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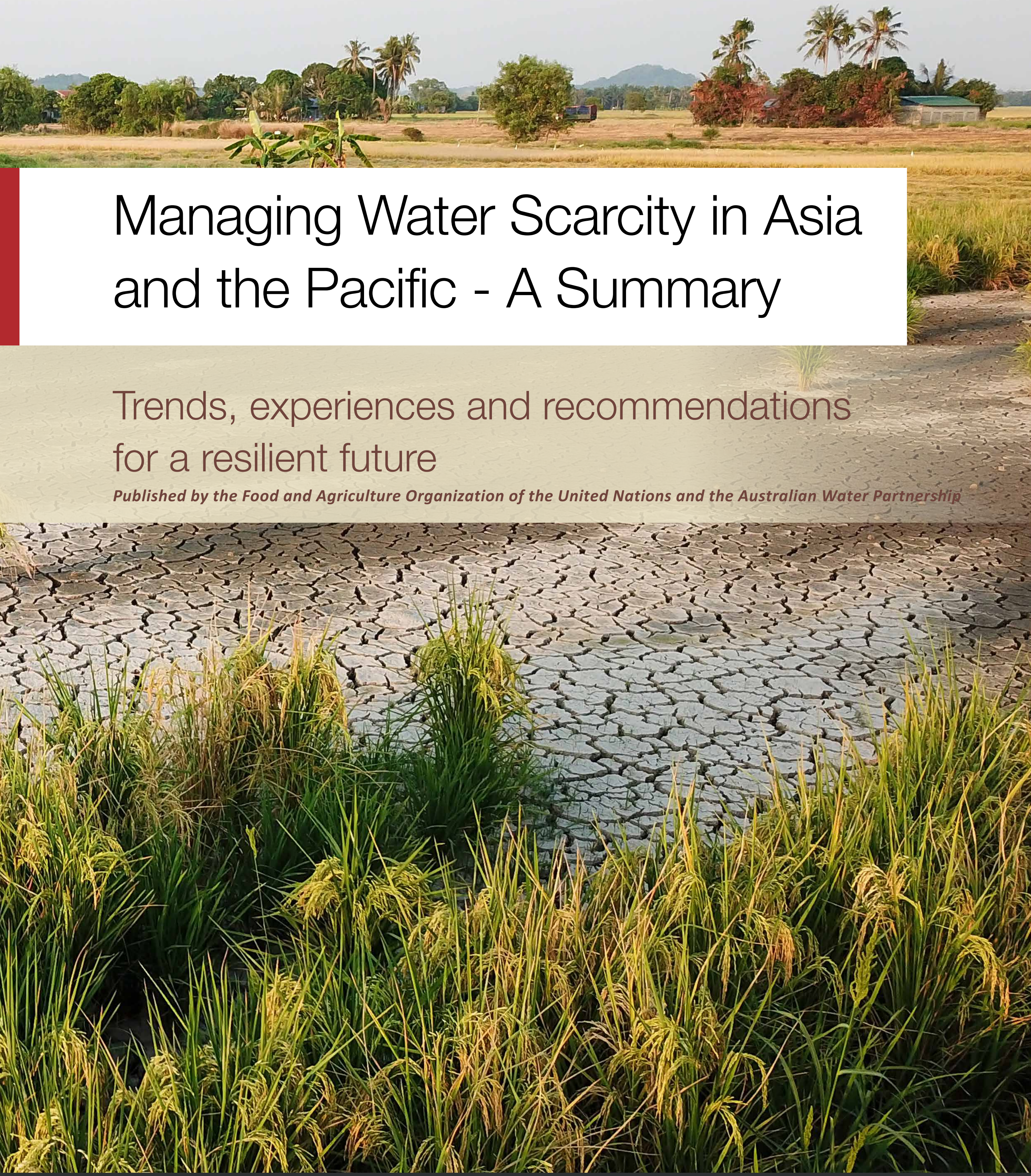
Managing Water Scarcity in Asia and the Pacific - A Summary

Trends, experiences and recommendations for a resilient future

Published by the Food and Agriculture Organization of the United Nations and the Australian Water Partnership



Managing Water Scarcity in Asia and the Pacific - A Summary

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Published by the Food and Agriculture Organization of the United Nations and
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About the Authors
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Cover image: Dry land at paddy field by Cloudyew / AdobeStock

1 Contents

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1 Highlights

- **Water scarcity refers to an imbalance between freshwater supply and demand in a given domain (e.g., a country, region or river basin) where demand exceeds available supply under prevailing institutional arrangements and infrastructure. Signs of water scarcity include unsatisfied demand, tensions and competition for water between users, over-extraction of groundwater and insufficient environmental flows (FAO, 2012).**
- The Asia–Pacific region encompasses several countries across four climate zones (arid, cold, tropical and temperate) and is home to a rapidly growing population of approximately 4.3 billion people (UNESCAP, 2013) with highly variable water scarcity risks.
- The Asia–Pacific region is undergoing significant economic development; while there is a growing diversification of the economies towards industrialisation, agriculture remains a key source of employment and domestic food security.
- The agricultural sector's dependence on freshwater for production, which accounts for 70 per cent of global freshwater withdrawals and over 90 per cent of its consumptive use, places strain on local hydrological systems in many areas of the Asia–Pacific region.
- There are significant regional differences in water scarcity profiles that vary from absolute scarcity in arid and semi-arid regions to seasonal or inter-annual scarcity. Various types of water scarcity, such as too little water, over-utilisation, too variable water or poor water quality, threaten to undermine the development progress of recent decades.
- The region's population living under high or severe water scarcity grew from 1.1 billion to over 2.6 billion between 1975 and 2010. For green-blue water scarcity, there was an increase from approximately 0.2 billion to nearly 1.5 billion people over the same period.
- Seasonal water scarcity predominates during the dry season in monsoonal, wet tropical and sub-tropical countries. Absolute scarcity is evident in Java, with hotspots in Central Viet Nam, Hanoi and Ho Chi Minh City, and fast-growing cities like Kathmandu. Nepal and Myanmar experience water scarcity due to insufficient investments in water storage and supply infrastructure to meet dry season demands.
- Groundwater over-abstraction is rising in some areas, including Bangladesh, the Central Highlands and central Mekong Delta in Viet Nam, the central dry zone and coastal cities of Myanmar, Jakarta, and some cities in Java.
- Water quality is declining rapidly across the region due to agricultural and urban runoff. Natural arsenic and fluoride contaminate groundwater resources in some countries, such as Bangladesh and Nepal. Salinity threatens Fiji, Central Myanmar, Thailand, Viet Nam, Australia and coastal Bangladesh.

- Countries across the region can be placed along four key stages of a trajectory of water scarcity management: (1) state-led irrigation development (Fiji); (2) multi-sector development (e.g., Lao People's Democratic Republic , Myanmar, Nepal, Cambodia and Bangladesh); (3) integrated water resources management (e.g., Viet Nam, Indonesia and Thailand); and (4) sustainable water management (e.g., those moving towards this phase, such as Australia).
- Water scarcity management varies across the region. While high-level regional and national water laws and policies are generally well-developed, implementation and compliance are weak for many reasons, including insufficient resources and capacity, conflicting economic incentives and goals, corruption or insufficient intent within governing bodies.
- Water quality issues need attention and political commitment through integrated planning and investment in city wastewater treatment and pollution regulations for industry and agriculture.
- Countries not yet facing severe water scarcity have an opportunity to establish frameworks for water sharing and management before over-allocation occurs and climate change amplifies scarcity issues through water accounting, safeguarding environmental flows and formal allocation processes.
- Countries in Asia–Pacific with existing water scarcity due to issues such as over-allocations similarly require long-term, well-informed policy planning, difficult consensus-building on best approaches, consistent effort and regular adaptation of strategies when required.

2 Managing Water Scarcity in Asia–Pacific

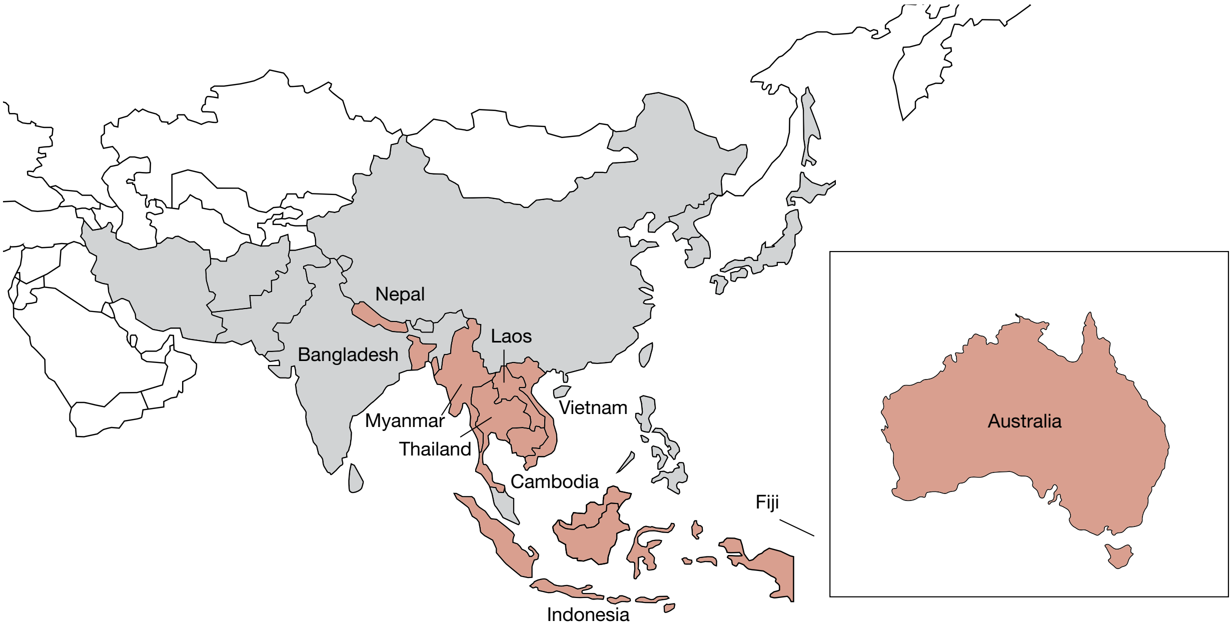

Figure 1. The map shows the Asia–Pacific region (in grey), with the ten countries studied highlighted in orange.

In the Asia–Pacific region, water resources form the basis of agrarian prosperity and economic development. However, increasing water demand due to population growth, rapid industrialisation and urbanisation, and a changing climate undermine those water resources. Like many parts of the world, Asia–Pacific faces increasing water scarcity, with varying characteristics, causes and trends across a diverse range of countries at different stages of development.

Understanding of the spatial and temporal differences in water scarcity across the region is, however, limited, and while policies and management strategies are under development in all countries, their effectiveness varies significantly. Responses to water scarcity are often reacting to acute issues such as drought or conflicts between competing water users; while regional and national level policies exist in most cases, they often lack subsidiary legislation, program development or the resources needed for successful implementation.

The main objective of the present study was to develop an understanding of the dynamics of water scarcity across Asia–Pacific and how countries manage that scarcity—ultimately informing more effective management approaches that can be scaled across the region.

Specifically, the study aimed to:

1. Provide insights into policy targets relating to water scarcity in the fields of water resources management, agriculture and urban and industrial development, including information related to water rights, emerging policies and practices on environmental flow provision.

