surface* supplies to be at 3,900 x 10^9 m^3 per year; the same authors revised the estimate to 2,780 x 10^9 m^3 per year in 2017 using satellite data. The official government figures on total available surface water supplies remains the 2010 value per year – see Tables 3 and 4, which is considerably higher than other estimates (Radhika et al. 2017). The use of higher surface water estimates when planning demand allocations might lead to over-allocation of water resources that do not exist on a multi-decadal basis and contribute to water scarcity for some regions in the face of climate change[3].

Table 4: Estimated surface water availability, using higher-end estimates (Hatmoko et al 2012 in ADB 2016).

Islands	Water Availability (million m^3/year) Qaverage	Q80%	Q90%
Java	164	88.909	69.791
Sumatera	840.737	571.703	485.732
Sulawesi	299.218	184.478	154.561
Kalimantan	1,314,021	900.381	727.301
Bali and Nusa Tenggara	49.62	35.632	32.165
Maluku	176.726	132.103	117.296
Papua	1,062,154	794.496	716.443
Total Indonesia	**3,906,476**	**2,707,702**	**2,303,289**



m^3 = cubic meter, Q = quarter.
Source: W. Hatmoko et al. 2012. *Water Balance of Water Availability and Water Demand in Indonesia River Basins, Water Resources Research Agency, Bandung* (Neraca Ketersediaan dan Kebutuhan Air pada Wilayah Sungai di Indonesia Puslitbang SDA Bandung).

[3] The Colorado River Basin in the United States provides a cautionary tale. The Colorado River Compact, regulating water allotments to seven US states, was negotiated in 1922 after a period of above average river flows that were not reflective of the actual long-term average. As a result, more water was allocated to the states for use than is often physically available in the river. Population growth, increasing water demand and climate variability are straining ecosystems in the region and contributing to the risk of water insecurity (Opitz-Stapleton 2017).

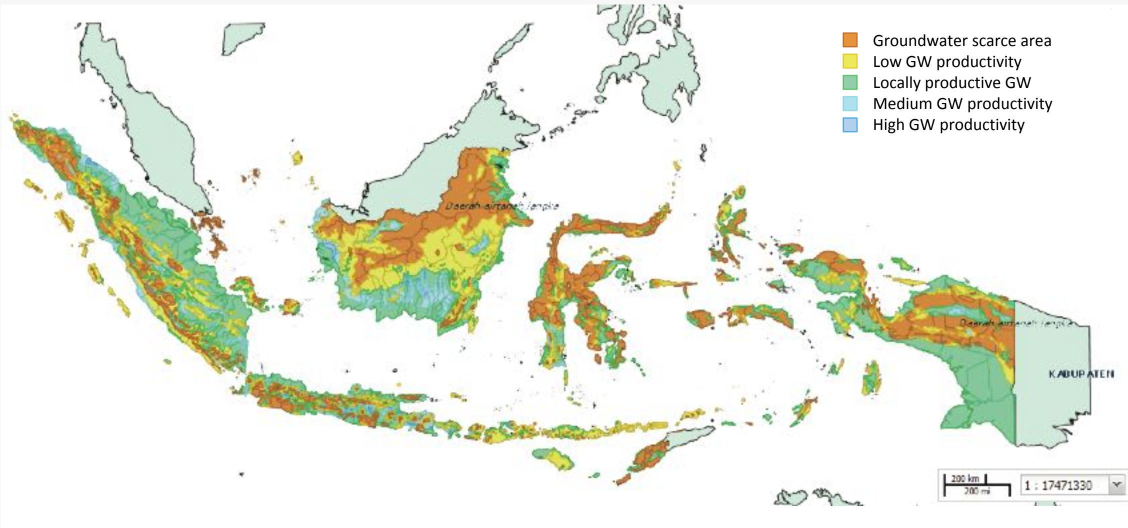
Per capita reservoir water storage capacity remains lower than other Asian countries, and currently is unable to keep pace with population increases (ADB 2016). The National Water Resource Council estimated 2018 water storage to amount to 68 m^3 per capita per year, well below the 1000 m^3 per capita per year threshold that the government considers necessary to provide an adequate buffer to drought and flooding. The central government announced ambitious plans in 2016 to construct 65 new reservoirs and restore several lakes by 2019 with the goal of bringing total storage to 20.7 billion m^3 compared with ~12.6 billion m^3 in 2014 (ADB 2016). The larger of the planned reservoirs are to serve as multi-function – hydropower, irrigation and flood control (Indonesia Investments 2016).

As of 2020, many of the planned reservoirs had not been constructed. The RPJMN 2020-2024 now specifies that the 65 dams should be completed by the end of the five-year planning period (Bappenas 2019b: 141). A rapid review of water-related infrastructure projects completed by 2019 for each of the islands as reported under the Peta Infrastruktur 2019 database indicates the following island-specific reservoirs have been completed or are planned (presumed to be in tendering or construction phase – see Table 5). The majority of planned multi-purpose water storage will occur in the two of the most water-scare islands – Java (also densely populated) and Sulawesi – and the densely populated island of Sumatra. High rates of sedimentation, discussed further in chapters 3.4 and 3.5, is silting existing reservoirs, of all sizes from irrigation dams to larger reservoirs, and decreasing their overall storage capacity. The reduced capacity in turn contributes to water scarcity during the dry season and drought, and flooding.

Table 5: Irrigation dam and large-scale reservoir infrastructure by island grouping according to the PETA Infrastruktur Indonesia Tahun 2019. Aggregate total planned additional storage volume is ~4.6 billion m3 or about half the planned expansion of 8.2 billion m^3. Note: Total flood control volume of an individual reservoir is designed to exceed its active storage volume; this amount represents the maximum amount of water a reservoir could hold in order to buffer the impact of flood waves. Data compiled by the authors from the infrastructure maps and rounded to the nearest decimal. (Source: authors' compilation from MoPWPH, 2020).

Island	Total Active Storage Volume (million m^3)	Flood Control Volume (million m^3)	Irrigation Potential (ha)	MHW
Sumatra				
completed			125,806	
planned	969.5	2821.3	25,370	8.3
Java				
completed			654,088	
planned	1504.7	1477.8	97,890	29.4
Bali and Nusa Tenggara				
completed	24.5	21.4	~1790	0.35
planned	75.8	20.48	3939	0.5
Kalimantan				
completed			4351	
planned	916.6	92.1	9972	4.7
Sulawesi				
completed				
planned	1145.9	275.6	25,142	12.3
Maluku Papua				
completed				
planned	15	471	10,000	6

ADB (2016) determined total safe extractable *groundwater* to be 155 billion m^3/yr, using a threshold of 30% of available resources, whereas FAO (2014) assumes 137.2 billion m^3/yr. The official estimates of safe extractable groundwater are based on older (2001 and 2008) estimates that might not actually reflect current conditions – see Figure 2 (ibid). While the RPJMN 2020-2024 does not specify what amounts are considered 'safe extraction limits', it specifically notes that groundwater extractions are currently meeting 46% of the population's domestic water needs and that these amounts are unsustainable, while contributing to land subsidence in some areas' (Bappenas, 2019:141). The RPJMN is prioritising bringing more of the population onto piped water supplies and increasing reservoir storage in order to reduce pressures on groundwater sources (see also chapter 3.3).



Region	Number of basins	Area (km^2)	Quantity (million m^3/year)		
			Unconfined	Confined	Safe Yield
Sumatera	65	272,843	123,528	6,551	39,024
Java and Madura	80	81,147	38,851	2,046	12,269
Kalimantan	22	181,362	67,963	1,102	20,720
Sulawesi	91	37,778	19,694	550	6,073
Bali	8	4,381	1,577	21	479
West Nusa Tenggara	9	9,475	1,908	107	605
East Nusa Tenggara	38	31,929	8,229	200	2,529
Maluku	68	2,583	11,943	1,231	3,952
Papua	40	26,287	222,524	9,098	69,487
Total	**421**	**907,615**	**496,217**	**20,906**	**155,137**

GW = groundwater, m^3 = cubic meter.

Sources: Geological Agency 2008; Bakusurtanal 2001; and Sistem Informasi Air Tanah Badan Geologi—PSDGATL. http://airtanah.bgl.esdm.go.id/?q=content/peta-hidrogeologi-indonesia (accessed October 2014).

