Food and Agriculture Organization of the United Nations

Sustainable management of freshwater resources for food security and nutrition in Small Island Developing States

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Foreword

The current report aims to address, 'How can freshwater management contribute to Food security and Nutrition in Small Island Developing States?' is. The study fits within The Global Action Programme on Food Security and Nutrition in Small Island Developing States, which prioritizes an integrated approach for freshwater management and actions to improve Food security and Nutrition (FNS) in Small Island Developing States (SIDS). The study follows the SAMOA Pathway where SIDS leaders[1] formulate ambitious commitments to eradicate poverty, promote sustainable patterns of consumption and production and protect the natural resource base for economic and social development. FAO believes strongly that supporting this ongoing transformation to more sustainable agri-food systems has great potential in achieving positive, concrete and constructive change across the SIDS.

FAO, UN-OHRLLS[2] and UNDESA (the UN Department of Economic and Social Affairs) work at an enabling environment for Food security and Nutrition through capacity building and strengthening the sustainable management of oceans, fresh water and territorial resources in the SIDS. In particular, the UN agencies share the concern that the fragile economies of the world's SIDS are increasingly experiencing freshwater shortages and degradation that directly affect the livelihood and food security situation of their populations. Indeed, the management of scarce water resources in the SIDS faces a multitude of challenges that relate to anthropogenic pressures, obsolete water acts, lack of institutional coordination and climate change effects. In response, FAO is active in supporting SIDS' access to climate change funds from the Global Environment Facility, the Green Climate Fund and other sources, with the aim to integrate and mainstream freshwater management into the SIDS policies.

There is, to be sure, widespread agreement that integrated water management policies should be based on high-quality data that accurately reflect the volumes and quality of water and its flows, in both geographical and temporal dimensions. Additionally, the data should be harmonized and organized in an analytical framework that can support effective decisions on essential functions of the islands' freshwater resources to support households, agriculture, tourism, and industrial sectors. Such an integrated approach should also address the rising concerns of untreated waste and polluted waters on human health and ecosystem risks to avoid pollution of aquifers and to prevent the destruction of the islands' ecological assets.

The contributions of freshwater management to FNS has become even more relevant during the COVID-19 pandemic as the SIDS grapple with a limited productive resource base and are blocked by food imports, while tourism revenues have dropped to almost nil. In these dire COVID-19 times, freshwater management can play an important role by supporting the fragile food systems in SIDS through the cultivation of fresh and healthy foods. In addition,

[1] Third International Conference on Small Island Developing States held in Apia, Samoa, 1-4 September, 2014.

[2] UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

the SIDS can take steps to empower people to grow their own food using allotment gardens, hydroponics or aquaponics systems and vertical farms, thus increasing their resilience and making the islands less vulnerable to external shocks.

Water policies to support FNS should also capitalise on the strong advantages of the SIDS. The relatively small size of the islands and the relative proximity of all actors could facilitate the organization of a cross-sectoral and ecosystem-oriented water management scheme that would involve all relevant stakeholders that would bring long-lasting solutions to the water supply problems. Through collective multistakeholder participation, gaps can be Identified for the priority areas. This process could inspire renewal, build-up and scale-up of existing partnerships, which would further new innovative partnerships such as the development of public-private partnerships.

This publication draws on the combined expertise of authors who brought various methods to an insightful and comprehensive analysis of the management of freshwater resources and its relation to the prevailing FNS in the context of the SIDS. We hope this study inspires the readers to greater awareness and knowledge for a better understanding of the island people and the need for conservation of their precious assets in the SIDS.

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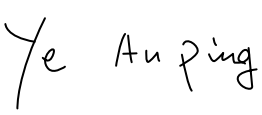

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Context

The Food and Agriculture Organization of the United Nations (FAO) and the Amsterdam Centre for World Food Studies of the Vrije Universiteit Amsterdam (ACWFS) agreed to collaborate on a study to support the implementation of the Global Action Programme (GAP) on Food Security and Nutrition in the SIDS, with a specific focus on Work Area 2.2.1: 'sustainable management and use of freshwater resources for food security and nutrition,' as detailed in FAO's Inter-Regional Initiative on Small Island Developing States (SIDS). The study aims to deepen the understanding of the challenges and opportunities in managing freshwater resources on the SIDS in the context of water scarcity for agriculture and climate change. The findings of this study should support the SIDS in managing water scarcity in agriculture, in an integrated, sustainable and innovative way. The study was sponsored by FAO's South-South and Triangular Cooperation Division (PST) and received technical support from the Land and Water Division. This report is the result of the above mentioned collaboration. An inception report presented in April 2019 at FAO in Rome proposed the scope of the study and was accepted as an outline for this report. Other slight adjustments in the final reporting are governed by logic and overall coherence.

Acknowledgements

This publication was prepared by the FAO Land and Water Division with the technical direction of Sasha Koo-Oshima, Deputy Director of the FAO Land and Water Division.

The authors are thankful to FAO's South-South and Triangular Cooperation Division (PST), represented by former division director Dr Shengyao Tang, his successor Mr Ye Anping and Ms Athifa who kindly supported this study and the missions to Barbados and Mauritius. PST jointly with the Land and Water Division (NSL) distributed the survey among water professionals in SIDS countries. Dr Amani Alfarra from the Land and Water Division provided technical assistance throughout the project. Also, we would like to thank FAO's regional offices in Barbados and Mauritius for their assistance and for organizing contacts with dedicated water managers, researchers and farmers, all of whom responded enthusiastically and without reservations to our in-depth interviews.

Additionally, the authors would also like to acknowledge the technical contribution as well as review of the following FAO colleagues: Marlos DeSouza, Oxana Perminova, Eva Kohlschmid, Manuel Maria Flores Ruiz, Antoine Asselin Nguyen, George Akoko, Taimur 'Tai' Khan, and Bart van den Boom.

Useful remarks and suggestions were received from two external reviewers: Dr Brinda Ramasawmy, Head of Department Agricultural Production and Systems, Faculty of Agriculture, University of Mauritius and Mr Robert C. Brears from Our Future Water, Christchurch, New Zealand. From FAO, input from Ms Vera Boerger, Senior Land and Water Officer in the Land and Water Division and Mr Chado Tshering, Programme Officer for Small Island Developing States (SIDS), Least Developed Countries (LDCs) and Landlocked Developing Countries (LLDCs) was much appreciated. Editorial comments and suggestions from Ms Ruth Raymond were very helpful. Special thanks go to Mr James Morgan for the design and layout of this publication.

Executive summary

This study investigates how freshwater management can contribute to Food security and Nutrition (FNS) in Small Island Developing States (SIDS). It contributes to FAO's Global Action Programme, which prioritises an integrated approach to freshwater management on FNS in SIDS.

The far-flung and often remote SIDS face enormous challenges to FNS. In the coming decades, their resilience will be further tested by extreme weather events arising from climate change. Increasing fresh and healthy food production is therefore widely advocated by international organizations and by SIDS governments Yet, the timely delivery of the freshwater needed for crop cultivation cannot be taken for granted. The agricultural sector is in fierce competition with other – often very vocal – water users, such as the rapidly growing urban population. Other 'users' are silent, such as the water flows needed to preserve the scenic beauty and support the unique ecosystems of the islands. The return of treated effluents from households, industry and agriculture to the system is crucial to avoiding the pollution of aquifers and coastal areas, which can compromise human health and ecosystem quality, but such efforts are often thwarted by cultural prejudice. This multitude of issues necessitates an effective water governance structure that can secure equitable and efficient allocation of water resources in SIDS.

Our study began with an effort to establish the research objective in the context of the geography, economy and water resources in SIDS. A water governance component captured the lessons learned from water projects through an analysis of case studies and primary data obtained from a survey and two field visits to Barbados and Mauritius. The synthesis of the analytical results provided the basis for a road map on water governance that would support FNS in the SIDS context.

Profiling the SIDS

The study found that most high-quality land in SIDS is under cultivation, mostly to monocultures of cash crops inherited from the colonial period. Remoteness and low connectivity to trading routes explain the relatively high transport costs for the SIDS and the high prices of imported foods. Many SIDS have fragile economies, with low incomes, high unemployment rates and little resilience to natural disasters. The fragility of the SIDS is particularly apparent during times of crisis, such as the COVID-19 pandemic in early 2020 when tourism was stopped and expected remittances from workers in affected regions elsewhere did not arrive.

Interestingly, the small size and remoteness of the SIDS are also the source of potential strengths, including a strong sense of island community and a ready-made platform for cross-sectoral and ecosystem-oriented water management schemes. The existing knowledge base

of ecosystem custodians can support transdisciplinary planning and the community-based management of island resources, which can synchronize production and ecological objectives.

The study revealed that, while a few SIDS meet food diversity standards, most islands suffer from micronutrient deficiencies with dire health consequences that particularly affect the poorest people.

Water flows

FAO's AQUASTAT provided water flow analysis for 42 of the 56 SIDS countries and territories. Data were not always complete and country- or territory-wide reporting had to be extrapolated from the diverse physiography of multiple islands belonging to a single SIDS.

Most 'high' islands obtain their renewable water resources from surface waters, while 'low' and 'mixed' islands have larger groundwater reserves. There is some indication that SIDS generally rely more on surface water than on groundwater resources. However, the risk of overextraction and sea intrusion loom large as rapid urbanization exerts an increasing pressure on shallow groundwater reserves near the coastlines.

Agriculture is usually the largest water user in SIDS, with the exception of high-income countries where municipalities lead, followed by industry. The share of cultivated land equipped for irrigation is very low, leaving ample room to increase water use efficiency for the intensification of agricultural areas.

Although most low- and middle-income SIDS do not experience water stress, even when subject to various forms of pressure over long periods, such as rapid population growth or reduced rainfall due to climate change, only a few are at the lower end of moderate water stress. Most high-income SIDS experience high water stress levels that will increase further, according to stress scenarios for 2030 and 2050, when countries will reach the alarming state of 'very severe water stress.'

The findings on water quality were not very positive due to two main causes. First, SIDS have low connectivity and limited sewer capacity for municipal and industrial wastewater, together with inadequate wastewater treatment. Second, and equally problematic, the high rate of pesticide use in many SIDS affects the quality of aquifers and surface waters as well as marine ecosystems and fisheries. Strong regulations and enforcement are needed to avoid water pollution and preserve the ecosystems.

This study indicates that good access to drinking water and sanitation services is key to the healthy development of children in SIDS. Hence, SIDS are urged to take urgent action to ensure that water sanitation and hygiene (WASH) conditions are available to everyone.

The case studies

Our challenge was to extract patterns from the sparse data emerging from a series of case studies to determine useful lessons for future water projects. What follows are the key lessons learned from this exercise.

A number of projects – sponsored by external donors – carried out similar interventions on multiple islands. Yet the SIDS governments were for the most part not motivated to undertake joint action and the creation of economies of scale through south-south cooperation between islands remains in its infancy.

Overall, the degree of transdisciplinarity in the projects was low. Greater attention to involving the full range of stakeholders would improve the sustainability of projects and better define the tasks of the custodians in the post-project period.

Most case studies do not include a reference to financing mechanisms in the post-project period. Thus, it is not clear if the financial viability of externally funded projects is assured or if the completion of the project means the end of the water services.

A water-energy-food (WEF) nexus approach seems particularly relevant for SIDS since the budgetary and physical constraints experienced by the countries could stimulate the use of renewable energy sources. Yet only a single project dealt with water and energy.

Many projects focus on capacity building rather than on making physical improvements to infrastructure. Capacity building can be helpful when careful planning and supervision of water management can compensate for the absence of a highly qualified and competitive construction market. Moreover, capacity building can enrich knowledge of nature-based solutions that align with the conservation of highly valued ecosystems. Nevertheless, every island needs its own network of utilities and, while the collective purchase of inputs that are unavailable locally may be cost-effective, this requires a lot of coordination.

The case studies also revealed that, within their limited budgets, SIDS tend to allocate small amounts of funding to climate change mitigation, although this does not do justice to the extreme challenges faced by low-lying islands and the atolls.

The survey

An online survey questioned SIDS water professionals about water governance. The survey was widely distributed among all 56 SIDS. However, the 63 respondents that registered did not fully represent all geographic and economic conditions on the islands. Nevertheless, the responses reveal some consistent patterns and contain interesting observations about differences in water issues, especially between the Pacific and the Caribbean regions.

Few respondents have confidence in the capacity of their water governance institutions and three-quarters believe that the water infrastructure in their country is inadequate. Confidence in national water management capacity is lower in the Caribbean than in the Pacific. Top-down water governance is widely practiced in the Caribbean, whereas local organizations in the Pacific play a more important role.

The participation of local agencies in decision-making processes is poor. Only a few respondents were satisfied with the execution of water laws. Weak incentive structures and few rewards discourage water managers from strictly enforcing water laws. Water policies in the Pacific are

better embedded in overall economic development strategies than in the Caribbean.

One-third of the responses indicated that the ecosystem is a target for water allocation.

A vast majority of respondents consider water scarcity to be a problem in the Caribbean and the Pacific alike.

Pollution concerns are high in both the Pacific and the Caribbean. The treatment of polluted water is widely considered to be unsatisfactory. Untreated or insufficiently treated water is mostly discharged into the sea. The reuse of water for agriculture, municipal uses and other purposes is rare.

Groundwater is a challenging issue that requires more and clearer regulations and active enforcement.

Flooding is considered a current problem or is expected to become a problem in future.

The study concludes that the mismanagement of water resources is intrinsically linked to the lack of enforcement and weak accountability mechanisms. Water governance suffers from the lack of information underpinning rules and regulations.

Missions to Barbados and Mauritius

Field missions to Barbados and Mauritius provided the opportunity for in-depth interviews with water professionals on key water governance issues. A detailed analysis of selected projects helped to identify key factors for success and failure.

The islands share a concern for water stress under future conditions. Interviewees in both countries indicated that the exploitation of groundwater reserves has reached its limits, with the result that further growth in water demand will have to be sustained by surface water resources and increased water use efficiency to allow groundwater recharge.

Both islands have implemented large-scale drip irrigation schemes through supervised and state-sponsored programmes. The two projects addressed in the study had well-planned irrigation interventions which, when combined with innovative farmer interventions, responded well to water scarcity and yielded successful and economically viable results.

Both islands maintain a water monitoring system, but enforcement to avoid free riders from overextracting groundwater is rare. Interviewees indicated that awareness campaigns could prompt positive behavioural change in water users, while reinforcing the need to penalize water abuse.

Similar to the findings of the case studies and survey, interviewees in Barbados and Mauritius believe that efficient enforcement of water laws is hampered by the lack of information underpinning rules and regulations. Interviewees indicated that more resources should be made available for data collection.

Both countries reported that large water losses (up to 50 percent) result from introducing pumped and collected water into the water distribution system. Interviewees indicated that that prices are a powerful instrument in water governance regulations, which can change the behaviour of water users and support the economic use of water resources.

Barbados and Mauritius both reported that traditional water rights should be updated to meet standards for modern water governance systems.

Information around water quality on the islands gives cause for alarm. Untreated or partially treated wastewater from households and industry and the overuse of pesticides in the agricultural sector directly affect aquifers and coastal zones. Few island inhabitants are connected to sewer systems.

A road map to foster SIDS strengths in agricultural water management

The following roadmap to improved water governance is not definitive but must be tailored to the characteristics of individual islands. With this in mind, the following steps can help to improve the functionality of freshwater resources:

1. *Greater efficiencies in water allocation and use.* Supplementing rainfed agriculture with irrigation expands the possibility for multiple cropping seasons per year.

2. *Water legislation.* The implications of continuing to employ colonial water laws on water allocation should be studied and serve as the basis for rescheduling and redistribution of these rights in addition to establishing tenure rights[1].

3. *Monitoring, data management and modelling.* There is a strong need to expand and harmonize data collecting and to use fresh data to develop analytical frameworks that can inform decision-makers as to the impact of various water policy scenarios.

4. *Control and enforcement.* Reinforced by awareness programmes, control and enforcement should prevent free rider water users. Regulations on water use should be unequivocal, substantiated by empirical evidence and well understood by all water users.

5. *Institutional collaboration.* There is much scope for evidence-based policy-making and enhanced cooperation between government institutes, NGOs and water users on SIDS.

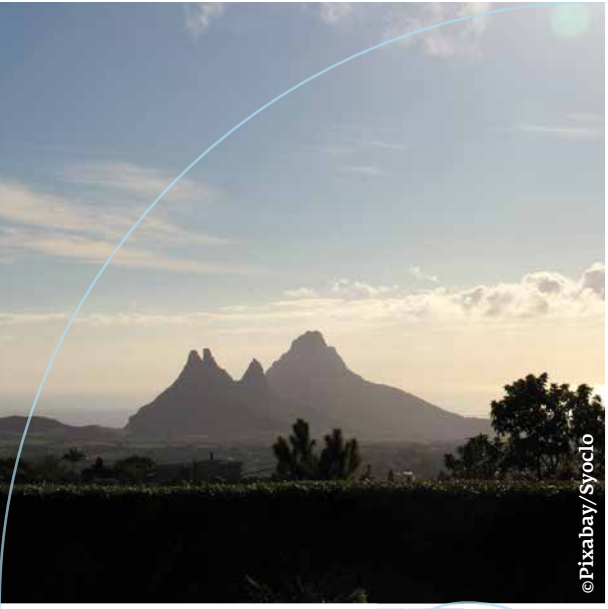
6. *Inter-island collaboration.* An active exchange between the islands of successful interventions, policies and lessons learned should compensate for the lack of scale experienced in SIDS. The FAO's South-South Cooperation Programme could play a leading role in promoting inter-island initiatives.

7. *Water quality.* The management of waste and polluted water should be given the highest priority to secure human health and prevent the destruction of ecological assets on the islands.

[1] See also FAO. 2020. Unpacking water tenure for improved food security and sustainable development. Land and Water Discussion Papers. Rome. (also available at https://doi.org/10.4060/cb1230en).

The contribution of freshwater management to FNS has become even more relevant during the COVID-19 pandemic as SIDS grapple with a limited productive resource base, blocked transport lines and a tourism sector that has come to a standstill. The obvious fragility of the food systems in SIDS emphasises the need to improve production, especially of fresh and healthy foods. In addition to stimulating the agricultural sector, SIDS can take steps to empower people to grow their own food using allotment gardens, hydroponics or aquaponics systems, thus increasing their resilience and making the islands less vulnerable to external shocks.

Nevertheless, many SIDS will, to some degree, continue to depend on foreign suppliers for their basic needs and on the international community for more general support and guidance. It is thus in their best interest to invest in strong and reliable international alliances that can support their efforts on FNS, while at the same time serving as partners and advisors on development, education, health care, climate change, and more concretely, water management. In these alliances, SIDS should be seen as preferred partners who can deliver unique information to support oceanographic and climate change studies. SIDS combine beautiful landscapes with coastal ecosystems and are host to authentic cultural heritages and historic ports and towns. The SIDS inhabitants are important assets in these partnerships because they understand the value of conservation and appreciate the innovations needed to preserve the quality of their fragile islands.



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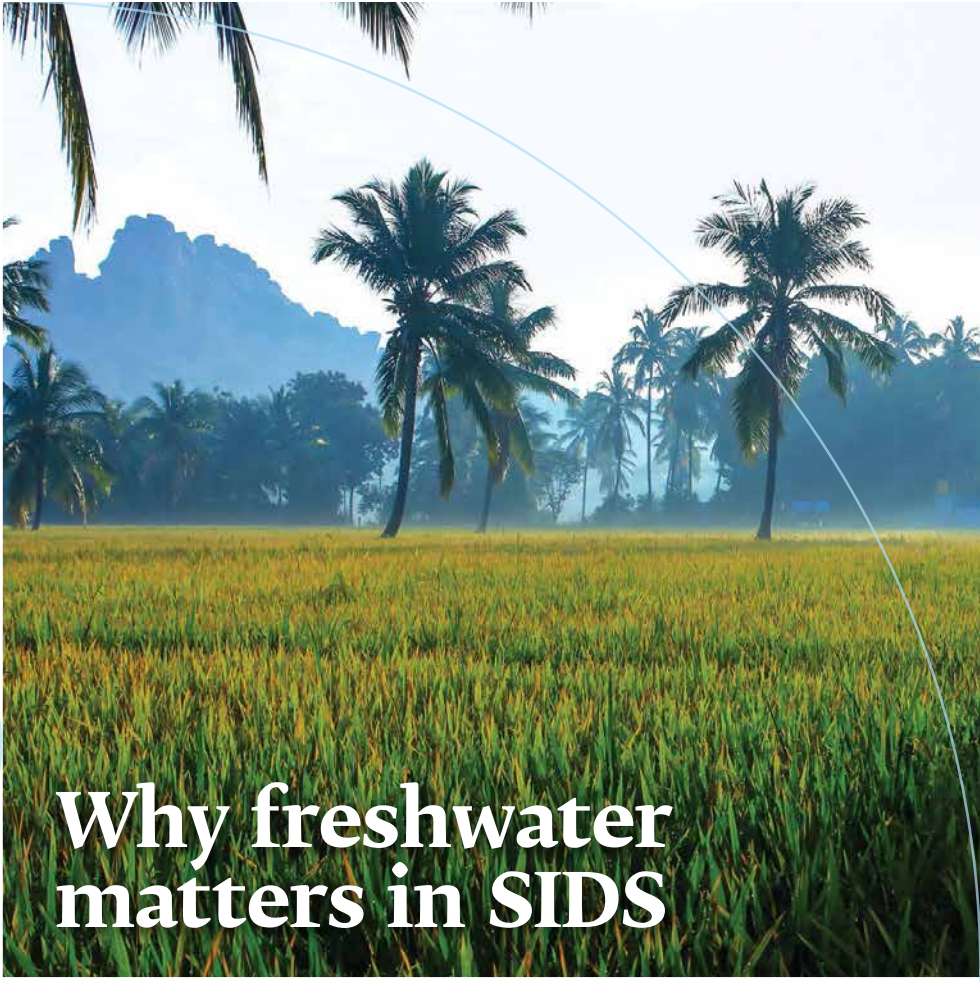


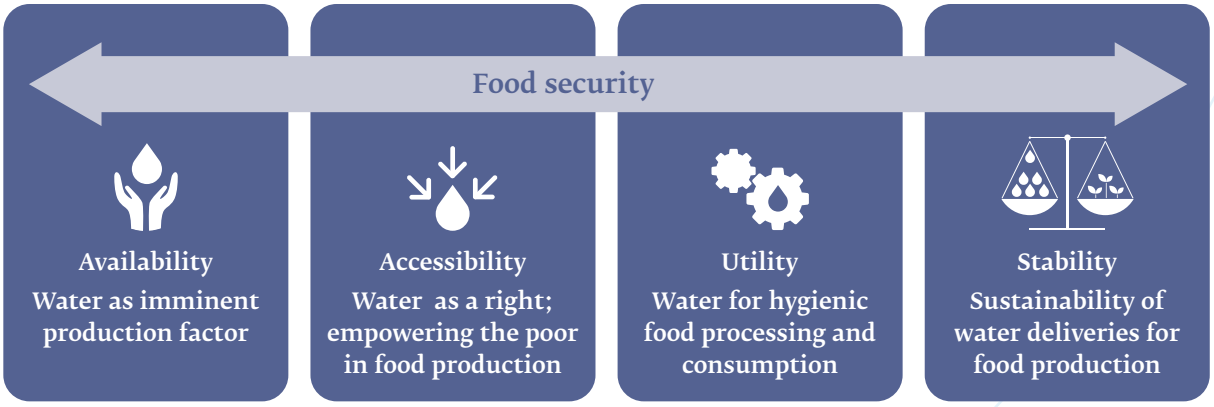
Why freshwater matters in SIDS

Freshwater resources are critical to stabilising and sustaining Food security and Nutrition (FNS) in Small Island Developing States (SIDS). Freshwater supports the four FNS pillars (see Figure 1.1) needed to diversify food production and reduce the triple burden of malnutrition in island states: undernutrition, micronutrient deficiencies and overnutrition (FAO, UN-OHRLLS and UNDESA, 2017; World Health Organization, 2018).

Circumscribed by their limited size, remote locations and high dependence on food imports, SIDS face a raft of FNS challenges in the coming decades (Nunn and Kumar, 2018). Increasing exposure to extreme weather events under changing climatic conditions may create greater FNS difficulties than exist at present (Scandurra *et al.*, 2018; Petzold and Magnan, 2019).

Figure 1.1

Fresh water serves the four pillars of Food security and Nutrition



Source: authors' diagram.

Increasing fresh and healthy food production would be enormously beneficial to the SIDS (FAO, UN-OHRLLS and UNDESA, 2017). Yet, there is fierce competition for the water resources needed to produce cultivated crops, fodder and livestock (Gohar *et al.*, 2019). A growing and more affluent population demands good quality water and sanitation, including the adequate treatment of return flows to avoid pollution of coastal areas and fishing zones and prevent the incidence of waterborne diseases. The tourism sector needs to maintain high standards of sanitary and hygienic conditions, while industry and manufacturing require large volumes of freshwater to meet production goals. Furthermore, freshwater feeds the ecological flows that preserve the scenic beauty and important coastal ecosystems in SIDS (Kaly *et al.*, 2002), a significant asset for local people and visitors. This myriad of sometimes conflicting interests calls for well-informed water governance that can secure equitable and efficient allocation of water resources in SIDS.

This study aims to support the formulation of water governance guidelines by understanding how freshwater management can serve Food security and Nutrition in Small Island Developing States. In particular, the study analyses the challenges faced by SIDS in managing freshwater resources and develops policy recommendations to assist SIDS in coping with water scarcity in agriculture.

Table 1.1

Small Island Developing States by geographical region and income group

AIS* (9)	Caribbean (27)	Pacific (20)
Bahrain	Anguilla	American Samoa
Cabo Verde	Antigua and Barbuda	Cook Islands
Comoros	Aruba	Fiji
Guinea-Bissau	Bahamas	French Polynesia
Maldives	Barbados	Guam
Mauritius	Belize	Kiribati
São Tomé and Príncipe	Bermuda	Marshall Islands
Seychelles	British Virgin Islands	Micronesia (Federated States of)
Singapore	Cayman Islands	Nauru
	Cuba	New Caledonia
	Curacao	Niue
	Dominica	Northern Mariana Islands
	Dominican Republic	Palau
	Grenada	Papua New Guinea
	Guadeloupe	Samoa
	Guyana	Solomon Islands
	Haiti	Timor-Leste
	Jamaica	Tonga
	Martinique	Tuvalu

	Montserrat	Vanuatu
	Puerto Rico	
	Saint Kitts and Nevis	
	Saint Lucia	
	Saint Vincent and the Grenadines	
	Sint Maarten	
	Suriname	
	Trinidad and Tobago	
	Turks and Caicos Islands	
	United States Virgin Islands	

Low-income Lower-middle income Upper-middle income High-income No data

* Africa, Indian Ocean, Mediterranean and South China Sea

Source: FAOSTAT, 2019; World Bank and OECD, 2017; OECD and the World Bank, 2016

The study supports the Global Action Programme (GAP) on Food Security and Nutrition, detailed in FAO's Inter-Regional Initiative, and the Third International Conference on SIDS, which established the SIDS Accelerated Modalities of Action (known as the SAMOA pathway). Both programmes prioritise an integrated approach to freshwater management and action on FNS (FAO, UN-OHRLLS and UNDESA, 2017). Within this context, the study considers the constraints and vulnerabilities faced by SIDS[1] due to their size and location, as well as their potential strengths. These issues are discussed in Section 2.

A special focus on SIDS, which occupy less than 1 percent of the Earth's surface and host fewer than 1 percent of the global population, is motivated by two reasons. First, the small size of SIDS prevents water management and FNS policies from achieving economies of scale, which makes interventions more expensive than in continental regions. Second, considering each island as a small universe with its own cultural identity and unique ecosystem enables decision-makers to study environmental and socio-economic vulnerabilities at close range and offers valuable information on the policies that could help take interventions to scale.

FNS solutions for SIDS should embrace an integrated approach to water management that ensures that freshwater resources can serve households, agriculture and industry. Water governance should capitalise on the geography of island states, which particularly intensifies interactions between human activities and land, freshwater and sea resources. The relatively small size of the SIDS can facilitate the organization of cross-sectoral and ecosystem-oriented water management schemes involving all relevant stakeholders. The participation of ecosystem custodians, such as natural resource managers, forest rangers, coastal guards and other formal and informal agents involved in ecosystem management and protection, in transdisciplinary planning and community-based management of island resources will help to harmonise production and ecological objectives.

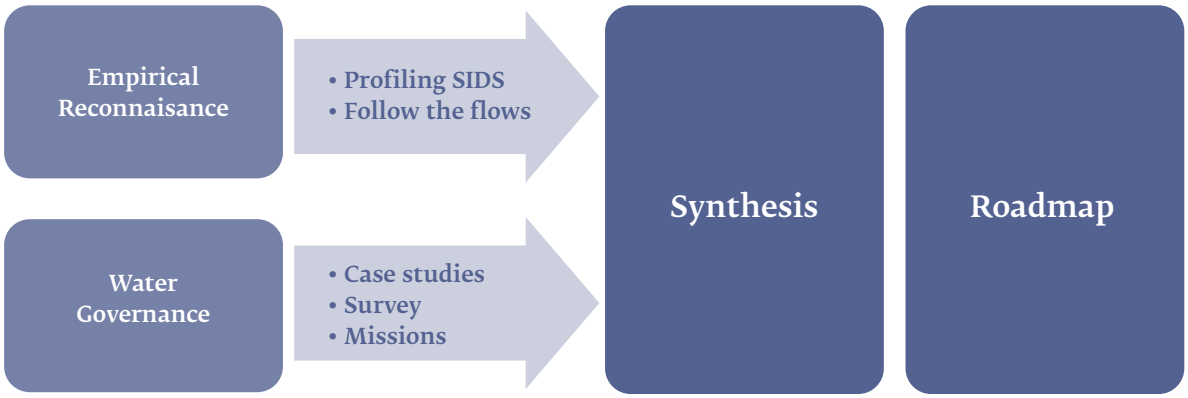
[1] The United Nations (UN) classifies 58 countries as SIDs, 38 are UN Members (https://www.un.org/ohrlls/content/list-sids). In FAO, there are 40 SIDS Members (http://www.fao.org/legal-services/membership-of-fao/en/)

The report is divided into three main themes:

1. The geography and socio-economic conditions (Section 2) of SIDS and their water resources (Section 3);
2. Water governance in SIDS, based on 23 case studies (Section 4), a survey of water professionals (Section 5) and two in-depth analyses of water policy interventions (Section 6);
3. A synthesis of findings from 1 and 2 leads to a road map for SIDS on water governance for Food security and Nutrition (Section 7).

Figure 1.2

The study framework



Source: authors' diagram.

Section 2 identifies the circumstances that affect FNS in SIDS, including population growth and urbanisation, the limited natural resource base, a colonial legacy of crop monoculture, remoteness and high transport costs, dependence on food imports, a fragile economy and vulnerability to natural disasters (2.1). The prevailing food diversity and micronutrient deficiencies in SIDS and their relation to the malnutrition status of island population are discussed (2.2). The study uses AQUASTAT data to follow natural and controlled freshwater flows, focusing on water distribution within economic sectors; water collection, treatment and reuse; and water sanitation and hygiene (WASH) (3.1). Section 3 also analyses water stress under various scenarios involving population growth, urbanisation and a growing tourism sector (3.2). Special attention is paid to water as a carrier of agrochemicals (3.3) and the relation of water characteristics to the malnutrition status of the population (3.4).

Section 4 takes stock of lessons learned from 23 water projects in SIDS and evaluates the factors behind their successes and failures. Section 5 presents the results from a survey of 63 water professionals concerning water governance and related issues in SIDS, including information gaps, commonalities and regional differences around water management and water scarcity. Section 6 describes the findings of missions to Barbados (6.1) and Mauritius (6.2), where in-depth interviews and detailed case studies elucidate island-specific water governance and FNS interventions.

The study concludes in Section 7 with a synthesis of the lessons learned from the water governance studies (7.1). It must be noted that each island is unique in its own way and thus requires its own set of policy prescriptions. With this qualification in mind, the synthesis provides the basis for a general road map for freshwater management in SIDS to ensure Food security and Nutrition, including a set of concrete action points (7.2).

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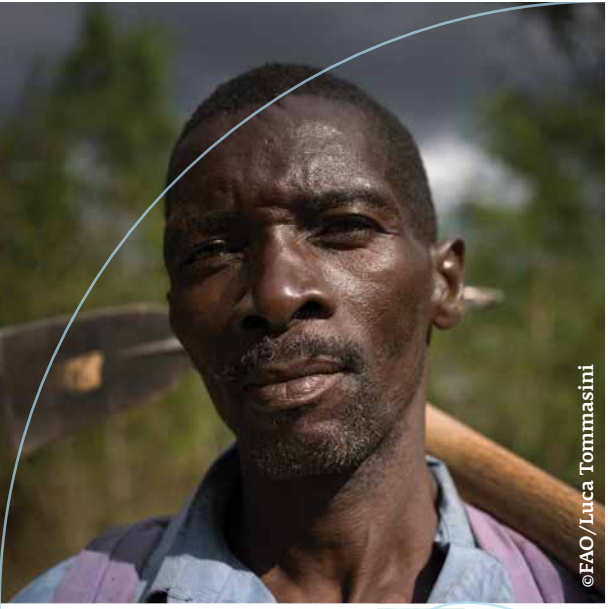

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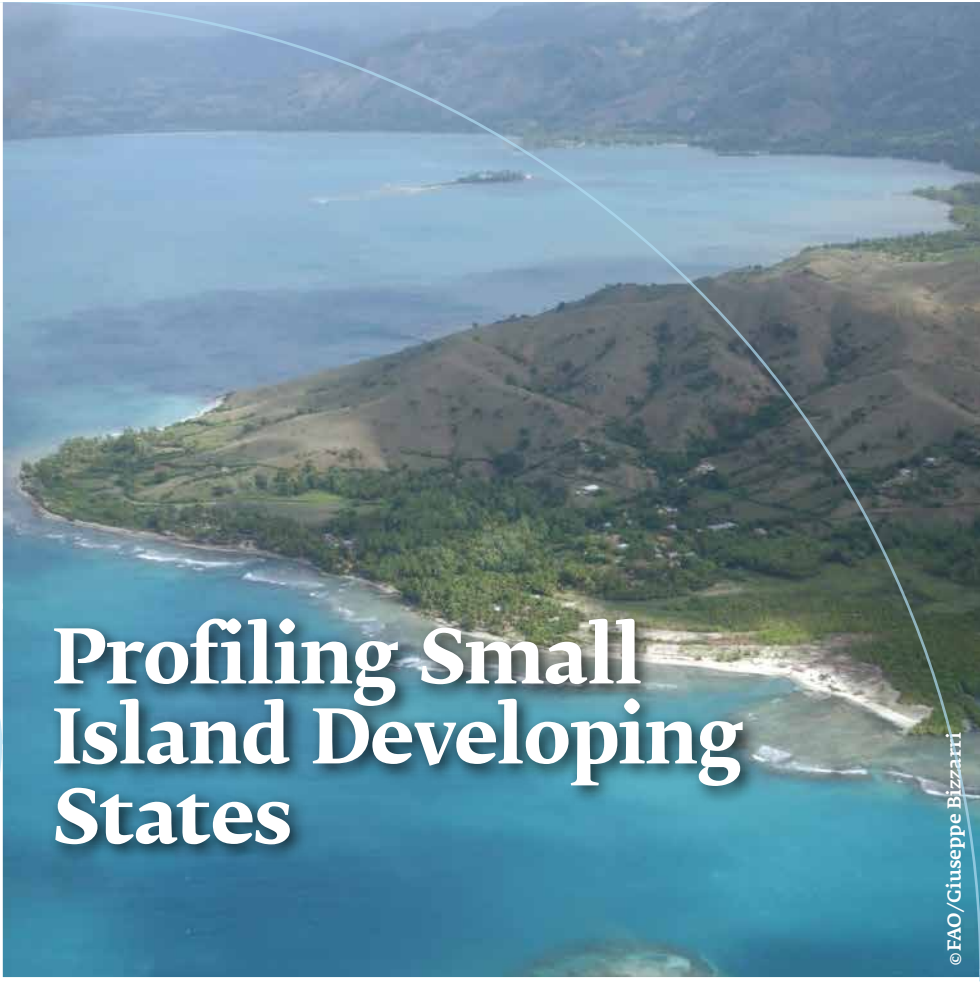
Profiling Small Island Developing States



This section contextualizes the study by profiling the diverse socio-economic and agricultural landscapes of Small Island Developing States (SIDS). This should improve our understanding of the role of freshwater management in addressing Food security and Nutrition within the context of typical SIDS characteristics[1].

2.1. SIDS VULNERABILITIES

The discussion below covers various characteristics of SIDS that affect their economies and the Food security and Nutrition (FNS) of their inhabitants. Specifically, this section considers population growth and urbanization, the limited natural resource base, the colonial legacy of crop monoculture, remoteness and high transport costs, dependence on food imports, the fragile elements of island economy and vulnerability to natural disasters.

Population growth and urbanization

Rapid urbanization has created a large number of poor city dwellers around the world (UNFPA, 2007). The urban poor lack access to natural resources and the opportunity to grow healthy fruits and vegetables to protect themselves against seasonal food shortages and price volatility. Many work in informal employment and live in slums, where basic utilities like water, electricity and sewerage systems are absent or highly inadequate.

Although the situation in SIDS cannot be compared to fast-growing megacities in Africa and South Asia, the percentage of low-income SIDS residents living in slums may well

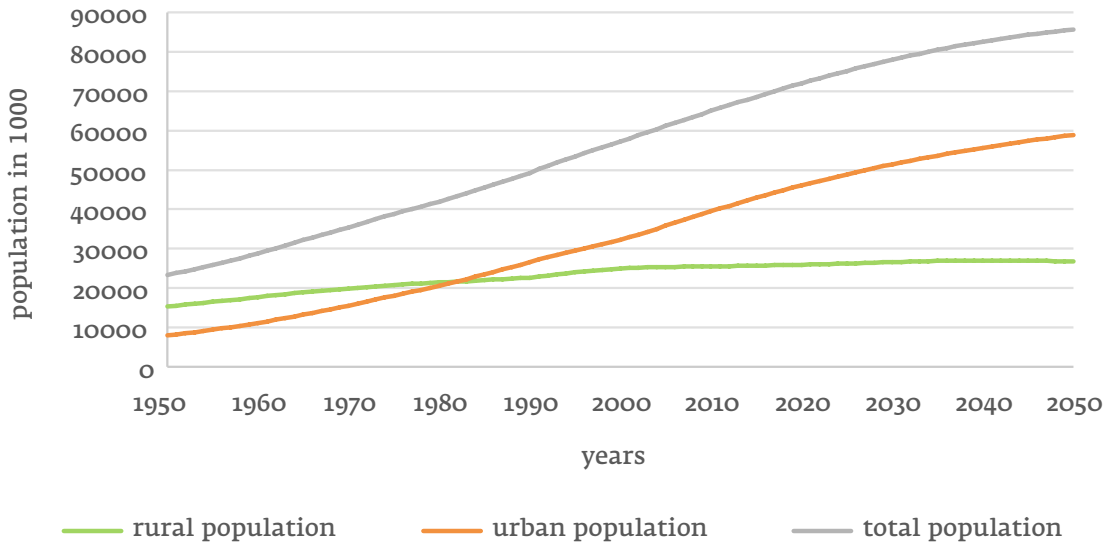
[1] Due to data paucity, certain sections only report on the subset of SIDS for which information is available.

match that in low-income countries generally (66 percent according to 2021 data from the World Bank). The overall population of SIDS grew from 23 million in 1950 to 49 million in 1990 to 72 million in 2020 and is expected to reach 85 million by 2050 (UNDESA, 2018). In the early 1990s, 53 percent of the inhabitants of SIDS lived in cities. Urban population is projected (Figure 2.1) to reach 70 percent by 2050 (UNDESA, 2018). Although data are scarce in many SIDS, the situation in Haiti (74 percent) and Jamaica (61 percent) provide some evidence of the boom in urban growth. Further anecdotal evidence comes from UN-Habitat[2]. The agency's Participatory Slum Upgrading Programme (PSUP) feature projects in Cape Verde, Haiti, Jamaica, Mauritius, Papua New Guinea, Solomon Islands and Vanuatu (UN-Habitat, 2016), confirming that a significant number of people in low- and low-middle income SIDS live in slums.

In many low-income SIDS, wastewater networks are completely missing or have very incomplete coverage. In the past, when population density was much lower than at present, the need for such networks was not considered particularly urgent, since wastewater could be discharged directly into the sea. While rapid population growth has created an urgent need for utility networks, cash-strapped governments can ill afford to build them, especially since many SIDS comprise multiple inhabited islands, all of which require the networks. These constraints also impede a cost-effective water (and electricity) pricing for the poor rural segments of the population (see case study C10 in Section 4 for a good example).

Figure 2.1

Development of rural and urban population (in 1 000 persons) on SIDS



Source: computations based on FAO, 2019a.

Limited land resource base

In SIDS, land size is an intrinsic restriction on food production. Total land area is further limited by soil and terrain characteristics, which reduce its suitability for crop cultivation.

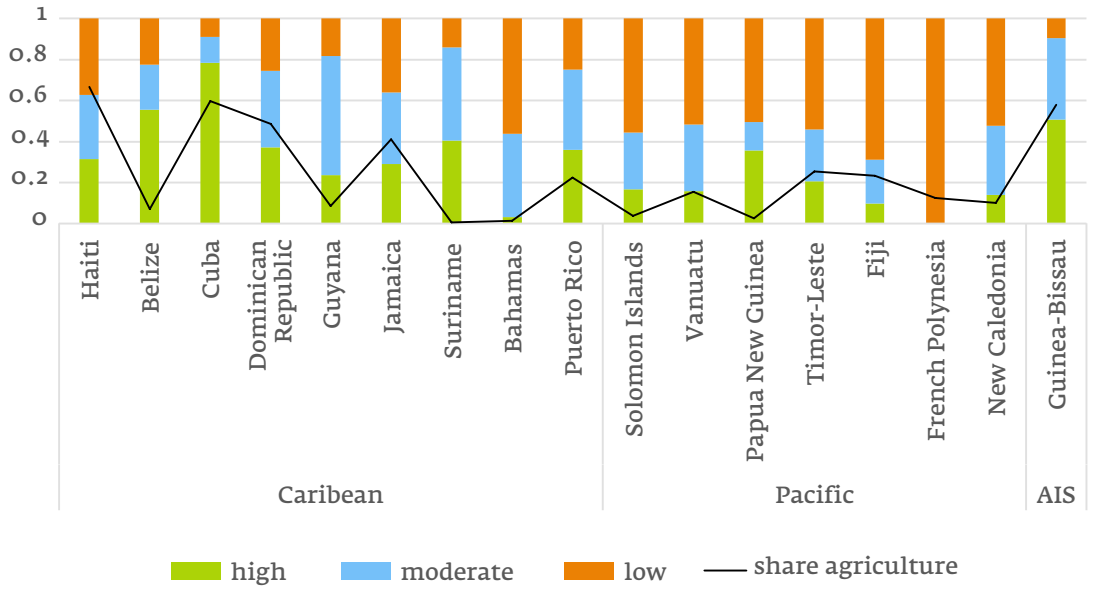
[2] Known as UN-Habitat, the United Nations Human Settlement Programmed promotes socially and environmentally sustainable cities, towns and communities.

Generally speaking, sloping terrain is a major restriction on high islands due to soil erosion, while lower-lying atolls have little area where soil development is conducive to crop cultivation. Meanwhile, rising sea levels threaten to consume coastal lands.

To assess the availability of suitable land for food production, land quality was calculated against cultivated area[3]. Data on land quality under two input levels, low and high[4], were derived for 17 SIDS countries from the Global Agro-ecological Zones (AEZ) project (IIASA and FAO, 2012). The share of agricultural land was drawn from FAO (2018b). For ease of interpretation, eight land suitability classes were aggregated into three: 'high', 'moderate' and 'low' (see Annex 1, Table A.2.1). Figure 2. 2 and Figure 2. 3 show cultivated agricultural land against suitability classes, under low and high input levels respectively.

Figure 2.2

Land suitability classes for low input levels as share of total land against cultivated agricultural land for SIDS countries, year 2017



Source: IIASA & FAO, 2012; computations based on FAO, 2018b

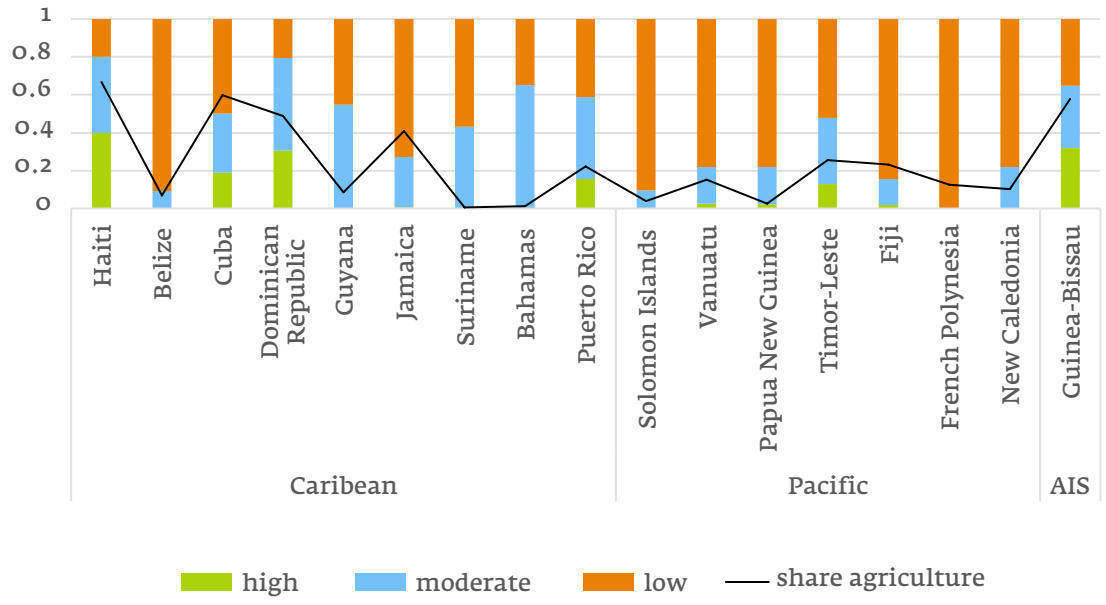
Near absence of suitable land has led many SIDS to use suboptimal sites, especially in Cuba, Haiti, Jamaica, Guinea-Bissau and Timor-Leste. Under high input conditions where land suitability can be improved through capital investment (e.g. irrigation, landscaping and soil management), there are possibilities for expansion in most countries or territories. Belize, Cuba, Suriname and Papua New Guinea, in particular, benefit substantially from land improvements. Most Pacific countries or territories – even those with very low suitability under low input conditions – can now achieve high land quality in their cultivated areas.

[3] Land used for cultivation of crops and livestock.

[4] Under the Global Agro-ecological Zones project, low input levels refer to traditional agriculture where agrochemicals and improved seeds are absent. High input levels use machinery, irrigation and agrochemicals and improved seeds.

Figure 2.3

Land suitability classes for high input levels as share of total land against cultivated agricultural land for SIDS countries, year 2017



Source: IIASA & FAO, 2012; computations based on FAO, 2018b.

To assess current input levels in SIDS agriculture, the 2017 yield figures for maize were compared with average yields in other developing countries. Figure A.2.1 shows that 37 percent of SIDS register lower yields than reported by other developing countries (1 877 kg/ha) and 73 percent produce less than the average yield (3 036 kg/ha) that is realized in the SIDS countries or territories. Nations with high yields, such as New Caledonia (9 010 kg/ha), Bahamas (8 818 kg/ha), Mauritius (7 492 kg/ha) and Montserrat (7 161 kg/ha) appear to be an exception. It can be concluded that agricultural production levels vary significantly among SIDS, but most islands have low, rather than moderate or high input levels.

Monoculture: an echo from the past

Most SIDS were colonized by European maritime powerhouses, which replaced traditional diverse agricultural systems with monoculture based on large plantations (Umemura, 2016). These plantations grew crops, such as sugar, coconut, cotton and tobacco, for the European market or to replenish supplies for trading ships (Washington University in St. Louis, 2011)[5].

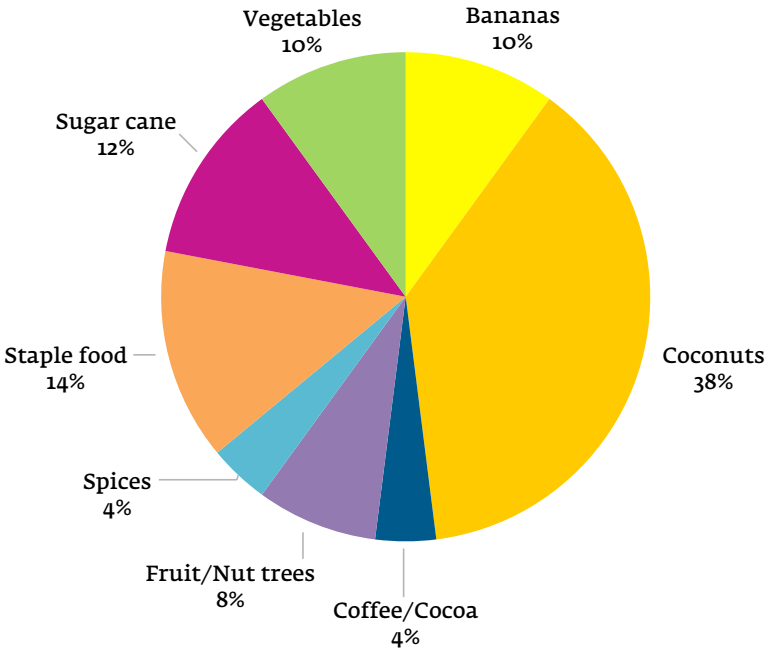
The introduction of monoculture led to the loss of biodiversity and large-scale deforestation. Moreover, monoculture depletes soil resources and makes plants vulnerable to diseases that can sweep through an entire crop. This study also reveals (section 6) that water rights ceded for the development of monocultures have not been released for other uses.