2. Reveal options, commonalities and differences in the institutional structures, legal underpinning, instruments, and possibilities for improvement and exchange of approaches between countries.
3. Highlight the features of water accounting, water allocation provisions and caps employed in the management of water scarcity in the region.

To characterise the nature of water scarcity across the region, we looked at the spatial and temporal patterns of water scarcity over the last five decades. We selected 10 countries reflecting a wide range of climate and landforms across the region: Bangladesh, Nepal, Cambodia, Viet Nam, Thailand, Myanmar, Lao People's Democratic Republic , Indonesia, Fiji and Australia. We reviewed each country's historical and contemporary approaches to managing water scarcity and examined what did (and did not) work.

The country-level analyses were used to develop a realistic framing of governments' strategies to manage water scarcity. The country profiles included a formal analysis and review of 10 or more policy instruments across all water-using sectors concerning the management of water scarcity. National policymakers were also interviewed to provide additional insight and context.[1]

Finally, we extrapolated from these experiences to summarise pathways for water reform. We sought to understand what best practices of water scarcity management could look like, as well as how countries could utilise these best practices to improve their water scarcity management strategies and avoid the mistakes and missteps of others. The present report summarises this study for the use of policymakers across the region, while more detail may be found in the longer Regional Report.

The structure of this summary is as follows:

- An introduction to the concept of water scarcity and the regional patterns and trends across the Asia–Pacific region.
- Summaries of 10 country case studies detailing the water scarcity profiles and water scarcity management approaches of each.
- Possible trajectories towards sustainable water management.
- Best practice guidelines for policy and overall outlooks for the region.

The study was conducted as part of the Asia–Pacific Water Scarcity Program, run by the Food and Agriculture Organization of the United Nations (FAO). The program's overarching objective is to prepare Asia–Pacific's agriculture sector for a future of increasing water scarcity by improving how government and non-government actors manage water scarcity and its implications for food production and rural prosperity. It seeks to provide countries in the region with a pathway towards sustainable social and economic development by providing tools for achieving food and water security. The program focuses on the sustainable use of water and the changes being forced on agricultural water use in response to drought, rising demands from other sectors and the continuing imperatives for food security and ecosystem health.

The findings of this study support the realisation of the Water Scarcity Program's long-term goal of sustainable use of water resources in all countries in the Asia–Pacific region and the achievement of the United Nations' (UN) Sustainable Development Goals relating to water access, poverty reduction and food security. **Mitigating and managing water scarcity will require long-term and well-informed policy planning, difficult consensus-building on best approaches, consistent effort and regular adaptation of strategies when required. Every country mentioned in this summary must act as soon as possible to address sustainable water management, scarcity and challenges.**

3 Water Scarcity in the Asia–Pacific Region

3.1 What is Water Scarcity?

Water scarcity refers to a condition whereby societal water requirements exceed the amount or quality of water available for these purposes (Alcamo & Henrichs, 2002; Falkenmark, Lundqvist & Widstrand, 1989; FAO, 2012; Vörösmarty, Green, Salisbury & Lammers, 2000). Ultimately, it comprises two key dimensions: **water availability** (supply and access) for a specific purpose and **water demand** (use) for that purpose. Water availability is primarily determined by geography and is affected by both spatial and seasonal precipitation patterns, as well as groundwater availability as a buffer and store for any seasonal and annual fluctuations in rainfall.

There are four key dimensions of water scarcity (see Figure 1): too little water, too variable water, over-utilisation and poor water quality. We assessed the Asia- Pacific region's water scarcity status and trends during the recent historical period of 1971 to 2010.2 Numerous approaches to estimating water scarcity exist (e.g., see reviews in Hussain et al. [2022], Liu et al. [2017], and Pedro-Monzonís, Solera, Ferrer, Estrela and Paredes-Arquiola [2015]), which may be because water scarcity is difficult to characterise and assess across scales (Rijsberman, 2006). Due to various limitations, none of the available indicators can provide a truly holistic view (Hussain et al., 2022). We therefore integrated three simple core indicators to build a more holistic picture of water scarcity. First, we assessed water shortage using the Water Crowding Index (WCI) (Falkenmark et al., 1989), which is an indicator of competition for water (i.e., as water availability per capita declines, competition increases for available water resources).

We then calculated water stress using the Water Stress Index (WSI) (Alcamo & Henrichs, 2002; Vorosmarty et al., 2000), which indicates excessive water use compared to water availability. Finally, we calculated agricultural water scarcity using the Green-Blue Water Scarcity Index (GBWSI) (Gerten et al., 2011; Kummu, Gerten, Heinke, Konzmann & Varis, 2014; Rockström et al., 2009) as an indicator of the sufficiency of local water resources in satisfying agricultural needs. The influence of water quality is also discussed in the country profiles (see Section 4) based on interviews and policy document analyses.[3]

We handled certain deficiencies in currently available water scarcity indicators (as highlighted by Hussain et al. [2022]) by considering the following: spatial and temporal variability in blue water (as water in rivers, streams, lakes and wetlands) and green water[4] (as actual water use in rain-fed and irrigated agriculture and pasture), environmental flow requirements, population, water use and spatially varying water requirements. Considering these factors offers a more reliable overview of regional water scarcity and provides a more detailed view of the evolution of water scarcity during the study period.

TOO LITTLE WATER Low natural precipitation and runoff conditions, inducing low per capita water availability and general water scarce conditions.	TOO VARIABLE WATER Seasonal and interannual variability in precipitation, producing highly variable water availability regimes and driving drought incidence.
OVER-UTILISATION Utilisation of water resources for domestic and agricultural purposes exceeding water availability, or causing water quality issues.	POOR WATER QUALITY Inadequate quality of water resources for water users and reduced effective availability of water for some or all users, depending on degree of pollution.

Figure 2. Four types of water scarcity. The four types of water scarcity referred to in this report (FAO, 2012).

3.2 Subregional Variability

Climate, landforms and population distribution are highly variable across the region.

There are substantial seasonal differences in water availability across the Asia–Pacific region, primarily due to the monsoon climate influencing a significant part of the region. Seasonal differences, combined with an increasing population and changing water use patterns, lead to varying degrees of water scarcity across the region. These differing climate zones and the distribution of cropland and population within the zones are shown in Figure 2.

The Asia–Pacific region can be divided into five subregions, each with similar characteristics:

1. **Arid and semi-arid West and South Asia**—including the Islamic Republic of Iran, Pakistan, Bangladesh and North and South India, where water scarcity has long been prevalent.
2. **Continental South-East Asia**—predominantly the Mekong countries.
3. **Island South-East Asia and the Pacific**—including Indonesia, the Philippines and Malaysia.
4. **East Asia**—predominantly China, Republic of Korea, the Democratic People's Republic of Korea and Japan.
5. **Continental Australia**—Australia.

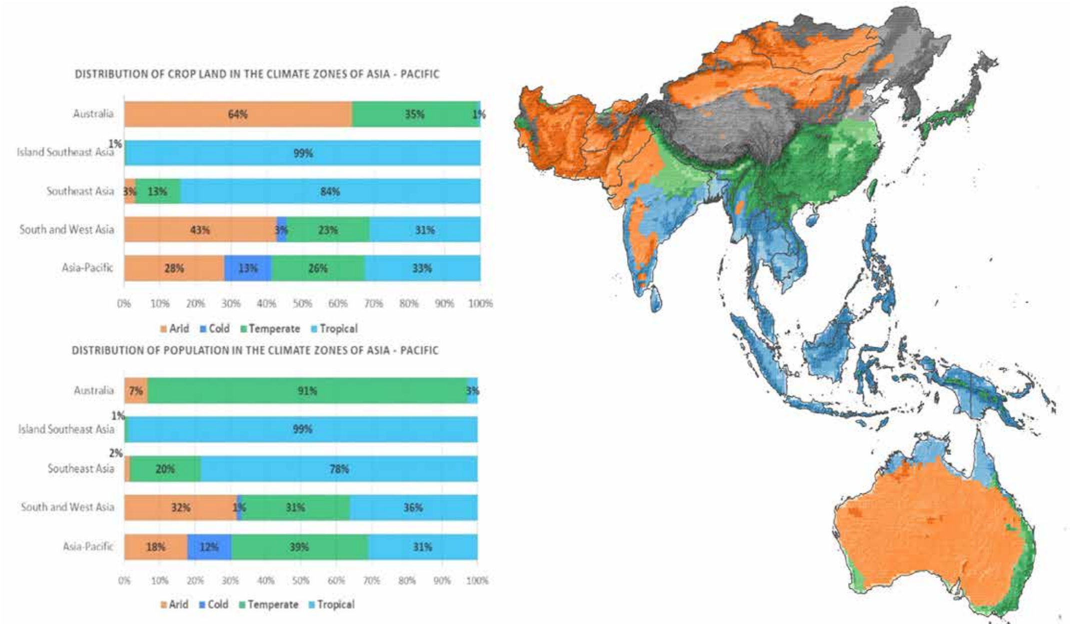

Figure 3. The proportion of cropland and population in each climate zone across subregions of Asia–Pacific. Data shown includes (a) cropland as a percentage, (b) population as a percentage of the total population in each subregion and (c) a map of the spatial distribution of climate zones. Data are based on the Köppen-Geiger climate classification in Beck et al. (2018)1 and cropland data from the HYDE 3.2 dataset (Klein Goldewijk, Beusen, Doelman & Stehfest, 2017).[2]

1 The Köppen-Geiger classification is based on temperature and seasonal precipitation (not only on mean annual precipitation), with different precipitation thresholds for aridity depending on whether more or less than 70% of precipitation falls within summer; the threshold is computed based on mean annual temperature (see Beck et al. [2018] for details) and main classes of 'Tropical, Arid', 'Temperate' and 'Cold'. Note that data are aggregated to 0.5 degrees spatial resolution, with climate zones aggregated based on the majority (i.e., they do not capture internal distribution of climate zones).

2 Cropland (land use) data were sourced from the ISIMIP experiment 2, originally from the HYDE 3.2 dataset (Klein Goldewijk et al., 2017). Agricultural areas are disaggregated into irrigated and rain-fed cropland and pastures. We did not use pastures in the computation.

In this study, we looked at 10 countries from four of these subregions to represent a wide range of climates, landforms and population distributions across Asia–Pacific: **Bangladesh** and **Nepal** in West and South Asia; **Cambodia**, **Viet Nam**, **Thailand**, **Myanmar** and **Lao People's Democratic Republic** in Continental South-East Asia; **Indonesia** and **Fiji** in Island South-East Asia and the Pacific; and **Australia** in Continental Australia (see Table 1 for background information on each country analysed). Some countries were outside the scope of the study, such as countries in East Asia and certain Pacific islands, due to their small size in relation to the resolution of the models used in the analysis.

Population sizes vary among the countries studied, with the highest number of inhabitants recorded in Indonesia (281.2 million people) and Bangladesh (169 million people). The selected countries have diverse economic backgrounds and include developed and developing countries. High-income countries include Australia, Fiji and Thailand, with gross domestic product (GDP) recorded unequally at US$1,553 billion, US$4.3 billion, and US$505.9 billion, respectively. The remaining low- and middle-income countries report significant differences in GDP, ranging from US$27 billion to US$1,186 billion. The share of employment in the agricultural sector in the region is high; however, the sector's contribution to national GDP is declining due to a shift towards industrialisation, particularly in Nepal and Lao People's Democratic Republic , where more than half of the workforce is engaged in agricultural activities. Although percentages of cultivated land vary among evaluated countries (with cultivated land accounting for between 8 and 75 per cent of total land area), it remains the highest water consumer in these countries, accounting for more than 85 per cent of the total freshwater withdrawals in the sector (excluding Australia and Fiji).