Figure 2: Believed groundwater supplies by aquifer type and major Eco-region. Source: ADB 2016: 20

3.3 Demand and Scarcity

Combined with estimated population growth rates, increased water demand will cause severe water shortages to occur, especially in Java and Sumatra. This unequal spatial distribution of demand compared with location of supply, along with the current water governance coordination, planning and enforcement challenges are also dominant factors contributing to current localized water scarcity issues (ADB 2016). For instance, Kalimantan and Papua have nearly 70% of the national water resources estimated at 690 x 10^9 m^3 and only 13% of the population.

Urban and rural domestic water demand - a country-wide average of ~32% of all households - access untreated groundwater through privately dug borewells for domestic supply; they do not have reliable, centralised piped water through a government or private utility supplier (ADB 2016; Nastiti et al. 2017). Many other households purchase bottled water or rely on standpipes and water tankers, including in major cities such as Jakarta, Medan, Semarang and Bandung (ADB 2012). The RPJMN 2020-2024 estimates that 46% of households access groundwater for domestic supply, with a further 28% utilising shallow springs or ponds, lakes, rivers (Bappenas 2019b: 141). Piped drinking water services are estimated to reach only ~20.3% of the population (ibid. and see Figure 3).

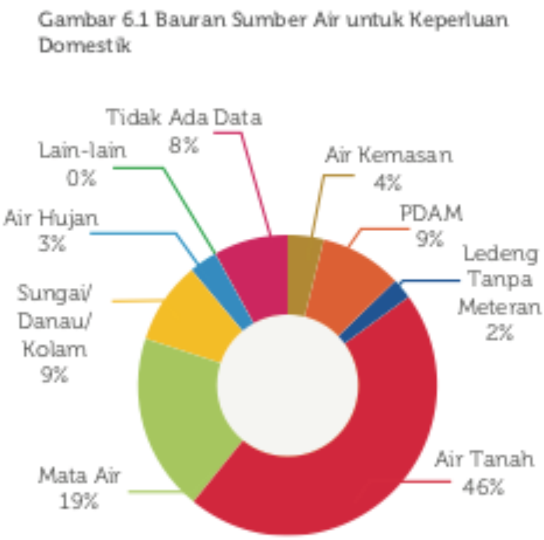


Figure 3: Mixture of water resources currently used to meet domestic purposes. (Source: Figure 6.1 of the RPJMN 2020-2024. Bappenas, 2019b:141).

Localised water insecurity is problematic in several islands, particularly during the dry season or periods of low rainfall. In Java, water insecurity is 'frequently caused by inadequate management of services and utility infrastructure, exacerbated by continuous degradation of infrastructure and catchments' (Deltares et al. 2012: ii). Bappenas also note that many of the PDAMs levy such low tariffs that they are unable to cover costs and are not adequately maintaining infrastructure, this 'results in a high level of water loss (non-revenue water or NRW) of 33 percent (2019b: 140). Only 60% of PDAMs are operating at break-even or profitable margins (ibid.).

Growth in demand that outstrips supply is becoming evident in tourism hotspots such as Bali, and is again related to poor water governance, including the inability of local governments to invest in and maintain piped water infrastructure. Large hotels and other tourist destinations can afford to dig deep wells for pumping groundwater to meet tourism demand, but doing so is: 1) creating water scarcity for local households reliant on their own shallow wells who can no longer access the deep water tables; 2) depleting shallow aquifers whose high water tables support the base flows of the rivers and large streams that supply rice farm irrigation; and 3) depleting water resources faster than they are replenished by precipitation (Cole and Browne 2015; Rai et al. 2015).

Agriculture currently accounts for nearly 70% of demand – yet, with the exception of rice, most crops are rainfed. Rice, maize, cassava, soybeans, groundnuts, oil palm, bananas, coffee and cocoa represented 86% of total water use, 71% of production value and 86% of total agricultural land between 2000-04 (Bulsink et al. 2010). The provinces with highest water footprints for rice are: Java - 2800 m^3/ton; Sumatra Utara - 3900 m^3/ton; and Sulawesi Selatan - 3800 m^3/ton. Java has relatively high yields and moderate evapotranspiration, which is the reason for its relatively lower footprint than the other two. The highest virtual water exporters (through crops) are Sulawesi Selatan, Sumatera Barat and Nanggroe Aceh D, with a combined 82% of total cross-province water flows within Indonesia (ibid.). The largest water importers are Jakarta, Java Barat, Riau and Banten, importing 55% of national cross-province totals. Riau exports a lot of coconut and palm oil, but imports rice and cassava. Sumatra exports virtual water internationally through palm oil, coffee and coconut oil. For Indonesia, as a whole palm oil exports accounts for 60% of international water virtual flows, with cocoa, coffee and coconuts also contributing to international virtual water exports (ibid.).

Commercial palm oil plantations are currently not widely irrigated. Additionally, oil plantations have grown in acreage significantly since 2004, and peatland drainage for this has accelerated (see chapter 3.4 on land use change). Palm oil processing is also water intensive; 1 ton of palm oil requires 6.7 m^2 of water for processing alone (ADB 2016). Rural farming is shifting, with many moving to work as farmers in commercial farming activities, rather than subsistence. This is changing rural demographics, land ownership and may lead to farming intensification. If more commercial farming operations are expected (or encouraged) for the future, Indonesia will have to think carefully about implications for water resources management.

The total water demand for domestic, agricultural and industrial uses is growing, in part due to population growth and shifting economic activities. In the SD model, an estimate of 147 litres/capita/day (l/c/d) is used (January 2019 LCDI workshop) for domestic use. However, ADB (2016) estimate that the total water demand (excluding water for the environment), is much higher at ~1,880 litres/capita/day when agricultural demands are combined with domestic and industrial demands. Urban water demand is projected to increase from ~240 m^3/s to ~280 m^3/s by 2030 through population increase alone (assuming no change in consumption per capita), though rural domestic needs are projected to decline (based on the sole assumption of 120 l/c/d in urban areas and 80 for rural - ADB 2016).

Estimates in the RPJMN 2020-2024 (Bappenas, 2019b: 22) shows that areas with water availability considered ‘scarce’ or ‘critical’ will increase from 6% in 2000 to 9.6% in 2045. While most of Java and Bali islands are presently considered water critical, Sumatra, West Nusa Tenggara and southern Sulawesi will be added to this list by 2045. Other regions will also be under increased water scarcity pressure due to the impacts of climate change. Recognising the interdependencies between the forest and water sectors, the RPJMN 2020-2024 has set a target to maintain a minimum of 175.5 million ha of national areas with ‘safe’ water (around 93% of the total land), and an individual water availability target above 1,000 m3 / capita / year on each of the country’s constituent islands by 2045 (Bappenas 2019b: 22). Chapter 3.4 discusses Indonesia’s deforestation challenges.

3.4 Land-use Change

Urbanisation has resulted in increased river discharge rates and surface runoff due to loss of impervious surface for rainwater infiltration, and higher flood risk in basins such as the Goseng and the Citarum (Nugroho et al. 2013; ADB 2007; Emam et al. 2016). Of the studies reviewed, land-use conversion is currently attributed to having a far more significant impact on streamflows and flood risks than climate change; with 72% of increased streamflow in the Samin catchment in Java attributable to land-use change (Marhaento et al. 2017).

Decreased forest and peatland cover due to conversion for agriculture and urban expansion alter the buffering capacity of rivers and leading to higher wet season flows and lower flows during the dry season (ADB 2016, 2007; Marhaento et al. 2017). Deforestation in Indonesia continues at an alarming rate of 480,000 hectares (ha) in 2017, albeit decreasing from an average of 1 million ha/year between 1990 and 2017 (Bappenas, 2019b). Out of the 189 million ha of total land surface, forest cover is projected to reduce to 72 million ha by 2045 (38% of total land area) from 94.8 million in 2017 (50% of total land area) (ibid.). Primary forest cover, including peatland forests, decreased from 52.5 million ha (27.7% of total land area) in 2000 to 43 million ha (22.6% of total land area) in 2019. Without significant intervention, nearly 7% of primary forests (around 4 million ha) will be lost by 2024; by 2045 almost a quarter of primary forest will be wiped out compared to 2019 (ibid.) – see Table 6.