Figure 2.4. shows that coconut is the dominant crop in 38 percent of SIDS. Coconut represents 100 percent of cultivated crops in the Marshall Islands, 91 percent in Tuvalu and 91 percent

[5] The mutiny on the HMS Bounty was triggered by Captain Bligh's harsh punishment of his crew for the theft of coconuts from the ship's store.

Figure 2.4

Area share of dominant crops relative to total cultivated area in SIDS countries or territories



Source: computations based on FAO, 2019b

in Guam. At the other extreme, Dominican Republic (17 percent of crops are food staples) Dominica (15 percent of crops are bananas) and Montserrat (13 percent of crops are vegetables) seem to have more diverse food production systems. A complete list of dominant crops with area shares is found in Annex 1, Table A.2.2.

The conclusion is that nearly half (22 out of 50) of SIDS devote more than 50 percent of their cultivated area to a single crop and 31 countries or territories devote over 40 percent of cultivated land to a single crop. This raises questions about the adequacy of food diversity on the islands.

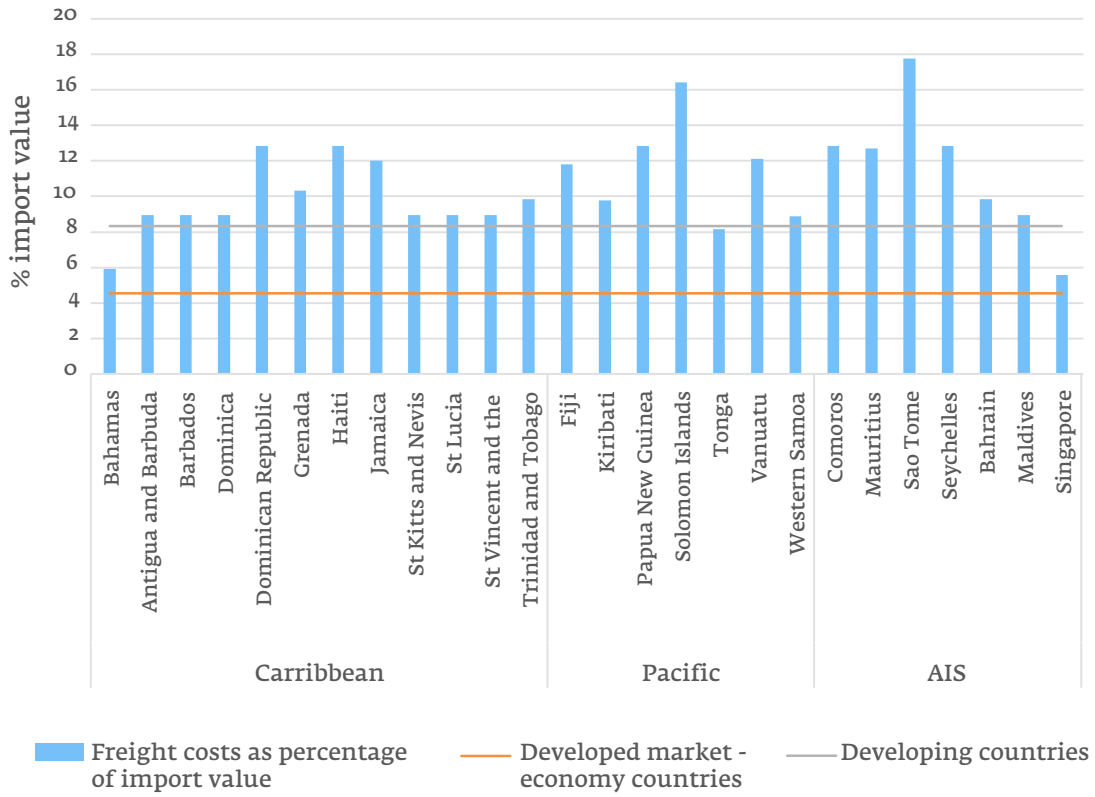
Remoteness

One of the challenges facing many SIDS is their remoteness from major markets. This, combined with small size (and relatively low export levels), leads to high transportation costs, making it hard to compete with other countries (OECD, 2018; Pratt, 2015) (see Figure 2.5.).

SIDS in the Pacific are among the world's most remote states (OECD, 2018), including countries or territories that are at least 3 000 km from the nearest continent (e.g. Nauru and Kiribati). Remoteness relates to shipping networks as well (see Box 1). As a group, SIDS are one-third less well connected to shipping transport than other developing countries on average (Briguglio, 1995). High transportation costs expose them to volatile international food prices and monetary risks, such as exchange rate fluctuations (FAO, UN-OHRLLS and UNDESA, 2017; Pratt, 2015).

Figure 2.5

Freight costs as percentage of import value by SIDS country and region, 2017. Reference lines indicate values for developed and developing countries



Source: UNEP, 2019.

Remoteness also complicates emergency assistance after a disaster (UN, 2014; FAO, 2018a) especially when SIDS comprise many small islands (Shultz et al., 2016). Finally, geographical isolation increases health hazards, whereby an outbreak of infectious disease could potentially have a heavy impact (WHO, 2017d), particularly when highly educated health professionals have moved abroad to pursue better employment opportunities (WHO, 2017d).

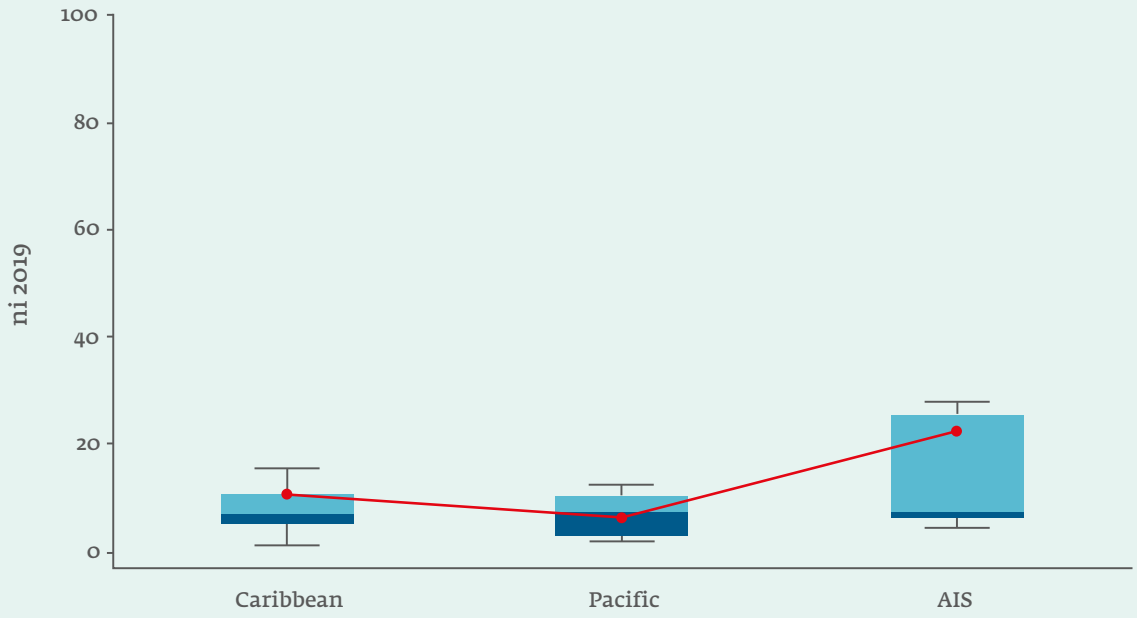
Paying the food import bill

Typically, SIDS have a small agricultural base and must import most of their staples, particularly cereals. In principle, they could import a rich variety of food to supplement the missing micronutrients in their domestic staples. Yet, such imports are only possible for countries with adequate foreign exchange earned through its exports.

The value of food imports against total merchandise exports is a useful indicator for showing whether a country has difficulties meeting its food import bill. Based on the data (seen in full in Table A.2.3), it appears that the overall situation for SIDS is the same as for high-income countries: at most 5 percent of the value of merchandise exports is spent on the food bill. However, this figure is heavily biased by the presence of the few very rich SIDS, such as Singapore and Bahrain, and conceals the huge heterogeneity of the SIDS, as shown in Figure 2.6. In fact, the indicator ranges from just above zero percent to around 400 per cent for some Pacific islands. The

Box 1

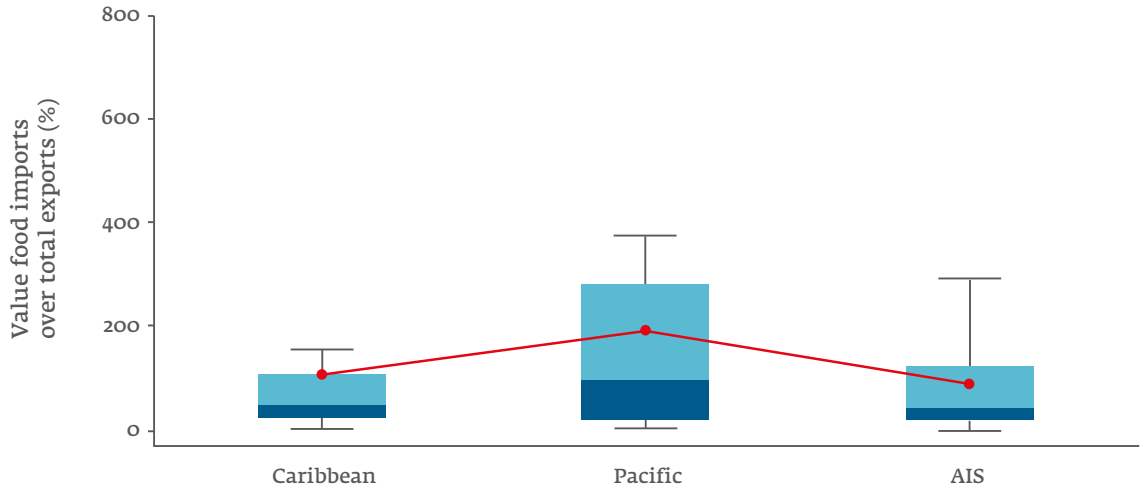
Liner Shipping Connectivity Index



The Liner Shipping Connectivity Index (LSCI) is a proxy of accessibility to global shipping networks based on the number of ships, carrying capacity, maximum vessel size, services and the number of companies deploying ships in a country (GICA, 2018). The graph shows LSCI by region (UNCTAD, 2014). Except for some outliers (e.g. Singapore LSCI 108), the majority of SIDS have low LSCI values.

Figure 2.6

Average value of food imports over total merchandise exports (percent), 2011-2013. The SIDS countries or territories are unweighted in their three groups



Source: FAO, 2019e.

situation in the Pacific is most alarming, not just for its high average, but also because it is deteriorating over time, as can be seen in Annex 2.1, Table A.2.3.

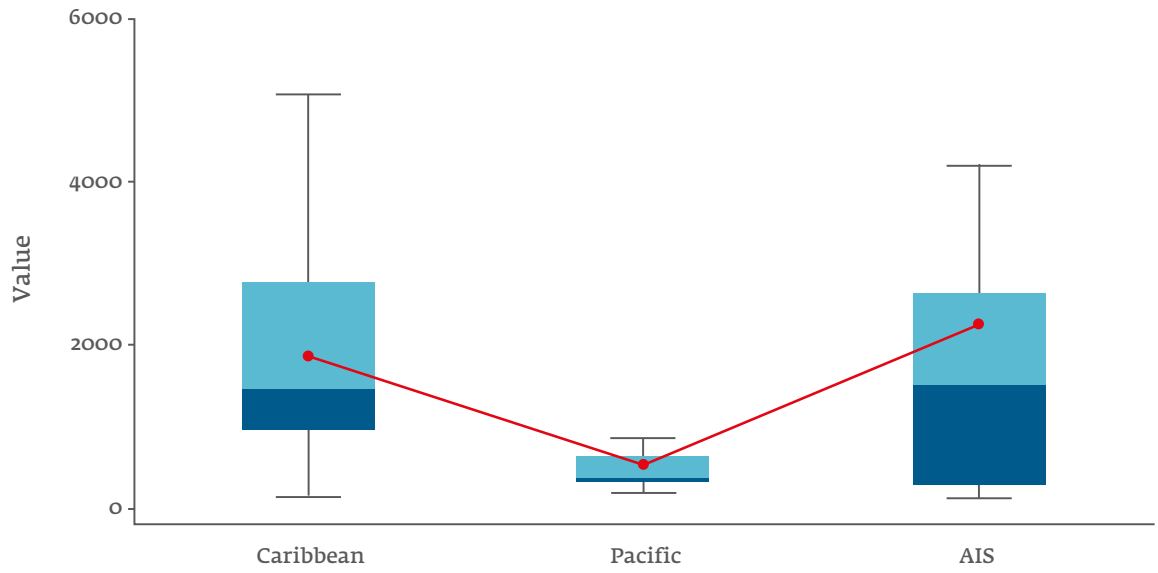
It is clear that quite a few SIDS can only pay their food import bills by increasing their debt, and/or relying on remittances and foreign aid. In general, trade liberalization has brought many countries, the SIDS no exception, substantial advantages. Consumers profit from lower prices and have access to a broader range of products. It may undermine the strength of local producer cartels. On the other hand, trade liberalization also undermines the competitive position of local farmers and fishermen in many SIDS and has resulted in an even larger increase in food imports (Dorodnykh, 2017). In addition, the foods imported by SIDS are calorie-dense, high-fat and high-sugar (FAO, 2014) and thus likely to contribute to an increase in chronic, non-communicable diseases. Since there exists no mechanism for winners to compensate losers, each individual country faces the trade-off between the pros and cons of globalization.

Fragile economies

There is a large variety in per capita income levels across the SIDS. Figure 2.7 shows GDP in United States dollars per capita by region (World Bank, 2019a). Included are 37 countries or territories with available data for 2017. In the case of Puerto Rico (2016) and Bermuda (2013), the latest available data has been used for the analysis. With an average of USD 5 729, the Pacific region has the lowest income, with Kiribati (USD 1 981) and Solomon Islands (USD 2 205) the poorest countries and Nauru (USD 12 895) and Palau (USD 13 240) the wealthiest. The average income in the Caribbean is USD 17 984 with Haiti (USD 1 653) and Guyana (USD 7435) the poorest countries and Puerto Rico (USD 35 044) and Bermuda (USD 50 669) the wealthiest. The AIS region hosts the SIDS countries with the largest variations. On average, the income in the region is USD 22 546, but there is a significant difference between the earnings in

Figure 2.7

GDP per capita in USD by main SIDS regions, 2017



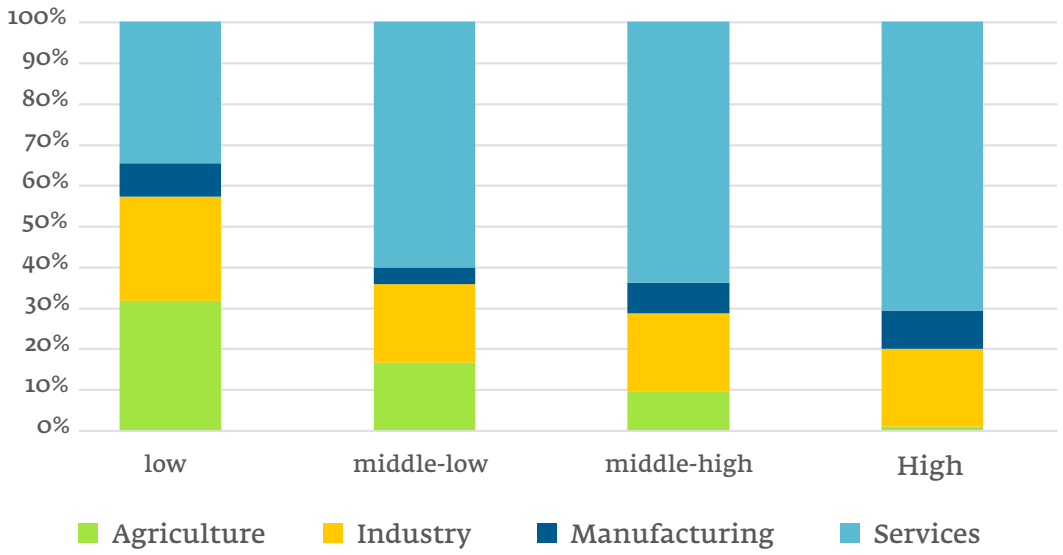
Source: World Bank, 2019a.

high-income countries, such as Bahrain (USD 43 290) and Singapore (USD 85 535), and low-income countries, such as Comoros (USD 1 413) and Guinea-Bissau (USD 1 548). Despite the large disparities in income, most SIDS are eligible for official development assistance (ODA) to compensate for their limited resources and support the expensive investments needed to cope with climate change (Scandurra *et al.*, 2018).

Figure 2.8 shows the contribution of economic sectors to GDP by income group. Annex 2.1, Figure A.2.2 details this information by country (World Bank, 2019b). We note that low-income countries depend mostly on their own agricultural production for their food supply (Remans *et al.*, 2014). The agricultural share in GDP ranges from 0 percent (Bahrain, Singapore and Trinidad and Tobago) to 49 percent (Guinea-Bissau), with a mean of 10 percent. The share of the agricultural sector in GDP reduces as per capita income rises. Overall, the service sector is the highest contributor to GDP, an important part of which comes from tourism (see Annex 2.1, Figure A.2.2 and Figure A.2.3). Dependence on the tourism sector highlights the fragility of the SIDS economies in times of crisis, such as during natural disasters or pandemics (COVID-19 in early 2020), which interrupt all air transport and much of shipping.

Figure 2.8

Economic sector contribution to GDP by SIDS

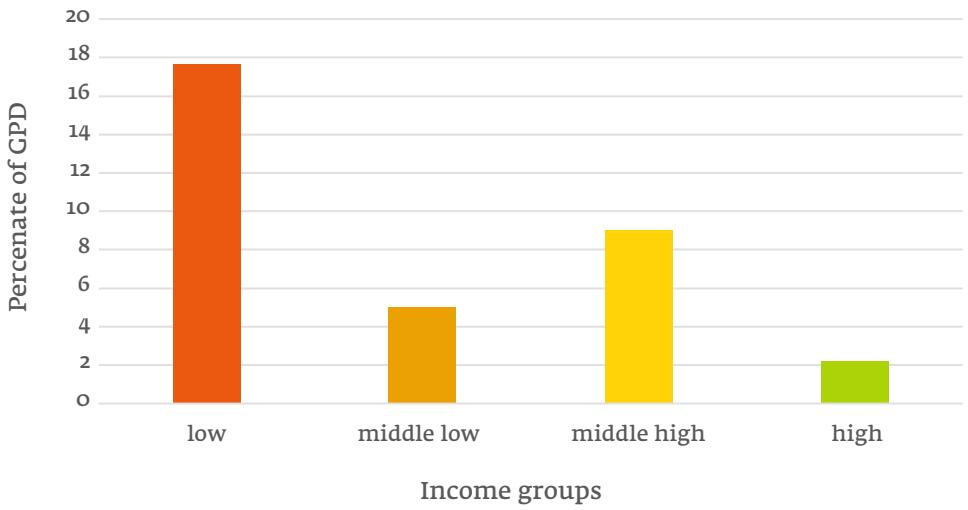


Source: World Bank, 2019b

Remittances are an important factor for low-income SIDS (World Bank, 2019c), averaging 18 percent of GDP (Figure 2.9; Annex 2.1, Figure A.2.4). Among low-income countries, Tonga has the highest share of remittances in GDP with 37 percent, followed by Haiti (32 percent), Samoa and Jamaica (both 16 percent). Heavy dependence on remittances, which are subject to external shocks and economic crises and are beyond the control of the remitters, jeopardizes livelihoods and FNS back home. Remittances are expected to fall significantly during the COVID-19 pandemic and the ensuing recession, since remitters may well be the first to lose their access to informal labour markets abroad.

Figure 2.9

Remittances as share of GDP by income group



Source: World Bank, 2019c.

Finally, the prevailing high unemployment in low-income and low- and middle-income SIDS (Annex 2.1 and Figure A.2.5) is a major concern for household income and youth employment opportunities (FAO, UN-OHRLLS and UNDESA, 2017).

Vulnerability to natural disasters

More than half of the 25 countries that experienced frequent natural disasters in the past decade were SIDS, which also accounted for two-thirds of the countries suffering the greatest relative losses from natural disasters (OECD, 2018). Natural disasters affect FNS directly through crop losses and damaged infrastructure, which interferes with food distribution, imports and aid (Iese *et al.*, 2018). Food scarcity after a disaster leads to an increase in prices (Forrester *et al.*, 2017; Wentworth, 2019), which especially affects lower-income groups. SIDS countries or territories lacking resilience, infrastructure and food aid can experience long-term food insecurity, with major health-related consequences (Bhopal *et al.*, 2019; Cabezon *et al.*, 2019).

Food aid might provide initial relief, although Wentworth (2019) reported that aid packages for the Ni-Vanuatu population lacked fresh foods, including rice, tinned fish and noodles. Lusk and Andre (2017) found that food aid packages were generally of poor quality and did not meet daily nutritional requirements.

To conclude, SIDS constitute an important group of countries that are particularly prone to natural disasters (Pelling and Uitto, 2001; Shultz *et al.*, 2016), which can seriously affect their food security.

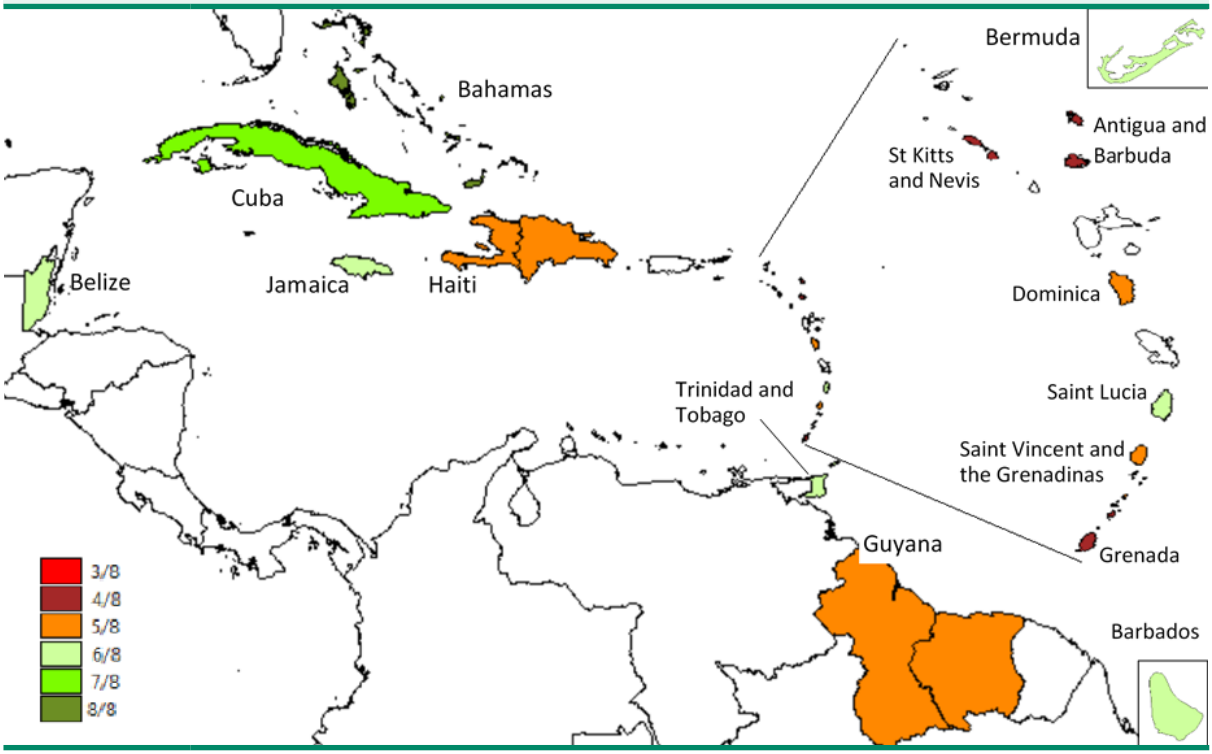
2.2. FOOD DIVERSITY AND MALNUTRITION IN SIDS

The consequences of food security and malnutrition in SIDS is evident in the dietary patterns and malnutrition status of the inhabitants. Annex 2.2 explains in detail how food diversity is expressed in food groups and micronutrient availability. Our main findings are summarised below.

Expressed as a share of essential food groups based on FAO's food balance sheets (FAO, 2019d), Figure 2.10, Figure 2.11 and Figure 2.12 indicate that most islanders in the Caribbean, Pacific and AIS regions, respectively, do not have sufficient availability of foods from the eight food groups required for a healthy diet[6]. São Tomé and Príncipe have insufficient availability in more than half of the food groups; eight countries have insufficient availability isn half of the food groups, while nine countries report sufficiency in five of the eight food groups. Ten countries have sufficient availability for six food groups and Cuba has adequate availability in seven of the eight food groups. The Bahamas is the only country with sufficiency in all food groups. On average, SIDS have sufficient availability in five of the eight required food groups.

Figure 2.10

Food group availability in Caribbean countries



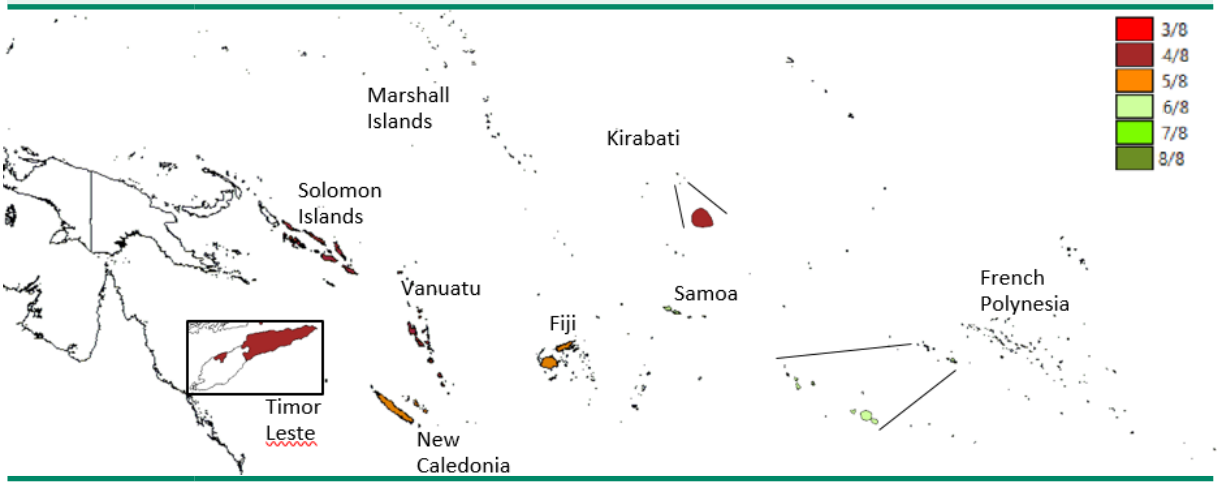
Source: computations based on FAO 2019e; FAO et al., 2006; FAO et al., 2010. UN. 2020.

Dietary imbalance leads to micronutrient deficiency, as illustrated in the risk maps for the Caribbean, Pacific and AIS regions in Figure 2.13, Figure 2.14 and Figure 2.15 respectively. With regard to individual micronutrients, only 10 percent of SIDS countries have enough iodine.

[6] According to FAO, et al., 2006 and FAO et al., 2010, the eight food groups required for a healthy diet are: staples/starchy foods, milk (products), meat/fish, legumes/peas/nuts/seeds, fruits, vegetables, fats and oils, and sugars and sweeteners (Table A.2.6)

Figure 2.11

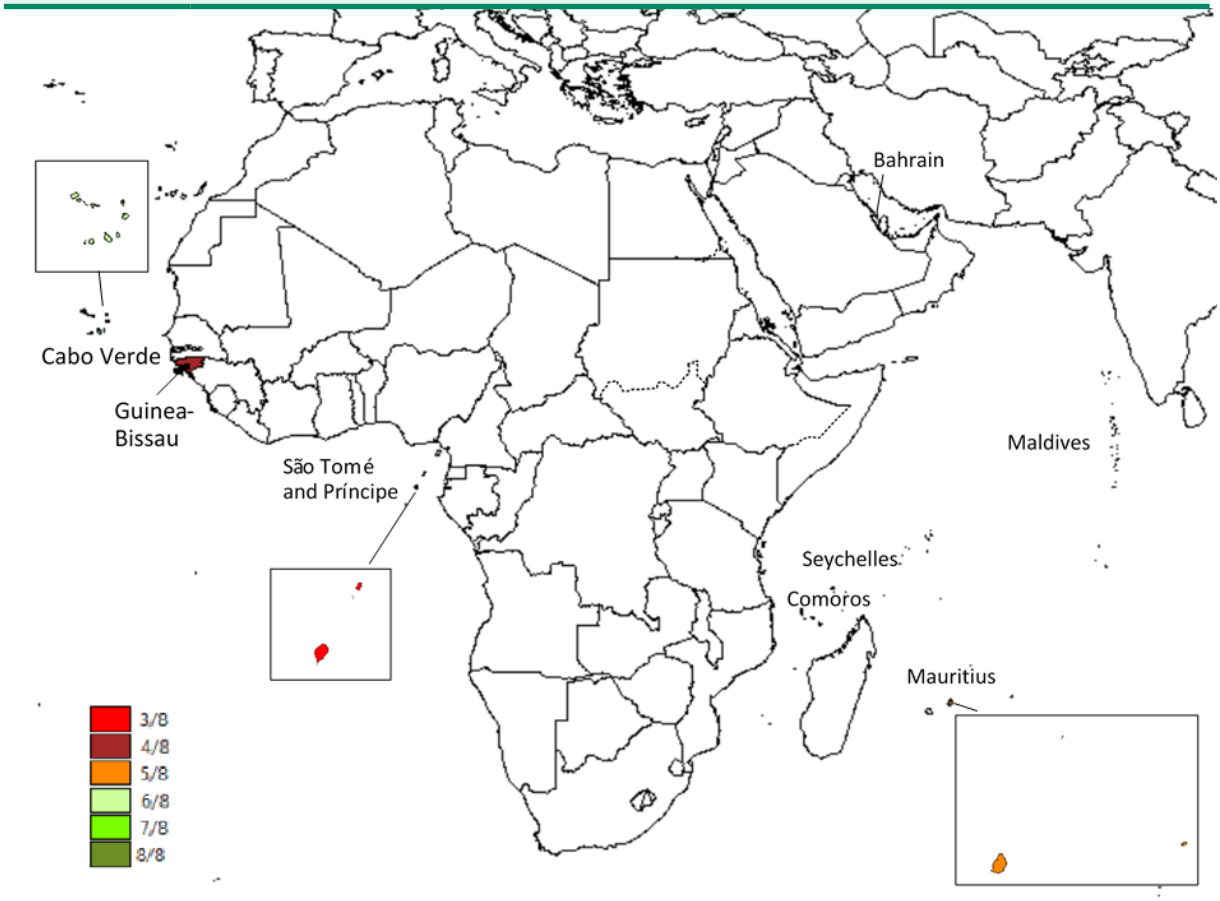
Food group availability in Pacific countries



Source: computations based on FAO 2019e; FAO et al., 2006; FAO et al., 2010. UN. 2020.

Figure 2.12

Food group availability in AIS countries

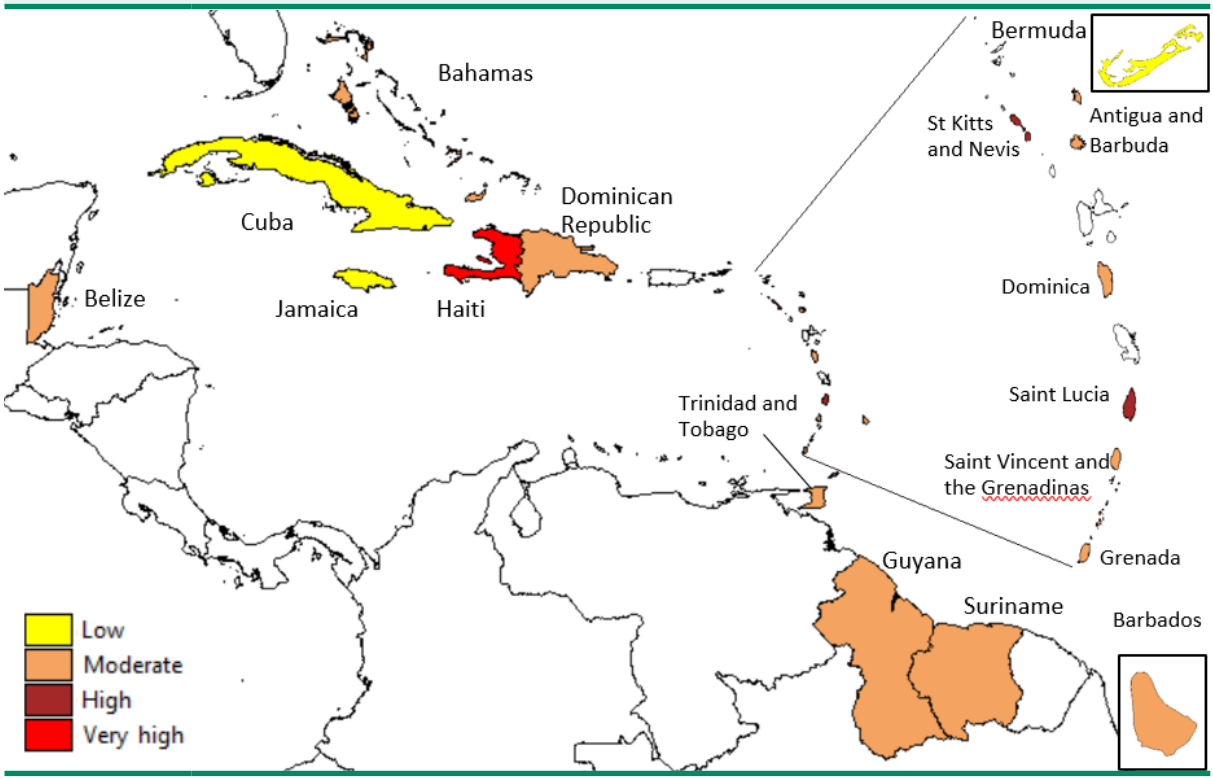


Note: Final boundary between the Sudan and South Sudan has not yet been determined.

Source: computations based on FAO 2019e; FAO et al., 2006; FAO et al., 2010. UN. 2020.

Figure 2.13

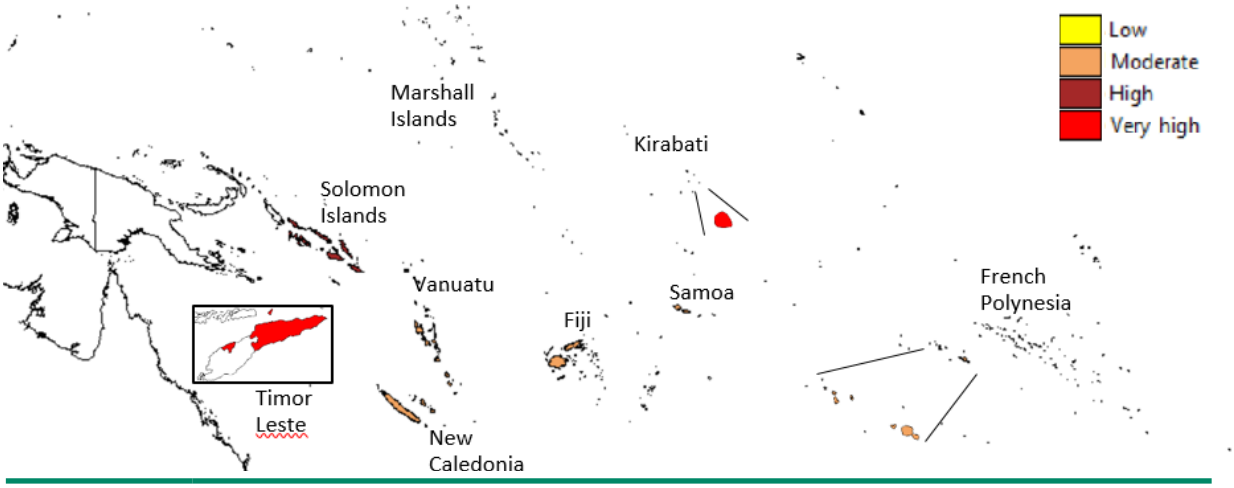
Micronutrient risk level in Caribbean countries



Source: computations based on FAO 2019e; FAO et al., 2006; FAO et al., 2010. UN. 2020.

Figure 2.14

Micronutrient risk level in the Pacific

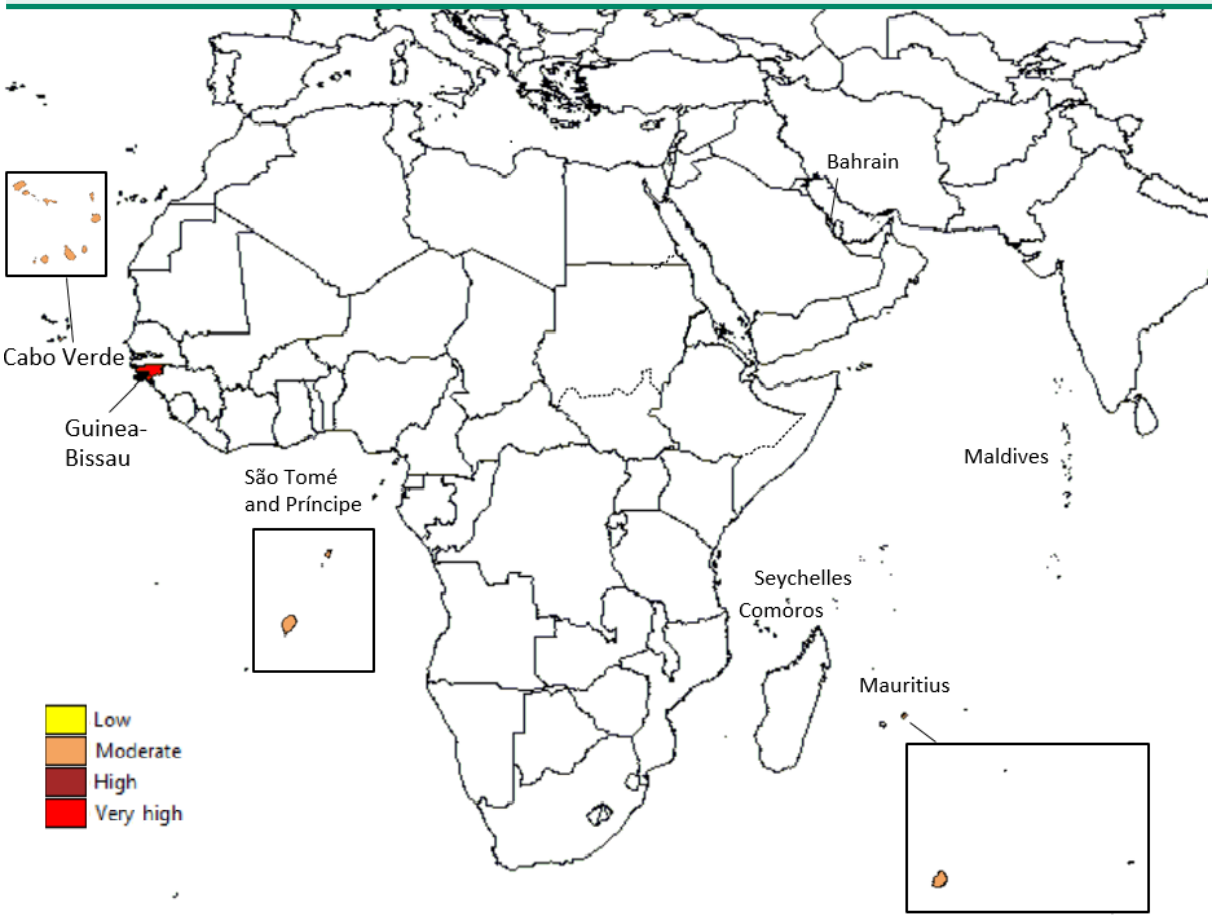


Source: computations based on FAO 2019e; FAO et al., 2006; FAO et al., 2010. UN. 2020.

Only 13 percent of the countries have an availability of vitamin A that is higher than the recommended daily allowance (RDA) levels (see Table A.2.4 and Table A.2.5). Sixty-seven percent of the SIDS countries do not meet RDA requirements for vitamin K; and rates in São Tomé and Príncipe and the Solomon Islands are disturbingly low. Fully 93 percent of SIDS countries have insufficient quantities of folate.

Figure 2.15

Micronutrient risk level in the AIS



Note: Final boundary between the Sudan and South Sudan has not yet been determined.
Source: computations based on FAO 2019e; FAO et al., 2006; FAO et al., 2010. UN. 2020.

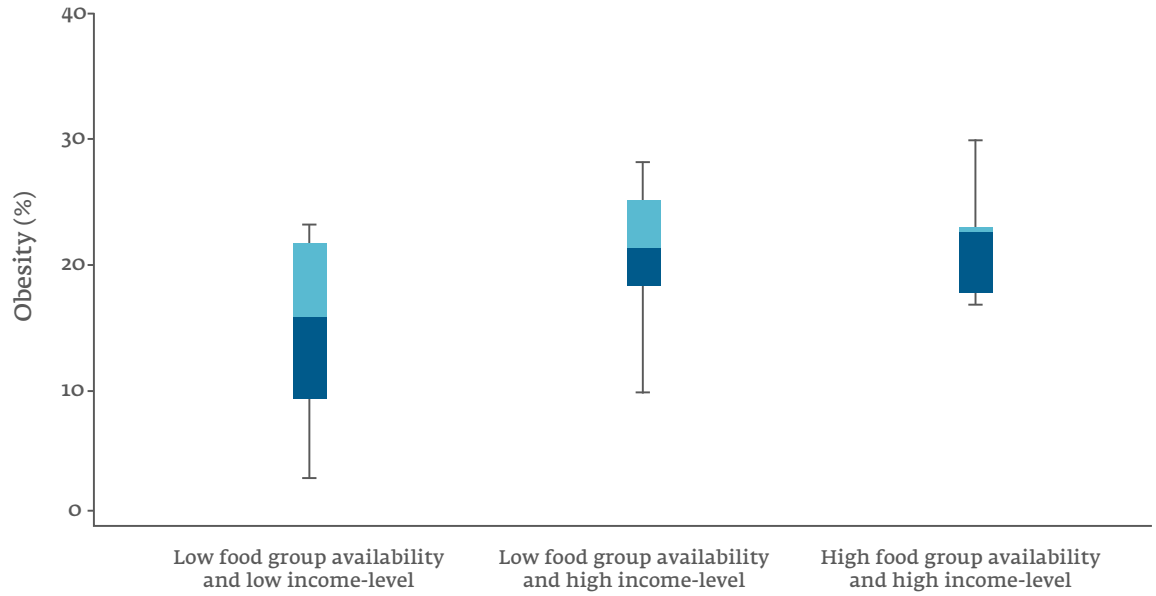
While the availability of food from the recommended food groups and micronutrients for many SIDS countries is low, and, in many cases, does not meet the required RDA, we found that the maximum RDA levels for sweets and fats are exceeded in many countries.

Figure 2.16 and Figure 2.17 show the impact of nutritional deficiencies on obesity (WHO, 2017a) and stunting of children under five years of age (UNICEF, WHO and World Bank, 2018) in the SIDS. We used the threshold of five out of eight food groups to define 'low' and 'high' availability and aggregated 'low' and 'lower-middle' income into 'low' and 'upper-middle' and 'high-income' into 'high' income group. It can be observed that prevalence of obesity is slightly lower for low food-group availability and low-income level compared to other groups. Differences between income and good group availability combinations were not significant.

The groups with low food-group availability and low-income level show higher percentages of stunting than the two higher-income groups. Differences between 'low food-group availability and low-income level' and 'high food-group availability and high-income level' are significant. Finally, data on the prevalence of anaemia for under-fives (World Bank, 2019e) shows that, on average, for every mg of iron available per day per capita, the prevalence of anaemia falls by 0.8 percent (see Figure 2.18)

Figure 2.16

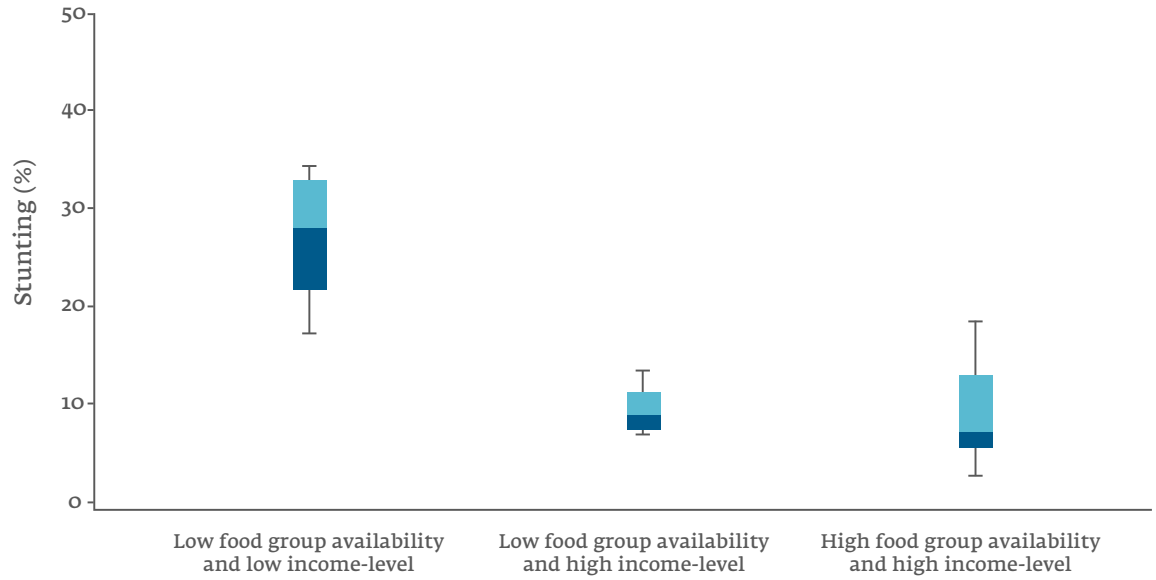
Combination of ratio of food groups and income level in relation to obesity



Source computations based on WHO, 2017a; World Bank and OECD, 2017.

Figure 2.17

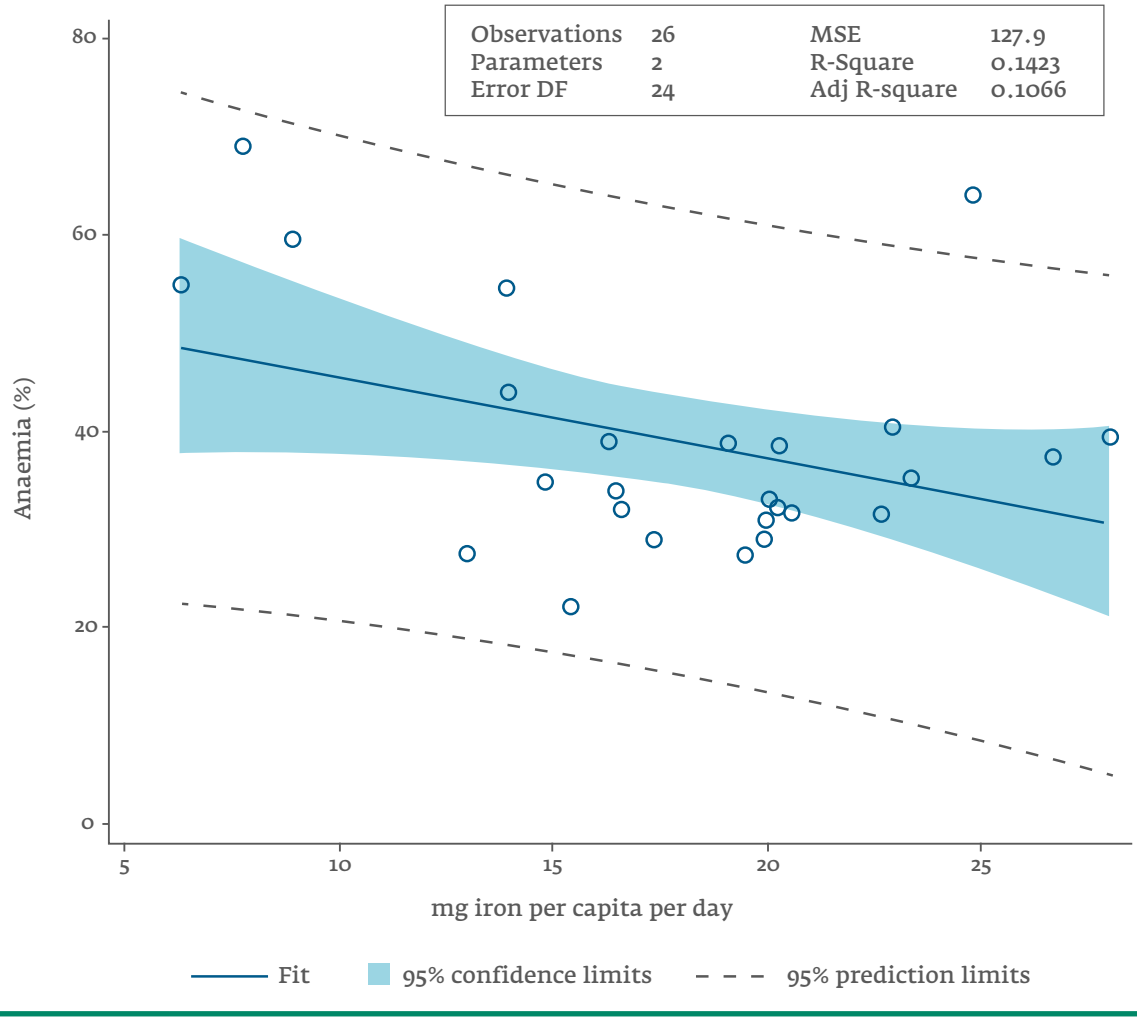
Combination of ratio of food groups and income level in relation to stunting



Source: computations based on UNICEF, WHO and World Bank, 2018; and World Bank and OECD, 2017.