Table 1. Country Profile Data

Country	Population (M people) ****	GDP (US$b) **	Agriculture % GDP **	Employment in agriculture (%) *	Agricultural land (%) **	Total water withdrawals (10^9 m^3/pr) *	Agricultural freshwater withdrawals (%)**
Australia	26.3	1553	2.3	2.6	46.3	9.8	58.4
Bangladesh	169	416.3	11.6	38.3	76.1	35.9	87.8
Cambodia	17.3	27	22.8	34.5	32.8	2.2	94
Fiji	0.9	4.3	14.5	17.6	17.1	0.08	58.9
Indonesia	281.2	1186	13.3	28.5	33.2	222.6	85.2
Lao People's Democratic Republic	7.6	18.8	16.1	61.4	8.8	7.3	95.9
Myanmar	55.4	65.1	23.4	48.8	19.9	33.4	88.6
Nepal	30.5	36.3	21.3	64.4	28.7	9.5	98.1
Thailand	70.3	505.9	8.5	31.4	45	57.3	90.4
Viet Nam	99.7	366.1	12.6	37.2	39.4	81.9	94.8

Note: *2019, **2020, ***2021, ****2023. Adapted from World Bank (2023) DataBank and Worldometers (2020) Population.

3.3 Regional Patterns and Trends

The Asia–Pacific region contains some of the most water-scarce areas in the world. Between 1971 and 2010, with some seasonal and temporal variations, high levels of water scarcity were reported, particularly in the most water-scarce countries (see Figure 3).

Countries such as Pakistan, the Islamic Republic of Iran, Afghanistan, northern China, and parts of northern, western and southern India experience chronic water shortages with more severe shortages in the dry seasons. Most South, East and South-East Asian countries experience extensive flooding in the monsoon season, which can be highly destructive. Though water scarcity in Laos and Cambodia is not yet as pronounced in the geospatial analysis (in terms of over-utilisation, too little water or too variable water, based on WCI, WSI and GBWSI), both countries have issues regarding inadequate water storage, which may exacerbate water scarcity in the coming years.

Most of the Indian subcontinent faces some degree of water scarcity. While water scarcity occurs to a lesser spatial extent in West Asia in the Islamic Republic of Iran and Afghanistan, scarcity is heightened near large population centres. In East Asia, most of China outside the Tibetan Plateau experiences low water availability per capita and high water use, resulting in high scarcity (i.e., all three indicators) in provinces between Beijing and Shanghai.

In South-East Asia, water scarcity occurs in distinct areas across the mainland and the Mekong region (covering Myanmar, Lao People's Democratic Republic , Thailand, Cambodia and Viet Nam). The central dry zone in Myanmar is affected by water stress and water crowding, as are certain locations north and east of Bangkok (Thailand). The indicators highlight the Mekong and Red River Deltas in Viet Nam as water scarce. Relatively dry areas north of Tonle Sap Lake (Cambodia) exhibit water crowding. While water scarcity is not pronounced in Lao People's Democratic Republic , there are concerning trends of water resource exploitation and seasonal water scarcity.

Islands in South-East Asia (Malaysia, Indonesia, Philippines, Papua New Guinea, Brunei Darussalam and Singapore) show similar water scarcity hotspots. Water scarcity issues are concentrated in the highly populated islands of Java, Bali and Indonesia's Nusa Tenggara Timur/Nusa Tenggara Barat, and around hotspots in the Philippines, such as the capital city, Manila. Similarly, Malaysia's cities of Kuala Lumpur and Malakka show water scarcity due to their concentrated populations. In Australia, many locations experience high water stress—particularly the Murray–Darling Basin in New South Wales and Victoria. Water crowding is experienced in larger cities, including Canberra, Sydney, Melbourne, Perth and Brisbane (see Figure 3).

3.4 Water Scarcity Hotspots

Competition is clearly emerging in hotspots where demand is highly concentrated, and water resources are either unavailable locally or financially and technically challenging to augment. Hotspots occur around large cities in all countries and are exacerbated by trends of declining water quality. A classic pattern of water development in cities has been extensive private groundwater pumping in response to limited surface water provision or poor and erratic public water supply. This often leads to an extensive cone of depression in groundwater below the city, which increases the cost of abstraction, leads to water quality degradation and may cause significant infrastructure damage due to land subsidence and flooding (e.g., as evident in Bangkok, Jakarta, Dhaka and Manila).

Competition within and between large irrigation systems is also evident in Thailand, Indonesia and Viet Nam. Groundwater levels are falling in many countries, resulting in economic competition between users and the loss of shallow groundwater for household use. **Deltas—such as those of Bangladesh, Viet Nam, Indonesia, Thailand and Myanmar—are particularly complex hotspots for water scarcity and stress.** They are also very vulnerable to flooding, particularly during high tides, and vulnerability will increase with the climate change –induced rising of sea levels and related increases in salinity, which will further contribute to water scarcity. Many countries in the region are highly dependent on transboundary river systems. As populations continue to increase and water availability per capita declines, the vulnerability of these downstream countries to upstream water policy increases. Given that individual countries may prioritise economic interests at odds with sustainable water management, some tough water scarcity challenges may emerge.

In the Asia–Pacific region, water scarcity is worsening in every country (see Figure 3). There are, however, more issues with water *shortage* than water *stress,* though water stress shows the most variation. As water scarcity increases in all countries, each experiences more severe categories of scarcity. Some countries experience little or no scarcity due to low populations and high rainfall, even if rainfall is seasonally distributed. Arid countries with high populations or high agricultural water use experience higher water stress. The trajectories of water scarcity typically alter over periods of around five years in response to factors including changes in climate, population and land use, as well as (often unknown) adaptations.

Countries respond to challenges water scarcity presents in various ways through different governance processes. Water governance consists of the structures and processes through which different state and non-state actors across society (including government and non-government organisations and civil society) interact and engage in decision-making to regulate, influence and shape water resource use and management. An important element of governance is the formal institutional arrangements based on legal rights and regulations. These, in turn, are implemented to varying degrees of success, depending on informal institutions based on history, culture, social networks and daily practices. To understand the various governance responses across Asia–Pacific, a national policy analysis was carried out for each country profile, with a focus on how governments allocate state resources to manage water scarcity and agricultural water security through different governance strategies, including policy instruments.

The following country-level analyses were used to develop a realistic framing of governments' strategies to manage water scarcity. The country analyses included a formal analysis and review of 10 or more policy instruments across all water-using sectors concerning the management of water scarcity, including issues around water quality. National policymakers were also interviewed to provide additional insight and context. The country profiles highlighted what has worked and what needs to be improved to mitigate water scarcity risks for a water-secure and resilient Asia–Pacific. Full country profiles can be found in the Regional Report.

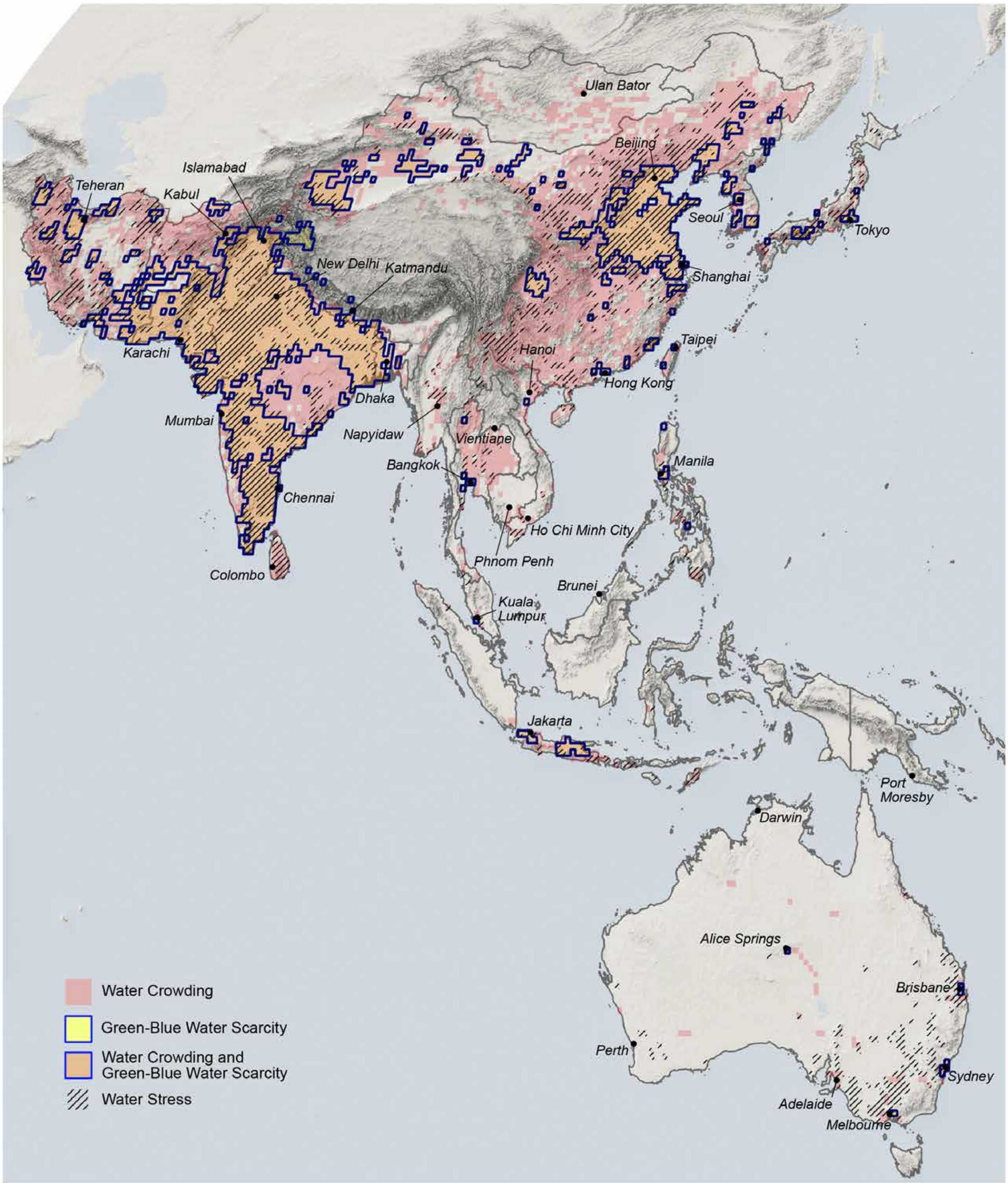

Figure 4. Water scarcity hotspots in the region during the historical 40-year period of 1971 to 2010. Map highlights areas with chronic (water-scarce in at least four out of five years) or variable (water-scarce in at least every one in five years) water scarcity across the three indicators used in the regional assessment.

4 Country Profiles

4.1 Bangladesh

KEY FINDINGS

- **Bangladesh experiences two types of water scarcity: too variable water and poor water quality. The country is approaching a situation of chronic water scarcity.**
- **Gaps between researchers and policymakers** inhibit the transfer of knowledge and science-based solutions. It poses a barrier to public discussion and decision-making for alternative solutions.
- Estimates suggest that **water scarcity could cost Bangladesh up to 6 per cent of its GDP** in the year 2050.
- **Natural arsenic contamination in groundwater is found in 60 out of 64 districts in Bangladesh.** Water and agricultural policies are progressive and based on sound technical analysis. However, policy formulation is siloed, and implementation, monitoring and regulation are weak, with low transparency.
- **Engagement between the private sector and the public sector is limited.** Policy frameworks that address irrigation and agriculture do not give adequate attention to the private sector in the development of supply chains for agricultural products.
- **Enforcement powers and support are limited.** Enforcement power remains with the Ministry of Home Affairs and there are no specific provisions for decentralisation from the agency.