Table 6: RPJMN 2020-2024 projected deforestation rates under base scenario (current trends). Source: authors' assessment based on Bappenas, 2019b

Forest type	Past	Current	2024 (projected)	2045 (projected)
Total forest (ha)		94.8 million (2017)		72 million
Primary forest including peatland forest (ha)	52.5 million (2000)	43 million (2019)	39 million	34.8 million

Widespread peatland drainage and logging, leading to degradation and conversion have been noted since the 1980s in some areas, such as what became the Ex-Mega Rice Project in Central Kalimantan[4] in which nearly half a million hectares was destroyed between 1995-1997 (Houterman and Ritzema, 2009; Hooijer et al. 2014). The pace of peatland destruction has increased dramatically between 1985 and the present, driven largely by expansion of oil palm plantations – see Figure 4 (Miettinen et al. 2012). The most recent data from the RPJMN 2020-2024 (Bappenas, 2019b: 19) shows that, albeit decelerating, peatland forest cover loss has continued, decreasing from 9.2 million hectares in 2000 (60.7% of total peatland area) to 7.5 million hectares in 2015 (49.5% of total peatland area) – see Table 7. This conversion of primary natural forest and peatlands to other uses is approximately equivalent to 5 times the area of Bali.

[4] The Ex-Mega Rice Project in Central Kalimantan was an expanded peatland drainage and conversion project during the 1990s under the Suharto government, with the aim of making Kalimantan the dominant rice producing region. The region started experiencing limited land conversion with settlement in the 1920s, and drainage accelerated under government programmes in the 1970s and 80s. The EMRP was halted in 1999 due to local and international opposition (Houterman and Ritzema 2009).

Table 7: Changes in forested peatland area (source: Bappenas 2019, p.19)

Island	Peatland area (ha)	Forested peatland area			
		2000		2015	
		ha	%	ha	%
Sumatra	4,120,325	1,789,500	43.43	837,675	20.33
Kalimantan	4,694,625	2,545,300	54.22	1,871,000	39.87
Papua	6,376,975	4,896,300	76.78	4,817,275	75.54
Total	**15,191,925**	**9,231,100**	**60.76**	**7,526,750**	**49.54**

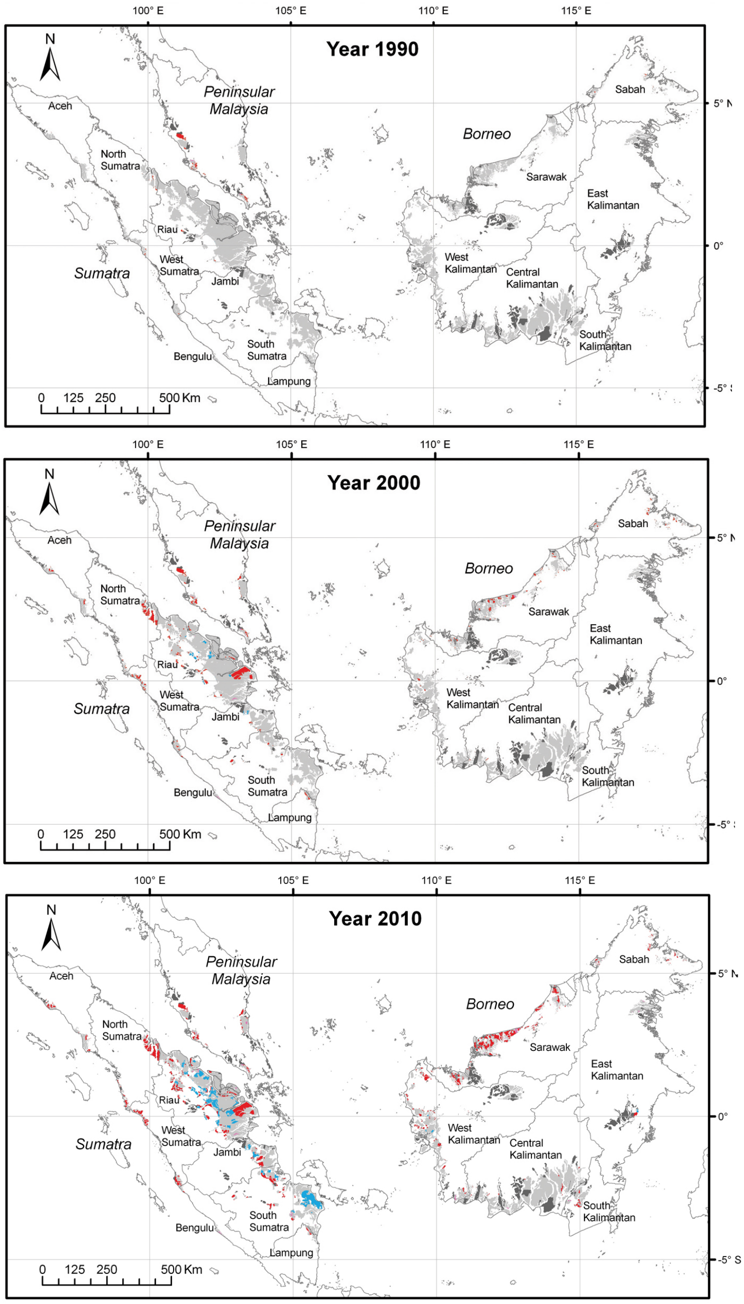


Figure 4 :Peatland drainage and deforestation for oil palm and other agricultural activities. Source: Miettinen et al. 2012: Fig 3.

Case studies such as Nugroho et al. (2013), Agaton et al. (2016), Suwarno et al. (2013) and Ritzema et al. (2014) indicate that land-use change is one of the most dominant drivers of changes in both surface and groundwater flow and quality. Drainage of peatlands for conversion to agriculture disrupts area hydrologies and ultimately contributes to local water scarcity, as well as increasing vulnerabilities to drought. As water tables are high in many peatland areas, drainage canals and piping are necessary to prevent agricultural lands from being inundated (Miettinen et al. 2012). Additionally, the drainage increases the vulnerability of peatlands to out-of-control, agricultural fires during hot and dry conditions, such as those prevalent during some El Niño cycles. These fires in turn contribute to significant greenhouse gas emission releases and can trigger a complete shift to a new ecosystem type (Kettridge et al. 2015).

The Indonesian government has taken a number of measures to conserve, rehabilitate and restore forests. A forest moratorium was introduced in 2011 to temporarily suspend (2 years) the issuance of new concessions for the utilisation of forest resources. A map was produced by the Ministry of Environment and Forestry to indicatively locate the areas under the moratorium ('the Moratorium Map'), covering an area of 66.4 million ha (Bappenas 2019a: 79). Since then, the moratorium has been rolled over on a regular basis. Yet, the moratorium has not been able to fully prevent deforestation and degradation: between 2011 and 2017, 3 million ha of primary forest and peatland has been converted (Bappenas, 2019b). A series of limitations affect the moratorium, namely i) 3.5 million ha of primary and peat forests are not included in the Moratorium Map; ii) the moratorium provides limited additional legal protection beyond what is provided by pre-existing laws and regulations (only 26% of the Moratorium Map enjoys additional legal protection); and iii) the exclusion of secondary forests (Bappenas, 2019a).

Between 2015 and 2019, the government has also embarked on a process of rehabilitation and restoration of various forest and water ecosystems, though progress has been slow. It has rehabilitated 1.5 million ha of forest and land out of a target of 5.5 million ha, recovered 11 conservation areas out of 134 targeted areas, as well as made some progress in restoring 15 priority watersheds and 15 priority lakes (Bappenas 2019b). Moving ahead, the RPJMN 2020-2024 has set a 'red line' of 43 million ha of primary forest cover and 94 million ha of total forest cover (the same area of 2019) to be maintained by 2025, as well as the implementation of 2 million ha of reforestation and 1.5 million ha of peat ecosystem restoration (Bappenas, 2019b: 273-274).

3.5 Pollution

Water quality is poor for most surface bodies, with few able to obtain compliance with national or local targets (ADB 2016). Sedimentation and agricultural runoff (most widespread), followed by industrial and urban runoff is leading to eutrophication and decreased water quality. Pollution of water sources in turn contributes to water scarcity issues. Much of Java's surface water is heavily contaminated, according to the Ministry of Forests and Environment.