Figure 2.18

Cross-country analysis between the availability of iron per capita and anemia percentage



Source: computations based on World Bank, 2019e; OECD, 2017.

The data in Annex 2.3, Table A.2.4 give evidence of the phenomenon known as the double burden of malnutrition: the coexistence of overnutrition (overweight and obesity) and undernutrition (underweight, stunting and wasting). In almost all SIDS, the prevalence of underweight is low, in most cases below 5 percent, while overweight and obesity are widespread. In the Pacific, overnutrition has reached alarming levels (WHO, 2015). Changing eating patterns, due to globalization and urbanization, have replaced traditional foods (e.g., vegetables, fruits, fish) with imported foods that are high in saturated fats and refined sugar.

It is clear that in many SIDS the recommended criteria for food diversity and micronutrient intake are not met and this impacts the health status of their inhabitants. Dedicated food policy interventions are needed.

2.3 CONCLUSIONS

Section 2 has described the myriad socio-economic and agricultural features of the SIDS. It shows their diversity as well as their common characteristics in relation to population growth, land resources and agriculture, economy, natural disasters, diet patterns and health.

First, rapid urbanization is a common feature. Most new urban settlements are located near the coastlines, thereby exerting considerable pressure on local groundwater reserves, with sea intrusion and salinization of aquifers presenting a serious threat. The expanding urban population tests the capacity of the SIDS to collect and treat wastewater.

Second, most high-quality land in SIDS is under cultivation and much is occupied by monoculture cash crops, a production tradition inherited from colonial days. A switch from low to high input agriculture would enable a sustainable expansion in land area, which could increase the supply and variety of fresh and healthy foods.

Third, the remote locations of SIDS and their lack of connectivity to trading routes mean high transportation costs and elevated prices for imported agricultural products. Many SIDS are highly dependent on food imports, which consume a considerable part of their export earnings. Low-income SIDS depend mostly on their own agricultural production for their food supply.

Fourth, there is a large variation of income levels on the SIDS. Yet, many SIDS have fragile economies in terms of: high unemployment rates and a low resilience after natural disasters.

The share of the agricultural sector shrinks as per capita income rises. Overall, the service sector is the highest contributor to GDP, an important part of which comes from the tourism sector.

Remittances are critical in low-income SIDS countries. Yet this exposes the countries to grave economic risk when external shocks (such as pandemics) affect money transfers to the home country.

High unemployment rates in lower- and middle-income SIDS, especially among young people, are a major concern.

SIDS are prone to frequent natural disasters that can affect their economies and Food security and Nutrition. Low resilience and an absence of external support can lead to long-term food insecurity and health-related consequences.

Finally, many SIDS suffer from the double burden of malnutrition, a lack of food diversity and micronutrient deficiencies that could partly be addressed by cultivating fresh and healthy foods on the islands. An analysis of suitable land shows that agricultural expansion is still possible, assuming the availability of sufficient water resources to sustain desired production levels. We will discuss this further in Section 3.

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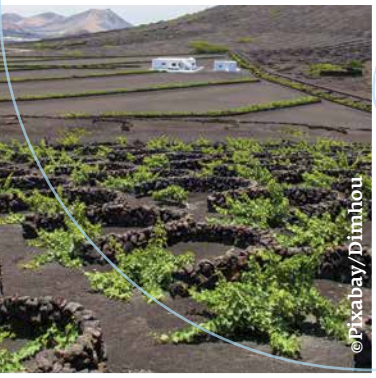
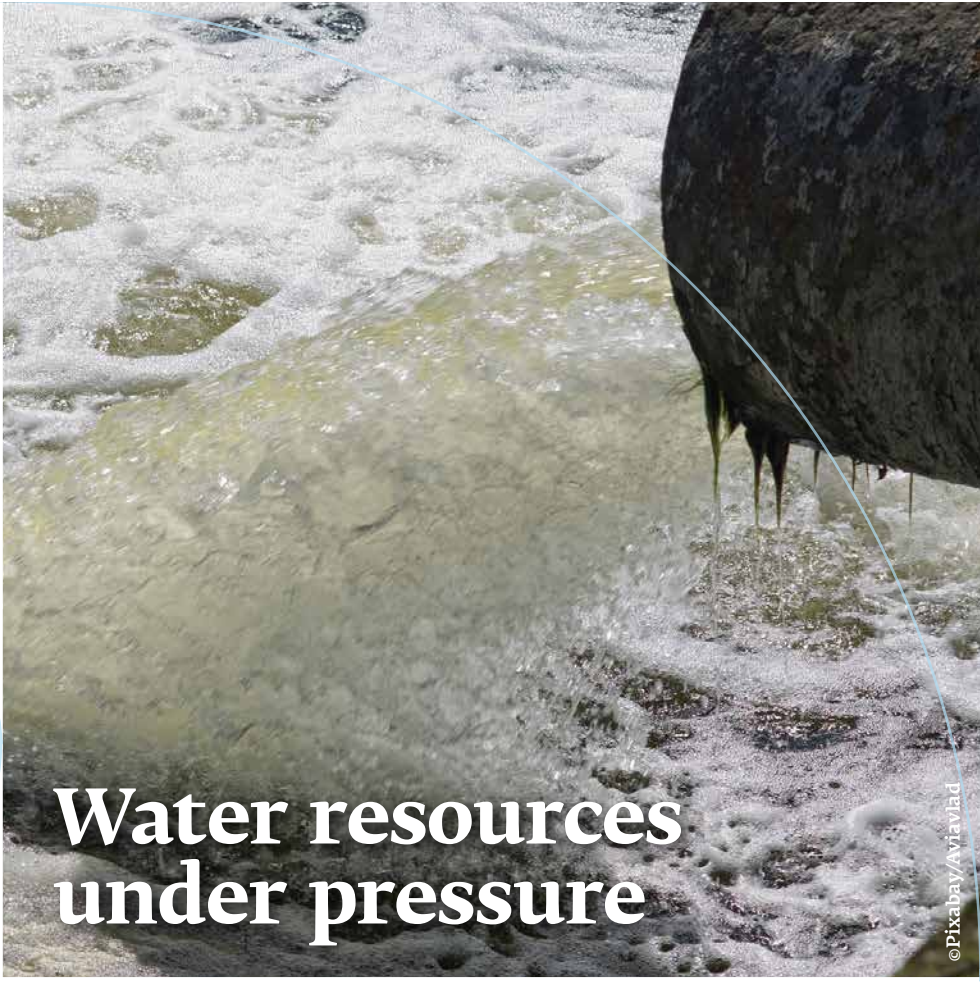


3

Water resources under pressure



Section 3 begins by analysing typical water characteristics of SIDS by following the water flows from renewable resources, extraction, use and reuse (3.1). Next, we consider the current pressures exerted on water resources (3.2), with special attention to the role of water as a carrier of agrochemicals and the pollution of groundwater resources (3.3). The following section (3.4) reflects on important water characteristics related to the malnutrition status of the population. Finally, Section 5 summarises and concludes (3.5).

3.1. FOLLOWING THE WATER FLOWS

We first consider the following questions:

1. What are the available water sources?
2. What are the sources for water extraction?
3. How is water used?
4. How much water is collected and reused?

The first and second questions concern the extraction and use of water sources (surface, groundwater and springs). The third question considers water use, with special attention to agricultural development and sanitation and hygiene at the household level. The fourth question aims to assess return flows, treatment and water reuse.

Data on the availability and use of freshwater in SIDS are drawn from FAO's AQUASTAT database, which provides key information on water resources and use at national levels. Most SIDS comprise multiple islands, each of which has its own geographical characteristics that influence the supply and storage of water. Our analysis attempts to account for this diversity, while presenting sufficient distinctive characteristics for each SIDS country to enable comparison with others.

Physical geography

The physical geography of island states is an important consideration when explaining their hydrological characteristics. Commonly (e.g., Tsiourtis, 2019), small islands are described as being 'low' or 'high.'[1] Low islands or atolls (see Figure 3.1) have limited soil formation, prevalence of sandy soils with low water holding capacity, do not have an effect on rainfall patterns and surface runoff is negligible. Low islands are prone to floods, an increasing risk given the anticipated rise of sea levels due to climate change. High islands (see Figure 3.3) influence rainfall patterns. Most high islands are composed of volcanic rock, while some originate from tectonic movements. In general, the soils of high islands have low permeability, with surface runoff concentrating in perennial streams. Our study introduces a third archetype, namely the 'medium' islands, which are exemplified by a raised atoll (see Figure 3.2). Unlike the low islands, medium islands have soils with higher water holding capacities which makes their hydrological characterization a hybrid of the low and high islands.

Figure 3.1

Atoll or low-lying island. Low surface and permeable soils/geology

© Ibrahim Mushan

1 Among high lying islands, Timor-Leste has the highest peak at 2 986 mamsl and Cook Islands the lowest at 520 mamsl. Among the low islands, the highest peak is found in Antigua and Barbuda, 357 mamsl, the lowest is in Maldives at 2.4 mamsl.

Figure 3.2

Raised islands: start of soil formation

© Jakob Owens

Figure 3.3

Elevated islands: high surface runoff, low soil permeability

© Timur Garifov

Two databases (UNEP, 2004 and Dahl, 1991) that extensively detail the physical geography of SIDS were used to assign geographical characteristics to the three terrain archetypes and their possible combinations, as presented in Table 3.1.

Figure 3.4 shows the frequency distribution of the SIDS countries by terrain characteristics. The high category dominates, followed by the low islands. Combined, the hybrid and medium terrains have 13 islands. The 'mix' category combines high and low islands and is represented by 12 SIDS. A full description of the data of physical geography characteristics for each SIDS and detailed descriptions of six terrain categories are found in Annex 3.1, Table A.3.1.

Table 3.1

Island terrain categories and criteria

Island terrain	Criteria
High	Dominant presence of volcanic or mountainous landscape
Medium/High	Volcanic or mountainous landscape with raised atolls
Medium	Raised atolls
Medium/Low	Raised atolls with atolls and low-lying islands
Low	Atolls and low-lying islands
Mix	A mix with high and low categories

Rainfall

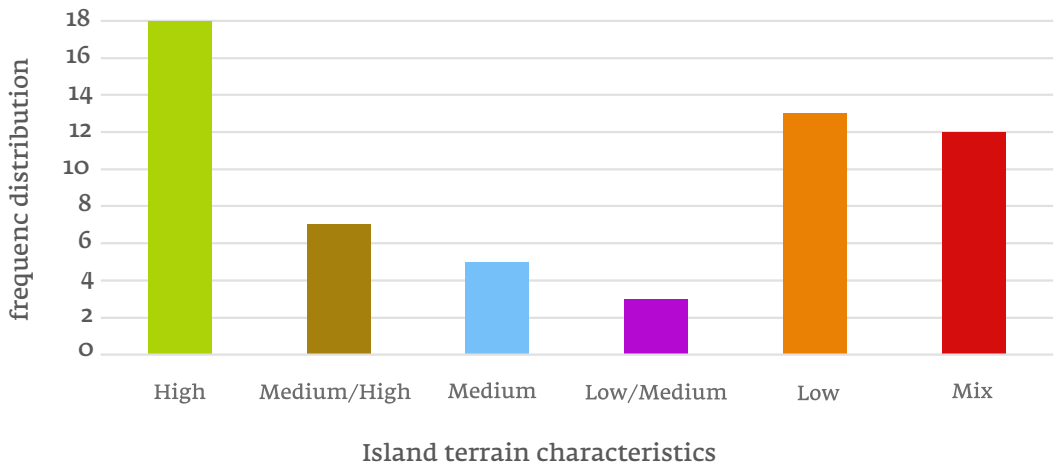
The main source of freshwater for SIDS is precipitation, which delivers surface waters and recharges aquifers. Figure 3.5 shows the average annual precipitation over the period 1985-2015 for 32 SIDS countries. In the Caribbean (17 countries), Antigua and Barbuda report the lowest (1 030 mm) and Guyana the highest annual rainfall (2 387 mm) with averages of more than 1 500. The Pacific (6 countries) has the lowest rainfall on Timor-Leste (1 500 mm) and highest in Papua New Guinea (3 142 mm). The AIS region (9 countries) reports the lowest figures for Bahrain (83 mm), Cabo Verde (228 mm) and Comoros (900 mm); averages are elevated by the high rainfall reported on Sao Tome and Principe (3 200 mm), Singapore (2 497) and Seychelles (2 330 mm).

Renewable water sources

The share of renewable surface groundwater and overlap[2] flows for SIDS grouped by terrain category are presented in Figure 3.6.

Figure 3.4

Frequency distribution of SIDS countries by island terrain characteristics

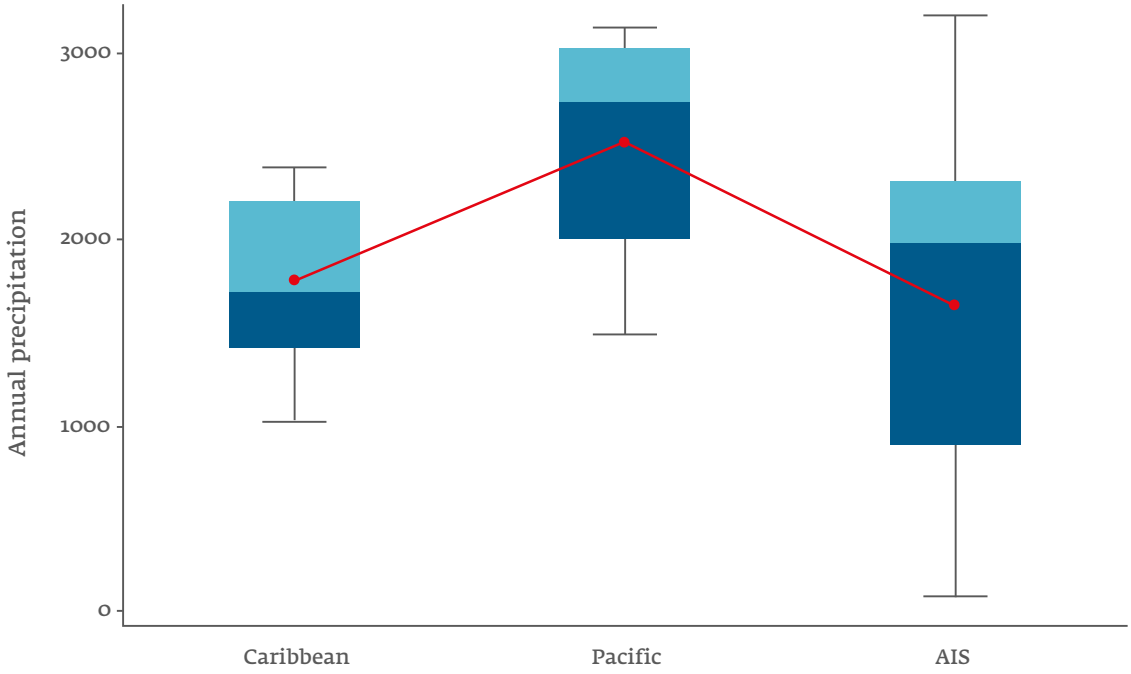


Source: Figure developed by authors, based on UNEP, 2004 and Dahl, 1991 and criteria presented in Table 3.1

2 Overlap flows are equal to groundwater drainage into rivers (typically, base flow) minus the seepage from rivers into aquifers.

Figure 3.5

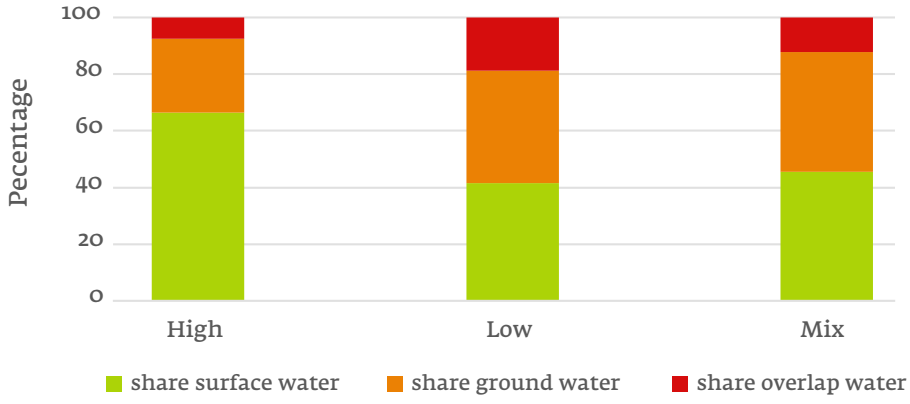
Plotbox, showing distribution of average annual precipitation (1985-2015) by SIDS region



Source: FAO, 2020a

Figure 3.6

Share of renewable water resources: surface water, groundwater and overlap. Year of observation 2014 (latest year available)



Source: Authors' computations based on FAO, 2019a

As expected, high islands have a larger share of surface water (67 percent) as a renewable resource compared to low islands (40 percent). Groundwater shares on high islands are an average of 26 percent and on low islands, 40 percent. The shares of the mix category are similar to low islands. Variation and exceptions are also present. Of the high islands, Haiti has the

highest share of surface water (85 percent). Six high islands have shares of 70 percent or more; Comoros is an extreme exception with only 17 percent surface water. The low category has, on average, 40 percent of its shares as groundwater. This percentage is skewed by Bahrain, which draws 95 percent of its renewable water resources from groundwater. Other low countries report 20 percent or higher. The details of the 21 SIDS countries that report on renewable water resources are presented in Figure A.3.2.

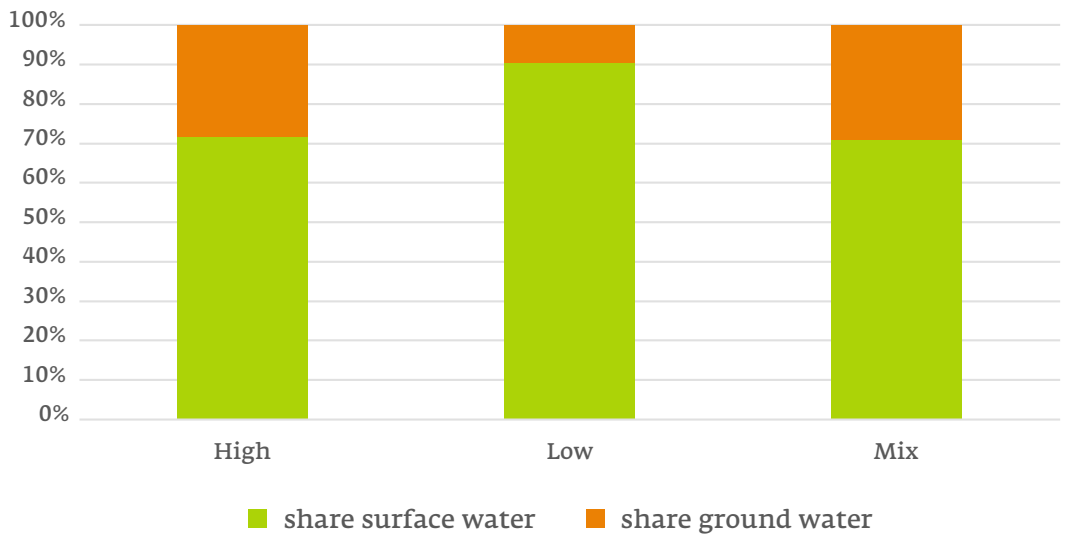
We conclude that there is a dominance of surface water on high islands. The expected higher share for groundwater on low islands is not supported by the results. The available renewable water resources per capita is presented in Figure A.3.3 and will be used in Section 3.4 to assess whether water availability can explain malnutrition status.

Water extraction

Figure 3.7 shows extraction shares for surface and groundwater sources by island terrain characteristics. A detailed overview by country and terrain characteristics is presented in Figure A.3.4. On average, surface water constitutes the largest share for water extraction, irrespective of island terrain category. High islands report an average of 72 percent withdrawal from surface water; for the low islands this is as much as 91 percent. The exceptions are Haiti (high) and St Kitts and Nevis ('mix'), with 92 percent and 82 percent from groundwater resources, respectively. As only 13 countries gave a complete overview of the source of water withdrawals, only cautious conclusions are warranted, but it appears that most SIDS countries withdraw a higher share from surface waters.

Figure 3.7

Share of surface and groundwater extraction by island terrain category. Last year of observation (1989-2014)



Source: Authors' computations based on FAO, 2019b

In a study on groundwater resources, 90 percent of SIDS reported intrusion of sea water caused by rising sea level, pumping, and wave overwash events (UNESCO-IHP and UNEP, 2016). Urban areas that rely on small coastal aquifers are at higher risk of saltwater intrusion (Gohar *et al.*, 2019). Hence, both water quantity and quality should be considered stress indicators.

Water use

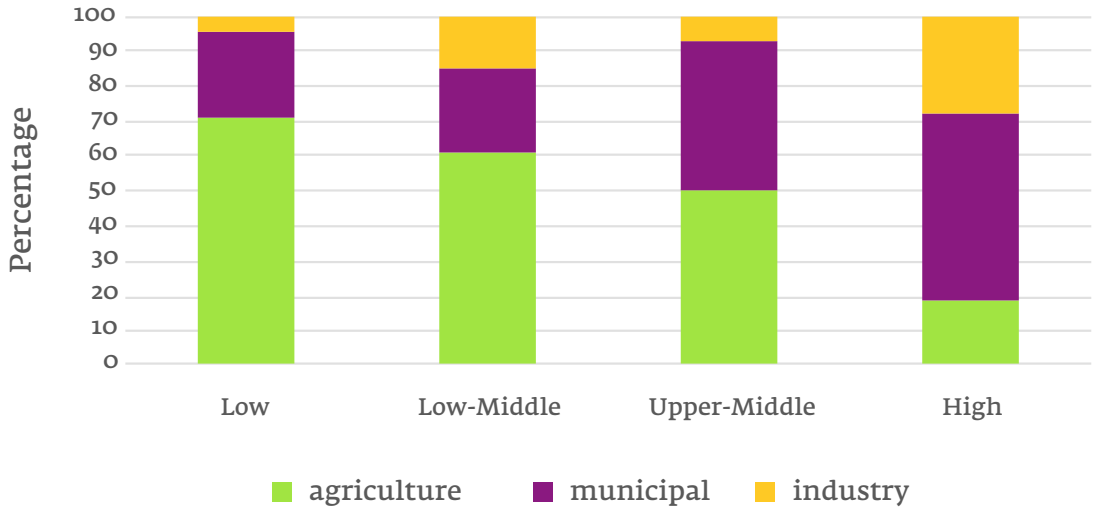
Figure 3.8 presents the share of water use by the three main economic sectors – agriculture, municipality and industry – for the four income groups of SIDS countries. Agriculture is the largest water user for the low-income group, accounting for over 70 percent of the water in use.

In the higher-income groups, agricultural water is the lowest share on average. Figure A.3.5 and Figure A.3.6 show the shares of withdrawals by the country for island characteristics and income groups, respectively. There is no clear pattern of withdrawals when islands are grouped by terrain conditions. The subdivision by income group largely confirms the trend presented in Figure 3.8, yet there are exceptions, such as the upper middle-income countries (UMICs) Dominican Republic and St Lucia and the high-income country Barbados, with shares for the agricultural sector that are comparable to low-income countries (LICs).

To assess the efficient use of water for agriculture, we analysed the area equipped for irrigation (see Figure A.3.7). On average, the share of irrigated areas is low: 20 percent, 18 percent and

Figure 3.8

Share of water use by agriculture, municipality and industry by income group. Latest year of observation 1999-2014.



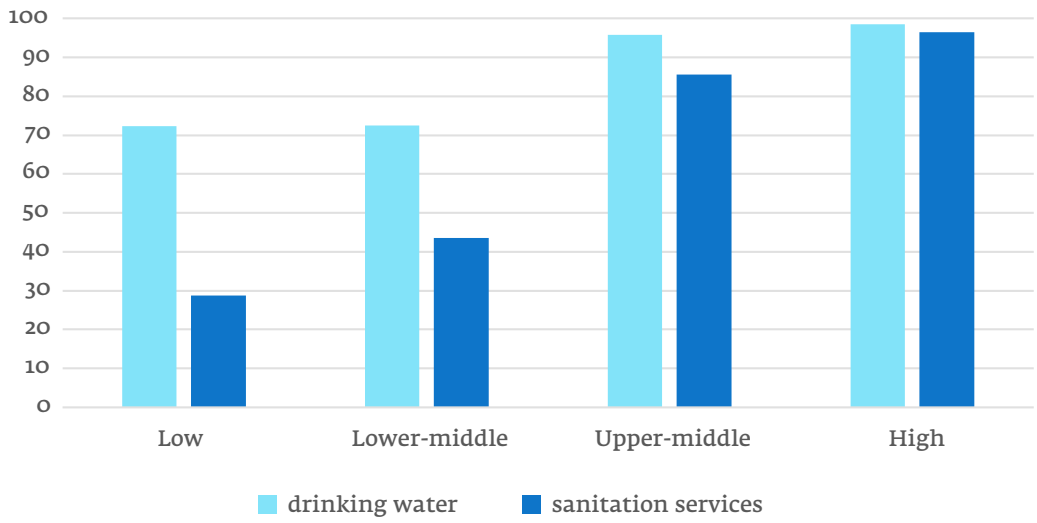
Source: Authors' computations based on FAO, 2018a

4 percent in the Caribbean, AIS and Pacific regions respectively. It is likely that substantial efficiency gains could be made if advanced irrigation techniques were to be introduced.

We analysed basic access to water, sanitation and hygiene (WASH) in SIDS municipalities. Both low-income countries and middle and low-income countries (MLICs) scored low for WASH (see Figure 3.9). On average, only 29 percent of the population in LICs has access to sanitation. The situation is slightly better in MLICs, at 43 percent. Middle-high and high-income countries score much better: 83 percent and 96 percent of their populations, respectively, have access to sanitation. Access to drinking water is 72 percent for both LICs and MLICs and near universal for middle-high and high-income countries (96 percent and 98 percent respectively). Nevertheless, the limited access to sanitation services in LICs and MLICs creates serious health hazard risks (see Figure A.3.8 for a detailed assessment of WASH conditions by country).

Figure 3.9

WASH conditions by SIDS income group. Latest year of observations was used; range 2010-2015.



Source: computations based on FAO, 2018b

Treatment and reuse

Only five countries (Bahrain, Barbados, Cuba, the Dominican Republic and Singapore) reported on the treatment of municipal wastewater. Table 3.2 indicates that on average 55 percent of the withdrawn water is collected. Approximately half of the collected water (51 percent) is treated. Yet, maximum and minimum values of collected and treated volumes vary widely.

Table 3.2

Water treatment in SIDS countries. Latest year of observations was used; range 1990-2016

	Mean (%)	Max (%)	Min (%)
Collected as a share of withdrawal	55	98	11
Treated as a share of collected	51	100	2

Source: FAO, 2019c

From the literature, however, it is known that treatment facilities are inadequate and most wastewater drains into the sea or into groundwater without proper treatment (e.g. Williams, 2018; IGRAC, 2016). Clearly, this is undesirable from a health perspective. Moreover, coastal ecosystems are affected, which has major consequences for the tourism industry.

3.2. FRESHWATER UNDER STRESS

Target 6.4 of the Sustainable Development Goals (SDGs) aims to reduce water scarcity by 2030 by increasing water-use efficiency across all sectors. Indicator 6.4.2 measures the level of water stress (WS), defined as the total freshwater withdrawn by major economic sectors (FW) as a proportion of total renewable freshwater resources (TR), taking account of environmental flow (EF).

In the formula:

$$WS = \frac{FW}{TR - EF}$$

Water stress values fall into four WS categories: low (WS<0.25), moderate (0.25<WS<0.75), severe (0.5<WS<0.75) and very severe (WS>0.75).

EF is an unknown factor, which for this exercise was estimated as a share of TR using data from FAO (2020a). Table 3.3 presents data on EF and TR from 11 countries. High islands tend to have a lower share of environmental flow compared to low islands. Given the scarcity of data, however, a sensitivity analysis is conducted that varies average EF shares for high (0.35) and low (0.73) islands and an imposed overall share (0.52) for other islands with plus and minus 30%.

Table 3.3

Environmental flow as a share of total renewable water resources by terrain category

Country SIDS	Environmental flow: share of total renewable water resources	Terrain
Cuba	0.23754	High
Dominican Republic	0.23217	High
Haiti	0.22723	High
Timor-Leste	0.49531	High
Trinidad and Tobago	0.56927	High
Belize	0.63139	Low
Guinea-Bissau	0.62739	Low
Guyana	0.83838	Low
Suriname	0.84253	Low
Papua New Guinea	0.62984	Mix
Puerto Rico	0.36915	Mix

Source: computations based on FAO, 2018d

Water stress is evaluated for the following scenarios.

A. under increasing population for the years 2014, 2019, 2030 and 2050;

B. as in A, but with an extra withdrawal for a growing tourism sector of 10 percent, 15 percent and 50 percent for the years 2019, 2030 and 2050, respectively;

C. as in B, but with a 30 percent increase (Cplus) and decrease (Cmin) of the EF.

Figure 3.10 shows the results for Scenario A by country and income group. It is notable how many high-income countries appear in the very severe category. In 2019, it appears that Bahrain had the highest water stress (>1 000), followed by Barbados (320), St Kitts and Nevis (212), Singapore (189) and Puerto Rico (138). UMICs, such as the Maldives and Mauritius, also fell into the very severe stress category. Timor-Leste and Antigua and Barbuda will face severe WS in 2050. Cuba and the Dominican Republic will transit from low to moderate and severe' water stress over the period 2019–2050. Sixty-two percent of the countries (Comoros, Haiti, Guinea-Bissau, Cabo Verde, Papua New Guinea, São Tomé and Príncipe, Belize, Dominica, Fiji, Grenada, Guyana, Jamaica, St Vincent and the Grenadine and Suriname) do not currently nor are they expected to experience water stress under Scenario A.

Figure 3.11 presents the share of countries that, over the years 2014, 2019, 2030 and 2050, fall into the various categories for the A, B, Cplus and Cmin scenarios.

Under Scenario A (blue line), the percentage of non-water stress countries remains the same (62 percent) in all years. The share of countries in the moderate stress category gradually decreases over the years, from 11 percent in 2014 to zero in 2050; the countries shift into the severe and very severe categories, which increase from 7 percent and 18 percent in 2014 to 14 percent and 22 percent in 2050, respectively. The growth of the tourism industry by 11 percent and 15 percent under Scenario B did not change the share of countries and retained the same distribution observed under Scenario A. Introducing a growth of 50 percent in tourism (grey line) causes a gradual shift from low stress to moderate, severe and very severe categories. The very severe class increases rapidly from 18 percent in 2014 to 35 percent in 2050. Scenarios Cplus and Cmin show the impact of environmental flow estimates. Higher EF estimates under Cplus causes a shift from low to moderate WS categories, Cmin compensates somewhat for the higher estimates under Scenario B, as expected. Water use efficiency gains under Scenario Cmin can also be realized with the introduction of advanced irrigation schemes in the agricultural sector.

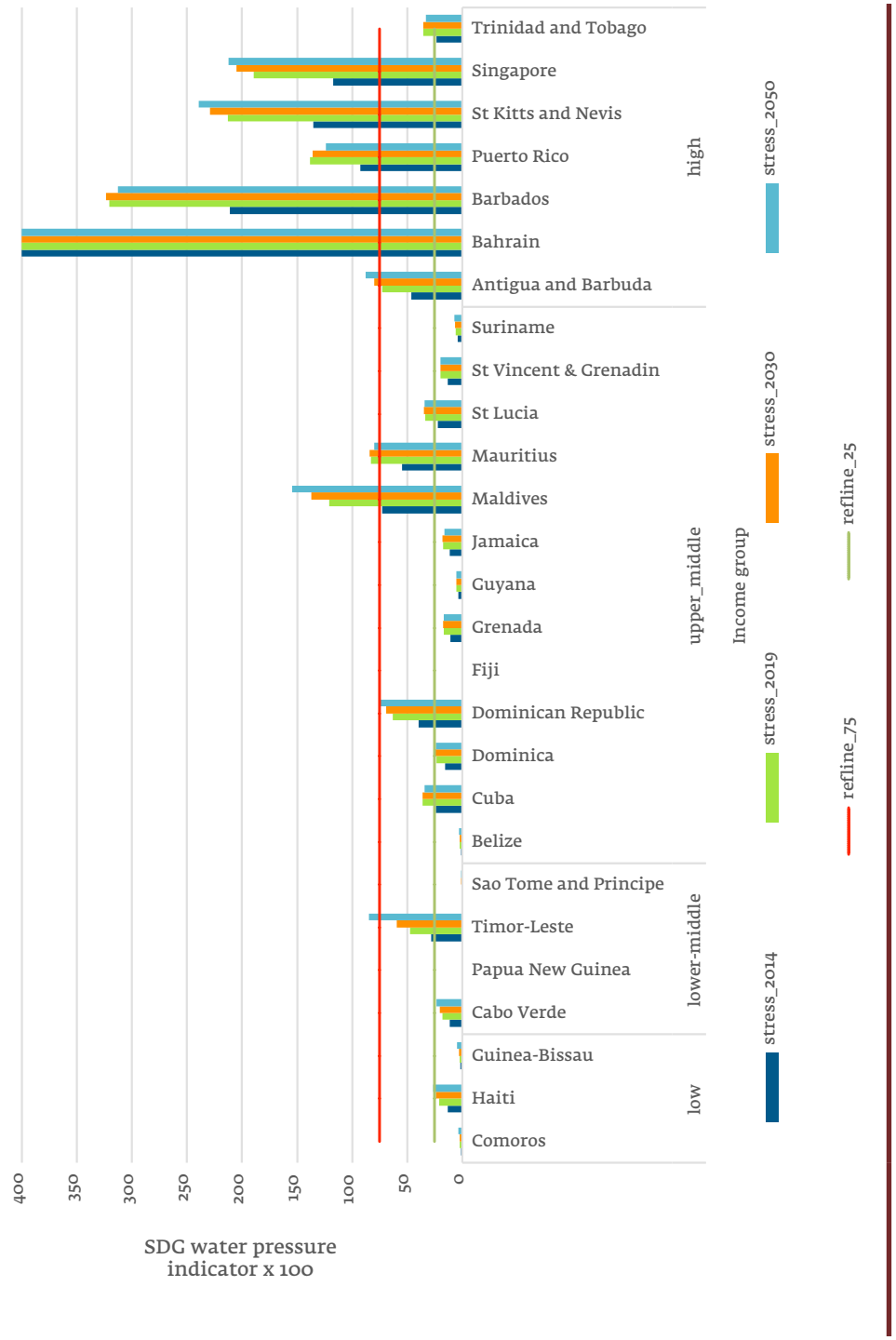
3.3. WATER AS POLLUTION CARRIER

The proximity of people and ecosystems make small islands reliant on careful pesticide management.[3] FAO, seeking to reduce risks from pesticide use, has played an active role in clearing obsolete pesticides lingering on many islands (FAO, 2014b). However, there remain serious concerns about the use of inappropriate pesticides and their effect on health, either directly during application or indirectly, when pollutants percolate into groundwater reserves. Moreover, pesticides can affect island biodiversity while the drainage of polluted surface water compromises coastal ecosystems.

3 particularly highly hazardous pesticides and persistent organic pollutants

Figure 3.10

Water pressure (expressed as water stress x100; SDG 6.4) for the years 2014, 2019, 2030 and 2050 by SIDS country and income group for Scenario A. Reference lines, Refline_25 and Refline_75, indicate threshold values for low to moderate and severe to very severe water stress, respectively.



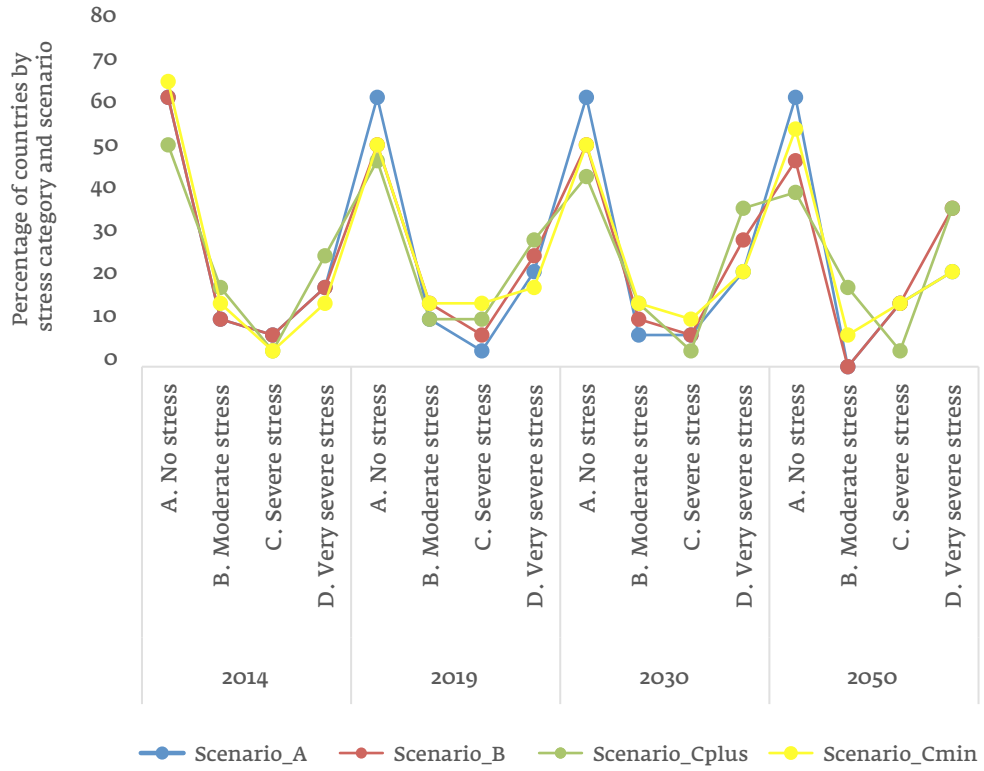
Source: Authors' computations based on FAO, 2018a

A GEF-funded project carried out by FAO in the Caribbean (Kohlschmid, personal communication, 2019) found that two out of 18 pesticides had high-leaching groundwater potential, six had moderate potential and 10 had low potential. Six compounds were highly toxic to fish, 11 were moderately toxic and one had low fish toxicity. Velde (2006) reported concerns about a ten-fold increase in the import and use of agrochemicals in Tonga.

Most models that analyse the leaching potential for groundwater require component-specific information that goes beyond the scope of this study. To assess the current pesticide

Figure 3.11

Share of countries in water stress categories for the years 2014, 2019,2030 and 2050 under Scenarios A (baseline), B (growth in tourism sector) Cplus (30 percent higher EF estimate) and Cmin (30 percent lower EF estimate)

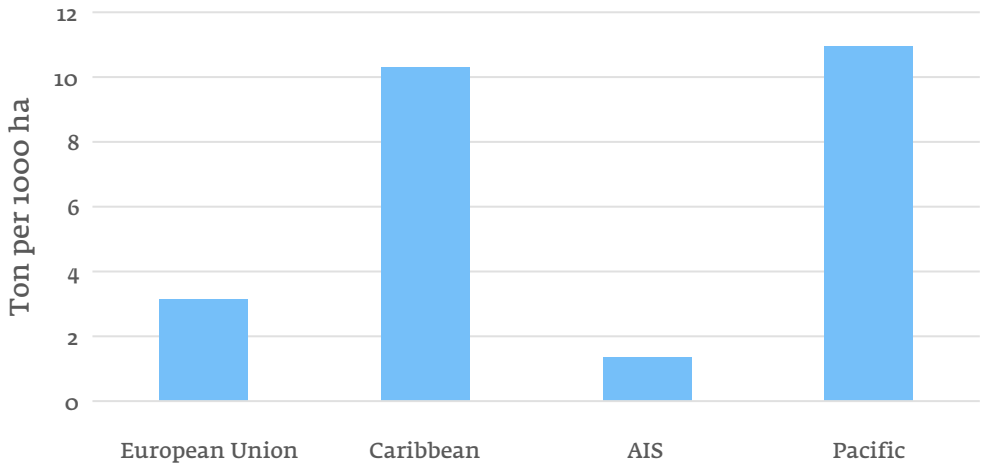


applications in SIDS, the total pesticides category from FAO (2020b) was used to compare the concentration of pesticide used on cropland by region and income group with overall use in the European Union. The results show (see Figure 3.12) that, especially in the Caribbean, AIS countries, UMICs and high-income groups (see Figure 3.13), the concentrations of pesticides was more than five times the concentration in EU countries.

Figure A.3.9 shows the concentrations of pesticide applications by country. Of the 30 countries reporting on pesticide use, 12 applied higher concentrations than in EU countries and ten applied concentrations that are at least two times higher than in EU countries. Saint Lucia, Barbados, Bahamas, Trinidad and Tobago and the Maldives reported the highest concentrations. Concerns about pesticide overuse and related environmental and health hazards are therefore to be taken seriously. A preliminary risk assessment by UNESCO-IHP and UNEP (2016) compared applied concentrations to polluted aquifer areas. Figure 3.14 presents the results in a scatter plot mapping the concentration of pesticide use against the share of polluted areas of aquifers by island terrain characteristics. There is a tendency for higher concentrations to result in more polluted areas. For a discussion of island characteristics, the number of observations is too small to determine a solid pattern. Clearly, more empirical research is urgently needed to assess the health and environmental hazards that are caused by the overuse of pesticides in the SIDS.

Figure 3.12

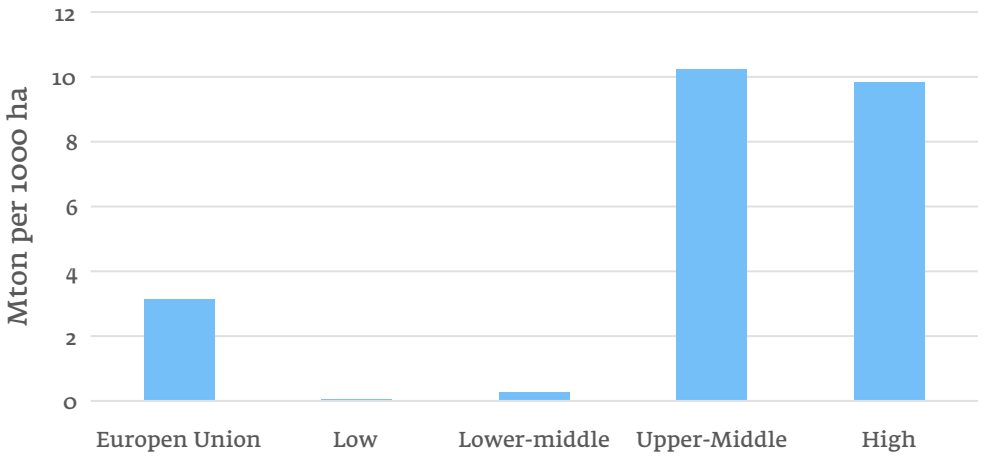
Concentration of applied pesticides (tonne per 1 000 ha) by region



Source: Authors' computations based on FAO, 2020b and FAO, 2020c

Figure 3.13

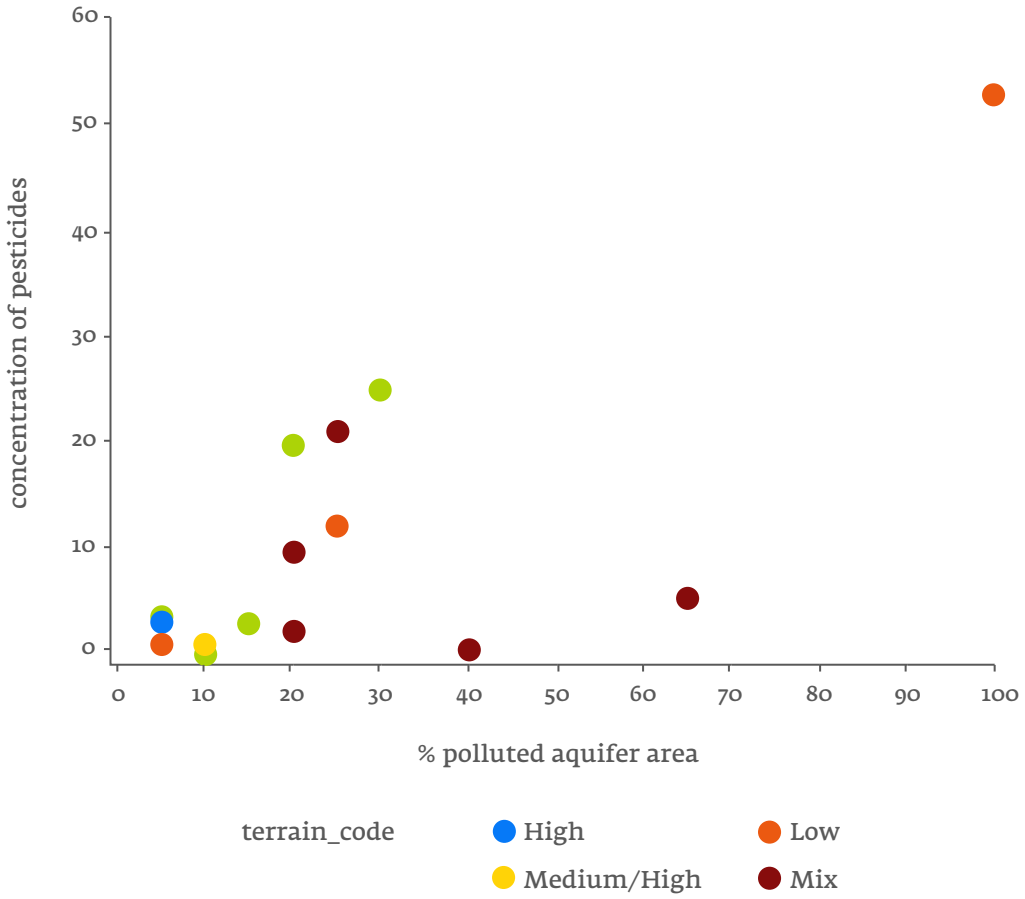
Concentration of applied pesticides (tonne per 1 000 ha) by income group



Source: Authors' computations based on FAO, 2020b and FAO, 2020c

Figure 3.14

Concentration of pesticides (tonne per 1 000 ha) applied in SIDS countries versus percentage of polluted aquifer area



Source: Authors' computations based on FAO, 2020b and FAO, 2020c; IGRAC, 2019 and UNESCO-IHP and UNEP, 2016

3.4. WATER AND HEALTH

The relationship between anthropometric data (obesity, overweight, underweight, stunting and wasting, see Section 2.2) and various water characteristics are considered by using Pearson's correlation coefficient (scatter plots of the bivariate analysis are presented in Figure A.3.10). The results are presented in Table 3.4. The first line of the matrix shows the Pearson correlation coefficient, the second line the probability that the correlation coefficient is zero and the third line the number of observations. Very strong ($p<0.0001$) and strong ($p<0.1$) correlations are found between stunting and wasting and access to drinking water and sanitation. The reverse is as expected: stunting and wasting are reduced by increasing access to drinking water and sanitation services. Obviously, good drinking water and sanitation has

a positive effect on children's development as it suppresses the incidence of communicable diseases. Better access to drinking water and sanitation also coincides with higher welfare which, as seen in Section 2, positively correlates with better anthropometric indicators.

There is some indication that obesity is related to the percentage of cultivated area equipped for irrigation, and overweight to water stress but using standard econometric criteria the null hypothesis will not be rejected, which also holds for all other correlations.

Table 3.4

Pearson correlation coefficients; prob > |r| under Ho: Rho=0, number of observations

	obesity	overweight	underweight	stunting	wasting
Water availability per capita per day	0.17620 0.3995 25	0.19188 0.3582 25	-0.19757 0.3438 25	0.00896 0.9676 23	0.03364 0.8789 23
Basic access to drinking water	0.16772 0.3508 33	0.06997 0.6988 33	-0.14145 0.4323 33	-0.80957 <.0001 29	-0.50051 0.0057 29
Basic access to sanitation services	0.24626 0.1671 33	0.23433 0.1893 33	-0.26978 0.1289 33	-0.82992 <.0001 29	-0.36280 0.0531 29
Water stress SDG Indicator 6.4.2	0.27310 0.2074 23	0.30321 0.1596 23	-0.16676 0.4470 23	-0.11033 0.6340 21	0.00207 0.9929 21
Water for agriculture as share of total withdrawal	0.04465 0.8397 23	-0.03936 0.8585 23	0.22526 0.3014 23	0.01044 0.9642 21	-0.18187 0.4301 21
% of cultivated area equipped for irrigation	0.32090 0.1454 22	0.30225 0.1716 22	-0.17541 0.4349 22	-0.32009 0.1689 20	-0.04178 0.8612 20

Source: Authors' computations based on results in Section 2.2 and Section 3.2 and 3.3

3.5. CONCLUSIONS

AQUASTAT is the major data provider for the water flow analysis in 42 of the 56 SIDS countries. Data were not always complete and nationwide reporting had to be extrapolated across the diverse physiography of multiple islands belonging to individual SIDS. Despite these data hurdles, the following empirical findings help to contextualize the role of freshwater and water governance on the SIDS.