High agricultural water requirements in the dry season put pressure on water resources, yet dry season yields remain higher than wet season yields due to complications from wet season flooding. During dry spells, moderate to severe scarcity spreads across a region of 5.46 million hectares, while water availability in 33 per cent of the total land acreage falls below the minimum sustainable cultivation threshold. The quality of surface water and groundwater is a primary concern in Bangladesh during the dry season. **Quality is significantly degraded due to economic and population growth, and climate change.** Increased urbanisation, industrialisation and agricultural development have raised water demand and led to high volumes of wastewater. Agricultural runoff contributes to the pollution load as it contains chemical fertilisers and pesticide residue.

Most of Bangladesh is situated within the deltaic flood plain of some of the world's largest rivers. Over the past four decades, Bangladesh's water management approach has focused on flood protection and drainage, and improved surface irrigation to increase crop production; agricultural strategy has played a central role in how water is managed in the country. However, **over the last decade, policy has evolved to consider issues around water scarcity.**

Strengths: There has been a significant policy shift towards a more holistic approach that considers sustainability measures and stakeholder participation, as observed in the government's policies around agricultural production, groundwater governance, and the role of energy in irrigation. To protect groundwater, the Bangladesh Water Act of 2013 gave the authority to fix safe yields for abstracting groundwater, while the Act and Water Rules 2018 instituted permits for large-scale groundwater withdrawal, with attention paid to issues such as climate resilience. The government has also issued multiple relevant policies reflecting the seventh Five-Year Plan (2016–2020), including those related to improving land and water productivity in irrigated areas.

Weaknesses: Policy formulation often takes a siloed approach and institutional complexity has led to an unclear distribution of responsibilities across governance scales. **Implementation, monitoring and regulation are also weak,** partly because policy formulation remains highly centralised and uncoordinated and is thus influenced by political pressures and interests.

4.2 Nepal

KEY FINDINGS

- **Although Nepal has abundant water resources on an annual basis, the country faces three types of water scarcity: too variable water, water stress and poor water quality. Nepal also faces issues such as flash floods in the wet season and drought in the dry season.**
- **Government ambitions of increasing groundwater use for irrigation face barriers**, including a lack of farmer incentives, poor electricity networks and the high cost of alternative energy sources.
- **There is a need for capacity building**, improved coordination between ministries, support by civil society organisations and improved data collection.
- **Transboundary water resources management could be strengthened**. Given the impacts of flash floods during the wet season and water shortages during the dry season due to dam operations in upstream countries, efforts are needed for stronger transboundary agreements.
- The current institutional structure is constrained by insufficient capacity and weak implementation in dealing with water scarcity. It leads to poor access to safe water resources for poor and marginalised families and communities.

Most regions of Nepal experience water scarcity during the dry season; erratic monsoons with concentrated cloudbursts and long, intermittent dry spells cause water stress due to extreme over-supply and under-supply within a short time frame (four months or less), leading to too variable water. This causes a threat to rain-fed agriculture and drinking water. For example, during 2006 to 2007, the late arrival of the monsoon and declined monsoon rainfall resulted in a 16 per cent decrease in typical monsoon rainfall, reducing rice yields by 21 to 30 per cent.

Poor water quality occurs in surface and groundwater in Nepal. Surface water and shallow aquifers have been polluted with heavy metals (such as lead, cadmium and chromium) and arsenic contamination in dense population regions like Kathmandu Valley due to the high load of untreated domestic and industrial wastewaters discharging in the river (Uprety, 2014). Lead concentrations in shallow groundwater have been recorded at levels that are five times higher than the World Health Organization's standard for drinking water (United States Agency for International Development, 2021). Microbial contamination stems (E. coli) have also been detected in shallow and deep tube wells, which is caused by poor sanitation systems (Thanju, 2012).

Over-use of water resources is a problem in Nepal and water demand has steadily increased since the 1970s due to population growth and industrialisation. Groundwater extraction has increased and, in places, exceeds aquifer-sustainable yields. For example, groundwater withdrawals in Kathmandu Valley have exceeded recharge rates since the mid-1980s.

Since the Constitution of Nepal as a Federal Democratic Republic was promulgated in 2015, the government has restructured with a move towards decentralisation and sharing of resources with local governments. It is believed that this will help the country to cope with climate change, particularly in relation to water scarcity. The government has adopted several policy instruments that affect water scarcity both directly and indirectly, including policies on livestock, irrigation, water resources, forest and soil conservation, land use, urbanisation and climate change. There has been limited focus on drought, except for immediate, short-term issues; however, the issue of water scarcity is implicitly embedded in certain water-related programs and policies such as the National Water Supply and Sanitation Sector Policy of 2014, and more explicitly in the Irrigation Policy of 2003 and National Water Resources Policy of 2020. More recently, a new Water Resources Act has been scheduled for consideration, which may increase the authorisation for water accounting and allocations to assist with water scarcity management.

Strengths: Nepal has introduced and adopted several sectoral policy instruments related to water scarcity. Civic voluntary bodies are involved in water crisis management. Decision-making and resource distribution are becoming increasingly decentralised, while current policies also emphasise the role of stakeholder engagement across scales.

Weaknesses: Inadequate legal policies focus on emerging issues of water scarcity policy and drought. There is also a lack of updated information from authorities regarding natural disasters. Nepal has several policy instruments and strategies for water management in place, but the country suffers from insufficient resources, regime uncertainty and limited capacity at the national level; at the local level, limited resources also undermine implementation. Poor data collection and a lack of credible data are also barriers.

4.3 Cambodia

KEY FINDINGS

- **Cambodia experiences water scarcity in the form of too variable water and poor water quality.**
- **Water supply for industry is important for economic development.** Ensuring sufficient quality and quantity of water supplies for the industry is critical for economic growth. Industry as a water user is a competitor to agricultural water users, so a clear strategy on how water can be sustainably supplied to the industrial sector is needed.
- **Operation and maintenance:** financing of irrigation schemes needs to include both the initial capital works as well as ongoing maintenance. Implementing water charging provides a pathway to funding ongoing maintenance.
- **Monitoring and evaluation:** support (finance and capacity) is needed to set up a strong monitoring and evaluation system to assess the impacts of policies and to enable adaptive management of water scarcity.
- **Capacity development is critical.** Capacity development is often needed to support implementation of new instruments (e.g., strategies, policies, tools and organisations).

Cambodia's water scarcity is particularly evident in rural areas; rural communities and agricultural activities are the most affected by water variability. The issues of too variable water availability and poor quality also interact; when there is no rain during the dry season, villagers in rural areas often face a shortage of drinking water and resort to using unsafe water from ponds, rivers or streams. Climate change may worsen intra-annual variability in water availability, with evidence emerging of a longer dry season (and a delayed wet season) and longer dry spells during the wet season (Ministry of Water Resources and Meteorology, 2012).

Over the last 30 years, Cambodia has been on a steady trajectory towards water-scarce conditions. The Delta and flood plain have begun to experience low water availability in recent years—as observed during several droughts between 2002 and 2022. Along with increasing pressures due to a growing population, water scarcity is expected to worsen in the coming years. The primary legal basis of water resources management in Cambodia is the 2007 Law on Water Resources Management, which outlines the regulatory framework of water policy for the country. An overarching water law is essential to provide an overall vision and responsibilities, but more detailed regulation is needed to outline how water scarcity can be dealt with within the confines of the law.

Strengths: There is increasing water supply coverage for domestic use in Cambodia (particularly in rural areas) and a strong establishment of main canals and reservoirs to assist with inter-seasonal water supply issues.

Weaknesses: The need for monitoring and evaluation of policies responding to water scarcity is urgent, as is the maintenance of existing irrigation schemes—many of which are failing due to a lack of maintenance and prioritisation of funding new schemes. Not all policies reviewed have adequate monitoring and evaluation processes in place, nor the funding or appropriate budget allocations to do so.

4.4 Viet Nam

KEY FINDINGS

- **Viet Nam experiences all types of water scarcity: too little water, too variable water, over-utilisation and poor water quality.**
- With 63 per cent of the country's surface water sourced from transboundary rivers, **downstream Viet Nam faces the impacts of the intensive water development** and increasing water demands by upstream countries.
- **Water scarcity is experienced differently across eight regions:** in Northern Viet Nam (which comprises the Northwest, Northeast and Red River Delta regions), water scarcity types are mainly over-utilisation and poor water quality; the North Central Coast region experiences too variable water and poor water quality; the Central Highlands and South Central Coast regions experience too little water and poor water quality; the Southeast region has faced over-utilisation and poor water quality; and the Mekong River Delta experiences too variable water, poor water quality and over-utilisation.
- **Decreasing transboundary water flows and deepening of river channels due to sand mining** have intensified saline intrusion in the Delta, while agricultural and domestic wastewater also contribute to pollution.
- **Groundwater is over-exploited in some areas**, leading to land subsidence and further water quality problems, especially in acid-sulphate and saline soils.
- **Viet Nam's legal framework regarding water resources management is comprehensive, though it is less successful in managing water quality**. Financial resources are constrained, and there are challenges in data collection and monitoring.

Water scarcity in Viet Nam has high spatial and temporal variability, driven by increasing demand and competition between sectors, dependency on upstream development and climate change.

The North Central Coast region has recently experienced **too variable water** and **poor water quality** due to extreme weather conditions such as drought and heatwaves. The Central Highlands and South Central Coast regions have also experienced **too little water** and **poor water quality** due to the wet–dry monsoonal climate causing a prolonged dry season, the over-abstraction of groundwater for coffee production, and untreated wastewater from domestic, agricultural, and industrial sectors. The Southeast region has faced **over-utilisation** and **poor water quality**, largely due to poorly planned reservoirs constructed before 1990, which were designed for irrigation without any consideration of domestic, aquacultural, power, flood protection, or tourism water needs. The Mekong River Delta experiences **too variable water, poor water quality** and **over-utilisation**. Declined water flows in the Delta, which subsequently intensifies saline intrusion, are primarily caused by decreasing flood flows and deepening of river channels due to sand mining.

Strengths: Viet Nam's legal framework regarding water resources management is comprehensive, and the country has several well-implemented programs on rural development, poverty reduction, and rural clean water and sanitation. Viet Nam is also undertaking a review and amendment of the country's water law, which may provide an opportunity to address some of the key issues related to water scarcity.

Weaknesses: The country faces high inter-annual and seasonal water variation, uneven geographical groundwater distribution and over-exploitation in the major agricultural regions (e.g., Mekong Delta, Central Highland), which lowers the water table and causes land subsidence. There is limited cross-sectoral cooperation and few incentives to promote private sector involvement, and financial resources are constrained, undermining data collection capacity.

4.5 Thailand

KEY FINDINGS

- **Thailand experiences all four types of water scarcity: too little water, too variable water, over-utilisation and poor water quality.**
- **Poor water quality is widespread across the country due to industrial and agricultural pollution** and high population density, with low rates of wastewater treatment (except Bangkok). Recent droughts have led to increased saline intrusion (e.g., in Chao Phraya).
- **Improved mandates and funding are expected to assist River Basin Committees**, but local-level support is still needed for collaboration between institutions, as well as innovation and technologies that could ensure farmers and local people have water access in the dry season.
- **Evaluation processes for the implementation of water policies, plans and strategies at the local level remain limited.**
- **River basin planning also remains fragmented** due to a lack of authority and financial resources for River Basin Committees, as well as competition between different sectors and historical institutional mandates.