Poor sanitation coverage is a significant source of pollution to both surface and groundwater supplies. Centralised sewage systems in urban areas are rare, and nearly non-existent in rural areas. Less than 5% of sewage is currently treated; the rest is discharged directly into surface and groundwater sources (ADB 2012; 2016). As of 2013, nearly 74% of urban households had on-site (communal or individual septic tanks - Darwati 2017) and ~80% of these are unlined septic tanks within 10-15 metres of drinking water borewells leading to cross-contamination from septic leach fields (ADB 2016). Less than 5% of sewage is currently treated; the rest is discharged directly into surface and groundwater sources leading to significant water quality issues. Rural areas have even lower access to toilets (~30%) or septic tanks (20% - ADB 2012). Poor solid waste management at the local level also frequently acts as a contaminant to water supplies, with trash frequently ending up in waterways (ADB 2012). As urban populations continue to rapidly grow, existing services are poorly suited to keep pace and expand with demand, further contributing to pollution and lack of improved water supply.

Rapid urbanisation is challenging efforts to achieve universal water and sanitation access, with population growth and densification rates outstripping government efforts to meet WASH targets under the RPMNJ 2015-2019 (World Bank 2017). Sanitation is not necessarily a priority for local governments; budget allocation and capacity of personnel remain low (Darwati 2017). In some major river basins, such as the Upper Citarum and Brantas, nearly 40% of water pollution was attributed to industrial sources in 2012 (ADB 2012). The poor water quality of many sources in itself contributes to water scarcity, as locally contaminate surface and groundwater supplies may be unfit for human consumption without significant treatment. Large influxes of tourists in tourism hotspots such as Bali and the Marine Tourism Park of the Gili Matra Islands (Lombok) without the water, sanitation and solid waste infrastructure in place to deal with the influxes is contributing to widespread water pollution in these areas (Kurniawan et al. 2016; Rai et al. 2015). Additionally, decades of uncontrolled groundwater pumping to meet domestic, agricultural and industrial demands has led to significant land subsidence in multiple cities, exacerbating coastal flooding and leading to saline intrusion into aquifers (Chaussard et al 2013; Marfai and Hizbaron 2011).

Lack of water treatment also presents challenges to the few centralised urban water utilities, who often use rivers for supply. This is concerning as few of Indonesia's rivers meet Class II[5] or higher water quality standards (approximately 68% are deemed heavily polluted), and many of its major lakes are hypereutrophic (ADB 2016). Poor populations in urban areas often have to wash and bathe in polluted surface sources (ADB 2012). This directly contributes significant health issues, water-borne and vector-borne, particularly for vulnerable populations like infants and children, the elderly, those with pre-existing health conditions and pregnant women. While the mortality rate for children under 5 years of age has declined from 84.3 per 1,000 births in 1990 to 26.4 in 2016 (UNDP 2019), progress in reducing child mortality is hindered by ongoing water quality, sewage and solid waste management issues. The pollutants also fuel algal blooms when combined with agriculture and industrial runoff in warm temperatures.

Loss of vegetation due to land-use change from urbanisation and peatland conversion is also exacerbating sedimentation as denuded lands are easily eroded, which in turn contributes to water quality issues (Anshori 2004). The location of degradation due to land-use change influences the types of water quality issues seen. Degradation in upper catchment areas and the loss of peatlands has been found to contribute high sediment loads to streams due to erosion (Deltares et al. 2012; Carlson et al. 2014) and lead to higher stream temperatures (Carlson et al. 2014). Streams draining newly planted palm oil plantations were found to have sediment concentrations between 4 and 550x the concentrations of intact forest streams in Kalimantan, and the runoff and sediments from plantations have high concentrations of fertilizers (ibid).

[5] Water quality is assessed under four classes, with Class I water deemed suitable for drinking water and domestic purposes and Class IV deemed only suitable for irrigation and industry.

The combined drivers of inadequate water governance; lack of investment in and failure to provide piped water supply and sanitation; poor solid waste management and pollution monitoring and control; growth in demand that does not match the temporal and spatial distribution of rainfall; and land-use change give rise to water vulnerabilities and inequalities across Indonesia. These vulnerabilities, in combination with exposures to climate-related hazards such as precipitation extremes, sea level rise and heat waves, give rise to a number of hydroclimatological risks. Such risks include the risk of water scarcity in different seasons, and that continues to grow in the face of dynamic vulnerability and climate change, and flood and drought risk. These are explored further in Chapter 5.

4 Climate hazards and climate change projections

Indonesia is exposed to a number of climate-related hazards, such as: high average day and nighttime temperatures; heat waves; precipitation extremes - rainfall deficiencies during the rainy season or excessive rainfall – spatially unequal across the country; and wave action during storms (Gov. of Indonesia 2018). Extensive rainfall deficits are common during certain types of El Niño events, and as a whole Indonesia's monsoons experience high multi-decadal variability linked with multi-decadal, large-scale ocean-atmosphere processes such as the Pacific Decadal Oscillation (Lee 2015).

Climate projections for Indonesia are derived from outputs of BMKG's climate modeling efforts under the Southeast Asia Regional Downscaling (SEACLID)/Coordinated Regional Downscaling EXperiment (CORDEX) project and from international climate literature, such as the recent IPCC (2018) *Special Report on Global Warming of 1.5°C*. The SEACLID/CORDEX project is a collaborative effort between multiple climate modelling institutes using different CMIP5 global climate models that are then downscaled using regional climate models to provide projections more relevant to Southeast Asia.

A prior report *Climate Risks and Adaptation: All Sectors Inception Report* (ODI 2019) and Bappenas' LCDI report (2019a) provide more detail about the greater range of climate changes that Indonesia could experience under different representative concentration pathways; we do not repeat that in this report. In summary, climate change is contributing to warming day and nighttime temperatures in all months and an increasing number of heat waves, as well as sea level rise. Precipitation variability, and the frequency, intensity, duration and spatial extent of rain extremes are likely to increase under climate change, including the potential for heavy rainfall and drought events in the same year (Gov. of Indonesia 2018; IPCC 2018). Warming ocean temperatures, sea level rise and ocean acidification will have impacts on coastal water resources, ecosystems and livelihoods and infrastructure.

Climate-related hazards act in conjunction with multiple non-climate related factors – contextual vulnerabilities and exposures due to water resource governance and management, land-use planning, pollution management and peatland-agricultural management – to create Indonesia's hydroclimatological risks. Some of the potential consequences (risks) to Indonesia's water security and risks related to climate hazards are highlighted in chapter 5.

5 Hydroclimatological Risks

5.1 Water security

The concept of water security is grounded on an overarching philosophy that seeks to appropriately manage water-related risks to people, economies and the ecosystems in a way that maintains peace and political stability (from Sayers et al. (2015) adapted from Grey and Sadoff (2007) and UN-Water (2013)). As such, water security provides an umbrella framework for the management of water related risks Figure 5.

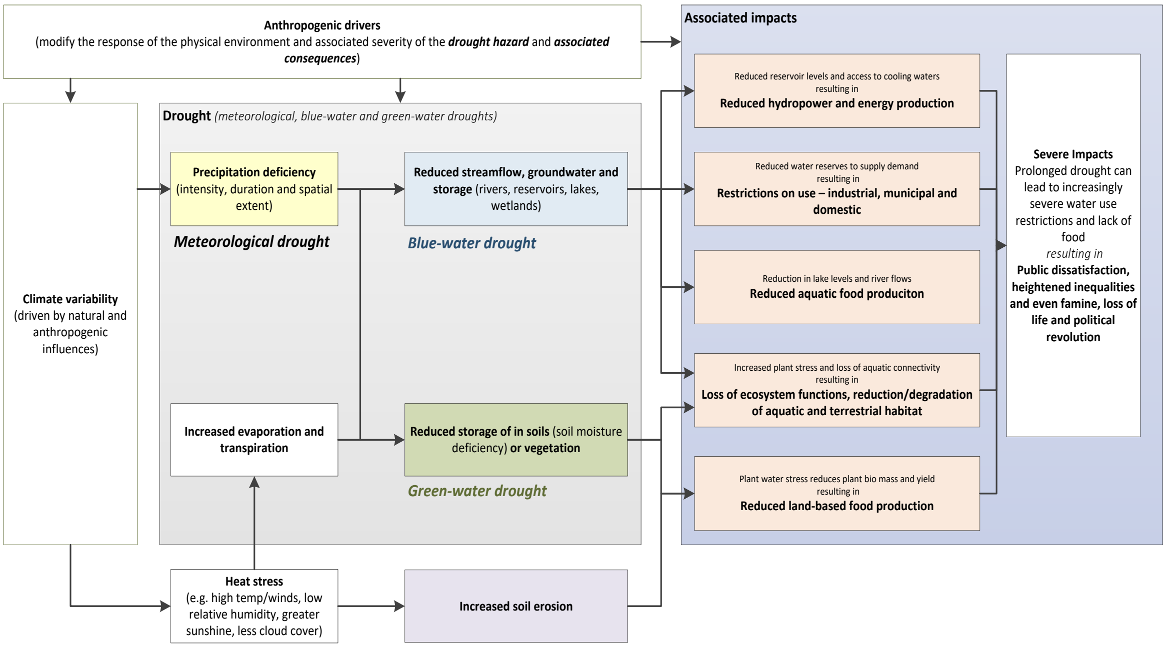


Figure 5: Defining water security, scarcity, drought and related concepts. Source: Sayers et al. 2015