The importance of groundwater and surface water for extraction varies greatly among SIDS countries. There is some indication that low and mix SIDS have larger groundwater reserves. The findings also show that, on average, SIDS rely more heavily on surface water than on groundwater resources for water extraction. However, it should be noted that the rapidly urbanising population in SIDS is increasingly dependent on shallow groundwater reserves near the coastline; indeed, the hazards of overextraction and sea intrusion into aquifers loom large.

Most extracted water goes to the agricultural sector, except for in high-income countries where municipalities are the largest water consumers followed by the industrial sector. The share of cultivated land equipped for irrigation is very low, leaving ample room to increase water use efficiency in the agricultural sector.

Most low- and middle-income countries are free from water stress. Even when subjected to various forms of pressure over long periods like presented by scenarios A, B and Cmin (3.2), few countries experienced low levels of moderate water stress. On the other hand, most high-income countries experience high water stress levels, which will continue to increase until 2050 when stress scenarios show that most countries will shift into the 'very severe' category.

The limited capacity for collecting municipal and industrial wastewater, together with the absence or inadequacy of water treatment facilities, have serious implications for human and ecosystem health in SIDS. With mounting populations and the increasing dominance of the tourism sector, strong and effective wastewater treatment policies are urgently needed.

The high doses of pesticides currently applied in SIDS are alarming. Pesticides can pollute aquifers and surface waters, making these water resources unfit for other purposes. Strong regulations, enforcement and awareness campaigns on the correct application of pesticides are badly needed. Incentives to convert to more organic farming will benefit consumers, the environment, soil and water quality.

Good access to drinking water and sanitation services is key to the healthy development of children in SIDS. This message does not need further elaboration, but it will require immediate action from the SIDS to ensure that good water, sanitation and hygiene conditions are monitored and applied.

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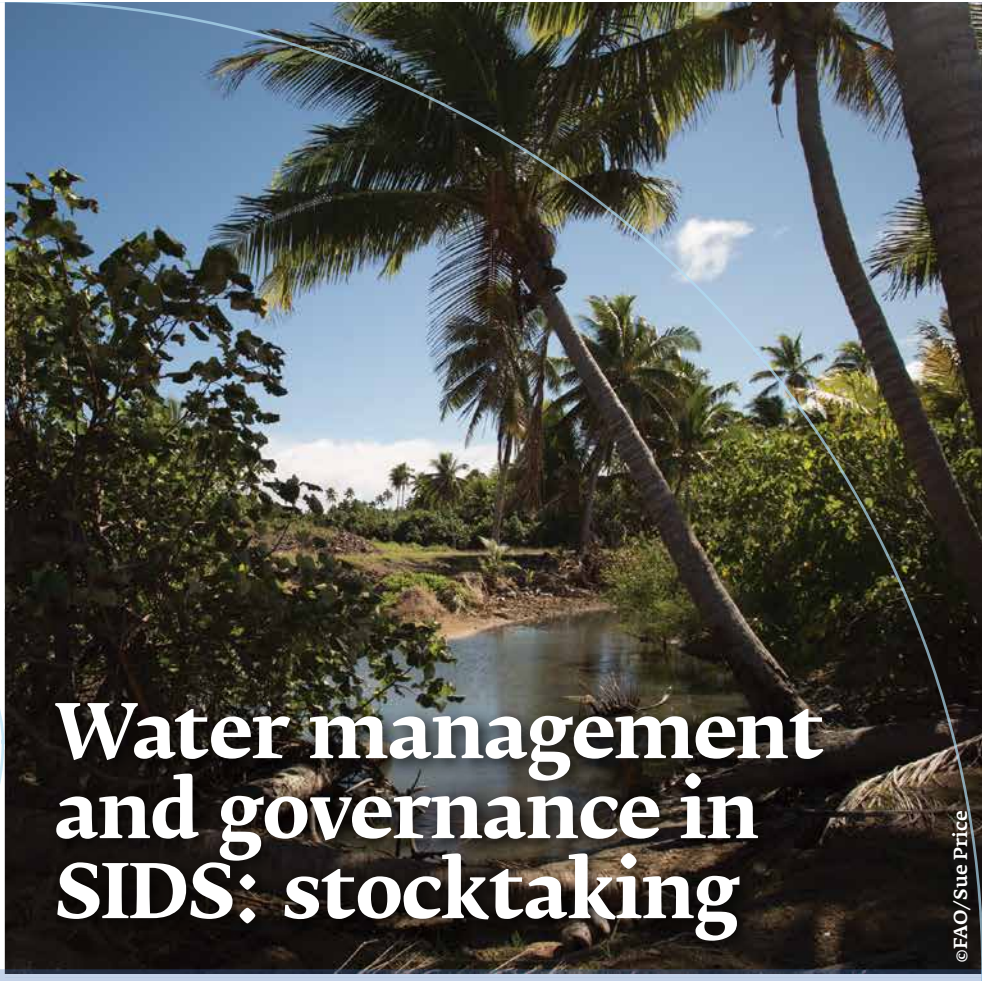
4

Water management and governance in SIDS: stocktaking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This section takes stock of key water management and water governance projects in Small Island Developing States (SIDS) to better understand success factors in water project implementation. The case studies showcased here contribute to the knowledge base around the water management-agriculture-food security nexus. Lessons learned from these studies should empower SIDS to develop the policies they need for sustainable and lasting water management, and healthy and diverse diets.

Section 4.1 presents 23 case studies, followed by an assessment of major findings in Table 4.2. The case studies describe a range of project elements, such as objectives, funding, partnerships, ecosystem impacts, incentive schemes and outcomes. These elements are listed in Table 4.1.

Methodology

This section evaluates a wide range of SIDS-based water projects to better understand why water management interventions succeed or fail. The objective is to determine the most effective interventions for water management. However, we found a serious bias in reporting on success stories as well as a lack of clarity around formal evaluations. Hence, the data set does not allow a probabilistic reporting of the results. Instead, associative patterns have been explored to explain possible outcomes of the water interventions.

Table 4.1

Rubrics evaluation for water management interventions

Code	Transdisciplinarity	Multidisciplinarity	Institutional collaboration	Funding sustainability	Lack of economies of scale	Rewarding custodians	Ecosystem improvements	Success/failure
--	Absence of transdisciplinary approach	Mono-disciplinarity	No collaboration	No funding	Very serious constraint	No acknowledgment of custodians	Degradation of ecosystems	Social and ecological objectives of interventions were not achieved
-	Transdisciplinary approach present but implementation unsuccessful	Mono-disciplinarity with consultations among other disciplines	Some collaboration	Ad hoc funding	Serious constraint	Role of custodians acknowledged but not supported politically	Light degradation of ecosystems, functions difficult to recover	Either social or ecological objectives of interventions was achieved
-+	Transdisciplinary approach present with some results	More than one discipline involved	Collaboration established with minor results	Funding beyond project time	Slight constraint	custodians acknowledged but not rewarded	Light degradation of ecosystems, functions can be recovered	Part of the social and ecological objectives of interventions were achieved
+	Transdisciplinary approach successful; clear involvement of transcendence stakeholder	Multidisciplinary approach without integration	Collaboration successful; alignment of activities	Revolving fund during the project phase	Neutral	custodians acknowledged and paid for services	Ecosystems not affected; eco-services in function	Social and ecological objectives of interventions were achieved successfully
++	Transdisciplinary approach very successful; stakeholders of transcendent disciplines fully participate in Nature-based Solutions from design to implementation	Multidisciplinary approach with full integration	Collaboration very successful; alignment activities and establishment of sustainable relationships	Revolving fund operational beyond the project phase	No constraint	custodians acknowledged, paid for services and rewarded for maintaining water quality	Ecosystems improved; eco-services function better as before the project	Social and ecological objectives of interventions were achieved successfully and mutually reinforce each other

Evaluation criteria considered in the case studies are:

- transdisciplinarity[1] (of stakeholders and beneficiaries);
- multidisciplinarity;[2]
- institutional collaboration;
- funding sustainability;
- lack of economies of scale;
- ecosystem improvements;
- success or failure.

Table 4. 1 provides a scoring guide to evaluating water management interventions in SIDS.

4.1. CASE STUDIES

This section describes the case studies, starting with a general introduction and followed by problem identification, objective of the intervention, funding, executing agencies stakeholders and beneficiaries, methods of intervention and outcomes.

Case 1. Water and sanitation services for informal settlements in Honiara, Solomon Islands

Overview[3]

The Solomon Islands, with their capital city in Honiara, consist of six major islands and over 900 smaller islands and atolls. The Solomon Islands lie to the east of Papua New Guinea and northwest of Vanuatu and cover a land area of 28 400 square kilometres. They comprise two major parallel island chains extending some 1 800 kilometers from the Shortland Islands in the west, to Tikopia and Anuta in the east. More than 90 percent of Solomon Islanders are ethnic Melanesians (The Commonwealth, 2020a).

The challenge

The main challenges for the Solomon Islands include the existence of multiple informal settlements, limited access to water and sanitation and environmental hazards. The informal settlements, established over time through unplanned processes, comprise multiple households that may or may not have formal approval to occupy the land. The population density in some settlements is extremely high and growth is likely to continue, despite land shortages. For example, the Ontong Java/Lord Settlement has a population density of 21 800 people per square kilometre.

1 Transdisciplinary research involves relevant stakeholders in a decision making process where scientific findings are integrated with case-specific knowledge.

2 Multidisciplinary research combines several fields of academic interests.

3 Country excerpts are from www.britannica.com and the CIA World Fact Book (www.cia.gov), and have been made during the period of writing (December 2018 - June 2020).

Life is extremely difficult in many of the settlements:

- Access to water is limited, even if water sources are diverse, such as springs, bores and shallow wells, rainwater tanks and surface flows (e.g., rivers, streams).
- Access to sanitation is limited. Every household uses on-site sanitation options and up to 50 percent of households have private household toilets, although most are basic water-based pits. None of the households are likely to have sanitation that would be considered 'safe' according to the standards set by Sustainable Development Goal 6.
- Some settlements are located in flood or landslip zones and many are on the coastal floodplain where groundwater is shallow.

Residents use a range of water and sanitation options in all of the informal settlements, and few of these provide reliable and safe water and sanitation. In Honiara, only 15 percent of houses currently have access to piped sewerage. The safe collection, treatment and disposal of septic sludge is not common practice.

Objective

The objective of the project was to advise the Solomon Islands Water Authority (Solomon Water) on potential service delivery models for water and sanitation services in informal settlements in Honiara. Many of the current models do not enable the delivery of safe and affordable drinking and domestic water services. Similarly, a range of sanitation practices are in use, most of which do not allow the safe containment of human waste.

Solomon Water is currently expanding and improving its water and sanitation services in Honiara and other towns and urban centres. This presented an opportunity to improve the water and sanitation services in informal settlements as part of a broader agenda.

The project set out to identify possible water and sanitation service models, and, with input from Solomon Water as well as informal settlement residents and other stakeholders, and backed by analytical information and lessons learned, to make recommendations about the best options for Honiara's informal settlements (Souter *et al.*, 2019).

Funding and executing agencies

The World Bank and the International Water Centre.

Stakeholders and beneficiaries

Solomon Water; local and national government agencies of the Solomon Islands, including the Ministry of Lands, Housing and Survey, the Ministry of Health, the Ministry of Environment, Climate Change, Disaster Management and Meteorology, and the Honiara City Council.

Methods of intervention

The following approach was used:

1. Characterisation of Honiara's informal settlements at the environmental, social and economic levels;
2. GIS information assembled for spatial identification of settlements and conditions;
3. Desk-based identification of possible service delivery models, including those currently in use (or not) by Solomon Water. Options were discussed and shortlisted in a workshop and then shared with residents through consultations in five settlements;
4. Service delivery models not currently in use in the Solomon Islands were analysed and evaluated for potential applicability to urban informal settlements and the identification of critical issues to be considered in their adoption;
5. Identification of water and sanitation options for informal settlements based on information and analysis.

Outcomes

The study identified three water service delivery models with potential applicability to Honiara's informal settlements and shortlisted five sanitation options suitable for Honiara's conditions and household preferences. A decision tree was developed to determine the best model for the needs of different households (Souter *et al.*, 2019).

Case 2.
Timor-Leste water sector development and roadmap

Overview

Timor-Leste is one of the smallest countries in Southeast Asia. It is located in the Lesser Sunda Islands of the Indonesian archipelago and has a population of 1.2 million people in 2015, 70 percent of whom live in rural areas. About 40 percent of the population lives in poverty (ADB, 2019). Access to basic services is low and the island is highly vulnerable to natural disasters. The economy of Timor-Leste depends heavily on declining oil and gas resources. An alarming 50 percent of children are stunted due to malnutrition and poor access to clean water and sanitation.

Agriculture is the most important sector in Timor-Leste after oil and gas, with coffee as the main commodity. The total cultivable area is 40 percent of total land area of around 1.5 million ha, of which 220 000 ha is cultivated and 35 000 ha is equipped with irrigation facilities (98 percent surface water and 2 percent groundwater). The use of irrigated areas is suboptimal, due to the inadequate maintenance of irrigation systems, lack of water and cultivable land (FAO, 2011).

The challenge

Addressing the multiple aspects of water management – crucial for stimulating development in Timor-Leste – requires coordinated multisector approaches. The existing approaches to groundwater development lack the planning framework needed to meet the government's strategic targets and to reduce risks to the sustainable management of groundwater.

Objective

The project developed a road map for a national management and development strategy to guide investment priorities in the water sector in Timor-Leste. The studies and analysis contributing to such a strategy aim to fill the many knowledge gaps that exist in the sector and to guide Timor-Leste onto an appropriate development path (World Bank, 2018).

Funding and executing agencies

The World Bank

Stakeholders and beneficiaries

Directorate for Water and Sanitation in the Ministry of Public Works, Transportation, and Communications; General Directorate for Water Supply and Sanitation.

Methods of intervention

Addressing water management is crucial for meeting Timor-Leste's national and international development commitments and to stimulate economic growth. Water management is multifaceted and requires coordinated multisector approaches. The government needs to establish sector priorities that align with national and international development targets to enhance economic growth, and improve the health and well-being outcomes of its citizens. The project supported a range of options identified by the Timor-Leste government to guide investments and decision-making, taking into account water-related natural disasters and climate change.

Outcomes

The project set out to develop a roadmap for the design of a comprehensive water management strategy that would include the following:

- *Institutional and legal framework.* Many of the institutional, legal and policy frameworks for the water sector are still being adapted to the government's new decentralisation policy. Decentralisation will have a significant impact on the delivery of water supply, sanitation and irrigation services to municipalities that currently

lack appropriate operational guidance from policy and law, while current tariff frameworks to support the cost recovery of the delivery of those services are inadequate.

- *Water resources development*. Timor-Leste has potential for the development of its water resources, although this is challenged by the steep catchment topography, land-use practices, the monsoon climate, and variable runoff, which transports large volumes of sediment. There are plans for irrigation diversion weirs, but no multipurpose dams have yet been constructed. Detailed investigations and surveys are needed to support decisions around the development of groundwater resources.
- *Irrigation*. The government strives to increase food production and thus has prioritised the identification of new irrigation schemes, small and large dams, and the expanded use of groundwater tube wells. This can be achieved by a thorough evaluation of cost-effective and conjunctive groundwater-based irrigation systems.
- *Urban water supply and sanitation*. Access by households to water connections remains low, and water supply systems in the national capital, Dili, perform poorly. So-called non-revenue water, i.e. the losses due to inefficiencies in water supply, is estimated to be as high as 90 percent of total water volume supplied. Better sector coordination is required to implement Timor-Leste's urban water and sanitation master plans.
- *Rural water supply and sanitation*. Investments in rural water supply systems rely heavily on financing from development partners, and on community water management groups for maintenance and operations. The Community Action Plan for Sanitation and Hygiene has only been successful in a limited number of locations and should be scaled up for wider coverage. This will require access to larger volumes of water necessitating better coordination with water supply development investments (World Bank, 2018).

Case 5: Sustainable management of water resources in the Caribbean Island States

Overview

This initiative focuses on the Dominican Republic, a country that shares the eastern two-thirds of Hispaniola, the second largest island of the Greater Antilles, with the Republic of Haiti. The Dominican Republic's shores are bounded by the Caribbean to the south and the Atlantic Ocean to the north. Between the eastern tip of the island and Puerto Rico flows the Mona Passage, a channel about 80 miles (130 km) wide. The Turks and Caicos Islands are located some 90 miles (145 km) to the north, and Colombia

lies about 300 miles (500 km) to the south. The republic's area, which includes such adjacent islands as Saona, Beata, and Catalina, is about half the size of Portugal. The national capital is Santo Domingo, which is on the southern coast.

The challenge

The limited exchange of knowledge between the Caribbean Islands results in inefficient water management systems in the region.

Objective

The Centre for the Sustainable Management of Water Resources in the Caribbean Island States sought to generate and transfer scientific and technical knowledge around sustainable water management in the Caribbean Island States in order to improve the efficient use of water resources in the region (UNDESA, 2014a).

Funding and executing agencies

Centro para la Gestión Sostenible de Los Recursos Hídricos en Los Estados Insulares del Caribe (CEHICA); the International Hydrological Programme (IHP); and the Government of the Dominican Republic.

Stakeholders and beneficiaries

Instituto Nacional de Recursos Hidráulicos (INDRHI), Santo Domingo, Dominican Republic; UNESCO Chair on Water, Gender and Governance; Instituto Global de Altos Estudios en Ciencias Sociales (IGlobal), Dominican Republic; UNESCO International Hydrological Programme (IHP)

Methods of intervention

- Implementation of the Samoa Pathway,[4] an UN-SIDS Action platform, through the establishment of a centre in the Dominican Republic, with a focus on the Caribbean Island States.
- The project supported capacity building and institutional collaboration, as well as activities for knowledge and information transfer to promote the sustainable management of water resources in the Caribbean Island States.
- The project studied hydrology and water management in the region and investigated technologies for a more practical use of water.

Outcomes

4 The SAMOA Pathway refers to the adoption of the Accelerated Modalities of Action for the SIDS, which were concluded at a series of conferences at Samoa and are administered by the UN-SIDS Action Platform.

- In 2013, the research activities of CEHICA included the simulation of climate variability effects on water balance and adaptation strategies on water use in the Yaque del Norte river basin; the conclusion of a three-year project on watershed erosion and sedimentation in reservoirs; water quality monitoring and studies in several river basins in the Dominican Republic for INDRHI; and a 5-day training course on rainwater harvesting, followed by a period of 30 days dedicated to practical work by 30 participants from Dominica and the Dominican Republic.
- CEHICA has been a strong contributing partner to the UNESCO Chair on Water, Gender and Governance, established in 2014 at the Instituto Global de Altos Estudios en Ciencias Sociales (IGlobal).
- Both CEHICA and the UNESCO Chair operate under agreements with UNESCO to contribute to the implementation of the eighth phase of the International Hydrological Programme in the Caribbean and have large number of partnership agreements with institutions in the region (UNDESA, 2014a).

Integrating water, land and ecosystems management in Caribbean Small Island Developing States (IWEco Project)

The project focuses on ten Caribbean Islands: Antigua and Barbuda; Barbados; Cuba; the Dominican Republic; Grenada; Jamaica; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines, and Trinidad and Tobago.

The challenge

Caribbean SIDS face multiple threats, including natural resources degradation, the depletion of biological endowments and the loss of ecosystem systems due to external developmental activities that compromise their brittle environments (GEF, 2012).

Objective

- *The long*-term goal of the project is to enhance the ecosystem services that support sustainable socio-economic development in the Caribbean.
- The global environment objective is to promote innovative tools for integrated water and land management and preserve threatened biodiversity.
- The project objective is to contribute to the conservation of Caribbean ecosystems and the sustainability of livelihoods through appropriate interventions that improve fresh and coastal water resources management, sustainable land and forest management to enh*ance the resilience of socio-ecological systems to the impacts of climate*

change.

Funding and executing agencies

IWEco is funded by the Global Environment Facility (GEF). The United Nations Environment Programme (UNEP) is the lead implementing agency for national and regional sub-projects, with the United Nations Development Programme (UNDP) as implementing agency together with the Caribbean Environmental Health Institute (CEHI), the Caribbean Regional Coordinating Unit (CAR-RCU), and the Land Based Sources of Marine Pollution (LBS) Regional Activity Centres (GEF, 2012).

Stakeholders and beneficiaries

A network of international, regional and national partners with a focus on water management in the ten Caribbean countries.

Methods of intervention

The project has four components:

1. development and implementation of integrated, targeted, innovative and climate change-resilient approaches to sustainable land management (SLM), integrated water resources management (IWRM) and the maintenance of ecosystem services;
2. strengthening SLM, IWRM and ecosystems monitoring and indicators frameworks;
3. strengthening policy, legislative and institutional reforms and capacity building for SLM, IWRM and ecosystem services management taking into consideration climate change resilience building;
4. enhancing knowledge exchange, best practices, replication and stakeholder involvement.

The project will be implemented through a network of international, regional and national partners according to their comparative advantage (GEF, 2012).

Outcomes

- reduced environmental stress at project sites in eight countries through appropriate and sustainable water, land and ecosystems management interventions that account for climate change;
- enhanced livelihood opportunities and socio-economic co-benefits for targeted communities;
- stronger national and regional systems for monitoring environmental status for key international agreements;
- stronger national policy and legislation for effectively managing water, land and ecosystems resources that account for climate change;

- stronger capacity of national and regional institutions and other stakeholders for water, land, and ecosystems management that accounts for climate change;
- improved engagement and access to information for practitioners and other stakeholders through targeted knowledge-sharing networks (GEF, 2012).

Case 5.
Pacific partnership for atoll water security

Overview

The Cook Islands are a self-governing island state with political links to New Zealand. Located in the South Pacific Ocean, the state's 15 small atolls and islands have a total land area comparable to that of a medium-sized city, but spread over about 770 000 square miles (2 000 000 square km) of sea – an area nearly as large as Greenland. The national capital of the Cook Islands is Avarua on the island of Rarotonga, and the land area is 91.4 square miles (236.7 square km).

Kiribati, officially the Republic of Kiribati, is an island country in the central Pacific Ocean. The 33 islands that make up Kiribati, only 20 of which are inhabited, are scattered over a vast area of ocean. Kiribati extends 1 800 miles (2 900 km) eastward from the 16 Gilbert Islands, where the population is concentrated, to the Line Islands, of which 3 are inhabited. In between lie the islands of the Phoenix group, which have no permanent population. The total land area of Kiribati is 313 square miles (811 square km).

The Republic of the Marshall Islands is a country in the central Pacific Ocean. It consists of some of the easternmost islands of Micronesia. The Marshalls are composed of more than 1 200 islands and islets in two parallel chains of coral atolls – the Ratak, or Sunrise, to the east and the Ralik, or Sunset, to the west. The chains lie about 125 miles (200 km) apart and extend some 800 miles northwest to southeast.

The Tokelau island territory of New Zealand consists of three atolls in the South Pacific Ocean. Tokelau lies about 300 miles (480 km) north of Samoa and 2 400 miles (3 900 km) southwest of Hawaii. Tokelau does not have a central capital; each atoll has its own administrative centre.

Tuvalu, formerly the Ellice Islands, is a country in the west-central Pacific Ocean. It is composed of nine small coral islands scattered in a chain lying approximately northwest to southeast over a distance of some 420 miles (676 km).

The challenge

More than a million Pacific Islanders collect their drinking water from polluted streams or wells and lack access to toilets, resorting to finding a safe and private place in the bushes or on the beach. Access to potable water and safe sanitation is a basic human right that is denied to two-thirds of Pacific Islanders, notably in the rural areas of Melanesia, in informal settlements on the fringes of the region's growing urban areas, and on hundreds of small atolls scattered across the Pacific (Pacificwater, 2017). This poses serious health risks, particularly for children, and is a fundamental development constraint for Pacific nations.

Objective

The project aims to meet the Sustainable Development Goal of achieving universal access to safe water and sanitation by 2030 for the inhabitants of all Pacific Islands (UN-DESA, 2018).

Funding and executing agencies

New Zealand funded the project over five years, with technical support from the Pacific Community (SPC) Water and Sanitation Programme and in-kind contributions from development partners and participating Pacific SIDS.

Stakeholders and beneficiaries

The Pacific Community (SPC); governments of five Pacific SIDS: the Cook Islands, Kiribati, Republic of the Marshall Islands, Tokelau and Tuvalu; New Zealand Aid Programme; International Federation of Red Cross (IFRC); UNICEF; National Institute of Water and Atmospheric Research (NIWA) of New Zealand; Australian Bureau of Meteorology; National Oceanic and Atmospheric Administration (NOAA); Secretariat of the Pacific Regional Environment Programme (SPREP); WHO; United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA).

Methods of intervention

The partnership sought to facilitate better knowledge sharing and advocacy among drought-affected Pacific SIDS, relevant development partners, and regional and international organizations. It supported practical information sharing on water security and drought resilience and preparedness activities in drought-affected countries and enabled an effective contribution of drought-affected atoll nations in international and regional forums. It also assisted Pacific governments and communities to build the skills, systems and basic infrastructure needed to anticipate, respond to, and withstand drought and its impacts on safe and adequate drinking water.

Outcomes

The partnership had the following deliverables:

- support for participating drought-affected atoll countries to undertake rapid drinking water security assessments (2014);
- establishment of a network of Pacific atoll country water security professionals (2015);
- country lessons and outcomes captured and shared (2016-2019);
- demonstration of practical measures to enable Pacific communities to better anticipate, prepare for and respond to the impacts of drought (2016 - 2019) (UNDESA, 2018).

Case 6.
Pacific partnership initiative on sustainable water management (PPISWM)

Overview

The Republic of Maldives is an independent island country in the north-central Indian Ocean. It consists of a chain of about 1 200 small coral islands and sandbanks (some 200 of which are inhabited), which are grouped in clusters, or atolls. The islands extend more than 510 miles (820 km) from north to south and 80 miles (130 km) from east to west. The northernmost atoll is about 370 miles (600 km) south-southwest of the Indian mainland, and the central area, including the capital island of Male', is about 400 miles (645 km) southwest of Sri Lanka.

Timor-Leste, also known as East Timor, is an island country in the eastern Lesser Sunda Islands, at the southern extreme of the Malay Archipelago. It occupies the eastern half of the island of Timor, the small nearby islands of Atauro (Kambing) and Jaco, and the enclave of Ambeno, including the town of Pante Makasar, on the northwestern coast of Timor. Dili is the capital and largest city. The country is bordered by Indonesia in the west and the Savu Sea in the north.

The challenge

The participating countries lack efficient and sustainable systems for water resource management (UNDESA, 2002).

Objective

- support the coordinated implementation of the Pacific Regional Action Plan on Sustainable Water Management and its sister strategies, the Pacific Wastewater Policy Statement and the Pacific Wastewater Framework for Action.

Funding and executing agencies

The costs of human resources and advisors are born by ADB, AusAID, DFID, EU, GEF and NZAID. The Pacific Partnership Initiative on Sustainable Water Management was established in 2002 with initial funding provided by ADB to facilitate and coordinate the partnership activities, but due to resourcing difficulties, the work over the last few years has mostly focused on communication.

Stakeholders and beneficiaries

Governments of Pacific Island countries and territories; Intergovernmental organizations; Pacific Islands Forum Secretariat (PIFS); Secretariat of the Pacific Community (SPC); South Pacific Regional Environmental Programme (SPREP); University of the South Pacific; Pacific Water and Wastes Association (PWWA); Australia Water Association (AWA); New Zealand Water and Wastewater Association (NZWWA); Asian Development Bank (ADB), AusAID; Department for International Development (DFID); European Union (EU); Global Environment Facility (GEF); NZAID; New Zealand Ministry of Foreign Affairs; Regional and global partners: NIWA, Bureau of Meteorology (BOM, Australia), WMO, NOAA, United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Global Water Partnership (GWP), Global Programme of Action (GPA), International Waters, United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), International Union for the Conservation of Nature (IUCN), IWC, UNICEF, WHO, UNHABITAT.

Methods of intervention

- establish and organize a network of water associations to promote and exchange information on sustainable water management initiatives

Outcomes

The following deliverables are expected but not yet reported (UNDESA, 2002):

- Pacific Water Action Matrix as logical framework;
- partnership meetings held when resources allow;
- information dissemination and exchange through the pacificwater.org website and newsletters.

Case 7.
Pacific Water, Sanitation and Hygiene (WASH) Coalition; SIDS Action platform - Samoa pathway

Overview

The Pacific Islands, also known as the South Pacific Islands, are the major group of islands located north of New Zealand and east of Australia. The Pacific Islands comprise three ethnogeographic groupings – Melanesia, Micronesia. The arc of islands located north and east of Australia and south of the Equator is called Melanesia; it includes New Guinea, the Bismarck Archipelago, the Solomon Islands, Vanuatu (the New Hebrides), New Caledonia and Fiji. North of the Equator and east of the Philippines are the islands of Micronesia, which form an arc that ranges from Palau, Guam, and the Northern Mariana Islands in the west through the Federated States of Micronesia (the Caroline Islands), Nauru, and the Marshall Islands to Kiribati. The Polynesian area stretches from Hawaii in the north, to Easter Island in the east and New Zealand in the west. The main Polynesian islands are the Cook Islands, French Polynesia, Samoa, Tonga and Tuvalu.

Problem identification

Various Pacific Islands suffer from restricted access to drinking water and sanitation facilities.

Objectives

- increased access to affordable and appropriate sanitation;
- improved community management of water supply, sanitation and hygiene;
- better access to safe and sustainable water supply.

Funding and executing agencies

The costs of human resources and meetings are borne by the donor/stakeholders.

Stakeholders and beneficiaries

SPC/South Pacific Applied Geosciences Commission (SOPAC); World Health Organization (WHO); United Nations Children's Fund (UNICEF); Pacific Island Forum Secretariat; International Federated of Red Cross Societies (IFRC); Fiji Red Cross (FRCS); Foundations of the Peoples of the South Pacific (FSPI); Live & Learn Environmental Education (LLEE); United Nations Development Programme (UNDP); University of the South Pacific (USP); UN-HABITAT; Habitat for Humanity; Wetlands International; International Union for Conservation of Nature (IUCN); Partnerships in Community Development Fiji (PCDF); US Peace Corps; Pacific Rotary Water for Life Foundation; Adventist Development Relief

Agency (ADRA Fiji); Fiji National University (FNU); Tuvalu Association of Non-Government Organizations (TANGO)

Methods of intervention

The Pacific Water, Sanitation and Hygiene Coalition is a group of WASH actors that is implementing projects in the Pacific region, sharing knowledge and lessons learned from their various activities and promoting effective collaboration and partnerships among WASH stakeholders. The priorities of the WASH Coalition are i) sanitation; ii) community engagement, education and awareness; and iii) water supply. Gender, climate change and disaster risks are important cross-cutting issues (Pacificwater, 2015).

Outcomes

The Coalition contributes to the sustainable development of SIDS by implementing WASH projects that help to achieve Goal 7 of the Millennium Development Goals, focusing on increasing access to water and sanitation (UNDESA, 2014b).

The following deliverables were included in the project:

- a platform for sharing lessons and enabling knowledge transfer of WASH between various actors (2007-2014);
- meeting minutes and WASH information disseminated to all Coalition partners (2007-2014);
- regular Pacific WASH Coalition meetings (2007-2014).

Case 8.
Support for the implementation of the Seychelles National Climate Change Strategy

Overview

The Seychelles archipelago lies in the Indian Ocean and comprises more than 115 islands that are formed on pinnacles of ancient volcano islands, with a total area of 450 km². The archipelago includes two main groups of islands: the Mahe-Praslin granitic group, of which Mahe Island covers 158 km², Praslin Island 42 km² and La Digue Island 10 km², and some other island groups, consisting of coral atolls and sandbanks.

The average annual precipitation is 2 330 mm, varying from 2 370 mm on Mahe Island to 1 990 mm on Praslin Island, 1 620 mm on La Digue Island and 1 290 mm on average on the other islands. The heaviest rains occur on Mahe Island, where the central plateau, with an altitude of 900 m above sea level, receives up to 3 500 mm/year, while the south of the island receives less than 1 800 mm/year.

The challenge

The Seychelles archipelago is expected to be hit hard by the impacts of climate change, including floods, rising sea level and coastal erosion and droughts, together with more frequent and intense tropical storms and cyclones. Coral reefs protect the islands, attract tourists from around the world and nurture the archipelago's world-class fisheries and biodiversity. However, these reefs are increasingly threatened by rising sea surface temperatures and changes to the ocean's chemistry. The Seychelles Sustainable Development Strategy (SSDS) 2012-20 sets the implementation priorities in line with Agenda 21. However, it is weakly integrated with other economic and sector programmes and lacks a detailed timetable with intermediate strategic objectives and milestones.

Objective

The project seeks to counter the negative impacts of global warming through practical actions on the ground and within the framework of international processes.

Funding and executing agencies

Funding mechanisms are provided by the International Monetary Fund (IMF).

Stakeholders and beneficiaries

- various levels, from the national to the community level

Methods of intervention

The project uses a public awareness campaign to disseminate knowledge of climate change impact and selects priority projects from the existing stock of climate change proposals.

Outcomes

Activities started in 2016, including the preparation of an integrated shoreline management plan and saltwater intrusion mapping. The project has two major components:

- strengthening the climate change policy framework;
- supporting adaptation to climate change in coastal areas.

The first component seeks to enhance the harmonisation of climate change policies; to mainstream climate change into sector strategies; to strengthen sector governance capacity, including coordination and monitoring; to create a budgetary framework to improve climate finance readiness; to build human resource and institutional capacities; to accelerate the implementation of climate change policy and strategy; and to raise the country's capacity to finance climate projects.

The second component supports coastal climate change adaptation. To respond to the impact of climate change in terms of coastal erosion and flooding in vulnerable areas, the project initiated studies and emergency remedial work in affected areas and approaches such as ecosystem-based adaptation (EbA)[5], in combination with various engineering technologies to address site-specific issues and opportunities for enhancing resilience to coastal flooding (IMF, 2017).

Case 9.
Global Climate Change Alliance Plus (GCCA+) programme for Vanuatu (2010 – 2016)

Overview

Vanuatu is an archipelago consisting of 83 small islands (65 inhabited) ranging over 1 300 km, with a population of 270 000. Most of the islands are steep, with unstable soils, little permanent freshwater and active volcanoes. Less than ten percent of the land is used for agriculture, supporting a population density of only 20 people/km² (The Commonwealth, 2020b). The prevalence of malnutrition is low at 7 percent but has been increasing over the past ten years. Agriculture is still an important sector, supporting about one-quarter of the economy. Other important sources of income are offshore banking and tourism (FAO, 2018).

The challenge

The challenges and costs of providing basic services make Vanuatu extremely vulnerable to the impacts of climate change. A narrow economic base with a large subsistence agriculture sector compounds the country's vulnerability. Sea level rise, frequent extreme weather events and increased variability in rainfall are among the expected effects of climate change. Climate change is likely to impact all sectors, especially agriculture, water, coastal and marine resources and tourism (GCCA+, 2009).

Objectives

- increase Vanuatu's capabilities to cope with the effects of climate change by improving the understanding of the effects of climate change;
- strengthen climate resilience and disaster risk reduction in key sectors and assist the Government of Vanuatu to develop policy on climate change.

5 Ecosystem-based adaptation describes a variety of approaches for adapting to climate change that involve the management of ecosystems and their services, see en.wikipedia.org/wiki/Ecosystem-based_adaptation.

Funding and executive agencies

The project was funded by the European Union.

Stakeholders and beneficiaries

Vanuatu Meteorological and Geohazards Department (VMGD); National Advisory Board on Climate Change and Disaster Risk Reduction; the World Bank.

Methods of intervention

Through providing funding and technical assistance, the programme sought: to foster the integration of climate change vulnerability into development plans and budgets, as well as the capacity to enforce environment-related laws; to assist in strengthening dialogue on climate change with partners; to support participation in international forums; to help finalise the ratification of international agreements; and to prepare budget support for actions on climate change. Specific actions included:

- strengthening resilience to climate and weather-related risks as identified in Vanuatu's National Adaptation Plan of Action;
- promoting traditional and improved farming practices to conserve soil moisture and nutrients, to reduce runoff and control soil erosion. These included rainwater harvesting and agroforestry to control flooding. This activity was strengthened by collecting data on agricultural sector adaptation practices.
- developing early warning and monitoring systems to assist farmers in watershed areas to prepare for and cope with flooding;
- scaling up practices, such as roof water harvesting and storage, to address water security issues in selected at-risk coastal communities;
- undertaking wetland restoration, replanting coastal vegetation and using indigenous afforestation methods. Hazard and risk mapping were conducted to demarcate high-risk areas and help coastal communities to avoid expanding settlements into flood-prone areas (GCCA+, 2009).

Outcomes

Only emergency actions have been completed, including the procurement of agricultural tools to assist affected farmers to regrow their gardens and sawmills to mill trees for the rebuilding of houses. Damage assessments for water, sanitation and hygiene (WASH) were conducted on Tanna. Repairs to the VMGD monitoring network have started with the first phase of urgent repairs completed and the Project Management Unit began preparations for repairs of damaged water assets (GCCA+, 2009).

Case 10.
Adapting water resource management to expected climate change in Comoros (ACCE)

Overview

The Comoros archipelago comprises four volcanic islands (Grand Comore or Njazidja; Mohéli or Mwali; Anjouan or Nzwani; Mayotte) totaling 1 861 km² with 427 km of coastline (FAO, 2003).

Comoros is a low-income developing country (GDP per capita based on PPP in 2019 is 3 195 current international dollars) with a population of 800 000. Agriculture is the dominant sector, contributing 50 percent to GDP. The economic situation has deteriorated over the past couple of years as growth has slowed and the economy remains undiversified, with a heavy dependence on remittances and agricultural exports. Severe shortages in electricity supply put a drag on all sectors of the economy. The fiscal situation is fragile, and the country is highly dependent on foreign aid.

The challenge

The climate of Comoros is strongly affected by large ocean-atmosphere interactions, such as trade winds, El Niño and monsoons. Climate change is likely to bring changes in rainfall levels and patterns, higher temperatures and sea level rise, with a consequent increase in salinisation and the frequency of climatic hazards. These effects, which reduce the availability of water and negatively affect the quality of water through pollutants, salts and sediment, are magnified by human practices, such as high rates of deforestation and inadequate water resources management.

Objective

The overarching goal of the project was "to reduce the risk of climate change on lives and livelihoods from impacts on water resources in Comoros (UNEP, 2017)." The three main objectives were:

- to strengthen institutions at national and community levels to integrate climate change information into water resources management;
- to improve water supply and quality in five selected pilot communities to combat the impact of climate change;
- to increase the awareness and knowledge of good practices in policy review and development.

Funding and executing agencies

The project was funded by GEF, UNDP and the Flemish Government and jointly implemented by UNDP and UNEP.

Stakeholders and beneficiaries

The General Directorate of Water and Forests (DGEF); the General Directorate of Energy and Water (DGEME); and the National Civil Aviation and Meteorological Agency (ANACM). The Water and Electricity Company (Ma-Mwqe) at Grande Comore; the Union of Water Committees at Anjouan (UCEA) and Mohéli (UCEM); and the Island Directorates for the Environment at Anjouan and Mohéli. Village water committees and inter-village water committees and municipalities. Important stakeholders included several similar projects, executed by UNDP, AfDB, EU and IFAD.

Methods of intervention

- The National Civil Aviation and Meteorology Agency (ANACM) installed five small automatic meteorological stations in 2012. The data generated by these stations were intended to serve as an input for hydrological modelling but were deemed insufficient. Improving the policy framework and developing a capacity strengthening plan for hydrological modelling was only partially achieved.
- The project conducted a number of activities under the second output of putting into place five pilot water supply schemes: improving parts of the water network; rehabilitating boreholes, water intakes and transmission mains; and installing new public stand-posts and slow filters. This was accompanied by a training programme on community management of water supply and the maintenance and repair of rural water supply networks by water committees, and sustainable and resilient agricultural land management and the installation and maintenance of drip irrigation kits given to farmers. After training in agro-sylvo pastoral systems, participatory reforestation was carried out within communities. The survival rate of trees on communal lands where is known to be extremely low, so a measurable increase in vegetative cover is unlikely.
- An inception workshop, community workshops and publicity materials were used to raise awareness about the project. Wider dissemination of the Comorian experience and lessons learned was pl*anned but has not been achieved (UNEP, 2017).*

Outcomes

- The goal of capacity strengthening was partially achieved. ANACM made clear progress in collecting data, modelling and analysis, and there is more widespread awareness about the need to improve the management and integration of data related to climate in general and climate change in particular. At a higher institutional, political level, there has been progress regarding the policy framework, which may be supportive of the drafting of a new water act, but there is still a long way to go.
- An assessment of efforts to improve water supply and quality in five pilot communities found that:

    - The quantity of water has increased, but due to the old distribution network, this is not fully evident to users.
    - Water quality has probably improved at sites where slow filters have been installed, but water quality measurements have not been carried out.
    - Access has only improved in sites of increased water pressure by returning water to the sectors connected.
- Awareness and adoption of good practices for the continued process of policy review and development have increased. As no measurement has been made, the impact is difficult to assess, nevertheless, there is a clear growing awareness of the impact of climate change. Specific technical documents on the lessons learned for knowledge networks have not been covered by policy makers.
- The community water supply projects have serious sustainability challenges since the water supply schemes in the pilot projects are too large to be managed informally by community water committees. To continue, operations and management must be formalised and funded, for example by setting up a system of tariff collection that covers maintenance costs. The reforestation activities on communal lands are not sustainable either. Such activity should start with an analysis of the factors that have led to the deforestation of the land in the first place and these factors should be addressed as part of the project. If they are not, the reforestation is unlikely to be successful (UNEP, 2017).

Case 11. Agricultural intensification and water control in the Maldives

Overview

The Maldives comprise a string of 1 190 islands and 16 atolls, 198 of which are inhabited, stretching over a distance of around 1 000 km. The Maldives have a tropical climate, with monsoons and uniform rainfall during the year with a dry period from January to March. The nation has a total population of 312 000, 16 percent (23 000) of whom are active in agriculture, which contributes 5 percent to the total GDP of USD 1 473 million. Agriculture rarely uses irrigation practices. Primary crops include maize, sweet potatoes, millet, cassava and tropical foods and vegetables.

The challenge

The Maldives relies heavily on groundwater reserves that underlie the atolls. The reserves are vulnerable to damage from environmental threats and pollution. This prompted the development of water management strategies based on desalination projects and modern water control methods. However, with the 2004 tsunami and intensified pollution, these attempts have remained in their initial stages. The poor availability of water has affected agricultural productivity and created substantial food

insecurity. Food and water insecurity is felt most deeply in rural communities, where access to agricultural services and effective water management strategies is particularly limited.

Objective

The Special Programme for Food Security, Phase I (SPFS) had the objective of raising productivity in the Maldives, while protecting the environment and ensuring equity and inclusion through crop improvement, water control and constraint analysis (FAO, 2000).

Funding and executing agencies

FAO funded the project with a revolving fund. The executing agencies are FAO and the Ministry of Fisheries, Agriculture and Marine Resources (MOFAMR). Given their history, MOFAMR delegated project activities to two agricultural centres, located in the southern Laamu atoll and the northern Haa Dhaalu atoll.

Stakeholders and beneficiaries

The main beneficiaries were rural communities at ten sites (20 communities in total), which received technical support to implement the SPFS.

Methods of intervention

The project used participatory rural appraisal to select participants through farmers' organizations (mainly women's groups) that can introduce new technologies into their communities to monitor: i) crop improvement; ii) efficient water supply; and ii) constraints to agricultural productivity and environmental harmony.

The project developed new strategies for the sustainable exploitation of groundwater reserves to improve crop production by experienced staff resources on the two selected centres and invited farmers with an interest in these strategies from the surrounding islands.

Outcomes

The project demonstrated the benefits of improved agricultural practices and innovative irrigation methods, based on an analysis of the factors hindering production. An evaluation of the project found that SPFS provided the tools needed to tackle food insecurity and economic degradation by empowering island groups to adapt production systems to improve their livelihoods. The project's capacity building component was the basis for this success (FAO, 2000).

Case 12.
Assistance in developing a national agricultural water resources information system in St. Lucia

Overview

The Caribbean island of St. Lucia is the second largest of the Windward islands, with a total area of 620 km² and a population of 182 000. Characterised by volcanic soils, diverse landscapes and a tropical maritime climate, only 28 percent of the total land area of St. Lucia is suitable for agriculture, 70 percent of which sustains permanent crops. The island receives ample rainfall, however, water consumption is increasing rapidly and water management strategies have yet to be implemented. Agriculture accounted for only 4 percent of the total GDP of USD 1 332 million in 2012. Tourism gradually increased its contribution from 9 percent to 13 percent of GDP from 1990 - 2006. St. Lucia requires effective water data collection and management techniques to enable it to use water reserves in a sustainable way (FAO, 2019).

Problem identification

According to the Water and Sewerage Act of 1999, the National Water and Sewerage Commission (NWSC) is responsible for the development and use of water resources and the promotion of a national policy for water. The Water Resources Management Unit (WRMU) was established in 2001. The WRMU is financed by the European Development Fund (EDF) and the Government of Saint Lucia.

The WRMU currently collects streamflow and water-level data. It needs to be expanded into an information service that provides stakeholders with water quality, availability, demand and supply data in an appropriate format. Training WRMU staff in data quality assurance, development of protocols, water availability and use assessment, and data analysis will be critical. Hydrometric monitoring has been a challenge due to the instability of monitoring sites. There is therefore a need to train technicians in the siting and operation of the equipment; this is not supported by EDF funding.

Objectives

The purpose of the project was to assist in developing a national agricultural water resources information system to combat the overexploitation of water resources in St. Lucia. The project recognised that a large number of institutions are involved in water management, many of which used incompatible data formats. The project thus sought to provide a standardised data collection system to effectively manage the water resources in St. Lucia under the Water Resources Agency (WRA) (FAO, 2004).

Funding and executing agencies

FAO was the primary funder of this project, with an estimated budget of USD 148 000. FAO funds were supplemented by government contributions.

Stakeholders and beneficiaries

FAO, the Ministry of Agriculture, Forestry and Fisheries (MAFF), the WRMU and the Government of St. Lucia were project stakeholders. The beneficiaries included the MAFF, WRMU, and the government as well as the St. Lucian population.

Methods of intervention

The project took steps to build the capacity of the WRMU to improve its monitoring functions and increase the accuracy of data collection. Mandated training programmes were carried out how to integrate this information into a harmonised national framework, and how to use data to formulate accurate responses to region-specific water management crises.

Outcomes

The project led to the creation of an information system designed to accurately monitor data on water quality, availability, demand, and supply. All information is available to stakeholders in St. Lucia. The results emphasised the benefits of investing in water management techniques in SIDS (FAO, 2004).

Case 13.
Savurua Rural Water Utilisation Project in Fiji

Overview

Fiji is an archipelago of 330 islands, 110 of which are inhabited. The two major islands, Viti Levu and Vanua Levu, collectively make up 85 percent of Fiji's total area (18 270 km^2). Volcanic in origin, these mountainous islands have a varied landscape, with farmland occupying most of the flattish lowlands. A tropical marine climate results in uneven rainfall distribution over the islands. The larger, mountainous islands can hold permanent surface water resources while smaller islands rely on groundwater. The geography and related water capacity have complicated Fiji's transition from subsistence to commercial agriculture. Rural areas are prone to water insecurity, which physically, economically, and environmentally disadvantages these regions (FAO, 2016). With a population of 900 000 and a GDP of USD 4 030 million, the country's agricultural sector accounted for only 12 percent of GDP in 2015, compared to 21 percent in 1994.

Problem identification

The Savurua Rural Water Utilisation Project targeted one of the poorest regions in Fiji. Rural communities in Savurua collect their water entirely from river sources that are shared with the local fauna. Untreated wastewater results in a high incidence of waterborne diseases. Rural communities suffer from water insecurity due to limited sources

of surface water, compounded by aggressive climate pressure (e.g. drought and flooding). Deprived of access to clean water, the poor health of Fiji's inhabitants results in low productivity and income (FAO, 2006).

Objective

The goal of the project was to build healthier communities in Savurua by making clean water available for consumption and to enhance food security.

Funding and executing agencies

FAO was the funding and executing agency.

Stakeholders and beneficiaries

The stakeholders were FAO, public works departments (PWD) and members of the villages and settlements in the Savurua region. The beneficiaries of this project were the residents of communities in the Savurua region. Women, in particular, received most of the project benefits, considering that domestic water use is traditionally tasked to them.

Methods of intervention

The project made water available to the settlements of Veninuqa, Kavika, Vituri, Lomaivuna and the village of Savurua for household purposes, the irrigation of small vegetable and root crop gardens, and small-scale livestock production. (FAO, 2006). The Irrigation system used sprinkler type overhead systems that could be accessed by a number of users through lateral pipes.

This project used three approaches to achieving its goal:

- a small dam was established at Savurua to secure water delivery to the settlements;
- simple irrigation systems were set up in strategic areas to sustain small-scale livestock and vegetable cultivation;
- a small seed purchase component introduced variety to cropping patterns as well as diversifying marketable output to stimulate economic and social growth.

Outcomes

The project provided clean water resources for simple irrigation systems and domestic uses in the target communities. The interventions reduced the risk of waterborne disease, as well as improving domestic crop and livestock production.

Case 14. Strengthening human resilience in northern Clarendon, Jamaica

Overview

Jamaica is the largest island in the English-speaking Caribbean with a total area of 10 990 km². Its landscape features the eastern mountains, the central plateaus and valleys, and coastal plains. With a tropical maritime climate, the island experiences tropical storms and hurricanes that affect a large number of its 2.7 million inhabitants. In 2013, the agricultural sector accounted for 7 percent of the total GPD of USD 14 362 million.