In conjunction with increased climate variability, population growth and economic development have driven a trend towards water scarcity across all geographic zones. Each region of the country experiences water scarcity challenges differently.

Too little water is a significant issue across large parts of the country—particularly in the central, north and northeast areas. **Too variable water** is an ongoing challenge across the country, where monsoonal rainfall patterns result in limited water availability during the dry season (except for that which is stored in reservoirs). There are also widespread reports of increasing inter-annual variability. **Over-utilisation of water** is also an issue in certain parts of the country; for example, the development of the Eastern Economic Corridor has rapidly increased water demand in the area, increasing water allocation to industry (Manorom, 2020). **Poor water quality** occurs widely across Thailand due to a high level of industry, high population density and low wastewater treatment rates in both industrial and agricultural sectors. Except for Bangkok, there are low wastewater treatment rates in the country, meaning industrial and agricultural pollution is widespread.

Climate change may have detrimental impacts on the country's agricultural sector. While overall annual precipitation is projected to increase, the variability is expected to increase both seasonally and geographically due to three distinct seasons (e.g., rainfall may decrease between September and October, which is a rice-productive phase), though there is high uncertainty regarding precipitation changes due to varying model estimates and emissions pathways. Temperature increases are also expected to impact crop productivity negatively under high-emissions scenarios, though little seasonal variability is projected. However, as with precipitation, the impacts of temperature changes on agriculture are expected to vary geographically (e.g., eastern, south-central and north-eastern areas likely to suffer most negative impacts) (World Bank Group & Asian Development Bank, 2021a).

Thailand's national water management institutions have undergone significant restructuring. This was primarily due to Thailand's Water Vision, published in 2000, which reported a lack of coordination between the seven ministries involved in water resources management, each with differing priorities and programs. Thailand's Water Vision findings would ultimately lead to restructuring the nation's water management institutions towards better coordination. In 2017, the Office of the National Water Resources (ONWR) was established to restructure the country's water management institutional framework. All other water-related departments must now coordinate with ONWR for all water-related issues. The Water Resources Act (the Water Law) was approved in January 2018 to streamline water management across the 48 government agencies that had previously managed water with overlapping mandates and identify key challenges such as inefficient water management. In 2019, the Cabinet of Thailand approved the 2018–2037 Master Plan, which outlined six strategies for managing water scarcity in the country. The Master Plan utilises a **water security framework** to inform priorities for action and measurement of outcomes, which is based on the Asian Development Bank's Asian Water Development Outlook and refined through engagement with Thai stakeholders.

Strengths: Recent systematic policy, strategy and institutional reforms in Thailand have begun to strengthen the enabling political environment. There are also generally good emergency responses to drought.

Weaknesses: There is little stakeholder engagement beyond large-scale water users to encourage buy-in to the reform processes in Thailand, and planning at the river basin level is fragmented due to a lack of authority and financial resources for River Basin Committees. There is also limited systematic monitoring and evaluation for policy implementation at the local level, which would be beneficial.

4.6 Lao People's Democratic Republic

KEY FINDINGS

- **Lao People's Democratic Republic experiences water scarcity in the form of variable water, over-utilisation and poor water quality.**
- **Increasing water demands from the agricultural, industrial and domestic sectors are likely to increase water scarcity** (likely to be localised). Intensive irrigation is already an issue in some areas.
- Significant regulation and **fragmentation of river hydrology due to hydropower reservoirs is a common cause of water scarcity** in the country.
- **Water quality issues occur due to human-induced pollution in industrial and urban areas** (e.g., Vientiane) and agricultural diffuse pollution. Arsenic contamination is also a minor issue for groundwater in central and southern regions.
- Given the country's relative abundance of water, Lao People's Democratic Republic has somewhat limited policy instruments explicitly linked to water scarcity. However, **growing pressures on water resources indicate a need for more concerted efforts to adequately prepare for and manage water scarcity.** This will be threatened by the country's over-reliance on the Mekong River for agricultural production and limited cross-sectoral integration and enforcement of existing regulations.
- In addition to financial resources for implementation, a focus should be placed on developing human resources.

Lao People's Democratic Republic has relatively abundant water resources per capita and is, therefore, one of South-East Asia's few water-scarce countries. Nevertheless, there is spatial and temporal variability causing too variable water, over-utilisation and poor water quality. Lao People's Democratic Republic generally has sufficient water resources, with the exception of the Xieng Khouang Plateau. Due to the monsoonal climate, water scarcity is seasonal. **Over-utilisation** by agriculture, industry and domestic use is currently a minor problem in Lao People's Democratic Republic , though some areas have intensive irrigation. A more common form of over-utilisation comes from the high degree of regulation and fragmentation of river hydrology due to hydropower reservoirs.

Water quality issues are predominately related to human-induced pollution in urban and industrial areas and agricultural diffuse pollution. Arsenic contamination is also a minor issue for groundwater in central and southern parts of the country (Chanpiwat et al., 2011). **Increasing water demands for agriculture, industry and urbanisation will likely increase water scarcity issues in Lao People's Democratic Republic** . This is expected to continue as the government prioritises economic development (e.g., expanding agriculture). Nevertheless, any water scarcity is likely to be localised. In areas of Lao People's Democratic Republic that rely on the Mekong River mainstream for water supplies, the construction of hydropower reservoirs on the mainstream Mekong will cause significant changes in the timing of water availability throughout the year (e.g., by flattening seasonal variability).

The occurrence of drought in the country may increase due to climate change and changes to peak flows may have complex implications for water resource management (World Bank Group & Asian Development Bank, 2021b). Research suggests that the construction of reservoirs in the Mekong River Basin will likely have a more significant impact on the Mekong's hydrology than climate change in the coming 20 to 30 years—particularly during the dry season—though climate change will increase the uncertainty of reservoir operation impacts (Lauri et al., 2012). Therefore, there is a need for better understanding of the impacts of climate change in river flow and increased transparency of reservoir storage and operations across the basin.

Strengths: Recent legislative and policy reforms have established a solid basis for integrated water management and relatively abundant water resources per capita mean water scarcity is not (yet) a significant issue in Lao People's Democratic Republic .

Weaknesses: There is limited cross-sector integration of water scarcity management in the country and regulation enforcement is generally weak. Limited water scarcity challenges mean it is not a focus of water management in the country. Several rice-producing provinces also rely on the Mekong River for rice production during the dry season.

4.7 Myanmar

KEY FINDINGS

- Myanmar has abundant water resources, but **experiences too variable water and dry season** shortages and has a lack of infrastructure for water storage to alleviate shortages.
- **The country is currently in a state of emergency and under military control, which has significantly impacted society and stalled many important projects related to water scarcity.**
- Prior to the current political unrest, Myanmar had made progress in developing a strong legal framework to manage its water resources; however, much of this progress is now stalled.

Myanmar experiences water scarcity in the form of too variable water; while there are sufficient water resources per capita and for growing food across most of the country, there is a high variability of water availability between wet and dry seasons and a lack of infrastructure to allow for intra-annual and inter-annual storage. Most regions of the country face high water scarcity during the middle of the dry season (November to April) and low water scarcity during the wet season (June to October). This is particularly evident in agricultural areas.

Two key drivers of water scarcity in Myanmar are population growth and urbanisation. The population increased from 21.7 million to 54.4 million between 1960 and 2020; rural population drastically decreased from 81 per cent to 29 per cent during the same period. This growing population has increased water demand for domestic water, agriculture and industry. Annual freshwater withdrawals increased from 2.26 billion m^3 in 1987 to 33.23 billion m^3 in 2017. Over-extraction of groundwater for irrigation has also led to groundwater depletion in several regions. **Climate change** has also driven water scarcity trends in Myanmar; the country is consistently classified among the most climate-vulnerable worldwide and is experiencing altered monsoon seasons (e.g., higher rainfall intensity and extended pre-monsoon droughts) (Nagpal, Rawlings & Balac, 2020).

Myanmar's Constitution provides the legal basis for water-related institutions, including the Directorate of Water Resources and Improvement of River Systems, the Irrigation and Water Utilization Management Department, the Department of Fisheries, the Department of Hydropower Planning and Implementation, and the Environmental Conservation Department. However, **no institution has a clear overarching responsibility for water resources management.** Myanmar's approach to water management has rapidly evolved since 2011. Collectively, these documents: (1) establish an overall requirement to protect and conserve the natural environment, including through provisions in the Constitution; (2) recognise the importance of protection and sustainable management of water resources and the benefits they provide; and (3) establish a legal head of power for managing freshwater resources, particularly via the Conservation of Water Resources and Rivers Law, and Environmental Conservation Law.

Strengths: Before the current unrest, Myanmar had successfully developed some water scarcity–related institutions and policy instruments (e.g., the formation of a national water resources committee) and strong relationships with bilateral and multilateral donors.

Weaknesses: With the current political unrest, many international donors have curtailed their funding in Myanmar, which is stalling the country's progress in managing water scarcity. There has also been low implementation of existing policy instruments, a lack of overarching water law and governance for transboundary and interstate planning, and limited supply management efforts (including infrastructure).

4.8 Fiji

KEY FINDINGS

- **Fiji faces two types of water scarcity: too variable water and poor water quality.**
- Although Fiji has abundant water resources with high annual rainfall, its **variable distribution across the islands and between seasons cause frequent droughts and floods.**
- **Degraded water quality occurs in areas of Fiji where urbanisation and industrialisation are increasing rapidly**. Poor wastewater treatment and management lead to untreated waste and effluent discharge into water bodies.
- **Fiji's water policy environment is somewhat fragmented** and in need of an overarching water sector policy to integrate the many sub-sectors and better define different departments' roles and responsibilities. More efforts are needed to explicitly deal with water scarcity.

Seasonal scarcity is pervasive throughout Fiji (particularly in dry zones) due to seasonal rainfall variability; the country often faces prolonged dry spells for three to four months.

Inter-annual variability is increasing in both frequency and magnitude in Fiji, causing water supply shortages in urban and rural systems in drought-prone areas (i.e., **too variable water**). This includes almost all of the Western Division, Northern Vanua Levu in the Northern Division, and many of the Yasawa, Mamanuca, Lau, Macuata and Lomaiviti groups.

Water pollution is a significant issue in dense urban, industrial and mining areas, leading **to poor water quality**. Poor wastewater treatment and management have led to untreated solid waste and untreated effluent discharge into water bodies. In the Vatukoula Goldmine region, cadmium, lead and manganese contamination levels in water bodies are higher than both Fiji and international standards (Kumar et al., 2021). Water quality is also poor in estuaries and marine recreational waters along the Suva foreshore, with high levels of E. coli and faecal coliforms (Lal, Juste-Poinapen & Poinapen, 2021). Groundwater over-exploitation is an issue in the Nadi Valley and other large islands, with the degradation of coastal aquifers in several islands due to both formal and informal settlements. Water conflicts also occur between different sectors due to poor water management—for example, between irrigation and other water-using sectors in the Sigatoka River.