In recent years, the RAN-API Secretariat has been conducting on-going studies in water sector using a water security lens including the development of a (water) Resilience Index. These studies are recognised as a first stage however, and more detailed analysis using the latest climate and socio-economic data along with more detailed hydrological system models will be needed to provide a credible assessment of the water security issues. In response to this issue, RAN-API Secretariat propose to further develop the water sector risk assessment focusing on water availability, drought and flood, and continue to develop a spatially disaggregated Resilience Index that considers issues of:

- Household Water Security
- Urban Water Security
- Environmental Water Security
- Economic Water Security
- Water-related Disaster

The goal of RAN-API water security resilience index approach is to develop a reference metric that can then be used to improve regulation and target investment in water sector. Ideally, this will be coordinated with ongoing activities by the Ministry of Public Works and Housing in conjunction with ADB and the World Bank.

5.1.1 Water resource related risks

The Country Water Assessment (CWA) provided by the ADB (ADB 2016) explores the balance between reliable and available water supplies and future demands for sustainable economic development in Indonesia. Although the focus of the CWA is restricted to Java, Sumatera, and Sulawesi - Indonesia's three main economic regions - it acts to highlight several important water resource related issues. These together with those identified from supporting literature highlight a number of risks to Indonesia's water security that can be exacerbated by climate change. For both surface and groundwater resources, higher temperatures and increasing precipitation variability, including the potential drying of some islands in the future under various climate change scenarios, along with the identified challenges below, can reduce supply reliability.

Groundwater resources – The combination of a projected increased variability in the precipitation, increased demand and pollution as well as a decreasing opportunity for infiltration, due loss of wetlands and forests and increases of impervious urban surface, will continue to reduce aquifer recharge and exacerbate groundwater depletion. Saline intrusion into coast aquifers as groundwater levels lows and sea level rise lead to further deterioration or available resources (ADB 2016; Deltares 2012). In response, coastal peatlands are sinking due to a combination of overdraft of groundwater supplies and peatland drainage; presenting an increasingly difficult challenge for coastal towns and cities. This is including, but not limited to, Jakarta where in the past few decades urban development has reduced urban green space necessary for groundwater infiltration and recharge from 35 per cent to 9.3 per cent and, similarly within the related catchments, many wetlands have been converted to industrial estates and urban development (Ismail 2016).

Surface water resources (rivers, lakes and reservoirs) - Indonesia has a total reservoir capacity of about 52.55 m^3 per capita; this is very small compared to other countries in Asia (ADB, 2016). During the previous RPJMN period (2014-2019), the government planned to build 65 new reservoirs for a capacity of 82 billion m^3 and increase the water availability per capita to 76.4 m^3 (see chapter 3.2.1 on supply).

When considered alongside difficulties in regulatory enforcement (and allocation) of environmental flows, the continued expansion of surface water storage reservoirs and peatland drainage has the potential to cause significant environmental degradation and emissions (Itoh et al. 2017). Without associated improvements in catchment management, it is also likely that sedimentation, due to poor upstream catchment management and deforestation, will reduce reservoir storage volume (existing and planned). Additionally, pollution from agricultural run-off and mining, as well as many industrial activities disposing the waste directly into rivers may significantly impact associated water quality (Seta et al. 2017), impacting water security for domestic and agricultural users relying on the reservoirs. Warmer water temperatures, associated with the potential for increased numbers of heat waves under climate change, and lower river flows – due to the combined action of increased rainfall variability and drying in some locations, withdrawals, and higher rates of evaporation – can also concentrate pollutants and worsen water quality situations.

The tabled LCDI development report highlights that agricultural expansion is a key priority for future economic development (Bappenas 2019a). Future expansion of agricultural area and agricultural irrigation (Rusastra and Simatupang 2016), as well as changing socio-economic development, will place new demands on surface water and groundwater sources.

Island water resources - increased water scarcity, particularly in locations in Java or that are priorities for tourism expansion, and agricultural expansion due to demand increases overlaid with increasing precipitation variability, greater likelihood of below average rainfall in some areas and warmer temperatures. Potential overestimation of available water supplies, particularly under a shifting climate and hydroclimatological hazards (such as flooding and drought), could to lead to maladaptation in the water sector, and the related sectors of agriculture, energy, forestry, land-use, and urbanisation.

Cross cutting resource challenges

Abstractions (both legal and illegal) and environmental flow enforcement - for both agricultural, industrial and domestic primarily and a lack of enforcement for environmental flows has lowered stream flows and continue to degrade freshwater ecosystem health. decreasing water quality due to lower instream flows (rivers, lakes and streams) and in groundwater. Causes: pollution (agricultural, urban and industrial runoff), land use change (sedimentation + forest fire ash deposition – need to understand where the fallout clouds are), poorly coordinated water diversions + more precipitation variability and higher temperatures. Secondary risks: algal blooms and eutrophication, leading to aquatic species die-off and species flipping, impacting fishing and water ecosystem services, including pollution filtering and nutrient cycling.

Higher water temperatures as a decreased water quality in reservoirs and other surface water bodies. Causes: over-abstraction leading to reduced instream flows + warmer water temperatures and/or less precipitation. Secondary risks: algal blooms and eutrophication, leading to aquatic species die-off and species flipping, impacting fishing and water ecosystem services, including pollution filtering and nutrient cycling; damage to infrastructure like hydropower.

5.2 Coastal and Riverine Flood Risks

With 81,000 km of coastline and 42 million people living on low-lying land less than 10 meters above sea level, Indonesia coastal floodplains are vast and face two significant threats: sea level rise and land subsidence. Although climate change is likely to influence an array of infrastructure (from rail and highways, to communications and power supply – Table 8) the impact on coastal protection infrastructure is highlighted here.

Table 8: Matrix of potential climate change risks for transportation infrastructures

Climate Hazard	Roads	Railways	Ports and Waterways	Airports
Temperature Changes	• Rapid asphalt deterioration • Substructure damage • Increase operation and maintenance costs.	• Expansion and buckling of railway tracks and joints	• Thermal expansion of bridge joints, paved surfaces	• Asphalt deterioration on runway • Concrete damage • Increased cooling costs

Precipitation changes	• Increased flooding of roadways • Increased erosion • Construction damage	• Increased flooding of stations	• Channel closure due to increased silt deposition due to flooding • Reduced navigability	• Travel disruption due to flooding • Damage to airport infrastructure due to inundation
Sea Level Rise	Permanent inundation of road, port, and airport infrastructure			

The combination of peatland drainage, groundwater extraction and sea level rise (SLR) pose significant threats of flooding to coastal cities. Some coastal areas, for example, in Java and Sumatra are sinking on average 10-20 cm a year (Deltares 2012; ADB 2016). Primary causes are peatland drainage for agriculture and groundwater abstractions by industry and households for water supply. In combination with SLR the potential impact on coastal cities is, in the absence of significant investment in adaptation, likely to be significant (Table 9).

Table 9: Expansion of potential flood area in Jakarta from 2000 to 2025, 2050 (Takagi et al. 2015)

Time span	Factors considered	Flooded area deeper than 1.0 m
2000–2050	Sea-level rise	12.9 km^2
2000–2025	Sea-level rise + land subsidence	25.7 km^2
2000–2050	Sea-level rise + land subsidence	110.5 km^2

Surface water flooding, in response to intense rainfall, and river flooding is also increasingly difficult to manage as ground levels sink. The conventional response to coastal flooding has been to pursuing the development of ‘hard’ infrastructure (including sea walls and embankments). In Jakarta for example, the focus has been on the development the Jakarta seawall project; however, subsistence is already lowing the design crest levels and when compounded by SLR the standard of protection provided is likely to be significantly eroded in the coming decades (personal communication with Deltares). In the SD model, the coastal peatland subsidence is calculated to be a national average of 5 cm/yr without intervention due to drainage of peatlands.