The challenge

Jamaica suffers from food insecurity and malnutrition and economic instability due to the loss of agricultural productivity and the degradation of natural resources. Climate change, together with natural disasters, is likely to exacerbate the situation further. Ensuring access to water has been identified as fundamental to addressing these burdens (FAO, 2017). Water management techniques are required to foster the sustainable exploitation of Jamaica's agricultural area (FAO, 2015b).

Objectives

The project aimed to develop an integrated water management approach that could increase agricultural productivity, while improving resilience to climate change and addressing water-related health and sanitation issues.

Funding and executing agencies

FAO, together with the United Nations Country Team (UNCT) and the Rural Agricultural Development Authority (RADA), had primary responsibility for the funding and implementation of the project.

Stakeholders and beneficiaries

The principal project beneficiaries were approximately 100 farmers in northern Calderon, where farming is challenged by poor access to sustainable water.

Methods of intervention

The project integrated agricultural development strategies with on-farm water management techniques to combat the limited availability of water. It sought to increase the productivity of agriculture, to increase resilience to disaster and climate change and to stabilise economic and social pressures by ensuring better yields and including young people and women in the project activities (FAO, 2017).

Outcomes

The project improved the capacity of farmers in Clarendon to cope with short water supply, while ensuring the maximum productivity of their crops. The approach has promise for establishing effective water management techniques in Caribbean SIDS.

Case 15.
The South Tarawa Water Supply Project, Kiribati

Overview

The Republic of Kiribati is a sovereign state in Micronesia in the central Pacific Ocean, with a population of more than 110 000. Kiribati comprises 32 atolls and reef islands and one raised coral island covering a total land area of 811 km² dispersed over 3.5 million km² (GOK, 2015).
Tarawa atoll is the capital of the Republic of Kiribati. The atoll comprises numerous low-lying islands and islets connected by causeways. South Tarawa is the main urban centre with a population of approximately 56 300 (KNSO, 2016). Water is supplied to South Tarawa by the Public Utilities Board (PUB) or obtained from private and community wells, through rainwater harvesting, with a residual amount provided by bottled water. Sixty-seven percent of South Tarawa households have access to PUB water, which supplies treated water from the Bonriki and Buota groundwater lenses (KNSO, 2016).

The challenge

South Tarawa has fragile water resources due to its small size, lack of natural capacity for water storage and competition for land use, combined with climate variability and overcrowding. Waterborne diseases, such as diarrhea and dysentery, are widespread. Up to 75 percent of the domestic wastewater produced by households is released in urban settings in the form of greywater[6] (Eriksson *et al.*, 2002). The way greywater is managed poses a growing challenge to the quality of the environment and groundwater. Households discharge greywater without treatment directly into their plots, where it infiltrates quickly due to the high absorption capacity of the sandy soil. People sometimes dig holes to bury smelly liquid substances or bring them to the beach for discharge into the sea. These practices have the potential of becoming aggravating nuisances once supply volumes significantly increase.

The contamination of coastal aquifers can be expected to increase due to the pollutants triggered by increased consumption, leading to an increase in bacteria, detergents, and nutrients (White, 2010). Discharge into the ocean through deep submarine outfalls (as is currently being done, together with the rest of household sewage in Betio, Bairiki, and Bikenibeu) would avoid these problems.

6 Greywater is defined as the wastewater derived from showers, bathtubs, sinks, kitchens, dishwashers, laundry tubs and washing machines, and excludes toilet water (commonly known as blackwater).

Objectives

The project objectives are:

- to increase access to a safe, reliable and climate-resilient water supply;
- to improve the performance of the water supply services provider in South Tarawa;
- to investigate the feasibility of greywater reuse in South Tarawa;
- to assess the benefits and potential threats to the underlying groundwater systems (Jazayeri et al., 2019).

Funding and executing agencies

The project is funded by the World Bank, the Asian Development Bank, the Green Climate Fund and the Government of Kiribati. The project, which is expected to be completed in 2027, will be managed and implemented through Kiribati's Ministry of Infrastructure and Sustainable Energy.

Stakeholders and beneficiaries

The main beneficiary is the community of South Tarawa; other stakeholders are government institutions, the private sector and research institutions involved in project implementation.

Methods of intervention

The South Tarawa Water Supply Project aims to expand and modernise South Tarawa's water supply network to enable the delivery of piped water to homes. It will also support the construction of seawater desalination systems that meet water demands and increase drought resilience up to the year 2040 (Jazayeri *et al.*, 2019).

This project includes:

- The construction of a solar-powered desalination plant that, when combined with the Bonriki and Buota groundwater reserves, should provide 50 litres per person/day to the people of South Tarawa by 2025, and 100 litres per person/day by 2030. The current freshwater lenses of Bonriki and Buota provide approximately 22 litres per person/day to the population of South Tarawa. The project also includes the expansion and refurbishment of the water supply network to reach all residents of South Tarawa. Infrastructure improvements are anticipated to support an uninterrupted supply of drinkable water.
- The construction of a new solar power plant, along with energy storage and transmission infrastructure to help offset the electricity requirements of the new water system. The project will also support improvements to the operations and capacity of the Kiribati Public Utilities Board.
- A five-year 'WASH Awareness Programme', together with the construction of sanitation systems throughout South Tarawa as well as the provision of training to

community organizations that manage sanitation facilities. This sanitation work is a pilot that is designed to be scaled up in the future.

Outcomes

The South Tarawa Water Supply Project will help provide people with better access to a safe, reliable and climate-resilient water supply. The sophistication of urban water management in South Tarawa, shaped by long exposure to water scarcity, illustrates the value that small island countries can bring to global discussions on urban water resilience. The convergence of droughts, anthropic pressure on water resources, and systemic infrastructure failures represents a clear societal threat, even more immediate than the potential effects of sea-level rise. An important finding of this study is that, following the planned modernisation of PUB's water system, the security of water supply can be significantly boosted by local, low-tech, low-cost measures that make the most of existing resources.

Case 16.
Pollution reduction through improved municipal wastewater management in coastal cities in ACP countries with a focus on SIDS

Overview

Eighty-six percent of untreated wastewater reaches coastal waters in the Caribbean, 80 percent in West and Central Africa, and 50 percent in East Africa. Poor water quality has caused the degradation of important fishing and tourism resources.

The challenge

The discharge of untreated municipal wastewater into rivers, lagoons and estuaries or directly into the ocean is a very serious threat to the marine environment, the health of coastal populations and sustainable coastal development worldwide.

Objectives

The objectives of the project are to:

- increase the capacity of municipalities in ACP countries to identify environmentally friendly, technologically feasible, and financially sustainable projects that collect, treat or and reuse municipal wastewater;
- develop the institutional capacity for effective multi-year financial planning. The capacity building also should strengthen mobilisation through 'user pays' and 'polluter pays' principles and the involvement of the private sector;
- promote the involvement of stakeholders in all stages of the planning process;

- improve the knowledge base and information exchange between practitioners (north-south and south-south knowledge sharing).

Funding and executing agencies

The project is funded by the Global Environmental Facility (GEF). The executing agency is the UNEP Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP GPA).

Stakeholders and beneficiaries

The project was implemented by UNEP-GPA in close coordination with regional and national focal points in the beneficiary countries and UNESCO-IHE to ensure high quality training. The regional focal points identified national partners that were responsible for organizing training and selecting participants. Potential instructors participated in training courses and received instructor training.

Countries

The Pacific: Fiji and Papua New Guinea
The Caribbean: the Bahamas, Barbados, Belize, Dominican Republic, Guyana, Jamaica, Suriname and Trinidad and Tobago
Africa: Angola, Benin, Cameroon, Congo, Rep. of Comoros, Eritrea, Ghana, Guinea, Kenya, Madagascar, Mauritius, Mozambique Namibia, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Tanzania and Togo

Methods of intervention

The UNEP-GPA has developed training materials for municipal wastewater managers, together with UNESCO-IHE Institute for Water Education and in the framework of the UNDP-GEF-supported UN/DOALOS Train-Sea-Coast (TSC) Programme.[7]

Integrating stakeholder involvement in all aspects of urban planning is an innovative approach. Stakeholders are informed through public meetings in early planning stages and experience public sensitisation campaigns around wastewater and waste management, as shown by monitoring wastewater discharge from hotels in Kumasi and the management of contaminated lands in Accra.

The programme has promoted global cooperation in training development and implementation through the creation of training networks.

With UNESCO-IHE as a partner, UNEP-GPA has developed a training programme on municipal wastewater management, which has successfully been implemented in

7 The chief objective of the train-sea-coast programme of the UN Division for Ocean Affairs and the Law of the Sea (DOALOS) is to enhance national/regional capacity-building through training on key transboundary topics in the area of coastal and ocean matters.

thirteen cities, training three hundred participants from twenty-two countries in four languages.

Outcomes

The outcomes of the project include:

- greater awareness of over 1 200 municipal wastewater management officials in 29 countries of the overall benefits of proper treatment of municipal wastewater;
- increased capacity to use objective-oriented planning for municipal wastewater infrastructure planning;
- increased capacity to develop and implement multi-year finance plans for municipal wastewater infrastructure investments that require operation and maintenance;
- improved coordination between technical project planning teams and finance committees;
- more systematic involvement of stakeholders in the planning process (IW-GEF, 2010).

Municipalities and national government agencies participated through the nomination of participants for the course. Public awareness involved the dissemination of posters and flyers to relevant partner organizations, the development of a website with a document library, links to planning tools, etc.

The project was designed to deliver training using a bottom-up approach at the municipal level. An analysis of training reports, however, shows that less than 50 percent of training participants were municipal.

Case 17.
Energy and water reform and development in Cabo Verde

Overview

Cabo Verde, an island state off the coast of Senegal, is a lower-middle-income country with a population of 560 000 inhabitants and annual population growth of 1.3 percent. The ten volcanic islands in its archipelago have a combined land area of about 4 033 square kilometres. The economy focuses on commerce, trade, transport and public services. The agricultural sector remains small due to lack of rain, representing six percent of the economy.

The project was developed in the late 1990s, at a time when Cabo Verde was entirely dependent on imported fossil fuels to generate power for, among other things, the desali-

nation of salty waters. Water scarcity is prevalent, with an average yearly rainfall of 227 mm and a low discharge (20 percent) of aquifers. The basic infrastructure for electricity, water and sewerage was old, beginning to deteriorate and covered only central parts of the major cities.

The challenge

Until the end of the 1990s, Cabo Verde had no public service law and the institutional framework for the power and water sector was weak. Electra, the national power and water utility, generated and distributed power and desalinated water on four islands. It operated at a deficit, lacking the financial and technical resources to conduct proper maintenance. The Government of Cabo Verde financed the operating deficit and subsidised customers by keeping tariffs low. Municipal utilities were the only source of power and groundwater on the other five inhabited islands. Access to utilities was low (World Bank, 2009).

Objectives

- improve the supply of power, water and sanitation systems;
- increase operational and end-use efficiency in the power and water sectors, in particular, the expansion and rehabilitation of power, water and sanitation systems in major urban centres;
- lower the barriers to the development of renewable energy resources, in particular, the development of wind power capacity and solar systems for decentralised use;
- foster sound management of water resources, enhancing regulatory and legal frameworks.

In the late 1990s, there was much enthusiasm for private participation in developing country infrastructure. This was reflected in the project design and the privatisation of Electra was a prominent objective of the project. The government was highly supportive of this objective (World Bank, 2009).

Funding and executing agencies

The project was financed by the International Development Association, with contributions from the Government of Cabo Verde, European Union, GEF and the OPEC Fund. The World Bank's Electricity and Water Unit executed the project.

Stakeholders and beneficiaries

The project targeted people and enterprises in major and secondary urban centres, including areas suffering from unsatisfactory power and water services and those in periphery urban areas. The project also targeted isolated households that were likely

to be excluded from a modern supply of electricity in the medium term (about 12 000 households).

Methods of intervention

- reform and development of the power sector, which includes support for the privatisation of Electra and the implementation of sound regulatory and legal frameworks;
- renewable energy promotion and development, which includes the extension of grid-connected wind farms and the development of photovoltaic (PV) public and individual systems;
- reform and development of the water sector, which includes support for the implementation of sound regulatory and legal frameworks, the creation of autonomous municipal water companies, the extension and rehabilitation of the primary and secondary water production and distribution systems in four major cities, and related studies, technical assistance and training;
- sanitation development, which includes the extension of sanitation systems in Praia and Assomada, the construction of wastewater reuse systems for Praia, and related studies, technical assistance and training.

Outcomes

While private sector participation in the water and electricity sectors increased in the initial years of the project, due to the failure of tariff regulations and ineffective management and supervision by its Board, Electra reverted to the state in 2008, without much if any benefit to show from the privatisation in terms of commercial performance or quality of service.

The renewable energy component of the project aimed to increase grid-connected wind farms and off-grid electrification services using photovoltaic and wind systems. This proved to be unsuccessful due to lack of financing and weak appraisal of market conditions for the PV systems and was largely superseded by on-grid electrification.

The project did increase connections to power, water and sanitation, albeit fewer than planned and insufficient to satisfy demand. No new renewable energy resources have been built, despite the availability of grant funding and extensive technical assistance. Cabo Verde had no experience or models for utility regulations that it could use to establish the legal and regulatory frameworks for the sector.

The GEF objective of removing barriers to renewable energy was not achieved, due to a mix of design, management and supervision failures.

Household access to water increased over the project period (2000-2008) from 22 percent to 45 percent in Praia (the capital) and from 51 to 61 percent in Mindelo (the second

city). Household access to sanitation increased in Praia from 9 to 18 percent. Water utilities were strengthened in 13 secondary centres and access to water improved in municipalities, but water consumption per capita in the two main cities dropped significantly since the supply of clean water could not keep up with increased connections. Additionally, none of the wastewater in Praia was recovered for irrigation or other purposes.

Overall, the project underestimated the difficulties and risks associated with privatisation; it was too complex and had an unrealistic timeframe for implementing legal and regulatory reforms. The utilities reacted to financial distress by cutting maintenance and reducing investments and their operational performance tended to deteriorate as a result. There was a lack of a robust and realistic tariff adjustment mechanism, which is essential for power and water sectors to ensure the affordability of water and electricity for the poorest consumers (World Bank, 2009).

Case 18.
Atlantic and Indian Ocean SIDS integrated water resources management

Overview

The Atlantic and Indian Ocean SIDS (Cabo Verde, Sao Tome and Principe, Comoros, the Maldives, Mauritius and the Seychelles) have small populations (ranging from 100 000 in the Seychelles to 1.3 million in Mauritius). They are moderately-densely populated (between 100-200 people/km^2), with the exceptions of Mauritius (660 people/km^2) and the Maldives (1 300 people/km^2). Their economic indicators vary from lower-income (Comoros, USD 1 600 per capita), lower-middle-income (Sao Tome and Principe and Cape Verde, USD 3 200 and USD 6 900, respectively), to higher-income, to rich (the Maldives and Mauritius, USD 20 000 per capita and the Seychelles, USD 30 000 per capita).

Comoros, a low-income country, realizes 50 percent of its GDP from agriculture with Sao Tome and Principe and Cape Verde at 12-15 percent. In the other islands, only 3 percent of the economy is related to agriculture; service sectors, such as tourism and offshore banking activities, play a more prominent part in the economy.

Total renewable water resources are low in the Maldives (69 m^3 per person/yr), moderate in Cape Verde (550 m^3 per person/yr), sufficient in Comoros (1 474 m^3 per person/yr) and high in Mauritius (2 175 m^3 per person/yr) and Sao Tome and Principe (10 671 m^3 per person/yr). There is no available data for Seychelles in FAO-AQUASTAT.

The challenge

Despite a wide variety of economic sectors and income, the Atlantic and Indian Ocean islands suffer from a shortage of fresh water and poor sanitation facilities. Water use is inefficient, due to a lack of knowledge and expertise. There is little or no capacity to manage aquatic resources and ecosystems and an urgent need for expertise to organize water projects in an integrated way. There is a general lack of funding to facilitate necessary interventions.

Objectives

The overall objective of the Integrated Water Resources Management (IWRM) project was to strengthen the commitment of participating countries to implementing an integrated approach to the management of freshwater resources, with a long-term goal of enhancing their capacity to plan and manage their aquatic resources and ecosystems on a sustainable basis (UNDESA, 2017).

Funding and executing agencies

The Global Environment Facility funded a project to support six SIDS, two located in the Atlantic Ocean (Cape Verde and Sao Tome and Principe) and 4 in the Indian Ocean (Comoros, the Maldives, Mauritius and the Seychelles). UNDP and UNEP were the executing agencies.

Stakeholders and beneficiaries

Project partners included government institutions in participating SIDS: the Ministry of Agriculture and Environment of Cabo Verde; the National Agency for Water and Sanitation for Cabo Verde; the Municipality of Tarrafal in Cabo Verde; the Association of Farmers and Breeder of Chao Bom Colonato in Cabo Verde; the Ministry of Environment, Energy and Water of Maldives; the Ministry of Production of Environment, Energy, Industry and Crafts of the Union of Comoros; the Ministry of Energy and Public Utilities of Mauritius; the Water Resources Unit of Mauritius; the Ministry of Natural Resources, Energy and Environment of Sao Tome and Principe; the Ministry of Environment and Energy of Seychelles (UNDESA, 2017). Beneficiaries included government representatives, local communities, women and farmers.

Methods of intervention

The approach used participatory monitoring and evaluation (PM&E) and lessons were shared with IWRM bodies and other government stakeholders as a model for other projects, programmes, and sectors, such as national sustainable development strategies, national environment action plans, national action plans for adaptation, and national action plans for disaster risk reduction. Further information provided through the PM&E approach on national baseline indicators and monitoring systems was main-

streamed into existing methods of reporting and monitoring. The approach involved various levels, starting from demonstration projects for learning and identification of new indicators, to improving existing indicators and building new, regional ones (Pacific-IWRM, 2017).

Outcomes

The project enabled lessons learned from IWRM and water use efficiency initiatives to inform the further development of existing local, national and regional approaches to water management. The adoption of an IWRM indicator framework led to improved institutional and community capacity at all levels, including the identification of appropriate financing mechanisms and political and legal commitments to support policies and plans to accelerate Pacific Regional Action Plan actions (Pacific-IWRM, 2017).

All six countries produced draft IWRM plans with supporting communication strategies. Two regional training-of-trainer programmes were organized and followed by 14 national workshops on topics related to IWRM. Finally, several exchange programmes between islands were held on topics such as gender mainstreaming in the water sector, policy reforms and financial mechanisms to support investment in water management.

In terms of concrete outcomes, Thoddoo Island (in the Maldives) now has access to clean and safe drinking water during the dry season, improving water resources from pollution by farming activities (UNDESA, 2017). An additional 500 households are now connected to the sewerage systems in the town of Tarrafal, Cabo Verde. Fifty farmers have been trained on the reuse of treated wastewater in agriculture.

In Comoros, the 30 000 people living in Mutsamudu have a cleaner environment, due to a new waste management system. In Mauritius, people in Grand Baie will eventually benefit from better water quality due to the monitoring system that was put in place to inform decision-making. Additional household connections to the sewerage system will help increase wastewater reuse for irrigation.

Significant reforestation activities have taken place in Sao Tome and Principe and Comoros.

In addition, increased awareness, and new policies and plans developed in the six project countries address inefficiencies in water governance and should lead to an efficient and integrated water resources regime that supports the sustainable development of participating SIDS. The indicator framework supports informed decision-making and monitors progress in achieving the SDGs. Local communities, through awareness-raising campaigns and river basin committees, have been empowered to care for their water resources and benefit from relatively healthier ecosystems. By organizing twinning exchange programmes and regional capacity building events, partner institutions are learning from each other.

Case 19.
Spring Hall Land Lease Programme, Barbados

Overview

Barbados is a single island nation, one of the Lesser Antilles in the West Indies. The country has a total land area of 430 km² and is 34 km long from north to south and 23 km from east to west. The country is divided into 11 parishes with the city of Bridgetown as its capital. In 2012, the cultivated area was estimated at 12 000 ha, of which 92 percent consisted of temporary crops and 8 percent of permanent crops. Permanent meadows and pasture cover 2 000 ha (FAO, 2015a).

Barbados has a tropical monsoon climate but lies outside the principal hurricane strike zone. This makes it especially suitable for sugar cultivation, which was the main source of income in colonial times. Now, the country has a diversified economy, with light manufacturing and strong service sectors in tourism and offshore finance. Barbados has become a high-income country, even though the level of public debt (>100 percent of GDP) is considered unsustainable.

The island is densely populated (over 600 people per km2), which places environmental pressure on groundwater resources, flora and fauna and the surrounding coral reefs. With its small size, dense population, and the remnants of sugar monoculture, the distinction between rural and urban areas is far from distinct, requiring continual land restructuring to maintain a viable agricultural sector.

The challenge

A comprehensive rural development strategy became a top policy priority in Barbados in the final decades of the last century. At the time, the sugar markets was in decline and food demand for a growing and richer population was increasing (Nurse, 1992).

Objective

Based in northern Barbados, the project was designed as a component of a rural development strategy to provide land, employment, and technical and marketing support to landless farmers.

Main beneficiaries

Landless farmers, who are offered long-term land lease contracts and assistance on 220 ha of crop and rangeland.

Funding and executing agencies

The Caribbean Development Bank and the Government of Barbados provided USD 2.3 million over the project period, 1980-88. At later stages, the national implementation was financed by the Government of Barbados.

Methods of intervention

Farms were allocated on long-term lease contracts. Farmers were trained in technical and marketing skills; they received assistance in procuring farm inputs and obtaining credit, and had access to a common pool of equipment and irrigation systems. The livestock sector was strengthened through the establishment of two dairy farms.

Impact and evaluation

The project had a difficult start since the suitable conditions for setting up viable farms involved significant trial and error. Initially, the plots were too large and tenants found it difficult to accept crops other than sugar. In addition, the design of the tenants' houses was inappropriate and it turned out to be difficult to recruit qualified tenants and to install appropriate and adequate irrigation technology. The land leases were often not paid. Project costs were overrun by about 100 percent. As was typical forty years ago, women were not targeted and hence not involved in the project (Nurse, 2011).

A strong point of project design was that the lease term was 30 years with the possibility of renewal. After the project period, the Barbados Agricultural Development and Marketing Corporation took over the monitoring and guidance of the settlements and improvements were made. Uncultivated areas were distributed among new participants, decreasing the average plot size to 5 – 15 acres per participant. Gradually, a more varied crop composition emerged, including sweet potato, tomato and peppers, cucumber and melons, onions and 'squash.' Large scale drip irrigation schemes were introduced and connected to the two operational pumps in the region.

Cases 20 - 23.
Water safety plan, Cook Islands

Overview

The Cook Islands comprise 13 inhabited and two uninhabited islands in the South Pacific that lie between Tonga and Samoa to the west and French Polynesia to the east. The northern Cook Islands consist of seven limestone atolls and the southern group consists of nine islands of volcanic origin. The total landmass is 237 km² spread over 1 830 000 km of ocean. The largest island and the capital is Rarotonga, which is home to the Central Administration of the Cook Islands Government and hosts around 191 500 inhabitants, more than half of the total population (WHO *et al.*, 2009).

The challenge

With the growth of the tourism industry, there are many private and commercial users of water that do not pay for the services, due to a lack of enforcement mechanisms. The country's water supplier, the Ministry of Works, is constrained in providing an efficient service due to the lack of funds. The government is unable to allocate the necessary budget to this area with the result that there have been only slow improvements. There is ample surface and groundwater in Rarotonga but no appropriate strategies for protection and sustainable use. During heavy rains, water quality deteriorates and the spread of water-borne diseases is common.

The following key water resource management issues demand an IWRM approach (Davie *et al.*, 2007):

- The country lacks legal and policy frameworks for water resource management.
- Capacity building is needed in the area of integrated management, where the available staff is overwhelmed by water projects.
- There is poor wastewater treatment in septic tank systems resulting in the transfer of nutrients into groundwater and the lagoon system.
- Leakage and waste of reticulated water is a major issue for Rarotonga, which lacks funding for the appropriate infrastructure.
- The water supply is highly vulnerable to climate volatility, especially drought.
- Land use practices affect water quality. This is particularly a problem with the piggeries adjacent to the streams as well as wetland taro cultivation.
- The land use tenure system does not encourage agricultural investment in water-smart irrigation systems and other water-saving technologies.

Objectives

The primary objective of the project was to develop a Water Safety Plan (WSP)[8] to minimise the contamination of water sources and prevent or eliminate contamination during water treatment, storage and distribution. These objectives were equally applicable to large, reticulated water supplies, smaller community-managed systems and individual household systems.

Funding and executing agencies

The WSP Programme was funded by AusAID in August 2006. The following agencies had a key role in the development of the WSP programme in the Cook Islands.

- Ministry of Water Works
- Ministry of Health
- National Environment Service

8 The WSP promoted by the WHO provides tools for proactive measures to ensure the safety of drinking water. It uses risk assessments and risk-mitigating strategies to avoid the contamination of water.

- NGOs, the Tonga Trust
- Commercial water producers
- Meteorological Department
- Local government (Vaka Council)

Stakeholders and beneficiaries

A WHO/SOPAC (South Pacific Applied Geosciences Commission) scoping mission was proposed to secure the commitment of key government counterparts. The Ministry of Works applied to WHO/SOPAC for support under the Pacific WSP Programme. There was strong interest from the Ministry of Water Works, Ministry of Health, National Environment Services and NGOs to work together to establish Water Safety Plans pilots in Rarotonga.

The main beneficiaries were local communities in the Cook Islands.

Methods of intervention

The following summarises four interventions in different catchments.

Case 20.
Avana intake

Overview

- The catchment area is about 243 hectares. The area is covered with dense forest and there are few human activities, except for those conducted by some adventurous tourists and locals.
- Freshwater is derived from streams at an elevation of 81 metres above sea level (60 m^3/day).
- There is an additional system to collect groundwater from a freshwater lens located about six metres underground.

The challenge

- The intake is located in a valley surrounded by steep mountains.
- Intake is susceptible to flooding due to heavy rains.
- High concentrations of suspended and dissolved solids enter the distribution system due to lack of sedimentation and filtration.
- The groundwater system is automatically shut off during high flows in the stream.

- In the rainy season and during flooding, dirty brown water enters the pipeline and siltation in the pipes is common.

Storage and treatment

- There is some settling before water passes into the holding tank from the infiltration gallery as it moves through the wall structure of the holding tank; large, suspended matter is removed.
- As the water enters the distribution main, it passes through a coarse wire netting (mesh), which removes any remaining debris and large solids or suspended matter.

Outcomes

- A draft water safety plan for Avana. The intake supplies water to about 3 000 people inland.
- The increased catchment and water storage can meet water demand. It is also a necessary measure to reduce contamination at the source.

Case 21. Rarotonga

Overview

- Rarotonga depends on surface water from several streams and spring catchments for its reticulated water supply. The system provides water for domestic, commercial, industrial and agricultural uses. During droughts, it becomes unreliable.
- From infiltration galleries, the water flows down an asbestos cement pipe where it joins the reticulation on the main road.

The challenge

- The Rarotonga water supply is unsatisfactory in many aspects and improvements are needed to the catchments, intakes, storage, treatment and distribution.
- The water network has weak spots, e.g. bolts that hold the metal pipes together are prone to oxidation, and the flexible couplings connecting the pipes tend to pop off during a flood.

Storage and treatment

- There is no storage facility in the system.

Outcomes

- A wire mesh wall was constructed to protect the pipes during the stream crossings.

- A piped network was established to transport water from Avana intake to the distribution point.
- The bolts that hold the pipes together are covered with diesel tape.

Case 22.
Takuvaine intake

Overview

- A freshwater intake is located at about 61 metres above sea level.
- Maximum water production per day is 1 933 m3.
- The catchment includes approximately 161 hectares of forest and dense bush. Tall grass is found in the valley. The area is surrounded by high, steep mountains.

The challenge

- Pollution occurs when water passes through the intake.
- The intake is contaminated by animal and birds.
- Tourists contribute to pollution as does the cultivation of terraced taro fields.
- Water samples indicate a high presence of bacteria.
- There is a lack of storage facilities at most of the intakes.
- There is low water flow in streams and high water loss due to damage in the distribution system.

Storage and treatment

- Water from the Takuvaine flows into two storage tanks with a capacity of 45 000 litres and 2.5 million litres respectively.
- Some households supplement their water with rainwater catchment tanks, which are also connected to the reticulation system.

Outcomes

- A draft water safety plan for Takuvaine.
- The storage and treatment infrastructure supplies water to one commercial centre and the existing reserve tanks.
- Two pumps were installed to supply water to elevated sites in Avarua.

Case 23.
Tupapa intake

Overview

- Located at an elevation of 65 metres.
- Production (max) is 1 232 m3/day.
- There is a small dam on the stream and the intake is about 100 metres away from farming activities.

The challenge

- Intake screens become blocked with leaves and other debris.
- A geotextile cloth is used to filter the water. The cloth is covered with algae, which is thought to provide additional filtration but also risks toxic cyanobacteria.

Storage and treatment

- The pipe replacement for Avarua is still to be completed.
- Most of Avarua Township uses a water distribution network that depends on gravity to move the water.
- Two pump stations supply water to higher areas of Avarua.

Outcomes for Tupapa

- A draft water safety plan was developed for Tupapa.
- The location of the Tupapa intake next to the Takuvaine intake improves the supply of water to commercial centres and settlements.

Outcomes at the national level (C21-23)

- A draft National Implementation Plan for the Cook Islands was used to prepare the water safety plans described above.
- It has been suggested that a user pays system be initiated to generate the funds necessary to supply water throughout Rarotonga for domestic, commercial, industrial and limited agricultural use.
- Water is essential for the existing and developing tourism industry, which Rarotonga depends on heavily. Paying for water will reduce water demand and therefore reduce the need for alternate water sources, storage facilities and other capital works.

- The environment also benefits by reducing the stream extractions.
- Stress on existing surface water resources will only increase future; thus, it is important to measure the sustainable safe yield from the water supply catchment areas of Rarotonga. This will require the installation of continuous stream gauging stations to build a database that can be used to analyse streamflow.

Conclusion

The WSP programme has raised awareness and also brought the Ministry of Water Works together during the planning stages. Due to the small size of the South Pacific economies, foreign intervention was necessary for the improvement of the water supply. It is anticipated that countries will make their best efforts to address their challenges with available resources.

Table 4.2

Inventory of case studies

Code	Transdisciplinarity	Multi-disciplinarity	Institutional collaboration	Rewarding custodians	Lack of economies of scale	Ecosystems improvement	Success/ failure
C1	(+)	(+-)	(++)	(+-)	(+)	(+)	(+-)
C2	(-)	(+-)	(+-)	(+-)	(++)	(+)	(-)
C3	(-)	(+)	(++)	(-)	(++)	(++)	(+-)
C4	(+/-)	(+)	(+)	(-)	(++)	(++)	na
C5	na	(+)	(+)	na	(++)	(+)	(+)
C6	(-)	(+-)	(-)	(-)	(++)	(+)	(-)
C7	na	(+)	(+)	na	(++)	(+)	(+)
C8	(+)	(+)	(+)	(-)	(+)	(+)	(+/-)
C9	(-)	(+-)	(+)	na	(+)	(+)	(+)
C10	(+)	(+)	(++)	(-)	(+)	(+)	(+-)
C11	(++)	(+-)	(+)	(++)	(+)	(++)	(++)
C12	(-+)	(+)	(++)	(+)	(+)	(+)	(+)
C13	(+)	(+)	(-+)	(++)	(+)	(++)	(+)
C14	(++)	(+)	(+)	(+)	(+)	(+)	(++)
C15	(+-)	(+)	(+)	(-)	(++)	(++)	(+)
C16	(+)	(+)	(++)	(-)	(++)	(+)	(+)
C17	(-)	(+-)	(+-)	(-)	(+)	(+)	(--)
C18	(++)	(+)	(++)	na	(+)	(++)	(++)
C19	na	(+)	(++)	na	(+)	(+)	(+-)
C20	na	(+)	(+)	(-)	(++)	(++)	(+-)
C21	na	(+)	(+)	(-)	(++)	(++)	(-)
C22	na	(+)	(+)	(+-)	(++)	(++)	(+)
C23	na	(+)	(+)	(+-)	(++)	(++)	(+)

4.2. SYNTHESIS

Compiling the case studies, which describe projects carried out in many diverse countries, was not an easy task. There were few opportunities for a detailed and independent evaluation of impact, efficiency and sustainability. The challenge for the authors was to extract patterns from the sparse data that could be helpful for future water projects. Some of our key findings are described below.

One or multiple Islands

Thirty percent of the case studies were concerned with more than one island (C3, C4, C5, C6, C7, C16, C18). All of the multiple island projects were sponsored by external funds, with the exception of C3 where the Dominican Republic was the main donor. The success rate for the projects was moderately good to good. Most of the multiple island initiatives took advantage of economies of scale by repeating similar engineering interventions; an exception was C6, which maintained a website for a large group of stakeholders. The question arises as to why there are so few collaborative efforts among islands. The scale factor and lessons learned should encourage neighbouring to share research and development initiatives. Future multiple island initiatives supported by external funds with the condition that there is a strategy for building on findings and results once the project comes to an end.

Transdisciplinarity/multidisciplinarity

The level of transdisciplinarity could not be derived from project descriptions in seven of the cases. Five cases had a low level of transdisciplinarity and only three indicated sufficient involvement of more than one sector in the project. This could be because the focus of most projects was the adjustment of infrastructure to improve water availability and the need to involve a large group of stakeholders may not have been clear. Only one of the three watershed interventions (C3, C8 and C19) that involved a wide range of stakeholders had a clear transdisciplinary approach (C19). Six projects (C7, C8 and C20 – C23) reported the involvement of local NGOs. The involvement of the local community was cited in C4, C9, C13, C15 and C20 – C23. Overall, it can be concluded that transdisciplinarity deserves far more attention during the lifetime of projects, from consultations with stakeholders during the planning phase to feedback sessions during the project and after it has ended to ensure sustainability and define the tasks of project custodians.

In terms of multidisciplinarity, most of the projects encouraged the participation of various public organizations. Yet, the partners were biased toward technical and engineering disciplines leaving economic and socio-economic fields largely untouched.

Financial sustainability

Ensuring the long and lasting impact of project results requires effective tools and strategies for financial sustainability. Most projects do not really consider financing mechanisms in the post-project period. Two studies (C2, C10) mention the lack of adequate

tariffs to support the cost recovery of water services. Case 11 mentions cost recoveries on irrigation systems but it does not describe the mechanism used to compensate for the investments. Case 19, on the other hand, was implemented with government funds, supplemented by regional funding. The project met with numerous problems, but it continued under national supervision and funding, and was an eventual success.

Most projects are funded externally over a set period with fixed funding. The question arises whether the project also accomplishes financial viability over a post-project period or whether the completion of the project means the end of financing needed to continue water services.

Water-energy-food nexus

FAO introduced a new approach to food security and sustainable agriculture, based on the water-energy-food (WEF) nexus, which describes the complex and interrelated nature of our global resource systems (FAO, 2014). In practical terms, the nexus concept is used to analyse interactions between the natural environment and human activities and to promote better coordinated management and use of natural resources across sectors and scales. This helps us to identify and manage trade-offs and to build synergies, allowing for more integrated and cost-effective planning, decision-making, implementation, monitoring and evaluation.

For the SIDS, having fragile economies and numerous dependencies, nexus interactions are as important as elsewhere, if not more, and the wider context of transformational processes – or drivers of change – should be an overarching concern.

Admittedly, it is not always very clear how the WEF nexus approach is useful in project formulation. Most of the projects in this study have, by selection, a rather narrow focus on water management. Occasionally this is combined with sanitation objectives (C1, C2, C5, C7, C15, C17, C18), water for agriculture (C9, C11, C12, C14, C18, C19) or is subsumed in a wider natural resources perspective (C2, C3, C4, C6, C12). Climate change concerns and the implications for water management are inevitably a major motivation for many water-related projects at present (C4, C8, C9, C10, C14). Water and energy are dealt with in C17, although from a utilities rather than a nexus perspective; the project teaches us that straightforward privatisation efforts, despite the lessons learned from many years of structural adjustment programmes, are not necessarily successful, and a careful assessment of local circumstances should inform such attempts.

That being said, the nexus approach seems particularly relevant for the SIDS, since their budgetary and physical constraints are more absolute and there are no obvious magic bullets that relieve these constraints easily. Integrated and cost-effective planning, decision-making, implementation, monitoring and evaluation is indeed the way forward, from which should naturally follow implications on how to prioritise and scale natural resources projects.

Upgrading physical infrastructure

Many of the projects in this study focused on capacity building, providing advisory services formulating plans for natural resources management, while a few involved improvements to physical infrastructure. For example, C10 supported the construction of five metro stations; C13 and C19 funded the improvement and installation, respectively, of an irrigation system; C15 restored a desalinisation plant and C17 and C20 repaired parts of a water network.

Of course, capacity building is a valuable objective in its own right, with tangible and intangible gains realized over time. This will help the SIDS to plan their water management strategies carefully. They may have few or no competitive markets for construction; the geography of many dispersed island and islets calls for additional planning and coordination and expertise in nature-based solutions may be scarce. Furthermore, every island needs its own network of utilities, and while the collective purchase of non-local inputs may be cost-effective, it requires a lot of coordination.

Macro issues

While most of the projects are local and relatively small, some address issues at the scale of the macro economy. Project C8, for example, reports that a comprehensive climate change programme for the Seychelles could cost up to 40 percent of GDP. For SIDS with low-lying islands and atolls, sea level rise is extremely challenging and the costs involved, either for mitigation of climate change or reallocation of their population, far exceed average project funding. Many island states consist of 30 – 100 sub-islands and islets spread over hundreds of kilometres; some are low-income countries with already unsustainable debt levels. Hence, it may be expected that future water management issues may require much larger budgets, which will call for country-wide planning and donor coordination.

Typically, SIDS have small budgets, a small if not a tiny share of which are dedicated to water management activities. For example, 50 percent of the government budget of Mauritius (a middle-income country) is spent on general public services and social protection, 1 percent on environmental protection, and 1 percent on the water supply. It is thus clear that project funding for water management is crucial and value-for-money is a key concern. Accountability and effectiveness, which receive little attention in project reports, should be far more transparent. Only one of the projects selected for our study (C9) established a baseline that allowed a proper impact assessment. Given the challenges ahead, vast resources will be needed, which implies that a concerted approach from a macro perspective will be needed as well.

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5

Survey of water managers and policymakers

This section presents the results of a short survey of SIDS-based water managers and policymakers. Its findings can be used to analyse political priorities and awareness around current and future freshwater scarcity conditions. The survey (SurveyMonkey, 2019) consisted of 43 questions and was launched online[1], shared by email with stakeholders, and administered by FAO offices at national, regional and global levels. Sixty-three people responded. Survey results were processed with the statistical software SAS 9.4 to clean the data, to merge survey results with regional and economic SIDS classifications and to facilitate tabulation.

The survey starts with a question about the institutions represented by the 63 respondents (5.1). This is followed by questions about the role of the institutions in water governance (5.2) water laws and water policies (5.3), water allocation and scarcity (5.4), pollution, groundwater and flooding (5.5), and finally information gaps perceived by the respondents (5.6). The final section (5.7) concerns commonalities and regional differences around water management and water scarcity in SIDS.

5.1. REPRESENTATIVENESS AND INSTITUTIONAL SETTINGS

The diversity of geographic and economic conditions in the SIDS was discussed in Chapter 1. Combining this information with data on the location of respondents enables us to determine the extent to which the survey represents the SIDS.

1 https://docs.google.com/forms/d/e/1FAIpQLSejRq9SeF9uoU9H_CeWK7P6vr9oouO4Ks3MgINhSVzkQ--RtA/viewform?usp=sf_link

Table 5.1

Question 1: Which SIDS do you represent?

Which SIDS do you represent? (N=63)					SIDS by region and income (N=56)			
	Caribbean	Pacific	AIS	Total	Caribbean	Pacific	AIS	Total
Low income	0	0	0	0	1	0	2	3
Lower-middle	0	10	0	10	0	6	2	8
Upper-middle	32	11	1	44	11	9	2	22
High income	7	2	0	9	15	5	3	25
Total	39	23	1	63	27	20	9	56

From Table 5.1, it appears that upper-middle Caribbean SIDS are largely overrepresented on the survey (32 out of 63), while less than 20 percent of SIDS actually fall into this category (11 out of the 56). On the other hand, there is only one respondent from the nine AIS countries, while there are none from the 3 low-income SIDS. The distribution of respondents follows the income classes in the 20 Pacific region SIDS fairly well, especially in the two middle-income brackets. Finally, it should be noted that high-income SIDS are underrepresented, with 45 percent of the countries (25 out of 56) and only 14 percent of the respondents (9 out of 63). In other words, 86 percent of the responses come from middle-income countries.

We conclude that the survey is far from representative of SIDS countries. The results should be interpreted cautiously because the sample is biased towards middle-income countries and the single respondent from the AIS. Accordingly, we will mostly report results for the entire sample, although in some cases, we will discuss differences between SIDS in the Caribbean and in the Pacific.

Table 5.2

Question 2: Who is your employer?

Employer	Frequency	Percent
Government official	26	42.6
Regional government	4	6.6
Local government official	3	4.9
Water authority	3	4.9
NGO	9	14.8
Other	18	28.6

Table A.5.1 shows that 48 percent of the respondents are employed by the central government or the water authority, while 11 percent are officials at lower administrative levels. The remaining 41 percent are employed by an NGO (15 percent of total) and a variety of other institutes (see Table A.5.1).

5.2. WATER GOVERNANCE

Table 5.3

Question 3: Which institution is formally entrusted with leadership on water governance?

Institution	Frequency	Percent
Water authority	40	39.6
Government official	37	36.6
Local government official	8	7.9
Local community leaders	4	4.0
NGO	3	3.0
Regional government	3	3.0
Water users association	3	3.0
Other	3	3.0

As respondents could identify more than one institution, Question 3 yielded 101 answers (see Table 5.3). More than 75 percent of respondents cited the water authority or the government.

Table 5.4

Question 4: Do responsible agencies, water management authorities/task forces at national, local and community level have sufficient capacities, budget support, and knowledge?

Column percentage	Caribbean	Pacific	AIS	All
Do not know	23.08	8.70	100.00	19.0
No	64.10	65.22	0.00	63.5
Yes	12.82	26.09	0.00	17.5

Table 5.4 shows that 19 percent of respondents do not know whether capacities, budget and water governance are adequate, while nearly 18 percent believe that these capacities exist. Almost 64 percent do not feel that the responsible agencies have adequate means to address their assigned tasks. Remarkably, the positive responses from the Caribbean are lower at 13 percent than from the Pacific with 26 percent.

Table 5.5

Question 5: Which Institutes/bodies/authorities are involved in water governance?

Institution	Frequency	Percent
National government	53	28.8
Specialized agency	33	17.9
Ministry of water	32	17.4
Local government	17	9.2
NGO	12	6.5
Local community leaders	11	6.0
Water users association	8	4.3
Farmer association	5	2.7
Regional government	4	2.2
Other	9	4.5

Table 5.5 lists the types of institutes involved in water governance. Here again, respondents could give more than one answer, resulting in 184 answers. It appears that more than 60 percent of respondents considered water governance to be a national level responsibility, whether of the government, the ministry of water or a specialized agency. The centralized management of water governance is much larger in the Caribbean (75 percent) than in the Pacific (50 percent) (see Table A.5.2), where local organizations play a more important role and where most SIDS are multi-island states.

The relative importance of local involvement in water governance in the Pacific is corroborated by what the respondents identified as the most important tasks (see Table 5.6). For example, law-making and overall supervision by the national government and the ministry of water are considered less important in the Pacific than in the Caribbean. Yet, as the latter part of the table illustrates, regional differences in responsibilities are minor when it comes to specialized agencies. At lower administrative levels, we found that local governments (see Table A.5.3) and NGOs (see Table A.5.4) focus on the distribution of water for the agricultural sector and households, with water treatment/ purification as a runner up. Multiple responses were permitted.

Table 5.6

Question 6: What are their most important tasks?

Column percentage	Caribbean	Pacific	All
[**National government**]			
Law making	45.16	29.82	36.5
Overall supervision	37.10	26.32	31.0
Control of abuse	4.84	10.53	7.9
Water distribution households	4.84	10.53	7.9
Water treatment/ water purification	4.84	7.02	6.3

Table 5.6

Question 6: What are their most important tasks?

Column percentage	Caribbean	Pacific	All
[**National government**]			
Water distribution agricultural sector	1.61	8.77	5.6
Water distribution industry	1.61	7.02	4.8
N (number of responses)	62	57	119
[**Ministry of Water**]			
Overall supervision	27.78	16.00	22.1
Law making	20.37	16.00	18.3
Control of abuse	18.52	14.00	16.3
Water treatment/ water purification	12.96	16.00	14.4
Water distribution households	9.26	16.00	12.5
Water distribution agricultural sector	5.56	12.00	8.7
Water distribution industry	5.56	10.00	7.7
N	54	50	104
[**Specialized agency**]			
Water treatment/ water purification	26.87	17.14	23.5
Water distribution households	22.39	17.14	20.6
Water distribution industry	13.43	22.86	16.7
Water distribution agricultural sector	13.43	17.14	14.7
Control of abuse	13.43	14.29	13.7
Overall supervision	5.97	5.71	5.9
Law making	4.48	5.71	4.9
N	67	35	102

Table 5.7

Question 7: Is the institute politically influential in water governance?

Influence level	Frequency	Percent
[**National government**]		
Very	30	54.5
Moderately	17	30.9
Not very	6	10.9
Not at all	2	3.6
[**NGO**]		
Very	3	13.6
Moderately	7	31.8

Table 5.7

Question 7: Is the institute politically influential in water governance?

Influence level	Frequency	Percent
Not very	6	27.3
Not at all	6	27.3

The most commonly mentioned water governance institutes (see Table 5.7), namely the government, the ministry of water and specialized agencies, are generally politically influential. Only 10 to 15 percent of the responses judged these institutions to be 'not' or 'not very' influential. The political importance of other agencies is less significant. For example, less than half of the responses considered NGOs and water users associations to be politically influential (see Table A.5.5).

5.3. WATER LAW AND POLICIES

This section discusses current water laws and policies in SIDS. Almost all respondents (86 percent) stated that their country has a water law in place and a large majority (78 percent) indicated that there is an existing water policy (see Table 5.8). Respondents asserting that there is no water policy in place are from the Pacific region (see Table A.5.6).

Table 5.8

Question 8: Is there a water law, by-law or act at the national and local community level?
Question 12: Is there an existing policy for water resources?

	Frequency	Percent
Water law		
No	9	14.3
Yes	54	85.7
Water policy		
No	14	22.2
Yes	49	77.8

Table 5.9

Question 9: Is the water law/by-law/act appropriately executed? Question 13: Are the water policies appropriately executed?		
Water law		
	Frequency	**Percent**
No	26	49.1
Yes	27	50.9
Water policy		
	Caribbean	**Pacific**
No	81.25	43.75
Yes	18.75	56.25
N	32	16

Table 5.9 shows that only half of respondents felt that existing water law was properly executed (51 percent), while one third held that water policy was well executed (31 percent). Interestingly, confidence in water policy is significantly lower in the Caribbean, at 20 percent, than in the Pacific at 56 percent.

Table 5.10

Question 10: Are there legal consequences if water laws are broken? Question 14: Are there legal consequences if water policies are not adhered to?		
	Frequency	**Percent**
Water law		
No	8	14.8
Yes	46	85.2
Water policy		
No	18	37.5
Yes	30	62.5

Approximately 85 percent (see Table 5.10) of respondents asserted that there are legal consequences for breaking water laws; six of the eight respondents who reported no legal consequences were from the Pacific region. The enforcement of water policy is a bit less rigid (63 percent).

Table 5.11

Are there incentive structures to reward solid implementation of water law (Question 11) and water policy (Question 15)?

	Frequency	Percent
Q11 [water law]		
No	47	88.7
Yes	6	11.3
Q15 [water policy]		
No	42	89.4
Yes	5	10.6

The great majority of respondents (almost 90 percent) indicated weak incentive structures in water management, for the implementation of both water laws and water policies (see Table 5.11).

Table 5.12

Question 16: How well is water policy embedded in other development sectors?

Column percentage	Caribbean	Pacific	Total
Very well	12.90	6.25	10.6
Moderately well	25.81	62.50	38.3
Not very well	58.06	25.00	46.8
Not at all	3.23	6.25	4.3
N	31	16	47

About half of the respondents indicated that water policy is well embedded in other development sectors; the embedding is considered better by respondents from the Pacific at 69 percent compared to 39 percent in the Caribbean.

5.4. WATER ALLOCATION AND WATER SCARCITY ISSUES

This section discusses challenges around water allocation and water scarcity.

Table 5.13

Question 17: Are water allocation issues perceived as water governance challenges?

Column percentage	Caribbean	Pacific	AIS	Total
No	35.9	17.4	100	30.2
Yes	64.1	82.6	0	68.8
N	39	23	1	63

Water allocation (see Table 5.13) is largely considered a challenge in the Pacific (83 percent), but less so in the Caribbean (64 percent).

Table 5.14

Question 18: What water allocation problems do you perceive?

Problem	Frequency	Percent
Not enough water for households	36	34.3
Not enough water for the agricultural sector	28	26.7
Not enough water for industry	14	13.3
Not enough water for the tourist sector	9	8.6
Too much water to the tourist sector	11	10.5
Too much water for industry	3	2.9
Too much water for the agricultural sector	2	1.9
Too much water for households	2	1.9

Water scarcity in households was mentioned most often (34 percent of the N=105 responses; most respondents gave more than one answer), followed by the agricultural sector (27 percent), industry (13 percent) and the tourism sector (9 percent). There were also concerns that too much water is allocated to particular sectors, starting with tourism (11 percent of responses). This might reflect the view that water demand is too high. Nearly three-quarters of the respondents held that water infrastructure of insufficient quality (see Table A.5.7). One-third of respondents (half of whom were from the Pacific region) indicated that water allocation is used to preserve the quality of ecosystems (see Table A.5.8).