Fiji's institutional framework for its water sector can be divided into government entities dealing predominantly with agriculture, water supply and sanitation, hydropower, environmental management and water scarcity risk management. While some departments, agencies and relevant non-government organisations have mandates for specific aspects of the water sector, many also have cross-cutting mandates. The newly established Ministry of Waterways is mandated to address the growing threat that water scarcity poses to Fijian communities. In Fiji, while some water management policies explicitly refer to water scarcity, many do not specifically contain measures for water scarcity.

Strengths: Fiji has a suitable enabling environment for water scarcity management. There is frequent intervention from non-government organisations focusing on natural resource management and best practices, which typically have a strong focus on climate change and resilience. This is highly important, as Fiji is expected to be significantly impacted by climate change in the coming decades due to combined threats of sea-level rise, storm surges and cyclones and increasingly variable rainfall.

Weaknesses: The country faces challenges in institutional coordination, leading to mission overlaps. There is also a weak legal foundation for actors in the water sector and a lack of data and surveillance in water management.

4.9 Indonesia

KEY FINDINGS

- **Indonesia experiences three types of water scarcity: too variable water, over-utilisation and poor water quality.**
- **Operation and maintenance** of irrigation infrastructure continue to be problematic in Indonesia, requiring continued subsidy and cyclic investment in rehabilitation and modernisation of existing works, in parallel to clear needs for further infrastructure development in new granaries. This comes at a cost of effective and sustainable use of water resources and complicates water accounting and allocation. Sustainable financing of operation and maintenance is critical.
- **Water supply for industry and services is important for economic development.** Ensuring sufficient quality and quantity of water supplies for industry is critical for economic growth. Industry as a water user is a competitor to agricultural water users, so a clear strategy on how water can be sustainably supplied to the industrial sector is needed. Poor regulation, monitoring and enforcement of industrial water pollution worsen the impacts of water scarcity and stress in key river basins in Java.
- **Monitoring and evaluation:** Support (finance and capacity) is needed to strengthen monitoring and evaluation systems to assess the impacts of policies and to enable adaptive management of water scarcity. A greater review of policy effectiveness would also be useful.

While Sumatra, Kalimantan, Sulawesi, Maluku and Papua have surplus water availability, Java, Nusa Tenggara Timur and Nusa Tenggara Barat experience localised water scarcity of varying types and severities. Scarcity levels range from absolute water scarcity in arid and semi-arid regions to seasonal or inter-annual scarcity to scarcity issues associated with groundwater dependency, water pollution and saline intrusion.

There is seasonal scarcity in parts of Indonesia, resulting in **too variable water**; during the dry season, 24 of 128 river basins are unable to meet water demands. **Over-utilisation** of water resources is also an issue in Indonesia, with water conflicts between users. Water demand is increasing due to economic pressures; industrial water demand alone is expected to increase from 9 billion m^3 to 36 billion m^3 between 2015 and 2045. Meanwhile, 108 rivers experience severe degradation and critical conditions due to **poor water quality**; 68 per cent of rivers are heavily polluted and only 2 per cent meet national water quality standards. One of the four pillars of Indonesia's overarching vision for 2045 emphasises the importance of water security. So far, 108 river basins have been identified for restoration before 2045.

Strengths: While there is good subsidiarity in legislation and regulation in Indonesia, implementation is challenging and varies across the country due to overlapping roles and responsibilities of different stakeholders. Detailed regulations support overarching laws: Government Regulation No. 20 of 2006 concerning irrigation, Government Regulation No. 43 of 2008 concerning groundwater, Government Regulation No. 38 of 2011 concerning rivers and Law No. 17 of 2019 on Water Resources Management.

Weaknesses: Devolution of responsibility to the lowest reasonable level needs to be supported with resources as well as a legal mandate for marginalised groups in decision-making. There is also weak law enforcement in the field of natural resources and water tenure, as Indonesia is complicated by customary land tenure.

4.10 Australia

KEY FINDINGS

- **Australia experiences all four types of water scarcity (too little water, too variable water, poor water quality and over-utilisation to varying degrees in various parts of the country.**
- **Coastal cities (home to around 80 per cent of the population and most industries) have exhausted reliable local catchment water resources**, and major capital cities have thus developed desalination plants to augment water supplies. Unlike many countries in the Asia–Pacific region, Australia's water resources are not extensively utilised for hydropower or transportation.
- Market-based mechanisms to compensate irrigation water users for transfers are often undermined by political sensitivities.
- **Australia serves as an example of how costly and difficult it can be to restrict water use** once a country's water resources have become over-allocated. The country continues to use a variation of policy and market-based instruments to manage its water resources.

Australia is a large country with differing water scarcity issues and characteristics. The two primary regions experiencing water scarcity are the south-eastern coastal area cities and the Murray–Darling Basin. All four types of water scarcity are experienced in various parts of the country.

Australia can be divided into 12 drainage regions, 246 river basins and 340 surface water management zones. On average, Australia receives around 2,789 billion m^3 of rainfall per year, equating to a relatively abundant 19,998 m^3 of renewable freshwater resources per capita; however, there is significant geographic variability in where this water is available. The south-eastern coastal area cities—where most of the population (around 80 per cent) and most industries reside—have exhausted reliable local catchment water resources. Major capital cities have, therefore, developed desalination plants to augment water supplies in dry years.

There are more than 820 public dams in Australia that collectively store more than 91 billion m^3 of water. Water supply accounts for 38 per cent of dam utilisation, with 18 per cent of dams used for hydroelectricity production, 17 per cent used for irrigation and the remaining dams used for recreation, flood control and multi-use purposes. In response to increasing pressures on water resources, **water management institutions in Australia have evolved from early state-based management to more centralised management by the federal government**, with a relatively sophisticated policy framework. Policy instruments can be categorised under four key areas: (a) building blocks to enable management of water scarcity; (b) national policy and legislative framework for water reforms; (c) planning framework with a focus on the Murray–Darling Basin; and (d) specific interventions and tools to achieve policy objectives.

Strengths: Over time, coastal cities have developed local catchments by building more dams as populations grow and droughts cause water scarcity. Urban storages have been progressively interconnected to optimise water availability for urban growth—for example, infrastructure exists to transfer water across the most heavily populated regions. Demand-side management and a total cost recovery approach to water pricing have also been introduced over the last 40 years.

Weaknesses: There is limited capacity to serve growing needs in certain regions of Australia (e.g., due to mountains separating large irrigation areas and major cities). Despite market-based and other mechanisms to compensate irrigation water users for transfers, significant political sensitivities continue to stand in the way and complicate reallocation efforts.

5 Trajectories Towards Sustainable Water Management

Water resources development and management across Asia–Pacific largely follows a trajectory whereby countries move from irrigation-focused water development towards increasing water withdrawals as economies develop. The goal of this journey is sustainable and equitable water management. The dynamism of the water sector means that countries must constantly balance and manage shifting water availability and utilisation. To learn from other countries' experience with water scarcity, it is useful to visualise and identify where those countries currently sit along the different stages of the trajectory—particularly to identify key opportunities for 'leapfrogging' problematic stages through well-planned water development.

Water scarcity in the region is primarily driven by population growth, associated economic development and agricultural expansion. However, climate change also poses major threats to already-stressed water systems and will continue to constrain opportunities for development and productive water use in the future. Climate change will further complicate the balance of water use between human needs and environmental requirements in countries where water resources will decline and become more variable (e.g., in arid and semi-arid regions such as Australia, northern China, West Asia and parts of South Asia), indicating a need for more emphasis on water scarcity management.

There are four phases (A–D) along the trajectory:

A. State-led irrigation development (increasing water demand).
B. Multi-sectoral development (increasing water competition between sectors).
C. Integrated water resources management (coordinated management of demand and supply).
D. Sustainable water management (balanced economic, social and environmental outcomes).

Each phase is represented along the ribbon flowing from the top left-hand corner to the end of Figure 4. The circles represent **milestones** in the four phases (light green, green, dark green and blue) that respond to **development drivers** (discs), which in turn often arise from **system shocks** (yellow triangles). It is important to note that the trajectory is not necessarily a linear path; countries might 'leapfrog' certain hurdles (examples of which are shown in Figure 4), and countries may encounter different aspects of each of the four phases simultaneously. This trajectory towards more sustainable and resilient water resources management is not a race but a way to find improvement opportunities.

5.1 Phase A: State-led Irrigation Development

Expansion of modern irrigation schemes in Asia has occurred since the 1960s, alongside the green revolution and opportunities to significantly increase the production of key staples such as rice and wheat (bred to be highly responsive to nitrogen fertiliser). International aid funding and technical assistance accounted for large proportions of irrigation development in the region from the 1960s to the late 1980s (Kajisa, 2021; Mukherji et al., 2009). However, international finance for irrigation has steadily declined in South Asia, Indonesia and China, with a shift towards programs related to the UN's water, sanitation and hygiene (WASH) goals, and from irrigation construction towards management.

Private groundwater exploitation started slowly in the 1960s, enabled by cheap pumps, cost-effective borehole drilling and subsidised power. This accelerated rapidly from the mid-1980s to the present day; in the case of India, groundwater became the dominant water source for agriculture by the early 2000s and has played a vital role in irrigation development in other countries such as China, Pakistan and Bangladesh. Investments into groundwater continued, however, in Viet Nam, Cambodia and Lao People's Democratic Republic , with a resurgence in the Asia–Pacific region since 2018.

Over-abstraction of groundwater in many of these countries has led to declining groundwater levels, rising costs, reduced yields, water contamination and public health issues from naturally occurring chemicals such as arsenic and fluoride. Such problems are more acute near large cities, where excessive groundwater use often results in a cone of depression below the urban area, leading to issues such as land subsidence, infrastructure damage and increased flood risk. Groundwater over-exploitation is common in major cities (e.g., Bangkok, Jakarta, Kathmandu and Manila), but is also emerging in smaller cities and towns. Excessive groundwater use for agriculture is also evident in parts of Viet Nam, Indonesia and Nepal. Bangladesh has made a bold transition from surface irrigation—vulnerable to seasonal flooding—to smallholder use of shallow groundwater (replenished by seasonal flooding), though this comes with additional risks of future over-exploitation.

5.2 Phase B: Multi-sectoral Development

With population growth and economic development, more diverse opportunities for employment and remuneration appear, driving rapid urbanisation and shifts in farming and rural living. However, declines in food prices (not including recent spikes after the financial crises and the COVID-19 pandemic) have made it harder for smallholders to satisfy food requirements and generate profits. Water demands typically broaden in this phase, increasing the proportion of water used by non-agricultural sectors. Investments in water infrastructure also expand, with interest in multi-purpose uses of dams—for example, hydropower, flood mitigation, urban water supply and irrigation. Where water shortages arise, policy tends to focus on supply-side solutions in this phase, even if resources are already highly developed. As observed in Nepal and China, more expensive engineering solutions such as inter-basin transfers follow, while Thailand and India are also interested in the same.

As water demand increases, its productive value simultaneously increases. The increased value can spark the transfer or capture of resources—for example, where irrigation companies sell bulk water supply to cities. At this stage, environmental needs are poorly recognised by governments, while evidence of degradation begins to arise from academic and activist spheres. Issues around climate change and variability or water over-abstraction receive little consideration. Countries such as Bangladesh, Lao People's Democratic Republic , Nepal and Cambodia are at this phase of the trajectory.