The higher sediment loads from land-use change induced erosion also contribute to flood risks as canals, river beds and reservoirs lose their carrying capacities. Flood risks are exacerbated in many urban areas, such as Jakarta and Semarang, by land subsidence which when coupled with sedimentation, has allowed many of the riverbeds to be higher than the surrounding land (Marfai and Hizbaron 2011).

6 Risk Management and Adaptation

As explored previously, Indonesia is facing a number of water sector risks that are being exacerbated and altered due to climate change. The government of Indonesia is starting to integrate natural hazard and climate risks into the development policies and plans, including through mitigation and adaptation initiatives, to overall address issues related to water scarcity in order to gain water security. Much work remains to be done in both understanding risks on an Eco-region level and in developing, implementing and monitoring effective, low carbon adaptation options that can improve water security and reduce flood and drought risks.

The first phase of the LCDI identified the need for strategic climate risk and adaptation assessment in the water sector, especially for the next phase of the LCDI (implementation phase). Total water demand growth coupled with potential declines in surface and groundwater supplies due to climate change, and thus implications for water scarcity, may be seriously underestimated in the SD model in the LCDI for the development of the RPJMN and Visi2045. Future background studies on the water sector that will inform future medium and long-term planning need to consider potentially higher growth in demand and scenarios of reduced supply.

The following chapters briefly explore (i) some considerations when choosing adaptation options, (ii) an iterative costing framework for identifying and appraising adaptation options in light of identified risks, and (iii) approaches taken to cost adaptation options.

6.1 Considerations when choosing adaptation options

Dealing with uncertainty in adaptation planning

Uncertainty is inherent in any type of investment or plan, be it from financing and managing economies to personal lives; it should not be used as a barrier excuse for adaptation planning. There is inherent uncertainty in future climate risks given incomplete knowledge of how socio-economic, political, cultural, technological and environmental (including climate) systems might change, and uncertainty grows the farther into the future one hopes adaptation options (e.g. infrastructure) might last. Some adaptation options like those associated with building stronger water governance or solid waste management programmes can be made today and do not need to account much for degrees of uncertainty. Other adaptation options, such as planning, building and maintaining water supply, sanitation and storm water management infrastructure require various risk management techniques that account for uncertainties.

Risk perceptions, values and priorities

Estimations of future climate risks and analysis of associated social, environmental and economic costs, benefits and trade-offs – and to whom – of undertaking a set of adaptation options or maintain the status quo, are also inherently values and priorities judgements by multiple stakeholders. As noted by Renn (1998: 50): ‘All risk concepts have one element in common, however: the distinction between reality and possibility’. Risk is a *story* about what negative impacts we think might happen to who or what if a particular threat or set of threats occurs because of underlying conditions – and dependent upon the perceptions of those assessing and/or deciding what to do about it. The IPCC (2014a: 1772) acknowledged this in its definition of risk as ‘the potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values’.

What is even considered a risk or opportunity, cost or benefit, and to whom and how it should be assessed and treated is a value-laden judgement (Opitz-Stapleton et al., 2019). All economic and social development, whether conscious or unconscious, entails a certain level of risk tolerance. This ‘tolerance for risk’ is highly variable, political and dependent on a range of factors and influences. Decision makers, businesses and individuals accept a certain degree of risk to the choices they make because of the assumption that it will bring significant benefits, and at times, because various risks are not well understood or ignored – these hinge on perceptions, values and priorities (ibid.).

Risks in adaptation and mitigation choices

The IPCC (2019: 696) further highlights that mitigation and adaptation responses can generate risks, ‘from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals’. As socio-economic, political, environmental and climate conditions evolve, new risks, opportunities, trade-offs and unintended consequences might emerge from previously implemented options as they interact with dynamic contexts.

Importance of the role of public and private sectors

Adequately constructing portfolios of adaptation responses requires an understanding of sub-national to national climate risks, and how these could evolve under different socio-economic, political, technological and cultural scenarios. Robust and flexible adaptation options can be crafted in low-information settings, but certain types of options, such as infrastructure, ideally incorporate detailed hydro-climatological information and are able to work within existing water governance structures (while seeking to build capacities). Costing certain types of infrastructure-based adaptation options does require more detailed information to be robust.

The government has a crucial role to play to ensure adaptation options are economically viable. In general, governments should be responsible for providing ‘public goods’, as many climate adaptation options, particularly related to building resilience in Indonesia’s water sector, might be considered ‘public’ rather than ‘private’ goods. Yet, governments cannot provide all the investment or implementation of adaptation options. Climate change risks, and currently observed climate-related impacts, are not always a ‘market’ failure as they also incur private costs (and in some cases, benefits) to individuals and companies. As such, individuals and businesses are starting to undertake autonomous or private adaptation actions in order to avoid the risks that they perceive might impact them, while trying to capture benefits, with or without government intervention. Governments should therefore also be responsible for creating an enabling environment for private investment in adaptation - there is a greater need to showcase the self-interest benefits adaptation investments can provide – and providing risk-based information to support autonomous actions and reduce the risk that such actions are maladaptive. This spurs opportunities for the government to engage the private sector and share risks (Parry et al. 2009; Watkiss 2014).

The value of some adaptation options should ideally be appropriately reflected in market prices, though this is not always done. As such, individuals and organisations should ideally take advantage of opportunities and act against some perceived climate risks through some market response (Parry et al. 2009).

6.2 Costing adaptation options

As associated climate risks and actualised impacts arise in the longer-term future (in the next 50 years), some adaptation economic benefits may not be fully realised today. Estimations of the near- to long-term benefits of various options is influenced by the discount rate and time horizon selected when costing options. A high discount rate and/or long time horizon will reduce expected benefits. Some costs of early adaptation action today may be high when compared to discounted benefits of adaptation in a distant future. Some discounted future benefits are extremely small and therefore rarely justify early action now. Other adaptation options are low cost, and no regret, bringing disaster risk reduction benefits and stronger water supply and demand management today.

It is important to balance resource allocations and benefits from financing current development versus investing in some adaptations to deliver future benefits – ideally some climate adaptation investments should be used to reduce current and future risks to development efforts. And arguments are emerging that two discount rates should be applied when costing climate policies and actions: a social-welfare equivalent discount rate and a finance-equivalent discount rate (Goulder and Williams, 2012). A *social-welfare-equivalent* discount rate is to be applied to determine 'whether a given policy would augment social welfare (according to a postulated social welfare function – ibid.: 1)' and a finance equivalent discount rate 'indicating how consumption levels are connected across time: if society forgoes one unit of consumption in any given period in order to increase the capital stock, this will increase the amount available for consumption in the next period' (ibid.: 7).

Many adaptation options might bear the following costs, though other types of costs might arise in the future (Parry et al. 2009). Methodological approaches to measuring the 'cost of explicit adaptation option' are often broken down into 'bottom up' and 'top down' approaches.

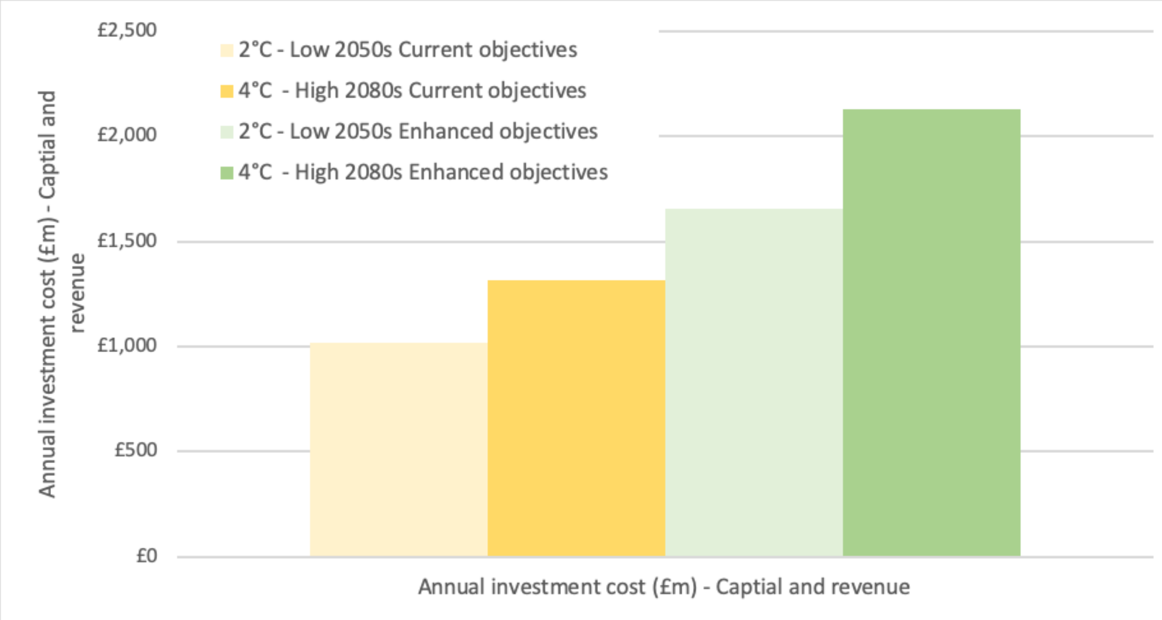
Cost = cost of explicit adaptation option + residual impacts of climate change + transaction costs of implementing adaptation option