Table 5.15

Question 21: Are water scarcity issues perceived as water governance challenges?

	Frequency	Percent
No	13	20.6
Yes	50	79.4

Water scarcity is considered a challenge for water governance by four out of five respondents (see Table 5.15) in the Caribbean and Pacific alike.

Table 5.16

Question 22: Does water scarcity directly affect ...[sector]... in your country?

Column percentage	Agriculture	Food security and Nutrition	Sanitation and hygiene	Ecosystems and eco-services	Tourism
No	2.0	6.1	4.1	6.3	16.7
Moderately	22.0	20.4	24.5	16.7	31.3
Seriously	40.0	46.9	36.7	50.0	39.6
Very seriously	36.0	26.5	34.7	27.1	12.5

A clear majority of respondents (see Table 5.16) perceived that water scarcity is a serious to very serious problem, affecting agriculture (76 percent), Food security and Nutrition (73 percent), sanitation (71 percent), and ecosystems (77 percent) and, to a lesser extent, tourism (52 percent). Some 17 percent of the responses indicated that water scarcity is not a problem in their country's tourism sector, while very few respondents said that there is no problem (2 to 6 percent) in the other sectors.

Table 5.17

Question 23: In your opinion, what is the main cause of water scarcity?

Causes	Frequency	Percent
Drought	36	48.6
Flooding	4	5.4
No or insufficient access to groundwater	16	21.6
No or insufficient access to surface water	18	24.3

Fully half of the respondents indicated that drought is the main cause of water scarcity; the other half holds the lack of access to the surface (24 percent) and groundwater (22 percent) accountable. A few respondents mentioned flooding.

5.5. POLLUTION, GROUNDWATER AND FLOODING ISSUES

This section discusses the problems of pollution and flooding.

Table 5.18

Question 24: Are pollution issues perceived as water governance challenges?

Q24	Frequency	Percent
No	20	31.7
Yes	43	68.3

More than two-thirds of respondents (see Table 5.18) believe that pollution issues are a governance challenge; pollution concerns are slightly higher in the Pacific than in the Caribbean. One out of four respondents finding water pollution a challenge considers the treatment of polluted water to be satisfactory (see Table A.5.9).

Table 5.19

Questions 26-29: Is treated water reused for ...[purpose]...?

Column percentage	Agriculture	Municipal objectives	Discharged in sea or inland waters	Other purposes
No	76.7	78.6	24.4	70.7

Table 5.19

Questions 26-29: Is treated water reused for ...[purpose]...?

Column percentage	Agriculture	Municipal objectives	Discharged in sea or inland waters	Other purposes
Yes	23.3	21.4	75.6	29.3

Table 5.19 shows that three-quarters of the responses indicate that treated water is discharged in the sea or inland waters; between 20 to 30 percent of the answers note that wastewater is reused for agriculture, municipal use and other purposes, listed on Table 5.20 (nine responses).

Table 5.20

Question 30: Reuse of treated wastewater

Other purposes
Treated water is released into oceans and waterways
Household
Greywater usage
Household cleaning and exterior sanitation
Tourism sector uses, e.g., for maintaining landscapes
Watering golf courses and gardens
Irrigation of hotel landscapes. This occurs to a minor degree
For distribution of pesticides

Table 5.21

Question 31: Are groundwater issues perceived as water governance challenges?

	Frequency	Percent
No	20	31.7
Yes	43	68.3

Forty percent of the respondents who indicated that groundwater issues are challenging (see Table A.5.10) noted that there are no groundwater regulations, and, where such regulations exist, 40 percent say that they are not enforced (see Table A.5.11). With a few exceptions from the Caribbean, there is consensus around the need to regulate groundwater exploitation (see Table A.5.8). Nevertheless, only one-third of respondents mentioned that groundwater exploitation is largely practiced (see Table 5.22), a situation that is more common in the Pacific (53 percent) than in the Caribbean (25 percent).

Table 5.22

Question 35: Is groundwater exploitation largely practiced?

Column percentage	Caribbean	Pacific	AIS	Total
No	75.00	47.06	100.00	64.3

Table 5.22

Question 35: Is groundwater exploitation largely practiced?

Column percentage	Caribbean	Pacific	AIS	Total
Yes	25.00	52.94	0.00	35.7
N	24	17	1	42

The last tables in this section indicate that flooding is considered a problem (see Tables 5.23-24). In most cases, an emergency plan exists (72 percent) (see Table A.5.13), while an early warning system is less common (58 percent) (see Table A.5.14).

Table 5.23

Question 36: Is flooding a problem in your country?

	Frequency	Percent
No	5	8.1
Yes	57	91.9

Nearly all respondents expect that flooding will become a serious problem under future climate change conditions (see Table 5.24).

Table 5.24

Question 39: Do you expect flooding to become a problem in your country due to climate change?

	Frequency	Percent
No	7	11.1
Yes	56	88.9

5.6. INFORMATION GAPS PERCEIVED BY THE RESPONDENTS

Most respondents (see Table 5.25) perceive a problematic lack of information on water management (86 percent) and advocate spending more resources to fill data gaps (96 percent) (see Table 5.26). Respondents provided a variety of reasons (see Table A.5.15) about the need for more and better data as well as the kind of data that are needed (49 responses).

Table 5.25

Question 40: Is a lack of information or data on water management a problem in your country?

	Frequency	Percent
No	9	14.3
Yes	54	85.7

Table 5.26

Question 43: Should the country spend more resources to meet the data demands for water management?

	Frequency	Percent
No	2	3.7
Yes	52	96.3

5.7. SYNTHESIS

In this section, we evaluate the results of our survey on the governance of freshwater resources in SIDS. The small sample size (N=63) and lack of representativeness in geographic and economic conditions of the respondents should be noted. For example, there was only one respondent from the AIS region, while there were no respondents from the two low-income SIDS and merely nine from the 25 high-income countries, the income bracket with the highest number of SIDS. Eighty-six percent of responses come from middle-income countries; 70 percent came from 11 upper-middle-income Caribbean SIDS.

Nevertheless, there are some consistent patterns in the answers from which we can draw general conclusions, while a few interesting points emerge about possible differences in water issues in Pacific and Caribbean SIDS.

Limited capacity for water governance in the SIDS

More than three-quarters of the respondents identify the government or a water authority as the responsible agency for water governance. Yet, fewer than one in five has confidence in the capacity of water governance institutions to deal with water challenges.

Top-down governance more common in the Caribbean; local organization more important in the Pacific

Interestingly, confidence in national water management capacity is lower in the Caribbean (13 percent) than in the Pacific (26 percent). Top-down water governance is more common in the Caribbean than in the Pacific, where local organizations play a more important role. The importance of local water governance in the Pacific is underscored by the fact that law-making and oversight by the national government and the ministry of water is considered less important here than in the Caribbean.

Weak political influence of local agencies

Not surprisingly, national agencies are generally influential. The political influence of local agencies, on the other hand, is rather poor. For example, less than half of the responses consider NGOs and water user associations to be influential.

Little incentive to enforce water laws and policies

Almost all islands have a water law and a water policy in place. Only half of respondents with a water law believe that it is properly executed, while only one-third perceive that water policy

is well executed. Most respondents indicated weak incentive structures for enforcement, with few rewards for water managers.

Links between water policy and development are better in the Pacific than in the Caribbean

About half of the respondents indicated that water policy is well embedded in development; the relationship between water policy and development is considered better by respondents from the Pacific (69 percent) compared to the Caribbean (39 percent).

Water allocation priorities

Households are mentioned as the highest priority for water allocation (34 percent responses), followed by the agricultural sector (27 percent), industry (13 percent) and tourism (9 percent). One-third indicated that the ecosystem is a target for water allocation; the concerns for ecosystems are somewhat higher in the Pacific (almost half of the responses).

Water infrastructure insufficient

Almost three-quarters of respondents perceive the water infrastructure in their country to be insufficient.

Water scarcity a serious concern

Water scarcity is considered a problem by 4 out of 5 respondents, in the Caribbean and the Pacific alike. Scarcity affects agriculture (76 percent), Food security and Nutrition (73 percent), sanitation (71 percent), ecosystems (77 percent) and, to a lesser extent, tourism (52 percent).

Drought and problems of access are equally important causes of water scarcity

According to the respondents, water scarcity is caused by drought (50 percent) or by a lack of access to surface water (24 percent) and groundwater (22 percent).

Pollution and groundwater issues are a challenge

Pollution is a key concern in both the Pacific and the Caribbean. Only one out of four respondents who consider water pollution a challenge believe the treatment of polluted water to be satisfactory. Three-quarters of the responses indicated that treated water is discharged in the sea or inland waters; between 20 to 30 percent of the answers noted that wastewater is also reused for agriculture, municipal use and a range of other purposes. Forty percent of the respondents that indicated that groundwater issues are challenging asserted that there are no groundwater regulations, and, when regulations exist, 40 percent held that there is no enforcement. With a few exceptions from the Caribbean, there is consensus about the need to regulate groundwater exploitation. Nevertheless, only one-third of respondents mentioned that groundwater exploitation is largely practiced, a situation that is more common in the Pacific (53 percent) than in the Caribbean (25 percent).

Flooding expected to remain a problem

Seventy-two percent of the respondents indicated that an emergency plan for flooding exists, while 58 percent reported that an early warning system was operational.

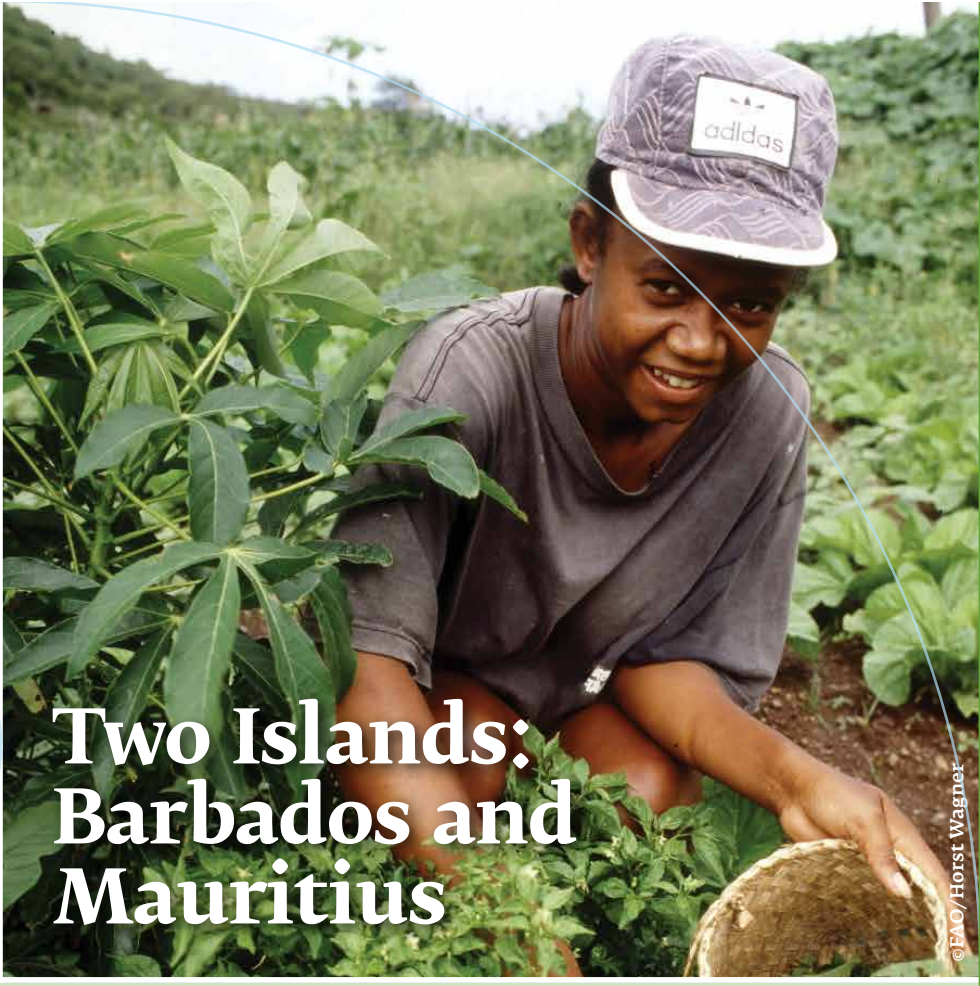
More resources needed to fill data gaps

Respondents provided a range of reasons for needing more and better data as well as about the kind of data that are needed, see Table A.5.15 below.

The findings of the survey indicate that water governance in SIDS faces a myriad of challenges requiring urgent attention. The discharge of untreated wastewater figures prominently on the list of priorities as it affects ecological assets and the tourism sector. There is limited capacity to collect and treat used water; reuse is mentioned but not applied at a large scale. Likewise, overexploitation of fragile groundwater resources causes sea intrusion and threatens the sustainability of water supplies on the islands. The mismanagement of water resources is intrinsically linked to a lack of enforcement of water policies and laws. A major issue is the lack of information to support effective rules and regulations and the monitoring of policies and laws. In the road map, found in Section 7, we will present possible solutions to some of these challenges.

6

Two Islands: Barbados and Mauritius



This section reports on a detailed water governance study that resulted from missions to Barbados and Mauritius.[1] [2] This section, together with Section 4, the case studies, and Section 5, the survey, provides insights that will be synthesised into concrete recommendations in Section 7.

The missions had two objectives:

- To obtain a detailed overview of the prevailing water governance situation in the islands and its relation to agriculture and food security. Particular topics of concern included current priorities for water management, water policies related to agriculture catalysts and constraints to water policy implementation, and the potential for water governance to contribute to a more diverse and healthy diet.
- To conduct an in-depth analysis of field projects, including the factors determining their success or failure. Project performance was matched against a set of objective criteria for project evaluation (see Annex 6.1, Table A.6.1).

In-depth interviews

The study of water governance and project performance used a two-level assessment approach: first a literature survey on water management-related organizations and second semi-structured in-depth interviews (IDI) with water professionals. The IDIs provided context

[1] Mission members for Barbados (10-14 February 2020): Amani Alfarra, FAO, Ben Sonneveld and Delia Atzori, Amsterdam Centre for World Food Studies (ACWFS), Vrije Universiteit Amsterdam. Mission member for Mauritius (2-6 March, 2020): Ben Sonneveld.

[2] During the mission, the FAO offices on the host islands were briefed on the preliminary findings of the study.

for our empirical research as well as the information collected through the survey and case studies. Furthermore, the IDIs provide personal interpretations of the challenges involved in implementing water governance policies and the interactions between water professionals. The gathered information through IDIs, jointly with other information sources was our basis for a more comprehensive and deeper understanding of the prevailing water governance in the visited islands.

The interviewers comprised a skilled team of researchers. The IDIs were open-ended and semi-structured and involved a small group of respondents. Annex 6.2 presents the interview questions, while Annex 6.3 provides the interview guide. Most interviews started with one or two questions to prompt further discussion. As such, the list of questions served as a checklist to assure that all topics were covered.

Project visits

The mission team visited project sites in Barbados and Mauritius, collecting information on agro-ecology and interviewing project staff and beneficiaries of the projects.

Sections 6.1 and 6.2 present our findings for Barbados and Mauritius respectively. Our conclusions are presented in Section 6.3.

6.1. BARBADOS FACES A CRITICAL WATER FUTURE

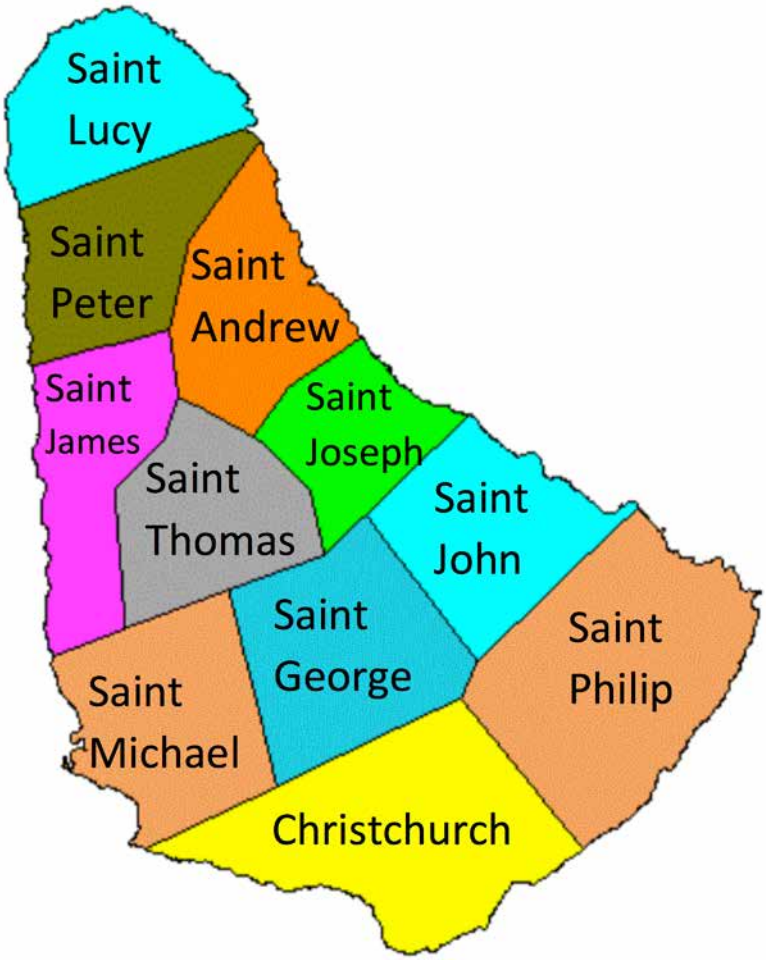
Water-stressed Barbados faces a raft of challenges to ensure continual water supply for rural and urban households, the agricultural sector and industry, while simultaneously coping with climate change-induced erratic rainfall. Moreover, the government has undertaken an ambitious development programme that aggravates water stress by expanding cultivated areas to increase production of fresh foods and doubling the number of beds available to the tourism sector.

The government's targets for the year 2020 were:

- expanding the agricultural area by 30 percent;
- training an additional 2 000 farmers;
- reducing food imports by 30 percent;
- expanding the number of beds in the tourism sector by 5 000, twice the current level.

Interviews were held with experts from the major water-related institutions in Barbados to explore the institutional responses to these political aspirations. An in-depth case study of the Spring Hall Land Lease Programme (SHLLP) provided detailed and useful information on the management of scarce agricultural water resources. The in-depth interviews and case studies are summarised below.

Text Box 6.1. Administrative map of Barbados



Land	Km²
Total area	430
Agric. land	100
Forest	63

Population	in 000
Rural	197,18
Urban	89,20
Total	286,64

Region: Caribbean

Geography and environment

- raised atoll
- precip/ann. 1 650 mm
- clay-rich soils
- fragile coral reefs
- high population/ density/
- tourism/wastewater

In-depth interviews: Barbados

The interviewees and their respective institutes are briefly introduced below.

- *James Paul, Director of the Barbados Agriculture Society (BAS).* Paul is a former parliamentarian. The Barbados Agriculture Society[3], an umbrella organization established in 1845, represents nine commodity groups[4], with 500 farmer members.
- *Nicole Austin, Alex Ifill and Jaime Paul, staff of the Barbados Water Authority (BWA).* Established in 1980, the BWA is charged with supplying potable water, wastewater treatment and disposal services to areas with a sewer system. BWA is responsible for monitoring, assessment, control and protection of water resources. It operates two wastewater treatment plants and a desalination plant. Various water acts give BWA control over

[3] https://basonevoice.org/

[4] The nine commodity associations are: pig farmers, egg and poultry producers, fruit and vegetable growers, floral producers and exporters, dairy and beef producers, sheep farmers, cotton growers, rabbit farmers, and bee keepers.

surface and underground water reserves. Most of the current acts were inherited from the colonial period.

- *David Coppin, Suzette Edey-Babb, Robert Saul, Leslie Sealy, Glenn Marshall, Jamekal Andwele, Gennia Oxley, Beverly Wood, staff of the Ministry of Agriculture (MoA).* According to its mission statement, the MoA aims to create a competitive agricultural sector that contributes to the socio-economic development and food security of the country.
- *Jean Fransen, Food Security and Rural Development Officer, FAO; Dawn Browne, Manager School Meals Department, Ministry of Education, School Feeding Programme (SFP).* The SFP is overseen by the Ministry of Education and is fully funded by the government of Barbados. Under the SFP, primary schools serve a meal to all children; secondary schools only feed children with financial challenges at home.
- *Hugh Sealy, a lecturer at the University of West Indies and advisor to the Prime Minister*
- *Jamekal Andwele, Manager of Agricultural Services and Leslie Sealy, Extension Officer of the Feed programme*, Barbados Agricultural Development and Marketing Corporation (BADMC)
- *Hamilton Cerbin*, President of the farmers' association at the SHLLP

The transcripts of the interviews are found in Annex 6.4. This section groups lessons learned from the interviews into thematic areas related to water governance in Barbados: 'water stress,' 'data,' 'environmental pollution,' 'gaining efficiency,' 'sustainable innovations' and 'institutional collaboration.'

Water stress

All interviewees acknowledged that Barbados is a seriously water-stressed country that requires full and integrated water governance to assure future timely delivery of water to the right locations. Yet the BWA, which is in charge of water legislation, indicates that current water laws[5] are outdated and require major revisions if they are to address government policies on expanding tourism and agricultural activities (see above).

Data

There seems to be some disagreement about the availability of sufficient data for policy-making. Most interviewees (Sealy, BAS and MoA) cited data paucity or outdated information on water resources. Water policy-making is also hampered by differences in water allocation figures. For example, Sealy pointed to BWA's assertion that 25 percent of freshwater resources are used for agricultural activities, while FAO's AQUASTAT (FAO, 2018) claims a share of 60-70 percent. The MoA indicates that important data on water resources are missing, with one official stating "It is not clear which type of water supply is being used for which type of usage…."

Decisions on water use are not guided by the prevailing price structure, which makes it difficult to follow the destination of water flows in the absence of an extensive metering

[5] e.g., the Underground Water Control Act. 1953, Irrigation Act. 1967; separate acts for the three streams in Barbados date from the 18th Century.

network. For example, some households, although paying higher prices than commercial water rates, use water for agricultural purposes.

Contrary to the assertions of inadequate data, BWA indicated that all information needed for policy-making is available and regularly updated through a well-functioning monitoring network. Occasionally, a lack of human resources prevented full data collection on water quality aspects (e.g., the effect of upstream pollution on downstream water users). Yet overall, major water flows and related water quality are mapped accurately, according to the BWA. Moreover, the Barbados Agricultural Development and Marketing Corporation (BADMC) referred to their monitoring network and regular reporting of observed water flows, which complements data from BWA.

The controversy over data availability could be addressed by Paul's call for all institutes, including the private sector, to disclose fully their information on water quantity and quality.

Major concerns on environmental pollution

Some interviewees (James Paul, Hugh Sealy, BWA and MoA) expressed concern about major pollution flows caused by untreated municipal waste waters: out of 11 million cubic metres (MCM) municipal wastewater that are produced, only 3.3 MCM are treated[6]. The remaining wastewater is discharged into aquifers or coastal waters. Sealy estimated that 40 percent of the coastal reefs are affected by polluted water flows from the urban areas.

On the positive side, new regulations require that large hotels have sewage treatment systems in place within the first year of their opening; smaller hotels are allowed three years. The Marine Pollution Control Act improved the situation considerably as discharges became illegal and, in principle, are subject to fines. Yet, as Paul indicated, "Law enforcement is quite hard in Barbados as we are on a small Island everybody knows each other, no one will harm another person."

Another concern relates to the overuse of pesticides. The MoA and Paul referred to high doses of pesticides being used in general. BWA claimed, however, that no traces of pesticides could be found by their monitoring system. Yet BWA reported that high nitrogen levels can be found in the groundwater due to the overuse of fertilizer in agriculture. Mr Hamilton Cerbin, President of the farmers' association of the SHLLP, also shared concerns on the overuse of pesticides and herbicides and indicated that farmers participating in the SHLLP aim to reduce pesticide use and, in the near future, to convert to full organic certified farming.

Gaining efficiency

Economic development will increase water demand among sectors and households. But, while calls for improving water use efficiency are justified, this will be no easy task. For example, the practice of rainwater harvesting in water-scarce countries is not customary in Barbados (MoA, BWA), unlike on other Caribbean Islands (St. Kitts, Virgin Islands). The MoA noted that laws and cultural norms prevent the use of water in tanks, instead, home gardens are irrigated with tap water.

[6] Barbados has two municipal wastewater treatment plants and some small package treatment plants.

Sealy indicated that the country is working towards new water acts since, under the current water act, the reuse of treated wastewater and rain harvested water for agricultural purposes is explicitly prohibited by the cabinet of the prime minister. Hence, the MoA does not actively promote the reuse of water. Wastewater treatment plants (WTPs) are located in urban areas far away from agricultural sites. Interviewees (BWA, MoA) indicated that the reuse of water is only practiced on a small scale to irrigate green zones around some of the larger hotels. Yet staff from the MoA were of the opinion that "... the forthcoming new act [which is currently being drafted at the specific request of the prime minister] should account for the prevailing water stress [and] also look at the reuse of water, rainwater harvesting and groundwater extraction policies."

Large efficiency gains can still be made by reducing the share of non-revenue water, which amounts to 49 percent on average. According to Sealy, "We're pumping twice as much water as we get actually to the consumer."

This does not necessarily mean that all non-revenue water is lost. Water will percolate to lower layers and discharge into aquifers, Yet the water exposed to the surface will evaporate and is no longer available. Energy is lost in pumping non-revenue waters.

A lack of information and low-efficiency gains has resulted in the undervaluation of water resources. Sealy observed that a water price that correctly reflects water scarcity will encourage users to increase water efficiency.

Sealy also indicated that conflicts over the amount of water allocated to agriculture have decreased since the government has given agriculture more prominence. Paul observed that higher water efficiencies can be attained by training farmers in drip irrigation, fertigation, hydroponic farms, water harvesting techniques and increasing awareness of water scarcity. The MoA informed us that it aims to increase water use efficiency by subsidising the purchase of drip irrigation systems and desalination of the groundwater. BADMC referred to the SHLLP programme, which is fully equipped with a highly efficient drip irrigation system.

Fransen noted that the prime minister is pushing for clear links between healthy food production and SFPs. Fransen and Browne would like to operationalise this concept by linking the country's agricultural educational programme, which focuses on the cultivation of healthy foods, to the SFP through the implementation of school gardens.

Sustainable innovations

Sealy noted that there are opportunities for expanding agricultural development by producing biofuels. He referred to the cultivation of sugar cane to produce ethanol, which aligns with future policy visions of a fossil-fuel-free economy by 2030. Yet this would require attaining historical production figures of several hundred thousand to a million tonnes of sugar cane. These production levels can only be obtained when water demand is fine-tuned, with a seasonal variation where rainfed periods are combined with irrigation.

Institutional coordination

Given that agriculture uses more water than any other sector, the full engagement of the MoA is indispensable for future water policy in Barbados. The agricultural sector has the possibility to implement appropriate and cost-effective water-saving technologies that will support its future development. Responsibilities for water governance should be decentralized where possible. For example, farmers actively use a dense water monitoring system, implemented by BDAMC, to regulate and reduce water supply when the hazard of over extraction looms. BADMC also plays an active role in implementing highly efficient irrigation systems that support water-saving policies. The data from the monitoring system are shared with the BWA.

Paul also pointed to the active role of farmers, "which will be good to make farmers engaged in the process of the development of water policy and understanding the importance of rain harvesting."

Fransen and Browne also indicated the need for institutional collaboration between ministries and departments to support the SFP.

Concerns and opportunities: Barbados

Given the concerns expressed by the interviewees, there seems to be a clear need for a data 'herding' process, whereby all available hydrological and water use data are harmonised and organized in an analytical framework with spatial and temporal components to reflect water balances by, for example, districts and months. Hot spot analyses could identify sites and periods where additional water governance actions are required. Policy-makers could greatly benefit from an approach that allows them to analyse the impact of prospective scenarios and to identify opportunities, constraints and interventions.

The creation of such an analytical framework will require consultation and feedback from multiple stakeholders. End users, such as farmers, households, industry and the tourism sector, should participate in a joint undertaking to ensure appropriate representation and to reconcile their frequently conflicting objectives.

The project: Spring Hall Land Lease Programme

The SHLLP project falls under the BADMC, a statutory agency of the MoA. BADMC was established by a legislative act in 1993 with a mandate to develop and support Barbadian crop and livestock production and agro-processing. BADMC's mission is carried out by three developmental divisions (Agricultural Services, Agribusiness and State Trading Enterprise). The Agricultural Services department was actively involved in the SHLLP.

Geography

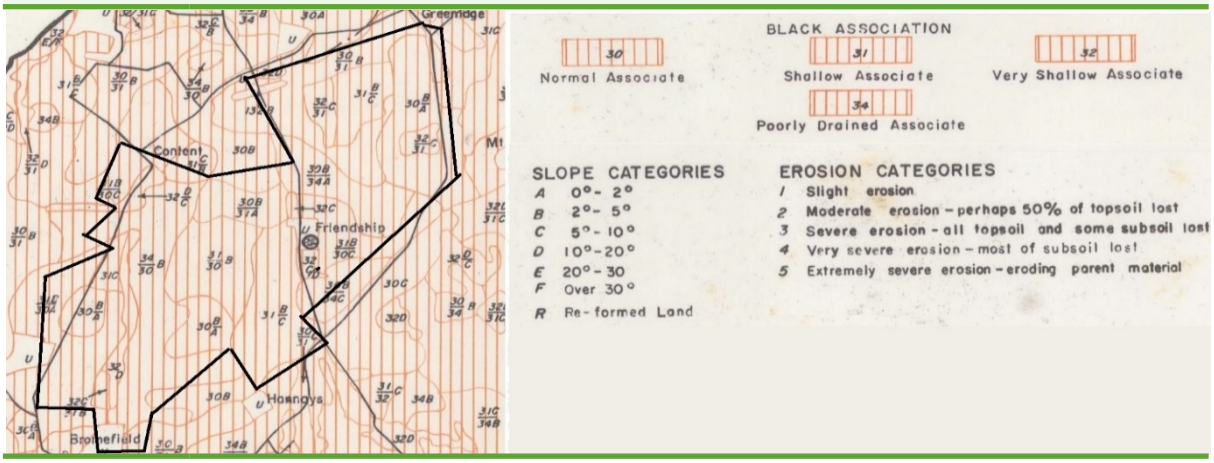
The SHLLP is located in Parish St. Lucy, the Northern part of Barbados (Textbox 6.1). The total area includes 420 acres for crop cultivation and 60 acres for rangeland.

The cultivated terrain of the SHLLP is slightly undulating, with occasional abrupt sinks.

Slopes mostly fall into the B category (2-5 percent) with occasional C slopes (5-10 percent) mainly in the north and sharper escarpments of the D slope category (10-20 percent) in the west (see Figure 6. 1). No clear river beddings are present.

Figure 6.1

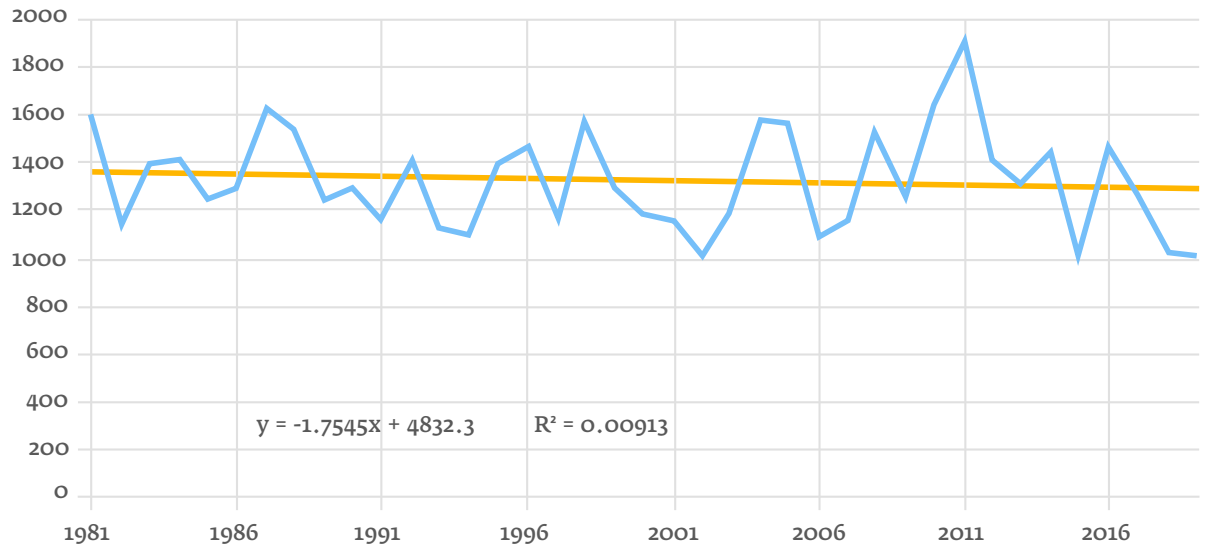
Soil map of the SHLLP. The delineation of the SHLLP border is approximated



Source: ICTA, 1966

Figure 6.2

Time series of annual precipitation in mm, 1981-2019



Source: BADMC, 2020a

The soils of the SHLLP are black, with some loam and organic matter in the topsoil. Cracks in the soil indicate a high content of clay. Most map units present soil associations of a normal soil type combined with another soil type described as shallow, very shallow and poorly drained. The normal and shallow associations are found in the central, southern and most northern part of the SHLLP. Normal and very shallow associations largely correspond to C

and D slope categories. Pockets of poorly drained soils are found in isolated locations on the western side of the SHLLP (see Figure 6.1). Soil erosion has not been reported, yet soil loss hazards can be expected on steeper (C and D) slope categories.

The prevailing annual rainfall in the SHLLP parishes ranges between 1 000 and 1 800 mm, with an average of 1 400 mm. The linear regression line for the period of 1981-2019 shows a slightly declining trend over the years (see Figure 6.2). Yet the R-square of the regression is very low and definitive conclusions on the changing trends should be made with caution.

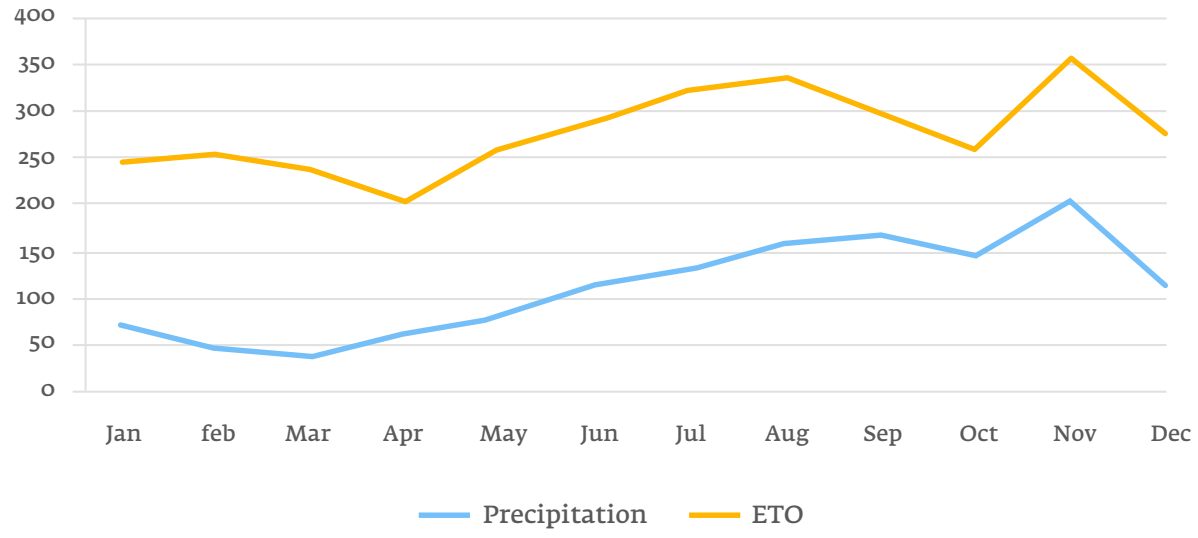
Dry months extend from January to April with the monthly average rainfall below 100 mm. From May to November, rainfall exceeds 100 mm with November as the wettest month. The evapotranspiration[7] follows precipitation patterns, with the highest levels in November[8]. The combined evapotranspiration and precipitation patterns indicate that careful planning is required to optimise rainfed cultivation to save water for irrigation (see Figure 6.3).

Groundwater

The analysis of groundwater reserves in SHLLP is based on a more general assessment for Barbados (Jones and Banner, 2003). Groundwater reserves consist of small, unconfined aquifers with limited residence terms that vary from a single year to decades. Hence, groundwater availability depends heavily on short- and long-term climatic fluctuations that influence the amount of recharge. Consequently, the recharge and use of groundwater reserves should follow interannual variations to avoid that water quality in these aquifers is affected by seawater intrusion.

Figure 6.3

Monthly precipitation in mm and reference evapotranspiration in mm for the Spring Hall Land Lease Programme. Average values for period 1981-2019



Source: BADMC, 2020a

7 Evapotranspiration from a reference surface that closely resembles an extensive surface of green, well-watered grass of uniform height, actively growing and completely shading the ground.

8 Data were kindly provided by the BADMC (BADMC, 2020).

History and development

The SHLLP is a government initiative that started to employ landless farmers and retrenched workers in the 1960s. Four hundred and two acres of project area were initially distributed among 22 participants, each of whom received plots of 10 to 25 acres. The land lease was approximately BBD 150 per acre annually. Two of the participants dedicated their farming systems to livestock, covering approximately an additional 60 acres of rangeland.

The Barbados Agricultural Development Cooperation (BADC) was assigned the task to equip the fields with irrigation infrastructure and to provide the two dairy farms with the required buildings and tools. The budget was BBD 2.3 million (USD 1 139 318), BBD 1.16 million (USD 574 612) of which was provided by the Government of Barbados and the Caribbean Development Bank. The mismatch between the required investments and the available budget led to a critical evaluation of project development: "serious cost overrun, inappropriate design of tenant houses, too large size of plots, non-acceptance of sugar cane, inability to recruit suitably qualified tenants, inappropriate and inadequate irrigation technology, lack of adequate marketing and insufficient technical support (Nurse, 1992)." Another criticism (Cummins, 1996) was that women were not involved in the project because they were not targeted.

At its core, the Barbados Agricultural Development and Marketing Corporation aims to empower farmers and agripreneurs to develop sustainable agricultural enterprises. BADMC is responsible for catalysing non-sugar agribusinesses in the island nation and offers critical assistance for agricultural development. It manages several commercial units that assist with marketing and distribution of local agricultural produce and agroprocessed goods.

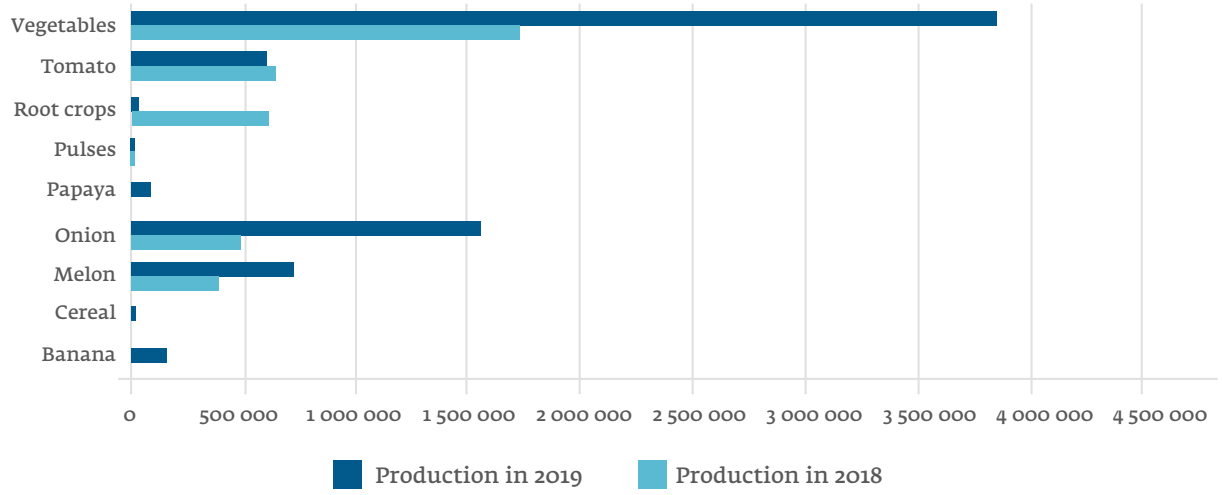
In 1996, BADC merged with its marketing counterpart to become the BADMC, which, together with participating farmers, proposed radical changes to address the project's problems.

The most important changes were as follows:

- Areas that remained uncultivated due to a lack of workers were distributed among new participants, increasing the number of farmers in the project to approximately 40 and decreasing the average plot size to 5 to 15 acres per participant.
- The crop composition was enriched by a large variety of fresh and healthy vegetables like tomato, peppers, cucumber and melons, onions and 'squash'. Figure 6.4 shows the crop composition (cucumbers and squash are aggregated under 'vegetables' (see Figure 6.4).
- Large-scale drip irrigation schemes were introduced and connected to the two operational pumps in the region. Subsidies by the Barbados government provided an extra incentive to transit from rainfed to drip irrigation.
- Water distribution was brought into line with the available water supply as determined in consultation with the Barbados Water Authority.

Figure 6.4

Crop production in lbs for the SHLLP in 2018 and 2019



Source: BADMC, 2020b

Water governance

The intensive collaboration between BADMC, the extension service of the MoA and farmers resulted in a high level of farming, with drip irrigation as one of the most advanced components. Concerning the water governance of the SHLLP, BADMC is responsible for extension services and water deliveries.

One of the pumps visited during the field trip had a capacity of 65 000 l/hr and 189 000 M^3 on an annual basis. Accounting for conveyance losses there is an irrigation potential of 46 mm per year. Assuming 25 percent of the land is unused, 61 mm on average is being provided per crop. Yet conversion from large to smaller-scale plots and increasing the number of participating farmers reduced the efficiency of water use, according to a BADMC staff member: "more farmers, more pumping, more water waste."

According to local farmers and BADMC staff, increasingly erratic rainfall has caused higher surface runoff and has reduced discharges to the aquifer. The lower groundwater levels and reduced head water pressure has caused salt intrusion that affect aquifer water quality.

The BADMC water governance policy was adjusted to the new situation. Initially, water demand was met without taking into consideration the impact of extraction on water resources. Now, the BADMC links extraction rates with the level of recharge. Additionally, important elements like pathogens (bacteria) and salinity are monitored to assess water quality. BADMC provides monthly reports on water quality and quantity to the Barbados water authority.

Upon request, the BWA issues a license to BADMC for water pumping. There is no fixed limit for extraction rates, but the water governance procedures of the BADMC aim to prevent overextraction.

Interview with Hamilton Cerbin, President of the Association of Farmers of the SHLLP

In a telephone interview, Cerbin explained that the success of the SHLLP was due to intense collaboration between the farmers' association, BADMC and extension services as well as the willingness of farmers to innovate and adapt when needed. This became clear in the interview, in which many novelties and adaptation measures were discussed.

Cerbin expressed major concerns about the availability and quality of water. In past decades, farmers regularly experienced long dry spells that could not be compensated by irrigation systems. Cerbin proposed rainwater harvesting techniques as a solution, using small catchments that are naturally formed by the accidental terrain to create different ponds. Cerbin also shared his concern about the overuse of pesticides and herbicides. His aspiration was to convert to a fully organic farming system and he mentioned that farmers are considering the use of compost and other biological farming methods. Cerbin also pointed to the growing consciousness of consumers on food safety issues. He expressed his interest in testing the concept of the water-energy-food nexus by using solar panels and windmills as alternative clean energy sources that can deliver energy for water pumping and cool cells.

Lessons learned and conclusions

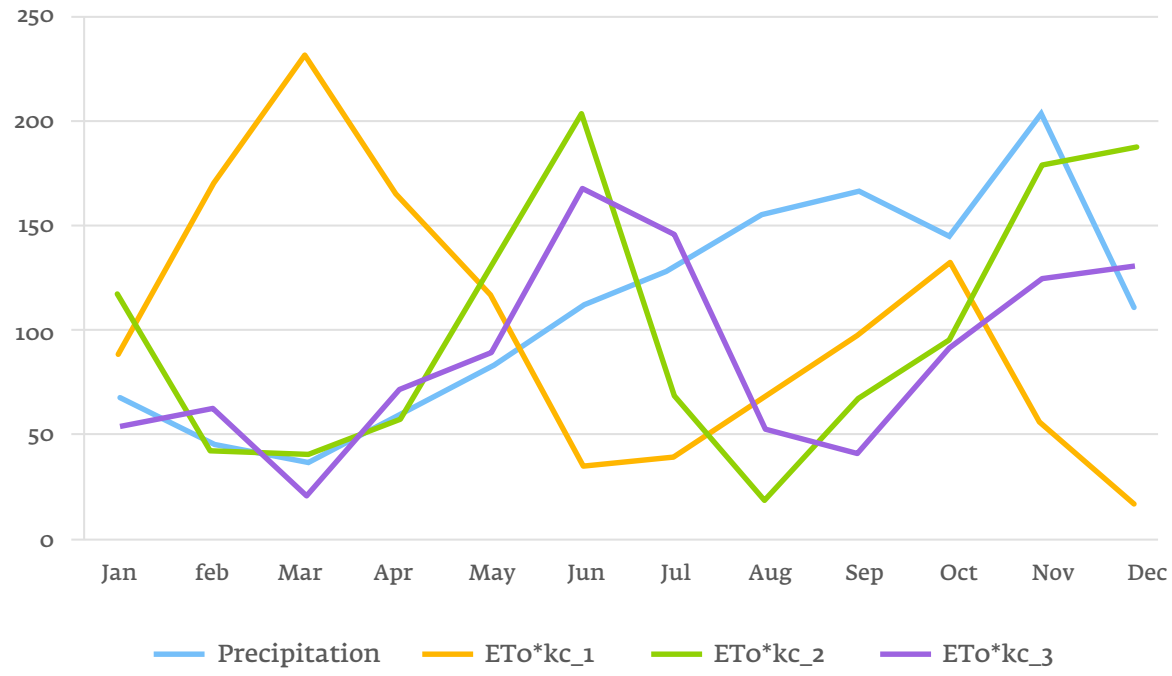
The following lessons learned from the Spring Hall Land Lease Programme emphasise the need to:

- clearly define target groups, canvas their views and design project components that are acceptable for the beneficiaries;
- select the appropriate executing agency to provide advisory services;
- spend more time on the planning of irrigation technology, crop selection and market opportunities.
- use a transdisciplinary approach that includes the target group in the decision-making process from project design through implementation;
- organize appropriate extension and support;
- ensure long term supervision and extension services;
- ensure that experiments and knowledge benefit the entire community;
- recognise that the perseverance and endurance of farmers and public agencies are key to overcoming challenges.

The mission team discussed various options for addressing seasonal water availability with the BADMC, the extension service of the MoA, and the farmers' association. Figure 6.6 illustrates some of these discussions by mapping monthly precipitation against monthly crop evapotranspiration in three crop rotations. The numbers used in Figure 6.5 can be found in Annex 6.4, Table A.6.2.

Figure 6.5

Monthly precipitation (blue line) against crop evapotranspiration (ETo*kc) for three crop rotation schemes: cassava-squash (brown line), sweet potato-beans with sweet potato planted in September (grey line) and sweet-potato beans with sweet-potato planted in January (light-brown line)



Source: computations based on Allen et al., 1990 and BADMC, 2020a

The results clearly show that well-planned planting schemes that take crop-specific demands into account might be a powerful measure for addressing prevailing water scarcity. Crop rotations of cassava-squash and sweet potato-beans (sweet potato planted in September) follow precipitation patterns and require small amounts, if any, of additional irrigation. The sweet-potato-beans combination where sweet potato is planted in January suffers from obvious water deficiency during the first four months.

Overall, the SHLLP programme received high marks for its performance (see Table 6. 1). That is not to say that the project did not experience difficulties: the initial stage was underfinanced and the public authorities could not meet the expectations of the farmers. The initial advice to retain an interest in sugar cane cultivation turned out to be inefficient and non-profitable. Yet the perseverance and endurance of farmers and support from public authorities resulted in a highly sustainable project. Water deliveries were assured by pumping systems. A wide variety of crops is grown that makes an attractive contribution to the fresh foods in local markets. The willingness of farmers to adopt novel energy-saving measures and organic farming methods will meet the future demands of environmentally-conscious consumers. Overall, the SHPPL was an interesting pilot that can serve as a model for similar activities in other areas of Barbados to meet the political targets of increasing the number of farmers and reducing the food import bill.

Table 6.1

SHLLP project evaluation

Trans-discipline	Multi-discipline	Institutional collaboration	Funding	Social impact	Ecosystem changes	Delivery	Success/ failure	Sustainability
++	+	++	+	++	+	+	++	++

6.2. SUGAR CANE IN MAURITIUS: COLONIAL INHERITANCE UNDER PRESSURE

In modern Mauritius, the colonial past is still evident in the overwhelming presence of sugar cane on the island. Sugar cane remains important to the economy, employing 11 percent of the workforce and contributing six percent to national income (Palerm *et al.*, 2012). Increasing labour costs and unfavourable prices, however, have led to a rapid decline in the sugar sector and large-scale abandonment of sugar cane land (see Text Box 2).