5.3 Phase C: Integrated Water Resources Management

Integrated Water Resources Management (IWRM) has been on the global agenda for almost 20 years, with numerous prescriptive ideas, funding packages and programs to develop it. Nevertheless, few countries have succeeded in adopting IWRM in practice. During the transition from development-focused policy to sustainable management, interest in improving the monitoring of water flows and quality increases. Formal and informal mechanisms are developed to manage water transfer from agriculture to other uses. Simultaneously, water laws and policies are reformed to emphasise management, sustainability and environmental stewardship—though often the necessary funds, capacity and tools for implementation are lacking. Countries such as Viet Nam, Indonesia and Thailand are at this phase.

5.4 Phase D: Sustainable Water Management

It is unlikely that a single country worldwide has successfully established a sustainable water management regime that fully balances economic, social and environmental outcomes. Instead, adaptive management processes, as established in Phase C, will continue to address water scarcity and related water issues as they evolve in different ways. While none of the countries studied are firmly within this phase, Australia has made some progress. Food security is a major policy and welfare concern for all countries in Asia (even those that make significant exports, such as Thailand and Viet Nam). The politics of constraining agricultural water use are complex and unforgiving in Asia–Pacific and structural changes in farming will be challenging. Despite the value of water for environmental flows beginning to be appreciated in Viet Nam, Indonesia and Thailand, trade-offs with urban, energy and industrial needs will continue.

Dead fish under the drought of Tri An Lake, Dong Nai province, Viet Nam. (Source: dantri.com.vn, 2023)

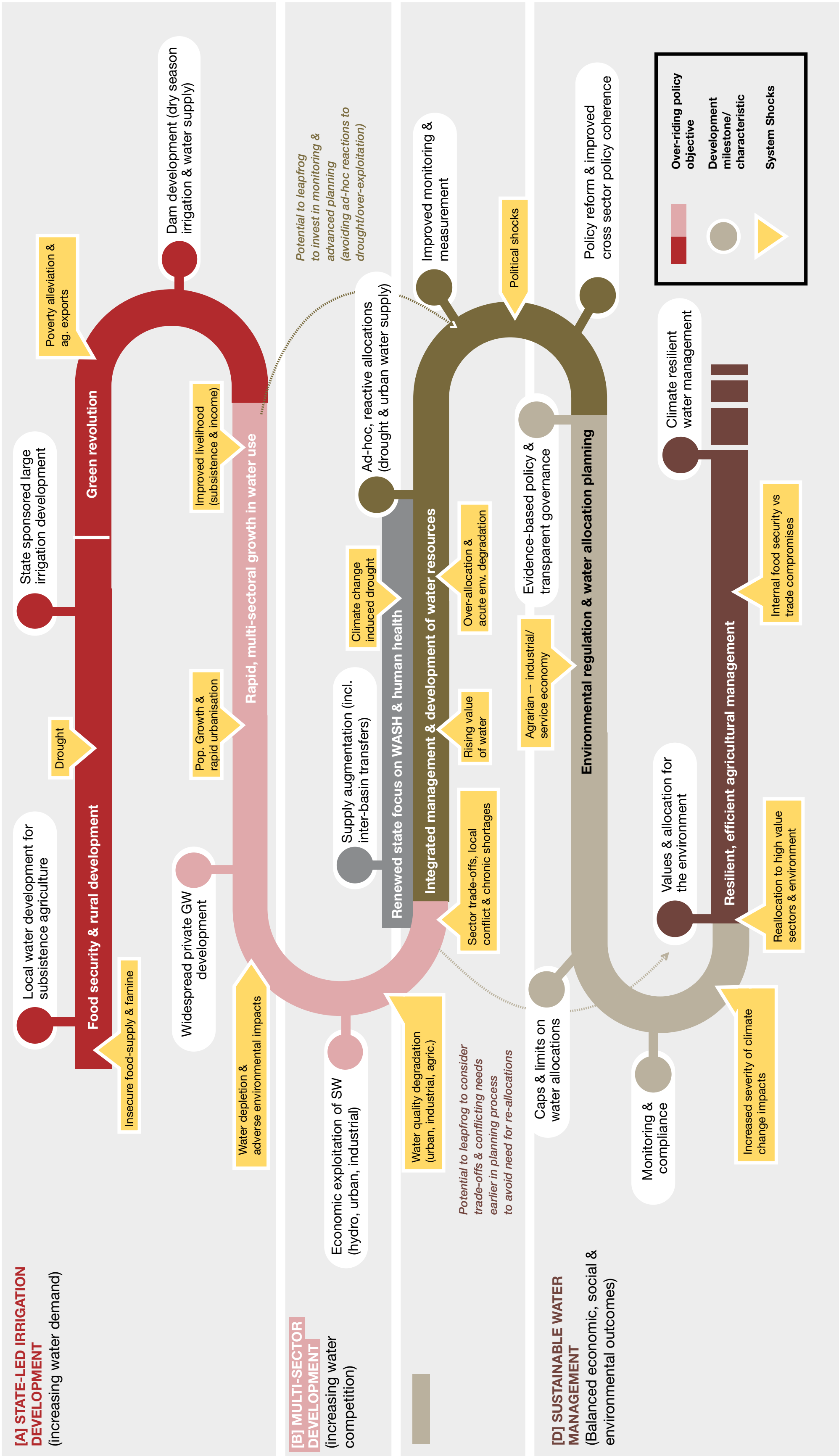

Figure 5. Water resources development and management in Asia–Pacific.

6 Best Practice Guidelines for Policy

Across the Asia–Pacific region, there is considerable variation between countries regarding how they manage water scarcity and their various legislative policies and regulations. Despite differences in how each country manages water, there are overlapping policy challenges and lessons drawn from the country profiles that indicate windows of opportunity for improved policy across the region.

6.1 Key Policy Challenges

A major policy challenge to achieving sustainable water resources management in Asia–Pacific is the differing approaches to balancing the benefits of excessive water use now and fixing problems later, versus realising benefits now that would avoid complex challenges later.

At the political level, most countries—particularly those with monsoonal climates—have limited awareness of established and emerging water scarcity trends and associated risks. However, drought awareness is generally increasing (e.g., with new drought policies in Thailand and Viet Nam), and the country profiles indicate a common interest in improving water scarcity management for the future, particularly considering the region's dependence on agriculture for livelihoods—a sector especially vulnerable to climate change.

6.2 Lessons for Managing Water Scarcity

Ten key policy lessons emerged from the case studies, indicating either areas in need of improvement or where benefits have already been realised with varying degrees of success. While every country has context-specific challenges, several lessons are applicable across the region. Many lessons also interlink with others; for example, the need for increased financial resources not only supports good water accounting and data collection but also regulatory enforcement and local government capacities.

Ten key lessons from the Asia–Pacific region regarding water scarcity management:

1. Water accounting is important for understanding water resource availability and dynamics.
2. River basin management and planning provide a useful framework for managing water scarcity.
3. Establishing water–sharing and allocation processes before water resources have been over-allocated helps avoid the difficulties and costs associated with restraining water use and reallocating water between sectors and jurisdictions once water resources are over-allocated.
4. Successful water scarcity policy implementation requires institutional coordination across scales and sectors.
5. Climate change policy may be an important leverage point for ensuring policy coherence.
6. Decentralisation of water management links higher-level policy to local-level action but needs adequate resources and incentivisation to succeed.
7. Good data collection and sharing support evidence-based decision-making; decision-making must also consider important non-technical factors, including political priorities (e.g., balancing water use between economically productive and environmental needs), existing legal frameworks, rationality and the time it takes to shift perceptions and roles within different agencies.
8. Genuine inclusive stakeholder engagement is important for ensuring equitable decision-making and allocation processes, including the involvement of civil society and the private sector, as well as gender equality concerns.
9. Water quality regulations and standards, as well as adequate monitoring, are urgently needed across the region.
10. Investment in resources (human and financial) is fundamental for implementing water scarcity management policies, building and maintaining infrastructure, and developing water-saving technologies and improved agricultural practices.

7 Outlook for Water Scarcity Management Across Asia–Pacific

Growing pressures on water resources across Asia–Pacific—including a growing population, increasing competition for water resources and unabated water pollution due to industry and agriculture—continue to exacerbate water scarcity across the region. This is compounded by climate change and requires urgent regulatory and financial attention, as exemplified by this study. If countries do not commit to developing their water scarcity responses, it may have severe impacts—particularly on the poorest and most vulnerable groups in society who are highly dependent on water resources for their livelihoods.

Water scarcity challenges in the Lower Mekong countries tend not to be about chronic scarcity but either 'too little' or 'too much' water (i.e., issues with water variability). This is typically exhibited as intermittent inter-annual drought and seasonal scarcity due to monsoonal climates, growing competition for water resources and pollution impeding access to good quality water. Water quality deterioration due to industrial and agricultural pollution also directly impacts human health, ecosystem health and food security.

Domestic agricultural production for food security remains a political priority in many countries in the region; to avoid the impacts of water scarcity on the agricultural sector, agricultural policies will need to be better integrated with water policies. Future climate change may intensify water scarcity and further impact crop productivity (Elliott et al., 2014; Liu et al., 2022). Pressure to produce high-value crops with dwindling water supplies, which is driving structural changes in farming throughout the region, will also likely refocus irrigated production towards fruit, vegetables, aquaculture and specialty crops (away from dry season rice irrigation). As farm management units increase in size and become more commercially orientated, regulatory challenges concerning water rights and allocation should become more straightforward and incur lower transaction costs (e.g., administrative costs).

Many governments place faith in irrigation efficiency measures, yet these do not automatically lead to water savings and may even stimulate greater water consumption. Similar hopes have been placed in groundwater as a strategic form of water storage to increase the resilience of water resources during droughts and in the face of climate change. However, irrigation and groundwater must be regulated and managed sustainably—a task that faces significant transaction costs associated with pricing, metering and monitoring, and subsequent potential trade-offs as faced in India (see Shah, Bhatt, Shah and Talati [2008]). Vast improvements in the scope, extent and quality of data for diagnosis and management are urgently required.

Considerations will be needed to improve crop production while using the same quantity or less water. Improving crop production will help to minimise the impacts of climate change, limit the loss of agricultural area due to construction and compensate for out-migration from farming areas. Past interventions that intensify production using high levels of fertiliser and agrochemical inputs will not be effective solutions, and the environmental footprint of agriculture will have to be reduced simultaneously as overall production increases.

7.1 Windows of Opportunity

As shown in Figure 5, policymakers may identify and act on windows of opportunity in terms of best practices and actions that can address multiple threats, challenges and associated impacts of water scarcity across Asia–Pacific. These include improvements in river basin planning (especially water accounting) and institutional coordination across administrative scales, as well as support for policy implementation and decentralisation. Both human and financial resources underpin these efforts.