Bottom up approach – estimating capital and operating costs over a specific period of time (ideally long term of over 30 years or in line with the estimated lifetime of the option) and across all different actors, plus residual damages**.** Incorporating a management strategy (mainly through maintenance cost over time) and different climate scenarios to the business as usual case allows a range of benefit cost ratio and internal rate of return to the economic and financial appraisals. This assumes perfect knowledge of water management practices, where in reality the adaptation option considered would be couple with activities that build adaptive capacity, especially in keeping up with the changing climate. Therefore, a need to consider a time lag to account for this decision-making process and associated additional costs and residual impacts during implementation.

Top-down approach - selecting generic relevant large-scale adaptation options, and estimating changes in hydrological characteristics using some form of macro-scale hydrological model. For example, the costs of adaptation to changes in water supply availability due to climate change can be indexed by the costs of providing additional storage capacity to maintain supply reliability. The costs of adaptation to flood risks can be characterised by estimating the costs of providing flood protection to a target standard of service. Costs would be estimated by applying generalised cost functions such as dollars per mega-litre of storage. This approach allows an indication of the potential magnitude of adaptation and residual damage costs in a consistent way; however, it is not always robust.

Large-scale adaptation costing approaches linked to risk assessment are maturing however, and could provide useful insights for Indonesia as a whole and the regions within it. A recent example from the UK is illustrated in Figure 6.

Figure 6: Example national scale assessment of adaptation costs for alternative flood management policy approaches in the United Kingdom (Sayers et al., 2020).



6.3 Iterative Frameworks for Identifying and Prioritising Adaptation Options

Adapting to climate change is an iterative, risk informed process are ideally embedded within socio-economic development planning that consider: multi-sectoral interventions; potential impacts to different actors in different geographic places given evolving vulnerabilities, capacities and exposures; and considers how climate hazards change over time and combine with human systems to create new risks or alter existing risks. When devising workable adaptation options, it is essential to continuously consider where to focus resources, and how to select and prioritise options based on risk perceptions, values and tolerances, perceived role of governance and costings of options. Following a Value for Money (VfM) framework can support the prioritisation of large numbers of adaptation options (Watkiss et al. 2014); and other tools such as Multi-Criteria Analysis, Feasibility Studies and Environmental Impact Assessments will also be needed to assess options (Willows and Connell 2003; IPCC 2014b).

Given the challenges in allocating funds towards adaptation options, a number of iterative adaptation option identification and prioritisation frameworks have been developed and recommended to maximise value for money (IPCC 2012, 2014b). An iterative VfM framework guides decision makers through a process for (i) selection of early priority areas for adaptation, and (ii) maximising the value for money through a combination of adaptation options. Thus, adaptation options can be designed that produce:

- **Benefits by reducing current adaptation deficit[6] in managing current climate variability and future climate change**. The adaptation deficit reflects the trade-off between the costs of reducing the deficit versus the costs of bearing the 'residual risks'. This means that it is optimal to reduce but not eliminate the deficit, i.e. only to reduce climate risks to the point where benefits are equal to costs. Investment in climate and other natural hazard resilient infrastructure, and integration of disaster risk reduction.
- **Future benefits and high uncertainty** associated with future climate change are now recognised, and therefore there is an emphasise on the use of more flexible frameworks that allow learning, iteration and adjustment of policies, investments and actions as conditions change. It is important to evaluate whether a particular option could be maladaptive and/or 'lock-in' a certain course of action if conditions change, and evaluate the risk tolerances and priorities of different stakeholders when pursuing options.

Adaptation options can be categorised – though this categorisation list is not all inclusive - as follows to address current and future climate risks (Watkiss et al. 2014; IPCC 2014b):

- Immediate action to address current adaptation deficits and can support current, overall disaster risk management within development needs (low or no regret options)
- Short-term actions whose effectiveness will be tested over time and can be flexibly adjusted, and
- Early action to address future risks, to keep options open based on best-available climate risk information and diverse stakeholder risk priorities and values, and avoid lock-in and maladaptation.

Adaptation options can then be further categorised into different phases according to the time horizon considered for benefits and/or risks to be realized, as illustrated in Figure 7:

- addressing the adaptation deficit allows benefits to be maximised in the short term;
- mainstreaming climate change considerations allows benefits to be realised for the medium term (next 20 years); and,
- early action for long-term change with review and iterative learning to update actions and policies to spur transformational change.

[6] Poorer countries often experience more severe impacts from existing weather and climate-related hazards within natural climate variability than richer countries, attributed to higher levels of intersectional vulnerability, reduced investment in disaster risk management and policies more focused on maximizing near-term economic growth than more resilient and sustainable growth. As such, poorer countries are also posited to face greater future climate change risk. Investment and governance efficiency deficits in climate resilient infrastructure, socio-economic sectors, disaster risk management and climate adaptation are termed 'adaptation deficits' (Fankhauser and McDermott, 2013).

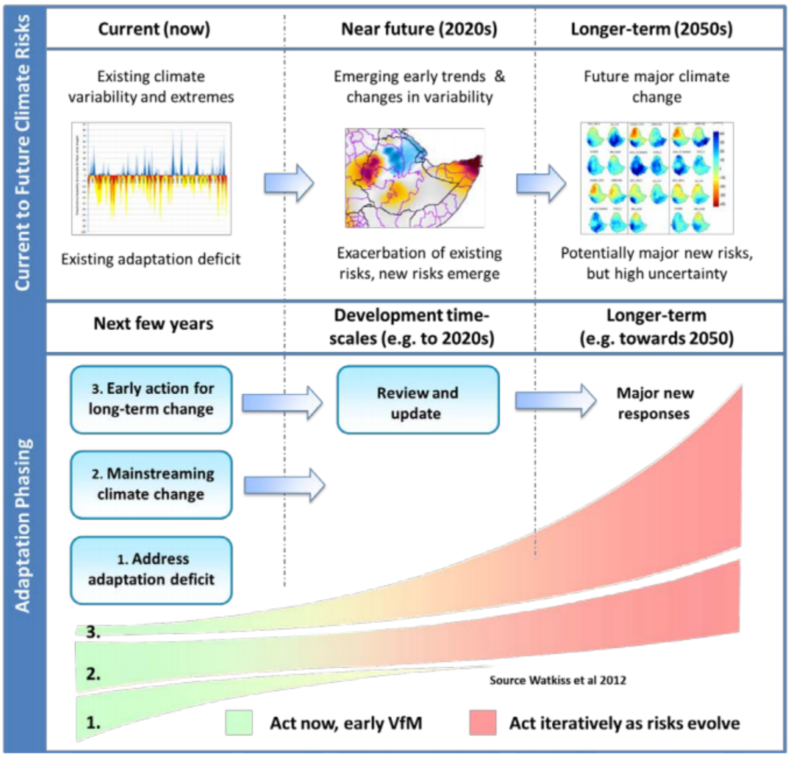


Figure 7: An iterative framework for climate change and adaptation options. Source: Watkiss et al. 2014.