Institutionally, the reduced importance of sugar has also become more visible: the Mauritius Cane Industry Authority, previously owned and organized by the private sector is now fully funded by the government.

Broadly speaking, there are two trends in land conversion in Mauritius, both of which influence water governance. Former sugar cane land is being transformed into built-up areas for universities, golf courses and housing, and agriculture is diversifying into food crops (e.g., macadamia and other nuts, cocoa, potatoes and onions).

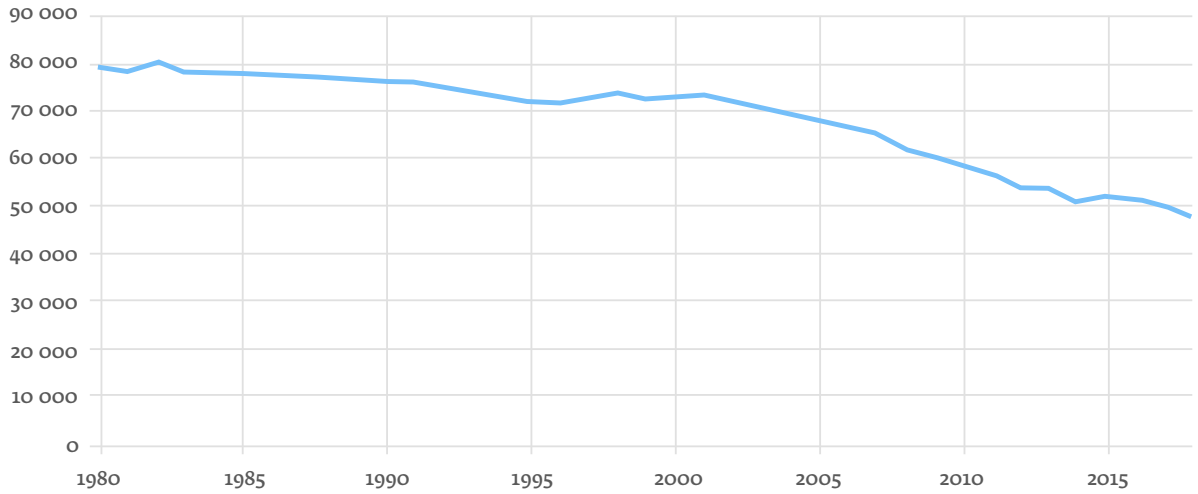
Surprisingly, sugar cane cultivation, despite the recent significant reduction in cultivated area (see Figure 6.6), still capitalises on the privileged water acts and related water rights that were issued during the colonial period. New water-demanding initiatives cannot rely on sources that are owned by the sugar cane industry. Indeed, based on the claim that Mauritius has reached the peak of its ground- and surface water resources, few opportunities are left for additional water-demanding activities.

Text Box 6.2: Sugar and prices

Sugar from Mauritius enjoyed tariff-free access to Europe since 1970s. Under preferential trade arrangements, Mauritius' export prices were comfortably above world market level. In 2005, the World Trade Organization forced the EU to reduce sugar subsidies. Sugar continues to be imported under the EU duty-free preferential agreement, but imports have fallen in recent years because of lower EU prices. As the EU moves towards increase production of removing its production quotas, the surge in EU sugar production will further reduce import demand.

Figure 6.6

Sugar cane area in ha over the period 1980-2020



The exploitation of water resources by a rapidly increasing urban population and tourism sector is currently testing the limits of the water supply. Hence, it may be that the future of Mauritius may depend on freeing up the water supply and water rights currently held by the sugar cane industry. Interviews were held with water experts in Mauritius to shed light on institutional responses to the changing environment. The responses of the interviewees are grouped into the following thematic areas: land conversion: implications for water management; water allocation to agriculture; water policies: drilling by smallholders; limitations to groundwater exploitation.

In-depth interviews

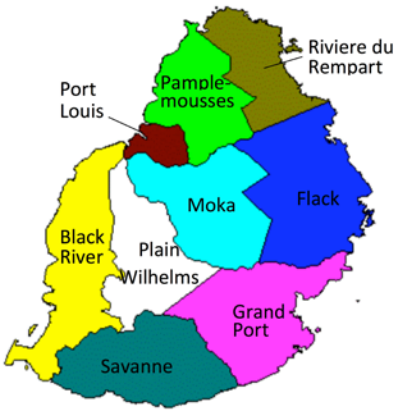
The interviewees and their respective institutes are briefly introduced below.

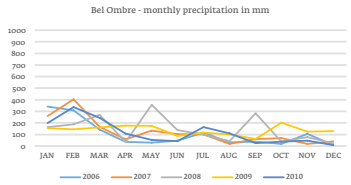
A full listing of attendees of the interviews is provided in Annex 6.5.

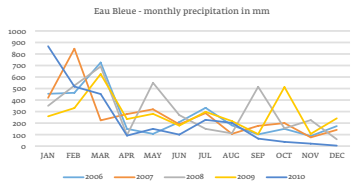
- *Chandrasen Matadeen, General Manager, Central Water Authority (CWA)*. The CWA was established in 1971 and operates under the aegis of the Ministry of Energy and Public Utilities. The CWA is responsible for the treatment and distribution of potable water for domestic, commercial and industrial usage. There are 104 service reservoirs and about 440 boreholes on the island, 195 of which are under CWA authority and are monitored daily in the dry season. Licenses are issued to private owners.
- *Ganeshan Seelavarn, Chief Executive Officer, Food and Agricultural Research and Extension Institute (FAREI)*. In 2014, FAREI was created to merge the functions of the Food and Agricultural Research Council and the Agricultural Research and Extension Unit. FAREI operates under the aegis of the Ministry of Agro-Industry and Food Security and is responsible for research and extension services in non-sugar crops, livestock and forestry. FAREI ensures that consumers have sufficient and healthy foods. FAREI employs 545 staff.

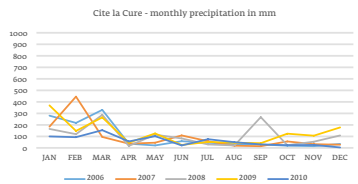
- *Raj Kamal Soniah, Chief Executive Officer, Mauritius Cane Industry Authority (MCIA)*. The mission of the MCIA, established in 2011, is to promote the sugar cane sector through innovative and efficient services, research and development. In Mauritius, the sugar cane industry directly employs about 20 000 people.
- *K.C.S. Kong Thoo Lin, Head of Operation and Maintenance Department, Irrigation Authority (IA)*. The IA is a parastatal body established in 1978 and operating under the Ministry of Agro-Industry and Food Security. Its overall objective is to study and develop irrigation and to carry out research on the optimum use of water. IA is responsible for issuing irrigation permits and manages around 2 500 hectares of irrigated land (the total irrigated area in Mauritania is about 17 000 hectares).
- *Lomush Juggoo. Water Resources Unit (WRU)*. The WRU, established in May 1993, operates as a department under the Ministry of Energy and Public Utilities. The WRU is governed by the Central Water Authority Act and is responsible for the assessment, development, management and conservation of water resources. The WRU issues groundwater abstraction drilling permits and supervises water rights.
- *Navindranath Jowaheer, Officer in Charge, Wastewater Management Authority (WMA)*. The WMA, established in 2000, operates as an autonomous organization under the Ministry of Energy and Public Utilities. Its core activities include the collection and treatment of domestic, commercial and industrial wastewaters for disposal in an environmentally acceptable manner. WMA employs about 495 staff.

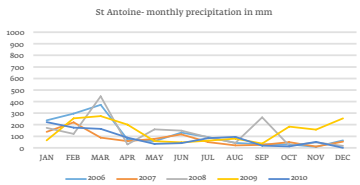
Text Box 3. Key facts about Mauritius

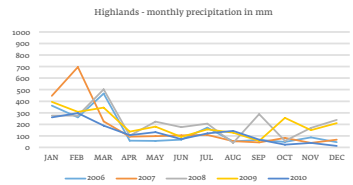


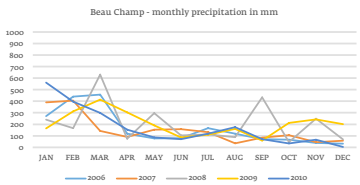












Land	Km²
Total area	1 865
Agric. land	860
Forest	390

Population	in 000
Rural	751
Urban	517
Total	1 267

Region: AIS

Geography and environment

- volcanic island
- precip/ann. 1 650 mm
- clayey soils
- fragile coral reefs
- stress factors: high population density/ tourism/ wastewater

Land conversion: implications for water management

Driven by the scarce availability of water resources, the Food and Agricultural Research and Extension Institute (FAREI) has developed special water management programmes for abandoned sugar cane parcels. FAREI encourages the use of sheltered agriculture to increase water use efficiency while reducing fertilizer and pesticide use. FAREI's recommendations were widely adopted and, over the past 20 years, the number of sheltered units increased from six to more than 1000. The research strategy of the Wooton Crop Research Station at Quatre Bornes is aligned with FAREI's policy, focusing on testing innovative drip irrigation systems for sheltered farming. Experimental settings at the Research Centre bring the irrigation systems under fully automatised conditions, using internet connections for control and system operations. Economic incentives are available from the government for the purchase of water-saving techniques[9], implementation of sheltered farming, rainwater harvesting and agricultural equipment for irrigation purposes. FAREI notes that the targeted cultivation of fresh crops under sheltered conditions is in line with the strategic plan of the Ministry of Agriculture to "improve agricultural diversification and productivity to ensure further food security (Ministry of Agro-Industry and Food Security, 2016)." Modernisation and investment possibilities should attract a new generation of farmers and curb labour shortages in the agricultural sector.

The land conversion schemes had implications for projects that fall under the Irrigation Authority (IA). For example, IA projects in North Mauritius started after extended droughts in the late nineties, when the production of sugar cane reached dramatically low levels. The centre pivot Irrigation scheme focused on sugar cane cultivation and met with success. Improved irrigation conditions yielded high production levels and farmers returned to the fields they had previously abandoned. Yet the revival did not last long. During the past decade, due to low prices and high labour costs, farmers started abandoning their fields again or started planting more profitable crops like vegetables. FAREI indicated that there is no interest in cultivating main staple crops (wheat and cereal), which are much cheaper to import. Moreover, local vegetables are much in demand by consumers. This has presented the IA with a dilemma since the weekly irrigation schemes of the centre pivot systems are not suited to the daily water requirements of vegetables, including peppers and potatoes. As a result, IA established several smaller pumping stations that connected a drip irrigation system to the fields (see the Northern Plains Project).

The land conversion also had impacts on soil erosion and flash flood hazards. Replacing the year-round soils that cover sugar cane with the intensive weed management of vegetable crops left soils very exposed to rainfall erosivity. FAREI aims to curb this threat through drainage systems of contour and infiltration ditches and contour ploughing in sloping areas to canalise excessive water flows. Yet these practices are uncommon and are still at their infancy.

Water allocation to agriculture

The government has established a national Water Resources Monitoring Committee comprising an interdisciplinary group of specialists from major water institutes in Mauritius. Generally

9 Other water collection initiatives are found at schools and colleges, where rainwater harvesting techniques are used to supply water for irrigation and domestic purposes. CWA pointed out that they are working with some banks to provide incentives to encourage rainwater harvesting.

speaking, agriculture has a low priority compared to other sectors (mainly industry and hotels) during times of drought. During dry spells, massive water cuts adversely affect farmers.

Water policies: drilling by smallholders

Smallholders who convert their land uses from sugar cane to other crops are not allowed to drill their own wells and must rely on water provided by the IA. The smallholders are obliged to apply for licenses to drill their own boreholes. Yet this frequently creates a problem when water from the newly-drilled boreholes is not only used for its intended irrigation purposes, but also to deliver potable water. This is considered an illegal activity since only CWA is authorised to supply potable water. Furthermore, licenses to operate private boreholes usually have an exploitation limit dictated by their position relative to CWA's boreholes. While borehole drilling is done under the supervision of the WRU, in practice sporadic checks are conducted by the same institute to control water abstractions.

Non-revenue waters

The representative of CWA indicated that large water losses occur when pumped water is injected into the distribution system; this is the main reason that water supply goals cannot be reached: "So, one of the problems of the moment is 24/7 supply of water because we have nearly about 65 percent, which receives 24/7 and our target is 100 percent." He noted that low water tariffs impeded the financing of more efficient water infrastructure, which could reduce non-revenue waters from its current rate of 50 percent.

Limitations to groundwater exploitation

CWA's main concern is groundwater abstraction. The CWA representative pointed out that Mauritius has reached the peak of its groundwater exploitation capacity; the government has now started to investigate possibilities for surface water exploitation. A groundwater license committee is working with CWA to check abstraction levels. The main focus of CWA is to promote the collection of surface water resources, mainly by constructing dams.

It should be noted that the overexploitation of the groundwater levels is contested by other institutes. FAREI attributes growing tension between water users around the water rights of the sugar cane industry and large corporate firms that use water for golf courses and tourism, leaving small growers with little to no access: "... small growers don't get access to ground and river waters for example because they don't have water rights. That's the issue we see very often."

The FAREI representative raised the following question: "... [S]hould we introduce for small farmers more efficient water systems or should we revise the water act that gives so much water to the sugar cane sector?"

Institutional collaboration

Mauritius has adequate institutional capacity – through CWA, WRU, IA and WMA – to cover the important elements of water governance. The institutional collaboration formalised in the Water Resources Monitoring Committee enables members to monitor, on a weekly basis, the availability of water resources. The committee oversees the allocation of water resources in times of scarcity.

The WRU representative explained that Mauritius follows an integrated management approach involving all water stakeholders. The approach, known as Ridge to Reef, involves a comprehensive water governance concept that focuses on the interaction between inland water flows, groundwater storage capacity and coastal waters. He added that sustainable development should take into consideration key elements, such as water quality, sustainable delivery to meet increasing water demand and the function of inland and coastal ecosystems: "... development should be in a sustainable way, meaning that it should take good care of the social component, the economic component, and also the environmental component."

Water users' associations are not represented on the Water Resources Monitoring Committee. For large water infrastructural projects, CWA and IA organize stakeholder consultations to ascertain present and future requirements of irrigation and water delivery schemes. WRU participates in working sessions of FAREI and collaborates in specific projects.

Reusing water

The FAREI representative observed that the reuse of water by the agricultural sector is highly unlikely: "People won't really go for reused, recycled water in agriculture. Except maybe some in hydroponics, maybe they can."

CWA noted that recycled wastewater is billed separately, i.e., as potable water and wastewater. Some treated wastewater can be mixed with groundwater and used for irrigation. CWA acknowledged that several hotels reuse grey water for irrigating lawns and golf courses. There is a policy for using treated water for irrigation (National Audit Office, 2020), as noted by FAREI, however, people do not yet accept the use of treated wastewater.

Water policies: water quality

WMA connects 89 000 customers to the sewage system; this represents about 27 percent of the population, mainly located in the central western part of Mauritius. In total, 110 MCM of wastewater are collected annually and 47 MCM are treated in four major and six minor wastewater treatment plants (WWTPs). About two MCM of the treated wastewater are used to irrigate sugar cane. About 60 hotels have their own WWTPs. WMA generates revenue from domestic and non-domestic tariffs and wastewater services: "The revenue collected covers 100 percent of the operational costs." Sewage blockages due to dumping of unsanitary disposal in toilets are a major problem.

Alarmingly, 73 percent of the population is not connected to a sewer system. On-site disposal systems consist of cesspits and septic tanks. About 80 private wastewater tankers discharge

the septic tanks into a wastewater station from which waste is pumped to a major wastewater treatment plant, where it undergoes preliminary treatment before disposal through a long sea outfall.

CWA explained that extracted water is chlorinated, put in reservoirs and then supplied to the public. Quality checks are done on a daily basis, including to measure the amount of residual chlorine in the water. These checks are assessed against WHO criteria. The water quality tests are done at CWA's laboratories. A water quality committee at the ministerial level monitors the quality of effluent discharge from treatment plants.

FAREI pointed out that there is a Pesticide Regulatory Office that oversees pesticide use. FAREI is also concerned with sampling at the farm gate to determine the quality of the pesticides used by farmers. Acknowledging that Mauritius uses large amounts of herbicides (5 kg per hectare), FAREI argued, that, " ... the issue of the figure is that we have 50 000 hectares in the sugar cane and in sugar cane a lot of herbicides goes in ...."

Concerns and opportunities: Mauritius

A typical concern that emerged from the interviews is the continuing claim of the sugar industry to water rights, despite declining interest in sugar cane cultivation. Farmers that switch from sugar cane to other land uses lose their water rights and must rely on the Irrigation Authority. Research on local water balances could reveal whether traditional water acts are still needed for sugar cane cultivation or whether traditional water distribution could be reallocated more efficiently to cultivate other more desired crops.

Greater representation of water users on the Water Resources Monitoring Committee could further strengthen and improve decisions on water allocation in times of scarcity.

The Northern Plains Project

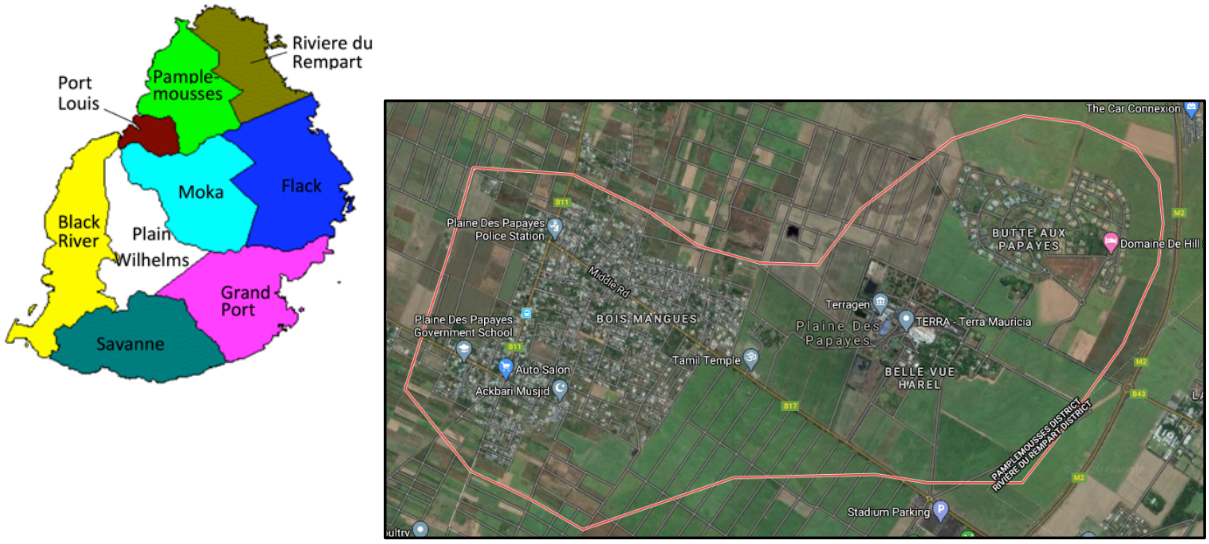
This section analyses recent water management and agronomic developments under the Northern Plains Project (NPP). The Northern Plains are located in the districts of Pamplemousses and Rivière du Rempart, close to the agglomeration of Plaines des Papayes (see Figure 6.7). The NPP covers 38 000 ha, more than 50 percent of which is used for agriculture, mostly sugar cane (17 300 ha).

We first describe the NPP in general and then focus in on the development of a farmers' association near Plaines des Papayes.

In the late 1990s, extended dry spells occurred in northern Mauritius, with dramatic drops in sugar cane production as a direct consequence. It was against this background that the Government of Mauritius approached in 2004 the African Development Bank (ADB) and the Arab Bank for Economic Development in Africa (BADEA) to assist in financing the installation of irrigation systems over 1 377 ha occupied by some 1 530 small planters in the northern region of the country (AfDB, 2004).

Figure 6.7

Northern Plains Project near the Plaines des Papayes (pink border), Pamplemousses District



With this investment, the NPP[10] sought to boost agricultural production in line with the government's strategy at the time to increase the revenue of small sugar cane planters. Feasibility studies showed that returns from irrigated production are higher than for rainfed production, even for simulations with high discount rates (10 to 20 percent) and high interest rates (9 percent) for loan repayment.

The history and outcomes of the NPP are detailed below.

Geography and climate

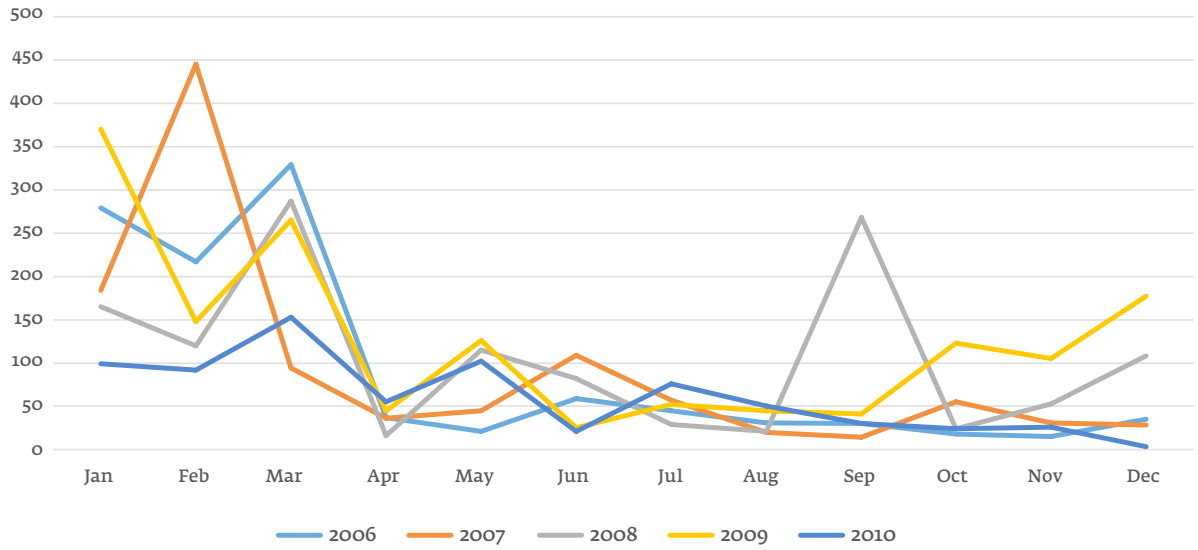
The NPP area is characterised by rainfall patterns as depicted in Figure 6.8. The principal rainy season occurs from January to March. Annual rainfall oscillates between 750 – 1 500 mm, with an average of 1 155 mm over the period 2006-2010. These figures do not reflect the extended dry spells that were experienced during the late 1990s, when sugar cane production dropped to 20 – 30 tonnes per ha.

The landscape is characterised by flat plains and slightly (< 8 percent) undulating terrain. The dominant soil types are Low Humic Latosols and Latosolic Red soils (Aldridge, 1973). Humic Latosols are well and deeply developed, with deep dark reddish-brown soils or brown silty clay soils on clay; little to no boulders or stones are found in these soils. Humic Latosols are characterised by a thin fertile layer of humus dropped from plants and animals, followed by an infertile second layer that is leached due to high rainfall. Latosolic Red soils are similar to Latosols, but contain more clay; the sand fraction largely consists of concretions. The soil structure of Latosols and Latosolic soils are generally strongly granular. Crossing from south-

10 NPP has four main components: land preparation; technical assistance; installation of irrigation infrastructure; and project management and institutional support (AFDB, 2020).

Figure 6.8

Monthly rainfall in mm. Station Cite la Cure 2006-2010



west to east- north in the Plain de Papayas area, we find shallow soils, which might indicate previous long-term erosion. Humic Latosols have a stone phase (see Figure 6.9). The soil type description shows that with additional (inorganic or organic) fertilization and de-rocking of the stone phase, soils are suitable for cultivating a wide variety of crops. On the sites visited for this study, the fields had well-structured soils, with a small organic layer in the topsoil. The suitability of the soils was confirmed by the variety of vegetables that were cultivated.

History and development

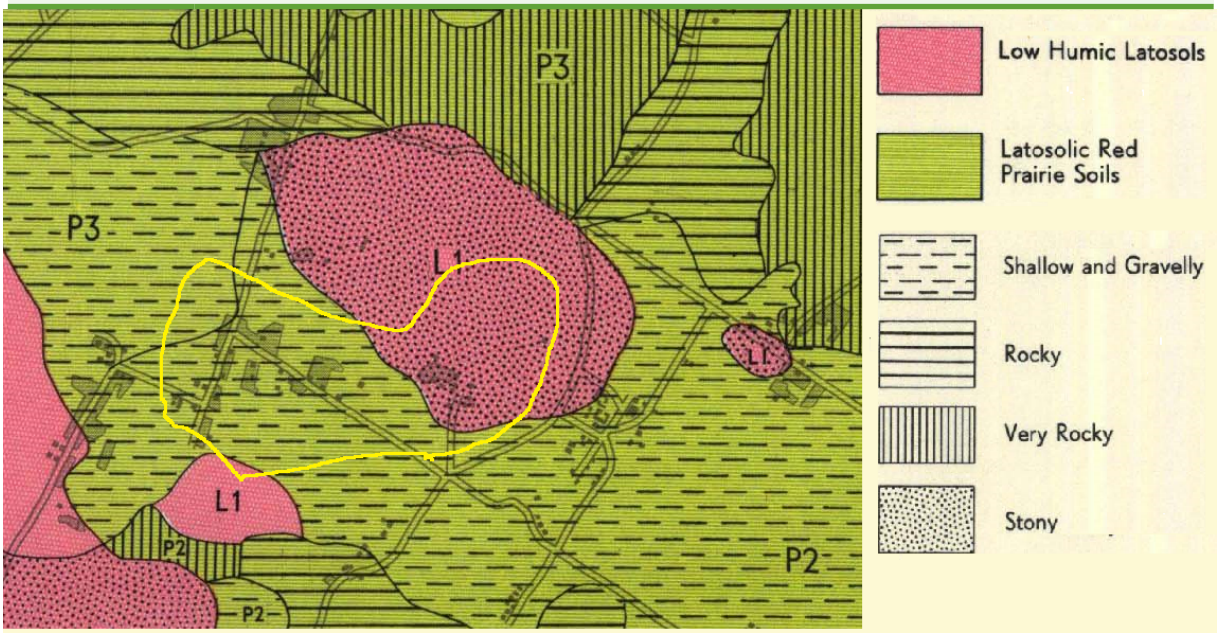
The NPP began in 2000 as a response to the vast droughts that occurred in the 1990s, leading many farmers to stop their agricultural activities. Orchestrated by the government, the IA was assigned to install an efficient irrigation system that could meet the water requirements of farming systems, with a major focus on the sugar cane industry.

The IA upgraded the conveyor system linking the La Nicolière Reservoir with the project area by constructing buried pipelines connected to the centre pivot irrigation systems (see Figure 6.10). These systems irrigate crops in a circular pattern around a central pivot. They use a radial pipe supported by wheel-driven towers, which contain equally-spaced nozzles that release water for irrigation. The subsurface pipelines connected to the centre pivot systems can cover 40 ha with 2000 m^3 per day. In total, IA established 26 centre pivot systems.

The centre pivot irrigation systems were welcomed by farmers, who returned to their fields en masse, achieving spectacular yield levels between 200 and 300 tonnes per ha (while less than 20 tonnes per ha had been produced during the dry years). A length of growing period analysis (see Figure 6.11) clearly shows the need for additional irrigation between July and November.

Figure 6.9

Soil map of Mauritius near the NPP. Border of Plain de Papayes indicated by the yellow line



Source: Department Survey, 1962

Another difficult time followed in 2005, when Mauritius enjoyed tariff-free access to Europe; various preferential trade arrangements became much less financially attractive and world market prices for sugar decreased rapidly. The government's Non-Sugar Sector Strategic Plan (2001-2005) urged a departure from cane monoculture and the diversification of crop cultivation to: i) increase food crop and livestock production in essential commodities; ii) liberalise markets and support private sector development; iii) optimise the use of water resources by introducing efficient irrigation systems and increasing water storage capacity; iv) make the best use of agricultural lands while maintaining annual sugar production between 625 000 – 700 000 tonnes; v) diversify agricultural production for local consumption and export; and vi) ensure national food security by producing adequate supplies of basic food items at competitive prices (ADB, 2004).

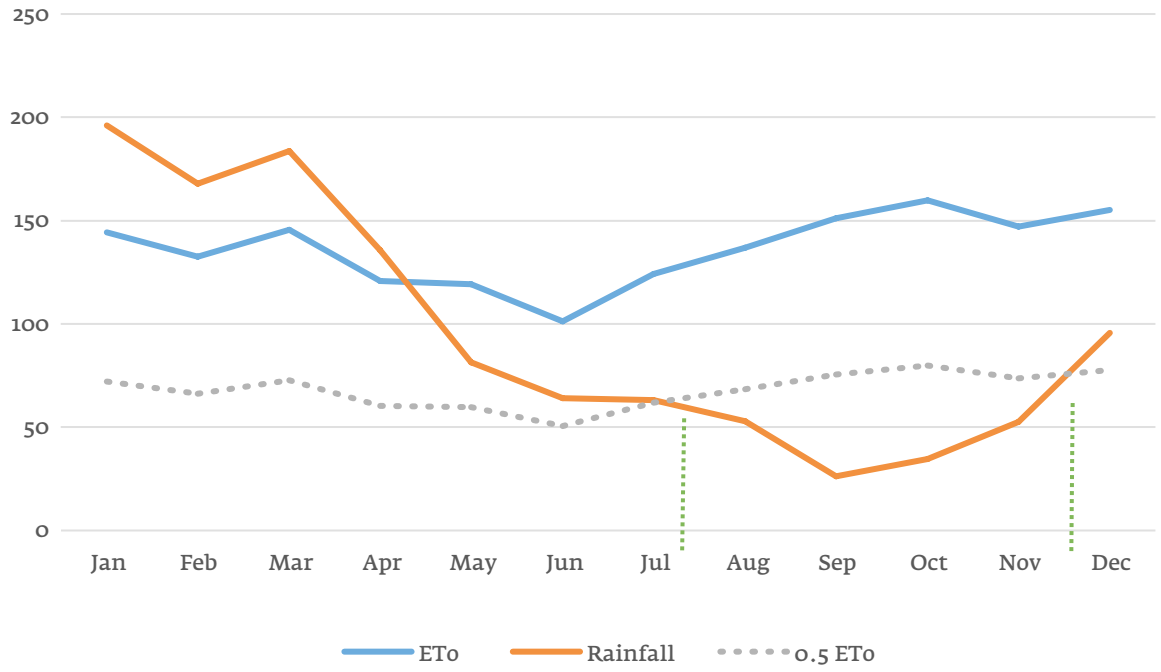
Figure 6.10

Centre pivot irrigation systems, Northern Plains Project

Source: authors' photo

Figure 6.11

Length of growing period analysis. Average rainfall (in mm) and evapotranspiration figures (in mm) for 2012-2019. The green vertical lines indicate the start (July/August) and end the growing period (November/December) when additional irrigation is needed



Source: Department Survey, 1962

The IA was willing to assist the NPP farmers to change their crop composition; however, this demanded serious adjustments to the irrigation infrastructure. The weekly irrigation schemes and spatial division of water of the centre pivot systems were not suitable for the daily water requirements of vegetable cultivation. The IA established several small pumping stations, which were connected to a drip irrigation system that could cover approximately 20 hectares. One of the farmers' association began to use drip irrigation successfully and are now producing a diversity of vegetables and other food crops. The vegetable farmers organized an association with a focal point to communicate to the IA. Nevertheless, in recent years, a shortage of labour and the difficulty of finding young people willing to inherit farming activities has harmed cultivation density and, once more, has led to the abandonment of fields.

From sugar to solar

Under the leadership of its secretary Vijaye Chutundharee, the farmers' association in the Plain de Papayes won a bid for the installation of a solar panel project of approximately 20 ha (see Figure 6.12) on the grounds that the land would be leased and not sold. The result was that each farmer that participated in the project received USD 1 833 per ha with a 2 percent increase annually while maintaining full access to the participating farms. The use and functioning of the original drip irrigation remained and placement on elevated standards guaranteed easy access below the solar panels. Though still in its experimental phase, a cultivation trial was

Figure 6.12

Solar panels on fields of the farmer association, Plain de Papayes

Source: authors' photo

Figure 6.13

Cultivation under solar panels

Source: authors' photo.

started, in between and under the rows of solar panels (Figure 6.13). The farmers' association wanted to convert to fully organic cultivation of the crops, which would allow them to strengthen their marketing position. The association is preparing a website where products can be ordered online, with a transport service for daily or weekly deliveries.

The endurance of the farmers in the NPP has been seriously tested over the past few decades. Yet those who were able to adjust witnessed a successful transition (see Table 6.2) from small-scale unprofitable sugar cane cultivation to the highly profitable cultivation of fresh crops using solar panels.

Table 6.2

NPP project evaluation

Trans-discipline	Multi-discipline	Institutional collaboration	Funding	Social impact	Ecosystem changes	Delivery	Success/ failure	Sustainability
++	++	+	+	++	+-	++	++	+

6.3. CONCLUSIONS

Water governance issues for the islands of Barbados and Mauritius must address shared concerns around growing water stress. Both islands have exhausted their groundwater reservoirs, which increases the need to collect and exploit surface water resources as well as increasing the efficiency of water use. Mauritius is concentrating on expanding the number of its surface water reservoirs and both countries have launched initiatives to encourage the use of rainwater harvesting techniques. The largest advancements in Barbados and Mauritius

are, however, in the improvement of agricultural water use efficiency. Both islands have implemented large-scale drip irrigation schemes through state-sponsored programmes. Our visits to projects on the two islands show that well-planned irrigation interventions, combined with innovative farmer interventions, can contribute to successful and economically viable agricultural undertakings.

Both Barbados and Mauritius maintain monitoring systems to supervise the exploitation of ground and surface water reserves. Yet maximum water extractions are seldom enforced, according to water management professionals. Given the precarious situation of groundwater reserves, both countries are considering metering systems. Yet without enforcement, the overextraction of water is likely to continue. According to the interviewees, social bonding impedes the imposition of penalties as it is ostensibly difficult to reprimand close friends and acquaintances. Hence, awareness campaigns might be a useful means to engender greater concern around the extraction of groundwater resources.

With the implementation of drip irrigation and sheltered farming, agricultural water management systems appear to have reached the limits of their efficiency. Greater water efficiency gains will require the improvement of water infrastructure. Both countries report that bringing pumped and collected water into the water distribution system leads to large water losses. Yet reducing non-revenue water losses will require large financial investments that are currently not covered by the low tariffs that in both countries are paid by water consumers.

Interviewees are aware that prices are a powerful instrument for defining water governance. Hence, an appropriate valuation of the water tariffs will lead to the improved economic use of water resources and neutralise the large investments that are required.

Barbados and Mauritius reported that traditional water rights require an update to meet the standards for modern water governance. The water rights held by the sugar cane industry particularly require attention, since the cultivated area occupied by sugar cane has decreased considerably in the last few decades. The release of water rights to small farmers will improve the reliability of water deliveries, which is key to agricultural development. Both case studies show that farmers tend to abandon their fields to seek other employment when water deliveries cannot be guaranteed.

Few island inhabitants are connected to the sewer system. Untreated or partially treated wastewater from households and industry, and the overuse of pesticides in agriculture directly affect the aquifers and coastal zones, which are a vast asset for the tourism industry. Monitoring systems in both countries can ensure that groundwater quality meets the required standards. Implementation of treatment plants should avoid negative ecological effects of untreated or partially treated wastewater flows.

The reuse of water has serious cultural constraints on both islands. The reuse of treated water for agricultural purposes is undesirable or even explicitly forbidden. There is some incidental use of treated water for irrigated green zones surrounding hotels. Most water professionals acknowledge that repurposed wastewater is used to alleviate water shortages, especially in times of drought.

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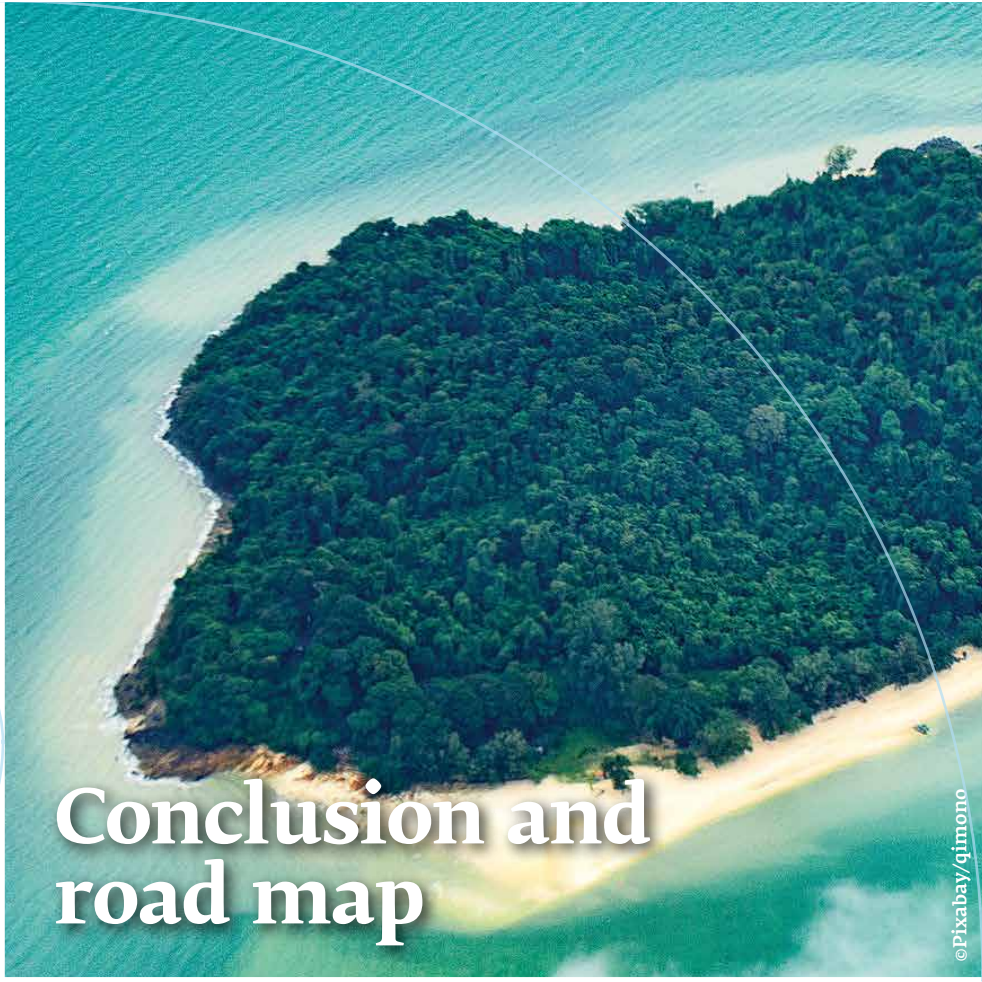


Conclusion and road map

We conclude this report by answering the question posed in Section 1: "How can freshwater management serve Food security and Nutrition in Small Island Developing States?"

The question is not a trivial one. This study has shown us that FNS conditions in SIDS merit a higher place on political agendas. Few SIDS meet food diversity standards and most islands suffer from micronutrient deficiencies, with dire health consequences, especially for the poor.

7.1. SYNTHESIS

This subsection synthesises the findings of the study and provides the basis for the road map presented in 7.2.

SIDS challenges

Small Island Developing States generally have a limited amount of land and water resources. They are remotely positioned with regard to continental areas and other islands and are poorly connected to shipping and trade routes. SIDS are disproportionally hit by extreme weather events, which are on the rise due to climate change; this aggravates the already precarious FNS conditions. These conditions make most SIDS highly dependent on food imports.

Restrictions on land and water resources

The so-called 'high' islands get most of their water resources from surface waters, while 'low' and 'mixed' islands have greater groundwater reserves. There is no clear pattern for groundwater withdrawals when islands are grouped by terrain conditions.

The study shows that limited land availability in SIDS impedes the supply of fresh and healthy foods under low input agriculture. Most high-quality land is occupied by monoculture cropping systems that were introduced during the colonial period. On the positive side, under high input conditions, prospects for agricultural development improve and provide agricultural entrepreneurs with opportunities to invest in high value chains that could enrich food diversity.

Efforts by SIDS to substantially increase the domestic production of fresh and healthy food are a necessary first step to reversing eating patterns dominated by imported foods that are high in saturated fat and refined sugars. Yet the expansion of land area and conversion of monocultures to more diverse crops are hindered by the limited availability of freshwater on the islands.

The study shows that competition with other water users is the primary factor limiting the availability of freshwater resources for agriculture, rather than the amount of rainfall or the small natural catchment areas. Under current water governance laws, the agricultural sector particularly suffers in times of water scarcity because it ranks lowest among all water-consuming activities.[1]

The main water competitors include:

- A rapidly urbanising population that claims more water rights as it becomes more affluent. Most new built-up areas near the coastlines practice uncontrolled overextraction from shallow groundwater reserves, leading to sea intrusion and the salinisation of aquifers.
- A growing tourism sector, an important source of income for the SIDS, which demands fresh and clean water.
- Ecosystems, whose silent calls for freshwater are now fully heard in the Sustainable Development Goals, where environmental flows demand their rightful shares.

According to the findings of the study, water competition is likely to become fiercer in coming decades, especially in high income SIDS countries, as increasing water scarcity and drought impair the delivery of fresh water. Stress scenarios show that most high-income countries will transition to the 'very severe' water stress category over the next 10-30 years.

Water governance

Water governance offers various options for addressing reduced water availability while upholding quality standards of freshwater resources in the SIDS. Discussions around water

[1] Survey respondents put agriculture in second place, after households, but before industry and tourism.

governance are concerned with legislation, control and enforcement; water use efficiency; institutional collaboration; trans- and multidisciplinary participation; and water quality.

Water legislation, control and enforcement

Survey respondents and interviewees attributed water legislation[2] to the national authorities. They indicated that water managers do not have incentives to implement or enforce water laws, with the result that they become obtuse and meaningless rules and regulations.

The study identified two reasons for the lack of oversight and enforcement:

- First, the close social and familiar bonds on small islands make it difficult to penalise acquaintances. Respondents suggested that awareness campaigns could prompt positive behavior by water users while explaining the need to penalise water abuse.
- Second, rules and regulations are often based on inaccurate water flow information and this can stymie efficient enforcement. The survey results indicated that more resources should be made available for data collection. The study also established that data scarcity problems do not only refer to the absence of information, but also to data that is poorly organized and thus not really available to inform water managers about critical issues.

Gaining efficiency

Increasing the efficiency of water use in SIDS can be realized by various means:

- Reducing large non-revenue water losses in conveyance systems. Both Barbados and Mauritius reported that 50 percent of pumped and collected water does not reach the distribution system. Reducing such losses would increase both water and energy efficiency. While the infrastructural interventions needed to reduce water losses will be costly, they will pay dividends in the long run, especially as energy prices continue to increase.
- Controlling and storing freshwater to ensure stability and the increased efficiency of water use in crop production systems. The use of rainwater harvesting is important in this context because it increases the efficiency of water flows at watershed (dam), field (small dam) and household (e.g. roof water) levels. The study found that the availability of water during dry spells is critical, not only for selecting appropriate crop rotations but also for deciding whether farming is still feasible or if employment has to be found elsewhere. Storing water for additional irrigation becomes even more important to compensate for increasingly erratic rainfall patterns under climate change. Water governance could advocate the upscaling of rainwater harvesting especially on islands where these techniques are not traditionally in use.
- Recycling water after use, provided that quality standards are met for the new purpose. The study found serious cultural – and sometimes legal – constraints to reusing water

[2] Water legislation assigns the basic principles of water management to ensure the sustainable exploitation of water resources and deliver penalties for non-compliance with prescribed water regulations.

for agricultural purposes. Some incidental reuse of treated water for irrigated green zones around hotels occurs in Barbados and Mauritius, but there is no widespread practice of repurposing wastewater. Nonetheless, many interviewees acknowledged that reusing water is important for alleviating water shortages, given the condition that water treatment procedures are up to date and of good quality.

- Increasing water use efficiency through advanced irrigation systems, especially when combined with sheltered farming. Projects in Barbados and Mauritius provide evidence that technical innovations increase water use efficiency and economic success. Additionally, water-efficient food production alternatives, like allotment gardens and hydroponic-related systems, can be established at a relatively small scale and empower poor people in urban and peri-urban areas to take food diversity into their own hands.
- Updating traditional water rights to meet standards for modern water governance. In Mauritius: water rights dating to the colonial era's sugar cane industry remain largely untouched, despite a considerable reduction in cultivated sugar cane area. The effects of releasing water rights to small farmers are very positive, especially when small farmers convert from industrial monocropping to a more diverse cropping pattern. On the other hand, when water deliveries cannot be guaranteed, farmers will abandon their fields to seek employment elsewhere.

Institutional collaboration

The study concludes that most water governance institutes use a top-down approach to decision-making with limited involvement of local agencies, NGOs and stakeholders. It is critical to understand that the full involvement of stakeholders is not an end in itself, but a means to align project development to social objectives. For example, while determining infrastructural adjustments to improve water availability might not need the involvement of a large group of stakeholders, interventions at the watershed level, where upstream activities impact downstream water users or when responsibility for the water system lies with water users, will most definitely require stakeholder support. Yet only a few watershed projects were found to utilise a clear transdisciplinary approach. The degree of transdisciplinarity deserves more attention at the start of the project for consultation and alignment with stakeholders, during the project phase for regular feedback and during the end phase to ensure sustainability and define tasks for custodians in the post-project era.

Most projects involve the participation of various public organizations. Yet these partnerships are biased towards technical and engineering disciplines. The case studies and project visits undertaken during this study provide evidence that including economic, social and communication disciplines in project management could improve the sustainability of results once a project has ended.

The study missions to Barbados and Mauritius revealed that freshwater resources are critical for fostering production systems of healthy vegetables and fresh foods on a small scale. Developing traditional (allotment gardens) and modern (hydroponic) techniques can start the production of fresh and healthy foods on small fields or even at the household level in urban, peri-urban and rural areas. The relatively low investment costs and high productivity make these small-scale crop production systems especially attractive for low-income groups.

Water quality

According to our research, all actors involved in water management in SIDS are highly concerned about water pollution. The collection of wastewater from households and industry is limited and the level of water treatment is far from satisfactory. Only a small percentage of the population is connected to a sewer system and, in many cases, treatment procedures fail to meet minimum water quality requirements. Large scale dumping of untreated or partially-treated wastewater is common, seriously affecting coastal ecosystems. The study found that, in some SIDS, pollution has entered the drinking water and sanitation systems with a negative impact on children's development. Our in-depth interviews during island visits revealed that legislation to stop the dumping of wastewater is in place but is rarely enforced.

Overuse of pesticides and herbicides affects water quality in both surface and groundwater reserves. Although monitoring systems in Barbados and Mauritius did not detect alarming levels, ensuring against overly high concentrations of pesticides will require appropriate policies and enforcement. The reactions of the farmers at the two projects we visited were encouraging, indicating that organic cultivation is seen as the future of agricultural development. Nevertheless, despite growing awareness, it seems that the SIDS are still turning a blind eye to their water pollution problems.

7.2. A ROAD MAP TO AGRICULTURAL WATER MANAGEMENT IN SIDS

Water policies to support FNS should capitalise on the strong points of the SIDS, such as the proximity and interconnectedness of water resources and strong social bonds in the relatively small island communities. The responsible management of water resources requires the involvement of all relevant stakeholders in seeking tailored and durable solutions, ranging from policies to sustain the supply of freshwater, to the appropriate treatment of return flows, to the development of particular niches in the water economy like high end water saving and water purification technologies and advanced sensored drip irrigation systems.

Water governance in SIDS should be based on a clear understanding of their heterogeneity in terms of geography, economy, ecology and politics. This report describes the explicit steps needed to develop such a governance approach. These include fact finding to characterise the SIDS resources; producing an inventory of reports on water management projects, preferably accompanied by an independent evaluation; conducting in-depth interviews on water-related issues with water authorities and representatives of water users; producing a synthesis of findings and developing a SIDS-specific road map to bring the water economy to a higher level. Within the scope of this report, there is only limited room to do justice to the diversity of the SIDS, and hence the road map presented here should be seen as a framework that needs additional tailoring for specific islands. With this qualification in mind, the following steps are useful for improving the functionality of freshwater resources, especially for FNS.

1. *Gaining efficiencies.* Limited water availability in the SIDS needs to be addressed by increasing efficiencies in water conveyance and water use. Costly infrastructural investments at both meta- and field levels are therefore required, bearing in mind that

the long-term benefits of such investments open up avenues to spread users' reimbursement over extended periods. Special attention is needed to reduce the high rate of non-revenue waters when pumped or collected water is injected into the conveyance system. Matching rainfed agriculture with irrigation systems in dryer seasons expands the possibility for stable multicrop schemes that can be used for higher value chains.

2. *Water laws.* The impact of colonial-era water legislation on the system of water allocation should be examined thoroughly. Some of these traditional water regulation mechanisms are still in use, although the monocultures they were intended to serve are in decline. Releasing these water resources could help to expand agricultural diversity in SIDS.

3. *Monitoring, data management and modelling.* Overall, water flow and quality monitoring and related data management activities are considered serious challenges for the islands. Monitoring mechanisms are either absent or inadequate, leading to uncontrolled and inefficient water use and overextraction of aquifers. Furthermore, there is a serious need to harmonise data for use in decision support tools (DSTs) to analyse the impact of prospective scenarios and reveal opportunities, constraints and the interventions needed to meet future water demand. The creation of the DSTs should be based on a multidisciplinary engagement strategy that draws on information from all stakeholders, from grassroot to ministerial levels. Including input from different sources increases the credibility of the tools and ensures that outcomes are better understood.