THREATS & CHALLENGES	WATER SCARCITY IMPACTS	GOALS	BEST PRACTICES & ACTIONS
• Growing population • Industrialisation • Urbanisation • Increasing water demands and sectoral competition (agriculture, domestic/urban, industry, energy)	**Over-utilisation** • Unsustainable withdrawals/ over-abstraction (especially agricultural) • Water quality issues • River hydrology fragmentation	**Sustainable water resources** • Sufficient water for ecosystem + human health • Climate change adaptation (e.g., drought preparedness, inter-seasonal storage)	**River basin planning and water accounting** • Water accounting • Long-term planning > ad hoc response • Evidence-based decision-making • Protection of environmental flows • Balancing conflicting needs/priorities • Transboundary/inter-basin agreements
• Seasonal water availability (monsoonal climate) • Climate change • Pollution (agriculture, urban + industry) • Poor wastewater management & treatment • Lack of seasonal storage (infrastructure)	**Too little water** • Low precipitation/runoff • Too little per capita availability	**Good quality water** • Reduced pollution (urban, agricultural + industrial) • Wastewater management + treatment	**Institutional coordination** • Inter-sectoral, inter-ministerial • Across scales (national to local) • Cross-cutting issues (e.g. climate change, agriculture, drought response, energy, rural development, land)
	Too variable water • Seasonal/interannual variability • Floods during wet season, drought during dry season • Lengthened dry season (climate change)	**Well-balanced allocations** • Management of water competition within/ between sectors • Evidence-based decision-making • (Re) allocation processes • Conflict resolution + trade-offs mediated between sectors • Political prioritisation + commitment	**Decentralisation & implementation** • Higher-level policy > subsidiary actions • Engage stakeholders across sectors + scales (incl. women, marginalised groups, private sector)

THREATS & CHALLENGES	WATER SCARCITY IMPACTS	GOALS	BEST PRACTICES & ACTIONS
• Low institutional coordination • Resource constraints (human + financial) • Uneven policy implementation • Low regulation & enforcement • Political priorities • Data & information gaps • Historical & cultural contexts	**Poor water quality** • Saline intrusion • Polluted water sources (E. Coli, faecal matter, fertilisers/pesticides, metals) • Reduced water availability	**Equitable water access** • Genuine stakeholder engagement • Empowerment of women + marginalised groups	**Resources (human + financial)** • Local/subsidiary implementation support • Data collection + monitoring • Infrastructure maintenance • Investments in innovations/technology • Investment in inter-seasonal storage • Capacity building, policy implementation • Regulation + enforcement

Figure 6. Linking water scarcity threats, impacts, goals and proposed best practices for Asia–Pacific.

For countries not yet facing water scarcity, there is an opportunity for establishing a legislative framework of water sharing before over-allocation occurs. This is much easier, less expensive, and less disruptive than recovering and reallocating water later (e.g., as observed in Australia's Murray–Darling Basin). River basin organisations may be strengthened through improvements in water accounting, data management, stakeholder engagement and the formulation of water allocation processes and rules that can be monitored and enforced. Appropriate conflict resolution mechanisms and the balancing of multiple needs and values across stakeholders and sectors will also need careful deliberation.

Improvements in living standards across the region are expected to reduce agricultural water use in favour of uses with higher economic value. This may, however, pose challenges regarding food security (particularly self-sufficiency) and rural livelihoods. Declining water availability for agriculture will also increase pressure to intensify cropping systems to maintain production; it will, therefore, be important to do so without exacerbating existing water quality and ecosystem health issues. There is thus a strong need for prioritising environmental flow requirements, which are often overlooked in favour of more economically valuable water uses, including irrigation (Jägermeyr, Pastor, Biemans & Gerten, 2017).

Responses to water scarcity must involve a redistribution of benefits among existing users and provide appropriate compensation for losers. Most countries in Asia have opted for industrialisation as the main development path and, as such, must manage a delicate transition over a period when most of the population remains engaged in agriculture, despite its declining proportion of GDP.

Ultimately, managing water scarcity in Asia–Pacific is a long-term task with no simple or quick fixes. Rather, water policy will require long-term political commitment, consistent financial support and adaptive approaches to navigate conflicting water demands and needs fairly, and under a changing climate. No matter where a country sits on the sustainable water resources management trajectory, the time for action is now.

8 References

Alcamo, J. & Henrichs, T. (2002). Critical regions: A model-based estimation of world water resources sensitive to global changes. Aquatic Sciences, 64, 352–362. doi:10.1007/PL00012591

Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A. & Wood, E. F. (2018). Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific Data, 5(1), 180–214. doi:10.1038/sdata.2018.214

Chanpiwat, P., Sthiannopkao, S., Cho, K. H., Kim, K.-W., San, V., Suvanthong, B. & Vongthavady, C. (2011). Contamination by arsenic and other trace elements of tube-well water along the Mekong River in Lao People's Democratic Republic . Environmental Pollution, 159(2), 567–576. doi:10.1016/j.envpol.2010.10.007

Elliott, J., Deryng, D., Müller, C., Frieler, K., Konzmann, M., Gerten, D., … Best, N. (2014). Constraints and potentials of future irrigation water availability on agricultural production under climate change. Proceedings of the National Academy of Sciences, 111(9), 3239–3244. doi:10.1073/pnas.1222474110

Falkenmark, M., Lundqvist, J. & Widstrand, C. (1989). Macro-scale water scarcity requires micro-scale approaches: Aspects of vulnerability in semi-arid development. Natural Resources Forum,13(4), 258–267. doi:10.1111/j.1477-8947.1989.tb00348.x

Food and Agriculture Organization of the United Nations. (2012). Coping with water scarcity: An action framework for agriculture and food security (FAO Water Reports 38). Retrieved from https://www.fao.org/3/i3015e/i3015e.pdf

Food and Agriculture Organization of the United Nations. (2021). FAO water scarcity program (WSP) for Asia-Pacific. Retrieved from https://www.fao.org/documents/card/en/c/cb4417en

Gerten, D., Heinke, J., Hoff, H., Biemans, H., Fader, M. & Waha, K. (2011). Global water availability and requirements for future food production. Journal of Hydrometeorology, 12(5), 885–899. doi:10.1175/2011JHM1328.1

Hussain, Z., Wang, Z., Wang, J., Yang, H., Arfan, M., Hassan, D., … Faisal, M. (2022). A comparative appraisal of classical and holistic water scarcity indicators. Water Resources Management, 36(3), 931–950. doi:10.1007/s11269-022-03061-z

Jägermeyr, J., Pastor, A., Biemans, H. & Gerten, D. (2017). Reconciling irrigated food production with environmental flows for sustainable development goals implementation. Nature Communications, 8(1). doi:10.1038/ncomms15900

Kajisa, K. (2021). Contemporary Irrigation Issues in Asia. Retrieved from https://www.adb.org/sites/default/files/institutional-document/731791/adou2021bp-irrigation-issues-asia.pdf

Klein Goldewijk, K., Beusen, A., Doelman, J. & Stehfest, E. (2017). Anthropogenic land use estimates for the Holocene – HYDE 3.2. Earth System Science Data, 9(2), 927–953. doi:10.5194/essd-9-927-2017

Kumar, S., Islam, A. R. M. T., Islam, H. T., Hasanuzzaman, M., Ongoma, V., Khan, R. & Mallick, J. (2021). Water resources pollution associated with risks of heavy metals from Vatukoula Goldmine region, Fiji. Journal of Environmental Management, 293. doi:10.1016/j.jenvman.2021.112868

Kummu, M., Gerten, D., Heinke, J., Konzmann, M. & Varis, O. (2014). Climate-driven interannual variability of water scarcity in food production potential: A global analysis. Hydrology and Earth System Sciences, 18(2), 447–461. doi:10.5194/hess-18-447-2014

Lal, P. P., Juste-Poinapen M. S., N. & Poinapen, J. (2021). Assessing the water quality of Suva foreshore for the establishment of estuary and marine recreational water guidelines in the Fiji Islands. Water Science and Technology, 84(10–11), 3040–3054. doi:10.2166/wst.2021.323

Lauri, H., de Moel, H., Ward, P. J., Räsänen, T. A., Keskinen, M. & Kummu, M. (2012). Future changes in Mekong River hydrology: Impact of climate change and reservoir operation on discharge. Hydrology and Earth System Sciences, 16(12), 4603–4619. doi:10.5194/hess-16-4603-2012

Liu, J., Yang, H., Gosling, S. N., Kummu, M., Flörke, M., Pfister, S., ... Zheng, C. (2017). Water scarcity assessments in the past, present, and future. Earth's Future, 5(6), 545–559. doi:10.1002/2016EF000518

Liu, X., Liu, W., Tang, Q., Liu, B., Wada, Y. & Yang, H. (2022). Global agricultural water scarcity assessment incorporating blue and green water availability under future climate change. Earth's Future, 10(4). doi:10.1029/2021EF002567

Manorom, K. (2020). Thailand's water shortage and inequality crisis. East Asia Forum. Retrieved from https://www.eastasiaforum.org/2020/03/20/thailands-water-shortage-and-inequality-crisis/

Ministry of Water Resources and Meteorology. (2012). Cambodia climate change strategic plan for water resources and meteorology (2013–2017). Retrieved from https://www.preventionweb.net/files/65011_cam182341.pdf

Mukherji, A., Facon, T., Burke, J, de Fraiture, C., Faures, J.M., Fuleki, B. ... Shah, T. (2009). Revitalizing Asia's irrigation: to sustainably meet tomorrow's food needs. Retrieved from https://www.iwmi.cgiar.org/Publications/Other/PDF/Revitalizing%20Asia%27s%20Irrigation.pdf

Nagpal, T., Rawlings, H. & Balac, M. (2020). Understanding water demand and usage in Mandalay city, Myanmar as a basis for resetting tariffs. Journal of Water, Sanitation and Hygiene for Development, 10(4), 680–690. doi:10.2166/washdev.2020.076

Pedro-Monzonís, M., Solera, A., Ferrer, J., Estrela, T. & Paredes-Arquiola, J. (2015). A review of water scarcity and drought indexes in water resources planning and management. Journal of Hydrology, 527, 482–493. doi:10.1016/j.jhydrol.2015.05.003

Rijsberman, F. R. (2006). Water scarcity: Fact or fiction? Agricultural Water Management, 80(1–3), 5–22. doi:10.1016/j.agwat.2005.07.001

Rockström, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S. & Gerten, D. (2009). Future water availability for global food production: The potential of green water for increasing resilience to global change. Water Resources Research, 45(7). doi:10.1029/2007WR006767

Shah, T., Bhatt, S., Shah, R. K. & Talati, J. (2008). Groundwater governance through electricity supply management: Assessing an innovative intervention in Gujarat, western India. Agricultural Water Management, 95(11), 1233–1242. doi:10.1016/j.agwat.2008.04.006

Thanju, J. P. (2012). Kathmandu Valley groundwater outlook. Hydro Nepal Journal of Water, Energy and Environment, 11, 72–73. doi:10.3126/hn.v11i0.7169

United Nations Economic and Social Commission for Asia and the Pacific. (2013). Statistical yearbook for Asia and the Pacific 2013. Retrieved from https://www.unescap.org/sites/default/files/publications/ESCAP-SYB2013-full.pdf

United States Agency for International Development. (2021). Nepal water resources profile overview. Retrieved from https://winrock.org/wp-content/uploads/2021/08/Nepal_Country_Profile_Final.pdf

Uprety, B. K. (2014). Eco-efficient urban water infrastructure development in Nepal. Retrieved from https://www.unescap.org/sites/default/files/Eco-efficient%20Urban%20Water%20Infrastructure%20Development%20in%20Nepal.pdf

Vörösmarty, C. J., Green, P., Salisbury, J. & Lammers, R. B. (2000). Global water resources: vulnerability from climate change and population growth. Science, 289(5477), 284–288. doi:101126/science.289.5477.284

The World Bank. (2023). DataBank. Retrieved from https://databank.worldbank.org/home

World Bank Group & Asian Development Bank. (2021a). Climate risk country profile: Thailand. Retrieved from https://www.adb.org/sites/default/files/publication/722251/climate-risk-country-profile-thailand.pdf

World Bank Group & Asian Development Bank. (2021b). Climate risk country profile: Lao People's Democratic Republic . Retrieved from https://www.adb.org/sites/default/files/publication/709846/climate-risk-country-profile-lao-pdr.pdf

Worldometers. (2020). Population. Retrieved from https://www.worldometers.info/population/asia/

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