7 Recommendations

This report has highlighted that Indonesia is facing incredible challenges and opportunities in managing its water resources in the face of ongoing deforestation, a strengthened focus on low-carbon development that improves the wellbeing of her people and climate change. Mainstreaming Disaster Risk Reduction and Climate Change Adaptation (through the lens of long-term risk and resilience) are recognized as of being of extreme importance in the National Disaster Management Strategy 2015-19, the RAN-API and economic plans such as the RPJMN 2020-24.

This mainstreaming will include efforts to both adapt to and mitigate climate change (delivering multiple benefits). Spatial planning will need to avoid (where possible) increasing the risk through good planning decisions that take account of climate change and supported by other adaptation and risk reduction measures. Restoration and conversation of forests, mangroves and peatlands will be central to managing water-related risks alongside more local protection measures. We explore some general recommendations for integrating climate risk and resilience planning within land use and socio-economic planning, and conclude with some more specific recommendations applicable to the water sector.

Recommendation: **expand protection and restoration of forest cover and peatlands**. For the water sector, and others such as meeting the emission reduction targets outlined in the LCDI, the protection and restoration of forest cover and associated peatlands will be central to this. The 2015 moratorium on peatlands has not been able to prevent the decline in forest cover on peatlands and continued loss will impact both water scarcity - especially on islands that have very low forest cover such as Java, Bali and Nusa Tenggara - and quality, and inland and coastal flooding. To be successful, this will need to be allied to a range of measures focused on embedded climate risks and resilience into all decision and sectors – from spatial planning, energy, tourism and the all others. This will also require working with communities and local government at a variety of levels to explore options for payments for ecosystem services and forest conservation, in conjunction with efforts to improve socio-economic welfare.

Recommendation: Conduct a national climate risk assessment on a regular basis, say on a five-year interval timed to support the development of the RPJMNs, as part of an iterative and learning adaptation process. Indonesia is dynamic and facing a number of changes: cities are growing, access to services is improving in some areas, forests and peatlands are under growing pressure for infrastructure and agriculture, and a new national capital has been proposed in East Kalimantan. Changes such as these, when coupled with improving insights into climate and more robust climate change projections require iterative assessments of climate change risks and risk, opportunities and trade-offs when pursing mitigation and adaptation policies and actions. This will require a more nuanced approach to climate risks analysis to multiple facets of Indonesia’s water sector, and in turn, influence the direction of strategic climate actions within the medium and long-term economic development planning process going forward.

Recommendation: Develop national guidance on how to mainstream climate risk assessments within water resource management planning and provide capacity building and resources to local governments to do so. Although the 2019 Water Law requires local governments to incorporate 'considerations of climate change' into their water resource management plans, there is little guidance within supporting explanation of how to do this within the regulations. The MoEF is supposed to provide guidance on climate change risk considerations and should be coordinating with BNBP, the national disaster management agency to develop co-guidance and oversight of mainstreaming DRR and CCA approaches. The needs for both stronger guidance and coordination are recognised in the RPJMN 2020 – 2024; it highlights the need for an innovative approach that will be a catalyst of development nationwide that equitable and adaptive.

Recommendation: promote iterative adaptation planning within the water sector. Adaptation options in the water sector can be identified to address climate risks to supply water quality, and to promote demand-side management. The following recommended adaptation options in Table 10 are derived from findings outlined in chapters 3 and 5, satisfying the three phases for prioritising options (Figure 7) and, in turn, further categorised into intervention types: Institutional/Policy, Technical or Market level. We emphasise the importance of selecting a combination of adaptation options that enable immediate (reduce adaptation deficit) to longer-term future benefits to arise, avoid lock-in and reduce likelihood of maladaptation.

Table 10: Recommendations for adaptation options given research done in this report.

Possible Adaptation Options 1st phase – short term - next few years
1. Address adaptation deficit *(Technical Level)* **Climate risk and adaptation assessment - while areas with higher populations and concentrations of infrastructure, economic activity and assets certainly require risk and adaptation assessments, areas with sparse populations also need to conduct such studies.** Some provinces[7] of the country have not received as much focus in internationally-backed climate risk and adaptation assessments, or water resource management studies. The oft-cited reason in the reviewed studies is that population centres are concentrated in particular provinces. Some of these provinces may have different vulnerabilities due to factors such as mixed levels of poverty, more subsistence dependent livelihoods, and lower levels of education, among others, and different risks related to the interplay of hazards with these vulnerabilities. *(Market Level)* **Enhance operations and management for existing areas protected by storage reservoirs.** There is a need to prioritise improved operations and management procedures of the existing areas protected by storage reservoirs, channels and land restoration up the stream of the reservoirs. This would ensure optimum capacity and life span of the reservoirs (ADB 2016). *(Market Level)* **Enhance operations and management for existing areas protected by storage reservoirs.** There is a need to prioritise improved operations and management procedures of the existing areas protected by storage reservoirs, channels and land restoration up the stream of the reservoirs. This would ensure optimum capacity and life span of the reservoirs (ADB 2016).
2. Mainstreaming climate change *(Institutional/ Policy Level)* **Mainstreaming climate resilience within the LCDI** – Opportunity to work with line ministries to develop the sector strategic plans as the LCDI is integrated into the next RPJMN: to mainstream water and climate-related risks across all sectors. *(Market Level)* **Assessment of water related investments in pipeline to evaluate whether their respective project designs have incorporated risks of climate shocks**. A number of government-led and internationally-sponsored WASH projects are underway across Indonesia. Some of them are exploring compact treatment plants and other innovations that acknowledge dense urban areas and premium land area. The plans for such WASH projects need to be evaluated for their considerations of climate risks and ability to withstand more intense and variable rainfall, higher temperatures that could accelerate eutrophication rates, flooding and so on.

[7] This is not to say that studies conducted by Indonesian researchers and ministries do not exist. They were not readily found in this rapid literature review. Expansion of the literature review may uncover more studies.

3. Early Action for long-term change:

(Institutional/ Policy Level)
The lack of a formal mandate to include climate risks within water resource planning represents a serious source of risk to future Indonesian water security. Inclusion of climate change risk were not considered in the 1974 Water Law, nor the relationships of spatial and land-use planning with water resource governance.

(Institutional/ Policy Level)
Monitoring and evaluation systems are critical for monitoring adaptation and mitigation activities: 1) progress and challenges toward implementation; 2) effectiveness at reducing particular risks; 3) ability to meet other benefits and criteria; and 4) for evaluating when conditions have changed and another round of risk-based planning might be necessary. Capacity building on the development of M&E systems, as well as resources and necessary mandates, is needed.

(Technical Level)
Trainings on interpretations of climate information for decision making. Another activity is training around interpretation of not only climate projections, but scenarios of future demographics, land-use change and so on. No model simulation will ever 'accurately' predict the future; the future remains inherently uncertain. Acknowledging uncertainty and accounting for it when developing socioeconomic development plans, spatial policies and infrastructure is crucial to minimizing maladaptive choices and selecting no-regrets, multi-benefit actions.

(Technical Level)
Establishment of national survey of data from the Basin Water Resource Management Units and a publicly available database of watersheds. Greater density of river gauges and aquifer pumping tests is needed on a long-term basis to establish water availability and trends. Estimating water availability on short records with poor spatial coverage can lead to maladaptation through under- or over-allocation of supplies. This adaptation option is crucial given flood damage is a prominent hazard, especially in low-lying densely populated areas and the current lack of data available on actual flood protection.

(Technical Level)
Establishment of national survey of data from the Basin Water Resource Management Units and a publicly available database of watersheds. Greater density of river gauges and aquifer pumping tests is needed on a long-term basis to establish water availability and trends. Estimating water availability on short records with poor spatial coverage can lead to maladaptation through under- or over-allocation of supplies. This adaptation option is crucial given flood damage is a prominent hazard, especially in low-lying densely populated areas and the current lack of data available on actual flood protection.

(Market Level)
Risk sharing financial instruments for new reservoir constructions, as per outlined in SD model in LCDI plans for hydropower and risks management. The provision of bulk water option contracts between urban water suppliers and agricultural users and insurance indexed on reservoir inflows has been shown to improve management of hydro-climatological risks to Manila's water supply. In turn, the insurance design has effectively smoothed water supply costs of hydrologic variability for both agriculture and urban water (Brown and Carriquiry 2007). Such options could be explored for Indonesia, particularly in light of ADB and World Bank investments in water infrastructure.

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Registered Office:

203 Blackfriars Road

London SE1 8NJ

United Kingdom

+44 (0)20 7922 0300

odi.org