4. *Control and enforcement.* The limited water resources in SIDS invite free rider behaviour that affects water availability for the entire community. Essential control and enforcement mechanisms are largely inadequate and inoperative. Such mechanisms will be effective when regulations on water use are clear, can be substantiated with empirical evidence and are well communicated to water users. Awareness campaigns can help to promote responsible and participatory water governance. The campaigns should influence positive conduct by water users as well as reinforcing the need for fines when regulations are contravened.

5. *Institutional collaboration.* While the projects and case studies included in this report are far from exhaustive, it is apparent that coordination and cooperation between government institutes in SIDS need substantial improvements. Water adjustment policies, water use interventions, collaboration and decision-making should be aligned through close institutional collaboration. Yet, the involvement of multiple government bodies is not sufficient. As we have seen, policy-making requires a broader context and the direct involvement of water users. A transdisciplinary approach is therefore desirable in order to broaden and enrich all aspects of the decision-making process.

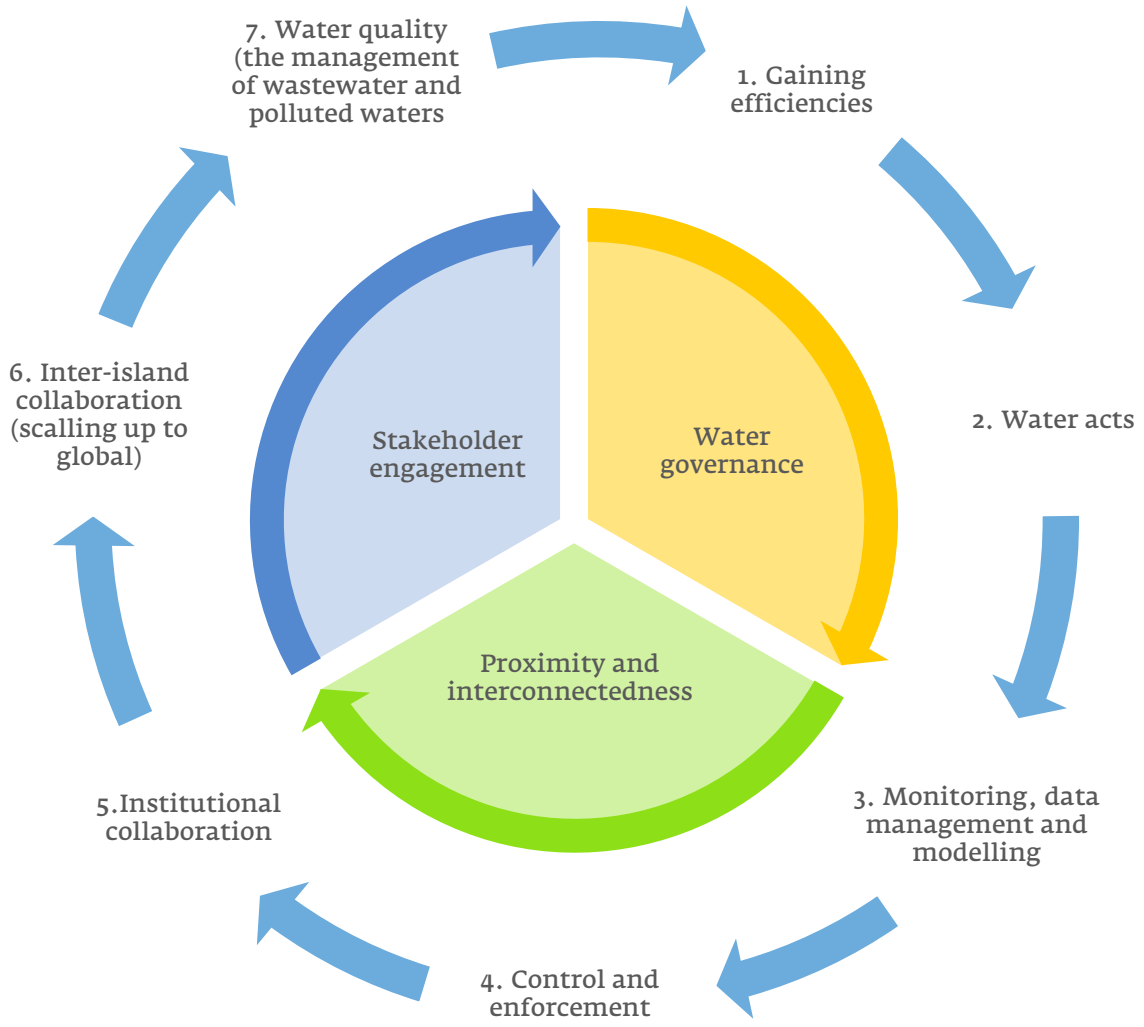
6. *Inter-island collaboration.* An active exchange between the islands on successful interventions and policies as well as lessons learned from past initiatives should compensate for the lack of economies of scale in the SIDS. The coordination of research activities can help to upscale successful results. The South-South and Triangular Cooperation

Divisions of the FAO could play a leading role in an inter-island initiative to facilitate exchange of knowledge and expertise among the SIDS.

7. *Water quality.* Small islands are seriously affected by wastewater produced at household and industry levels as well as polluted water flows from agricultural activities. This study shows that only a small share of the population is connected to a sewer system and that, in many cases, the treatment of wastewater is inadequate. Hence, the management of wastewater and polluted water should have the highest priority to secure the health of the population and prevent the destruction of ecological assets on the islands. Immediate investments are needed to collect and treat wastewater and to prevent overuse of pesticides.

Figure 7.1

The SIDS water management road map



Source: authors' diagram

The contribution of freshwater management to Food security and Nutrition is ever more urgent in these times of the Covid-19 pandemic, when SIDS are confronted with blocked transport lines and tourism revenues have dropped to nil. Even if food safeguards are in place, many SIDS continue to depend on foreign traders for their basic staples. The SIDS need to invest in strong and reliable international alliances around water management and FNS. The SIDS have much to offer to such alliances: vast data for oceanographic and climate change studies, ecosystems that house enormous biodiversity, unique cultures and vistas, and inhabitants who understand that they live on vulnerable and fragile islands that are very much worth preserving.

Annex 1.1. SIDS key figures

Table A.1.1

Land area, population, per capita income and population density in SIDS countries and regions. Source: computations, based on FAO, 2020. In cases where FAOSTAT data are missing, data were taken from other sources, notably the World Development Indicators (World Bank & OECD, 2017)

	Land area (km2)	Population 2017 (thousands)	GDP 2017 (million USD)	GDP 2017 (USD per capita)	Density 2017 (persons per km2)	Population in cities 2017 (%)
Caribbean (27)	598 474	44 512	391 681	8 799	74	71%
Aruba	180	105	2 701	25 630	585	43%
Anguilla	90	15	281	19 281	162	100%
Antigua and Barbuda	440	95	1 510	15 825	217	26%
Bahamas	10 010	382	11 792	30 888	38	86%
Belize	22 810	376	1 902	5 062	16	45%
Bermuda	54	63	6 269	99 437	1 168	97%
Barbados	430	286	4 713	16 465	666	31%
Cuba	104 020	11 339	96 851	8 541	109	78%
Cayman Islands	240	63	4 030	63 589	264	97%
Dominica	750	71	497	6 951	95	73%
Dominican Republic	48 310	10 513	75 932	7 223	218	82%
Guadeloupe	1 690	400	8 705	21 780	236	100%
Grenada	340	111	1 127	10 164	326	35%
Guyana	196 850	775	3 543	4 571	4	27%
Haiti	27 560	10 982	8 521	776	398	54%
Jamaica	10 830	2 921	14 827	5 076	270	55%
Saint Kitts and Nevis	260	52	931	17 884	200	33%
Saint Lucia	610	181	1 718	9 495	297	18%
Montserrat	100	5	60	12 030	50	9%
Martinique	1 060	376	9 067	24 118	355	91%
Puerto Rico	8 870	3 164	104 219	32 942	357	100%
Suriname	156 000	570	3 807	6 673	4	65%

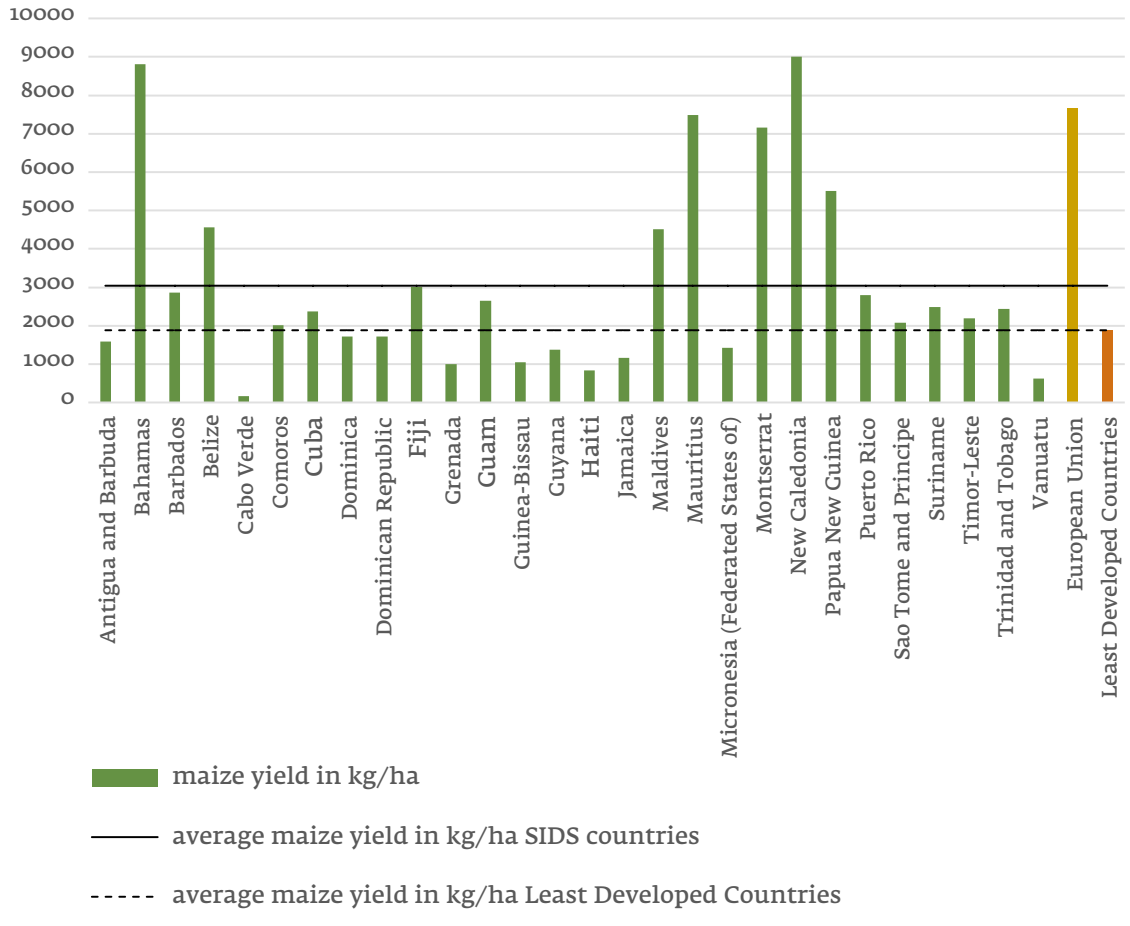
Turks and Caicos Islands	950	37	1 017	27 399	39	89%
Trinidad and Tobago	5 130	1 384	22 105	15 971	270	53%
Saint Vincent and the Grenadines	390	110	780	7 103	282	52%
British Virgin Islands	150	30	996	33 664	197	50%
United States Virgin Islands	350	105	3 782	36 100	299	96%
Pacific (20)	555 570	12 950	57 561	4 445	23	24%
American Samoa	200	56	1 049	18 861	278	87%
Cook Islands	240	18	309	17 669	73	74%
Fiji	18 270	877	4 874	5 554	48	58%
Micronesia (Federated States of)	700	111	336	3 018	159	21%
Guam	540	164	5 011	30 500	304	95%
Kiribati	810	114	197	1 728	141	54%
Marshall Islands	180	58	199	3 434	323	70%
Northern Mariana Islands	460	57	1 308	23 117	123	89%
New Caledonia	18 280	277	9 894	35 700	15	70%
Niue	260	2	9	5 800	6	44%
Nauru	20	11	114	10 792	529	100%
Palau	460	18	292	16 372	39	97%
Papua New Guinea	452 860	8 438	22 006	2 608	19	13%
French Polynesia	3 660	276	5 606	20 302	75	63%
Solomon Islands	27 990	636	1 212	1 905	23	22%
Timor-Leste	14 870	1 243	2 955	2 377	84	32%
Tonga	720	102	427	4 183	142	25%
Tuvalu	30	11	44	3 862	379	61%
Vanuatu	12 190	286	864	3 027	23	24%

Samoa	2 830	195	856	4 380	69	19%
AIS (9)	39 250	12 446	383 540	30 816	317	75%
Bahrain	780	1 494	35 326	23 644	1 915	89%
Comoros	1 861	814	1 082	1 330	437	29%
Cabo Verde	4 030	537	1 773	3 298	133	66%
Guinea-Bissau	28 120	1 828	1 347	737	65	44%
Maldives	300	496	4 866	9 802	1 655	35%
Mauritius	2 030	1 264	13 366	10 570	623	41%
Singapore	709	5 708	323 901	56 745	8 051	100%
Sao Tome and Principe	960	207	393	1 896	216	71%
Seychelles	460	96	1 487	15 419	210	55%
SIDS (56)	1 193 294	69 908	832 782	11 913	59	63%

Annex 2.1. Supplementary material for Section 2

Figure A.2.1

Yield of maize in kg/ha for SIDS, average EU and average least developed countries (LDCs), with references lines indicating average yields for SIDS and LDCs



Source: FAO, 2019c.

Table A.2.1

Conversion of AEZ suitability classes to classification used in this study

AEZ suitability class	Suitability class of this study
very high and high	high
good and medium	moderate
moderate, marginal, very marginal and not suitable	low

Table A.2.2

Share of cultivated land assigned to dominant crops

SIDS	Share of cultivated land	Dominant crop
Marshall Islands	1,00000	Coconut
Tuvalu	0,91202	Coconut
Guam	0,90732	Coconut
French Polynesia	0,87964	Coconut
Cayman Islands	0,87419	Banana
Singapore	0,87292	Vegetables
Micronesia (Federated States of)	0,85952	Coconut
Vanuatu	0,84969	Coconut
Kiribati	0,83816	Coconut
Suriname	0,83388	Staple foods
Mauritius	0,83319	Sugar cane
British Virgin Islands	0,74194	Banana
Bahrain	0,70181	Fruit/Nut trees
Nauru	0,65101	Coconut
Niue	0,63399	Coconut
Bermuda	0,62281	Vegetables
Guyana	0,62113	Staple foods
Cook Islands	0,61576	Coconut
São Tomé and Príncipe	0,59257	Coffee/Cocoa
Samoa	0,54864	Coconut
Guadeloupe	0,52813	Sugar cane
Guinea-Bissau	0,50625	Fruit/Nut tree
Barbados	0,49218	Sugar cane
Solomon Islands	0,48832	Coconut
Maldives	0,48094	Vegetables
American Samoa	0,4443	Staple foods
Cabo Verde	0,44202	Staple foods
Fiji	0,4362	Coconut
Grenada	0,42298	Spices
Saint Kitts and Nevis	0,40301	Coconut
Saint Lucia	0,39617	Coconuts
Saint Vincent and the Grenadines	0,39297	Banana
Martinique	0,37533	Banana
Antigua and Barbuda	0,34556	Fruit/Nut trees

Tonga	0,33594	Coconuts
Seychelles	0,33116	Spices
Puerto Rico	0,32765	Coffee/Cocoa
Cuba	0,31043	Sugar cane
Timor-Leste	0,31014	Staple foods
Jamaica	0,30419	Coconut
Comoros	0,2885	Coconut
New Caledonia	0,28689	Vegetables
Belize	0,28582	Sugar cane
Bahamas	0,26341	Sugar cane
Trinidad and Tobago	0,25372	Fruit/Nut trees
Haiti	0,21016	Staple foods
Papua New Guinea	0,18999	Coconut
Dominican Republic	0,17465	Staple food
Dominica	0,15371	Banana
Montserrat	0,12804	Vegetables

Source: FAOSTAT, 2019b

Table A.2.3

Time series of the value of food imports against total merchandise exports (percent) (3-year average).

Country	1999-2001	2000-2002	2001-2003	2002-2004	2003-2005	2004-2006	2005-2007	2006-2008	2007-2009	2008-2010	2009-2011	2010-2012	2011-2013
Antigua and Barbuda	50	50	52	51	62	64	71	78	95	115	129	148	149
Bahamas	21	59	56	49	56	63	58	49	47	48	49	47	45
Barbados	45	46	54	52	49	44	42	43	47	51	51	48	49
Belize	18	16	13	13	14	15	17	19	23	23	22	22	24
Bermuda	110	107	107	87	94	131	220	349	353	428	509	759	912
Cuba	43	43	46	45	50	48	45	47	50	46	36	31	32
Dominica	40	46	49	51	54	55	63	75	88	88	90	92	103
Dominican Republic	45	49	50	46	42	40	40	26	21	17	17	17	16
Grenada	47	50	61	92	109	159	160	172	163	193	198	184	156
Guyana	16	14	14	14	15	15	16	16	17	18	17	16	15
Haiti	99	105	108	109	99	103	104	127	129	143	125	121	117
Jamaica	24	25	26	26	28	27	27	27	34	41	49	48	48
Saint Kitts and Nevis	51	45	42	43	46	47	47	54	64	72	71	65	67
Saint Lucia	113	103	93	85	89	90	89	75	63	52	50	47	49
Saint Vincent and the Grenadines	57	69	82	96	98	97	104	117	131	143	145	155	142
Suriname	15	14	13	11	10	9	9	8	9	8	8	7	8

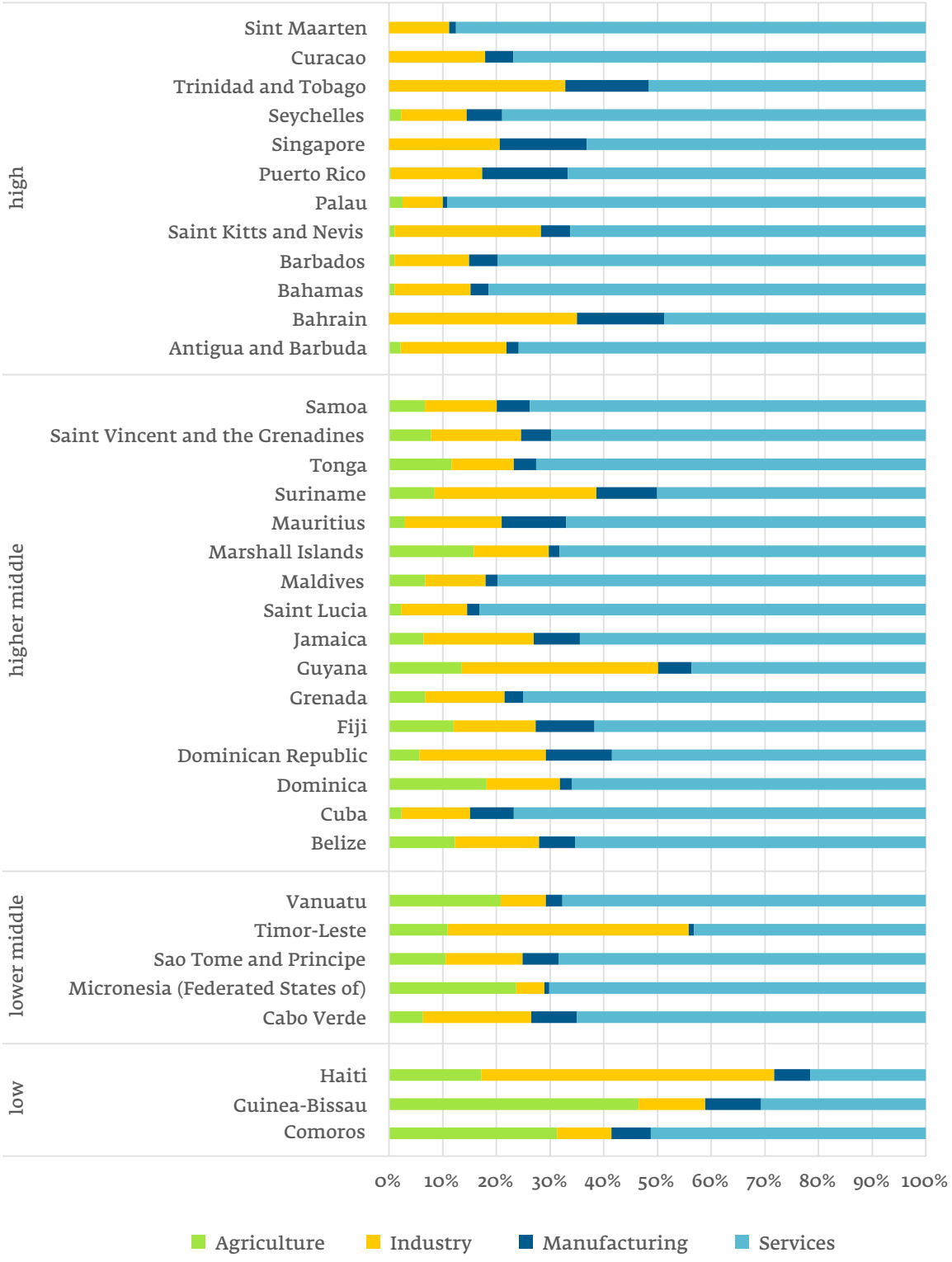
Trinidad and Tobago	7	6	6	6	5	4	4	3	4	4	5	5	5
American Samoa	5	5	4	2	2	3	3	3	3	3	3	4	4
Cook Islands	135	128	146	169	199	288	363	415	466	482	520	456	390
Fiji	17	19	20	22	23	25	27	30	33	32	30	26	26
French Polynesia	52	65	104	120	128	128	135	153	180	200	208	218	226
Kiribatis	132	121	86	61	63	56	67	81	107	145	155	184	291
Nauru	3	3	4	4	3	3	3	4	4	4	4	5	8
New Caledonia	17	20	20	18	16	16	13	14	16	21	20	20	22
Niue	298	336	435	491	311	172	81	65	54	58	49	55	56
Papua New Guinea	9	9	9	8	7	6	6	6	8	8	8	8	9
Samoa	133	167	178	218	252	312	309	137	122	98	107	100	112
Solomon Islands	17	28	30	26	29	32	32	31	30	34	28	22	20
Timor-Leste	129	130	81	48	45	48	79	101	156	210	290	323	343
Tonga	103	106	116	151	184	232	218	225	243	377	329	312	293
Tuvalu	110	182	168	204	215	221	185	232	390	1265	1032	1051	1106
Vanuatu	53	71	89	65	56	52	69	77	82	83	85	93	100
Bahrain	6	7	7	6	5	4	4	3	4	5	6	6	6
Cabo Verde	578	564	633	646	663	637	694	665	602	475	365	334	306
Comoros	118	96	92	92	104	125	160	232	310	399	303	281	234

Guinea-Bissau	49	56	59	62	52	44	47	46	56	53	48	46	45
Maldives	89	83	78	74	78	84	77	64	65	76	81	80	80
Mauritius	14	15	14	15	15	15	16	19	23	24	24	24	24
São Tomé and Principe	133	133	133	133	133	133	133	133	133	133	133	133	133
Seychelles	21	21	20	19	18	19	22	21	19	17	16	16	15
Singapore	2	2	2	2	2	1	1	1	2	2	2	2	2

Source: FAOSTAT, 2019e.

Figure A.2.2

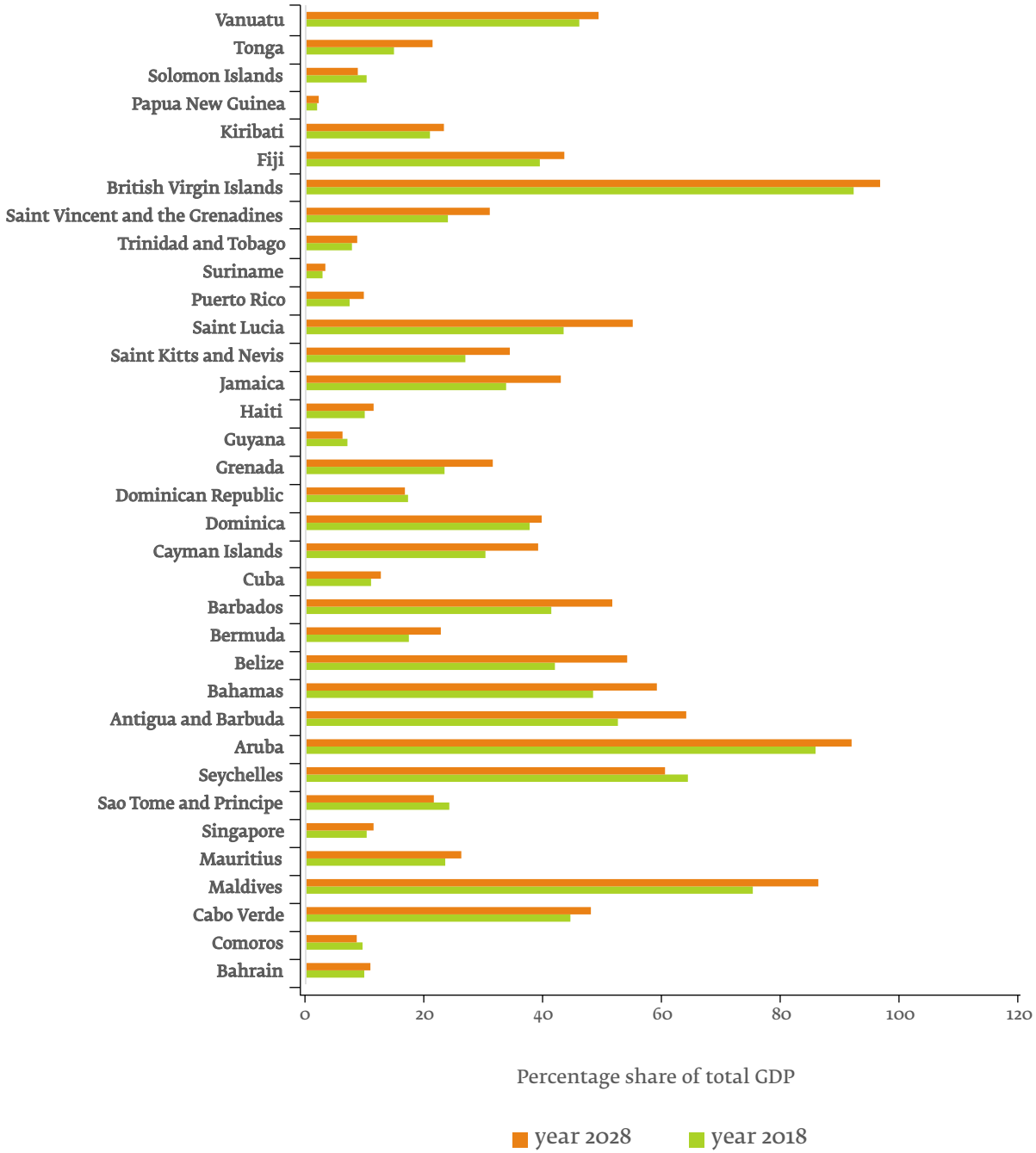
Percentage contribution of economic sectors to GDP in 2017 by income group



Source: World Bank, 2019b

Figure A.2.3

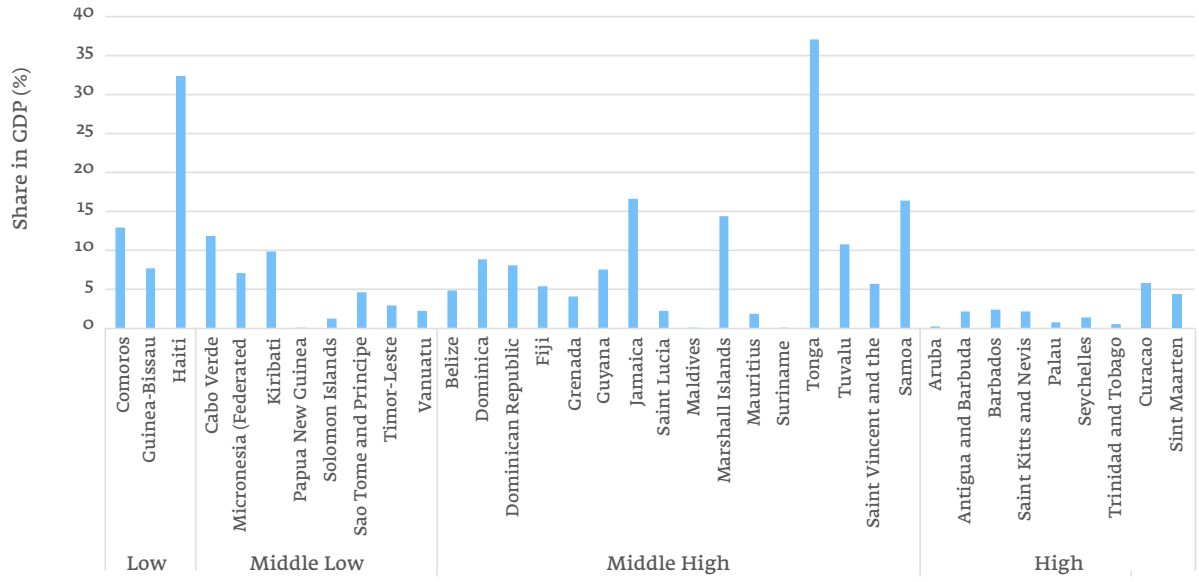
Travel and Tourism direct contribution to GDP



Source: World Travel and Tourism Centre, 2019

Figure A.2.4

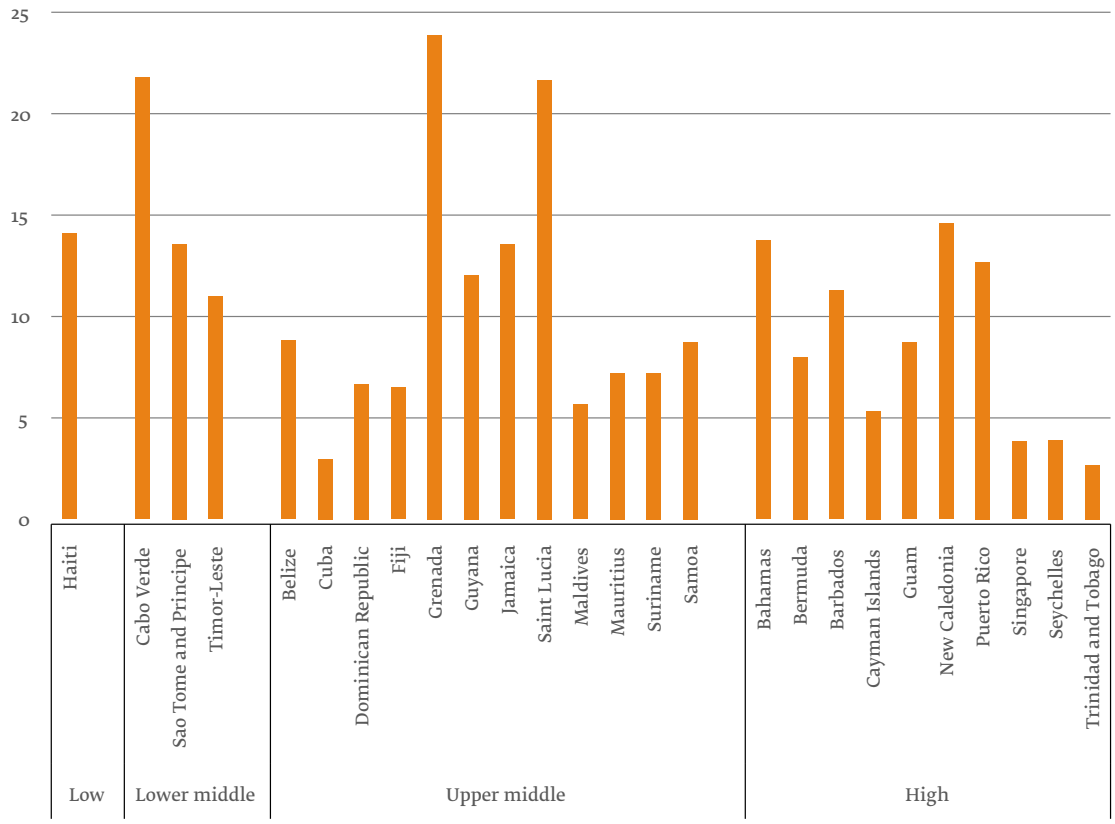
Remittances as share of GDP, 2017



Source: World Bank, 2019c.

Figure A.2.5

Percentage unemployment rates in SIDS by income group



Source: World Bank, 2019d

Annex 2.2. Food groups and micronutrients

The assessment of food diversity in SIDS was based on the availability of food groups and micronutrients. We used Food Balance Sheets (FBS) from the FAO for 2013 to determine the availability of food items for human consumption. FBS assessments were corrected for food loss and waste using regional parameters from FAO (2011). Two further corrections for the availability of micronutrients were made: the demand for children under-five and for babies who are exclusively breastfed (0-5 months).

From food items to micronutrients

The Dutch Food Composition Database (RIVM, 2019) was used together with data from the USDA (2019) to calculate the availability of micronutrients in various food items. The availability of micronutrients for each of the SIDS was compared to the recommended daily allowance (RDA) for adults and children derived from the Food Nutrition Board (2011).

Table A.2.4

Micronutrients in this study, with recommended daily allowance for adults

Minerals	RDA	Fat soluble vitamins	RDA	Water soluble vitamins	RDA
Iron	M: 8 mg/d F: 13 mg/d	Vitamin A	M: 900 µg/d F: 700 µg/d	Vitamin B1	M: 1.2 mg/d F: 1.1 mg/d
Zinc	M: 11 mg/d F: 8 mg/d	Vitamin D	M: 15 µg/d F: 15 µg/d	Vitamin B2	M: 1.3 mg/d F: 1.1 mg/d
Copper	M: 0.9 mg/d F: 0.9 mg/d	Vitamin E	M: 15 mg/d F: 15 mg/d	Vitamin B6	M: 1.5 mg/d F: 1.4 mg/d
Selenium	M: 55 µg/d F: 55 µg/d	Vitamin K*	M: 120 µg/d F: 90 µg/d	Folate	M: 400 µg/d F: 400 µg/d
Iodine	M: 150 µg/d F: 150 µg/d			Vitamin C	M: 90 mg/d F: 75 mg/d
				Vitamin B12	M: 2.4 mg/d F: 2.4 mg/d

RDA: Recommended daily allowance. M: male. F: female. Mg/d: milligram per day. µg/d: microgram per day.

Source: FAOSTAT, 2019b.

Table A.2.5

Micronutrients in this study, with recommended daily allowance for children under five

Minerals	RDA	Fat soluble vitamins	RDA	Water soluble vitamins	RDA
Iron	7.3 mg/d	Vitamin A	400 µg/d	Vitamin B1	0.5 mg/d
Zinc	3.3 mg/d	Vitamin D	14 µg/d	Vitamin B2	0.5 mg/d
Copper	0.3 mg/d	Vitamin E	6 mg/d	Vitamin B6	0.5 mg/d
Selenium	20 µg/d	Vitamin K	30 µg/d	Folate	150 µg/d
Iodine	95 µg/d			Vitamin C	25 mg/d
				Vitamin B12	0.9 mg/d

RDA: Recommended daily allowance. Mg/d: milligram per day. µg/d: microgram per day.

Source: Food Nutrition Board (2011)

From food items to food groups

Food items were divided into FAO's 12 food groups (Kennedy *et al.*, 2010; Kennedy *et al.*, 2007) to represent food diversity (Habte & Krawinkel, 2016). Food items in food groups were expressed in kcal. For comparison with minimum recommended daily servings (RDS), we used the food-based dietary guidelines of St. Kitts and Nevis, and St. Vincent and the Grenadines (FAO, *et al.*, 2006.; FAO *et al.*, 2010). As RDS data are known for eight food groups we mapped the 12 food groups of the FAO to the eight RDS food groups and divided the summed kcals by total population on the SIDS. We used the lowest level of the range of the dietary guidelines for comparison.

Table A.2.6

Recommended daily allowance in servings, based on a diet of 1 600 – 2 800 kcal

Nr.	Food group	Nr. of recommended daily servings	Calories in one serving	Minimum calories
1	Staples / starchy foods	7 – 12 servings	70 kcal	490 kcal
2	Milk (products)	4 servings	18 kcal	72 kcal
3	Meat / fish	4 – 7 servings	146 kcal	584 kcal
4	Legumes / peas / nuts / seeds	1 – 2 servings	73 kcal	73 kcal
5	Fruits	5 – 11 servings	40 kcal	200 kcal
6	Vegetables	2 – 5 servings	36 kcal	72 kcal
7	Fats and oils	3 – 6 servings	45 kcal	135 kcal
8	Sugars and sweeteners	5 – 8 servings	20 kcal	100 kcal

Kcal: kilocalories

Source: FAO et al., 2006; FAO et al., 2010.

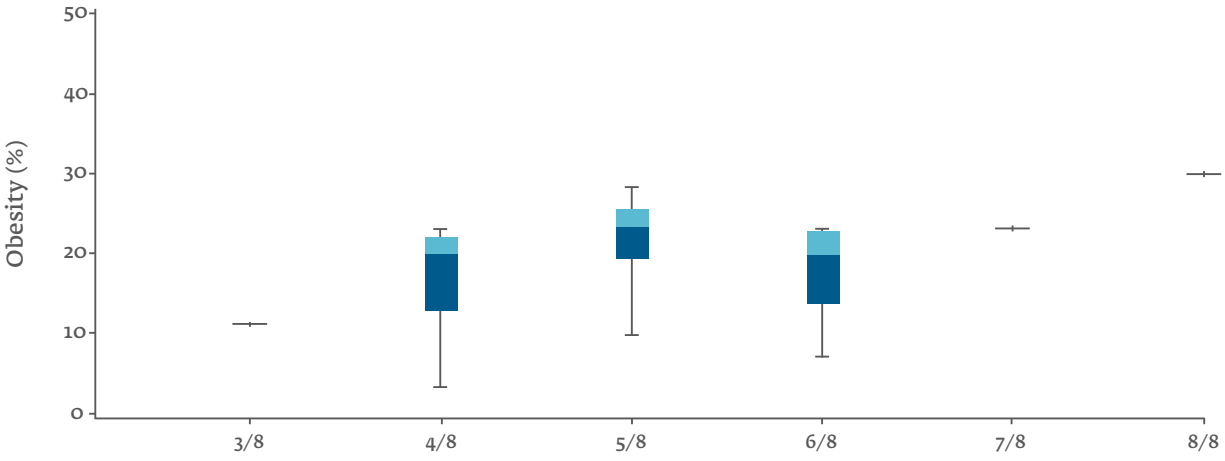
Annex 2.3. Results of food group availability by malnutrition status

Data on obesity, underweight and overweight were obtained from the WHO for 35 countries (WHO, 2019a; WHO, 2019b; WHO, 2019c). Data for stunting and wasting in 29 countries were obtained from UNICEF (UNICEF, WHO and the World Bank, 2018) but reported for different survey years (e.g. 1985 for Kiribati and 2015 for Belize and Solomon Islands).

Obesity. Figure A.2.6 gives the impression that a greater availability of food groups corresponds to a higher percentage of obesity. However, the food group ratios '3/8', '7/8' and '8/8' include only one country.

Figure A.2.6

Ratio of food groups in relation to obesity



Source: computations based on FAO, 2019d and WHO, 2017a.

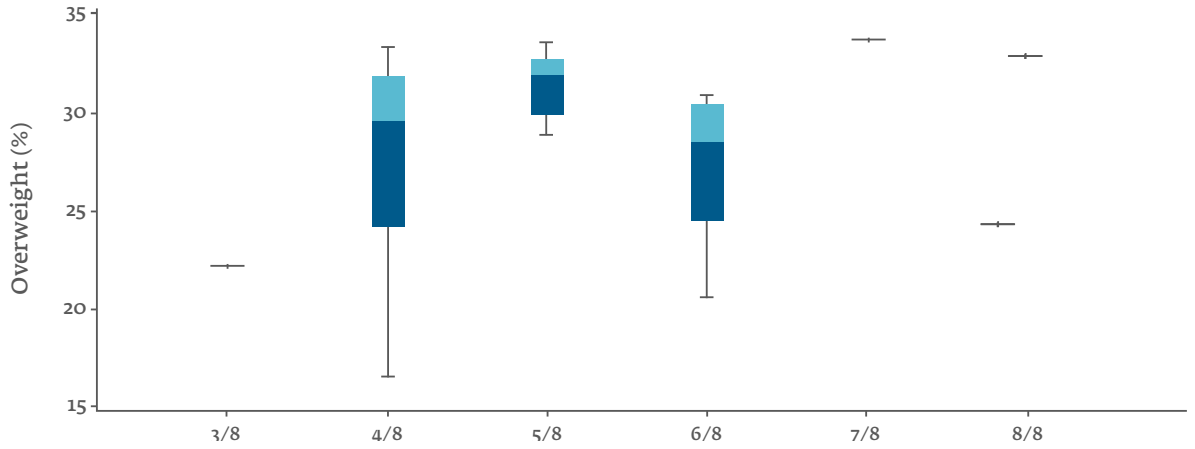
Overweight. The country with 3/8 available food groups, and countries with 7/8 and 8/8 available food groups seem to differ significantly (Figure A.2.7), where the group with the most available food groups have a higher percentage of overweight people. However, the 3/8 group contains only one country, which makes a comparison cumbersome.

Underweight. SIDS countries with lower availability of food groups seem to have higher percentage of underweight compared to countries with more available food groups. However, three of the six groups contain only one country, which makes comparisons difficult (Figure A.2.8).

Stunting. The boxplots in Figure A.2.9 show that countries with less availability of food groups have higher percentages of stunting. However, two of the five groups contain only one country.

Figure A.2.7

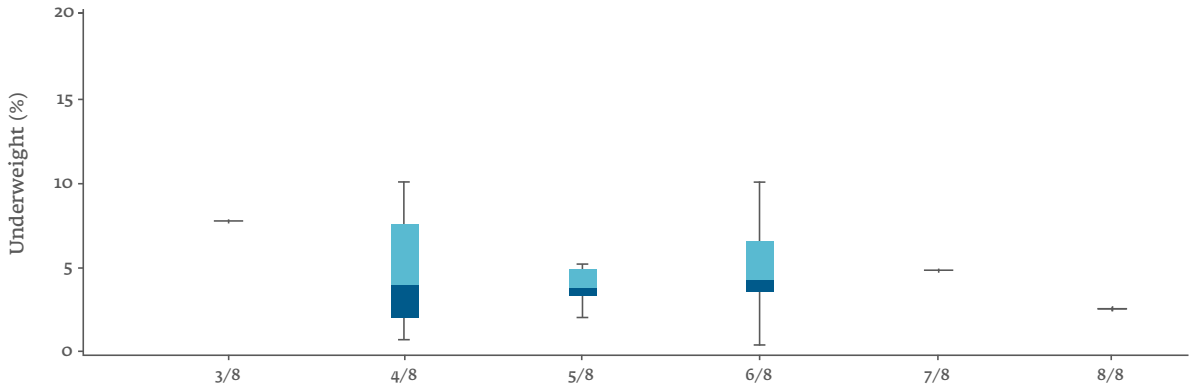
Ratio of food groups in relation to overweight



Source: computations based on FAO, 2019d and WHO, 2017b.

Figure A.2.8

Ratio of food groups in relation to underweight

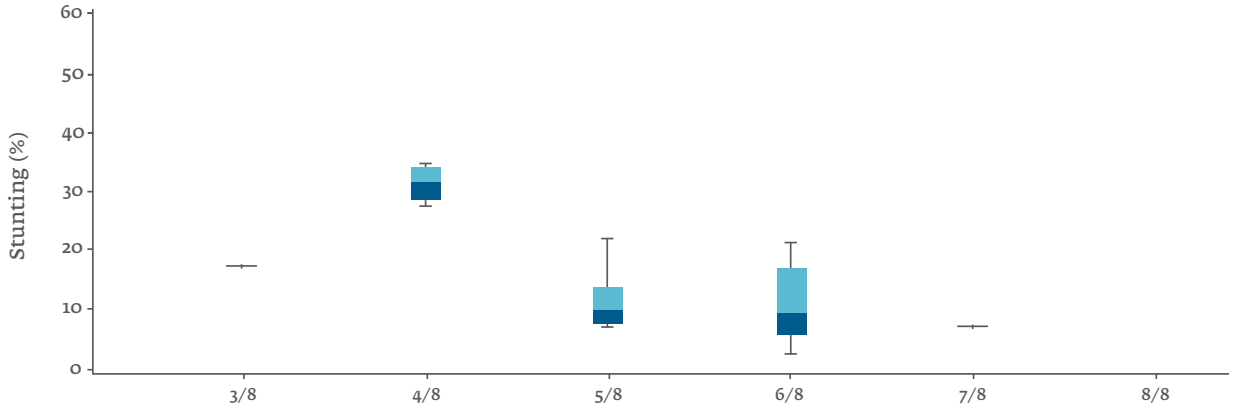


Source: computations based on FAO, 2019d and WHO, 2017c.

Wasting. The boxplots in Figure A.2.10 show a decline in wasting when food group availability increases, with the exception of the lowest food group availability: 3/8. However, two of the five groups contain only one country, which makes the comparison difficult to interpret.

Figure A.2.9

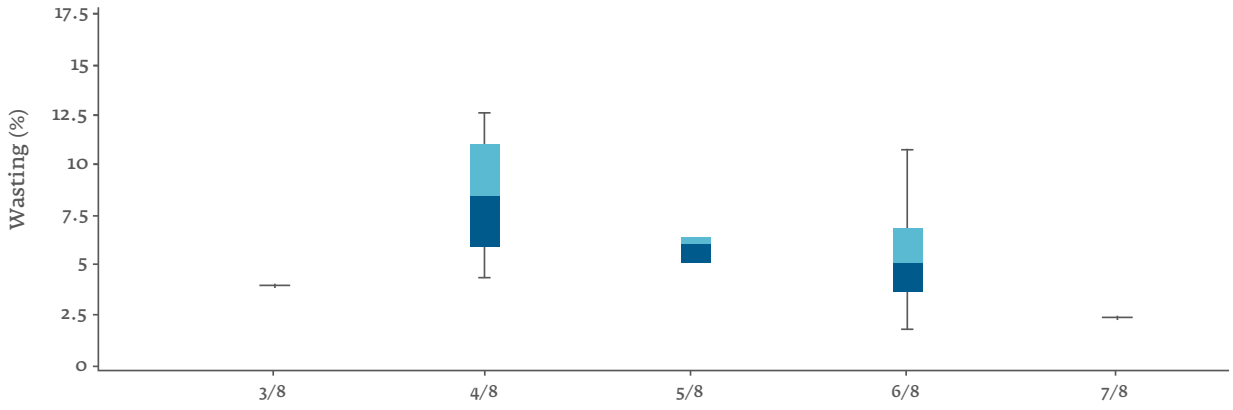
Ratio of food groups in relation to stunting



Source: computations based on FAO, 2019d and WHO, 2017c.

Figure A.2.10

Ratio of food groups in relation to wasting



Source: computations based on FAO, 2019d and UNICEF, WHO & World Bank. 2018.

Table A.2.7

Prevalence of underweight, overweight and obesity in SIDS countries for 2013

Country	Underweight	Overweight	Obesity	Obesity + overweight
Antigua and Barbuda	5.0	28.8	17.5	46.3
Bahrain	3.2	35.9	28.2	64.1
Barbados	3.7	29.1	21.4	50.5
Belize	3.5	30.5	22.5	53.0
Cabo Verde	8.3	22.2	10.7	32.9
Comoros	10.7	18.7	6.9	25.6
Cook Islands	0.3	29.5	54.3	83.8
Cuba	4.8	33.7	23.1	56.8
Dominica	3.2	32.2	26.2	58.4
Dominican Republic	3.5	33.2	25.3	58.5
Fiji	2.0	33.7	28.3	62.0
Grenada	4.2	29.8	19.6	49.4
Guinea-Bissau	10.2	19.6	8.3	27.9
Guyana	5.2	28.9	18.4	47.3
Haiti	4.7	31.6	20.2	51.8
Jamaica	4.4	30.5	22.9	53.4
Kiribati	0.8	33.4	44.1	77.5
Maldives	10.2	20.5	7.2	27.7
Marshall Islands	0.5	31.2	51.3	82.5
Mauritius	8.4	21.1	9.9	31.0
Nauru	0.2	28.0	60.0	88.0
Niue	0.5	30.8	47.6	78.4
Palau	0.5	30.4	53.7	84.1
Papua New Guinea	2.5	31.2	19.6	50.8
Samoa	0.3	30.9	45.4	76.3
São Tomé and Principe	7.8	22.2	11.2	33.4
Seychelles	6.9	22.3	12.8	35.1
Singapore	6.3	25.3	5.7	31.0
Solomon Islands	1.8	32.1	20.6	52.7
Suriname	3.5	32.4	24.9	57.3
Timor-Leste	17.1	16.5	3.1	19.6
Tonga	0.3	31.1	46.1	77.2
Trinidad and Tobago	4.2	27.0	16.9	43.9
Tuvalu	0.4	31.0	49.4	80.4
Vanuatu	2.1	31.8	23.2	55.0

Source: WHO, 2019a; WHO, 2019b; WHO, 2019c.

Annex 3.1. Supplementary material for Section 3

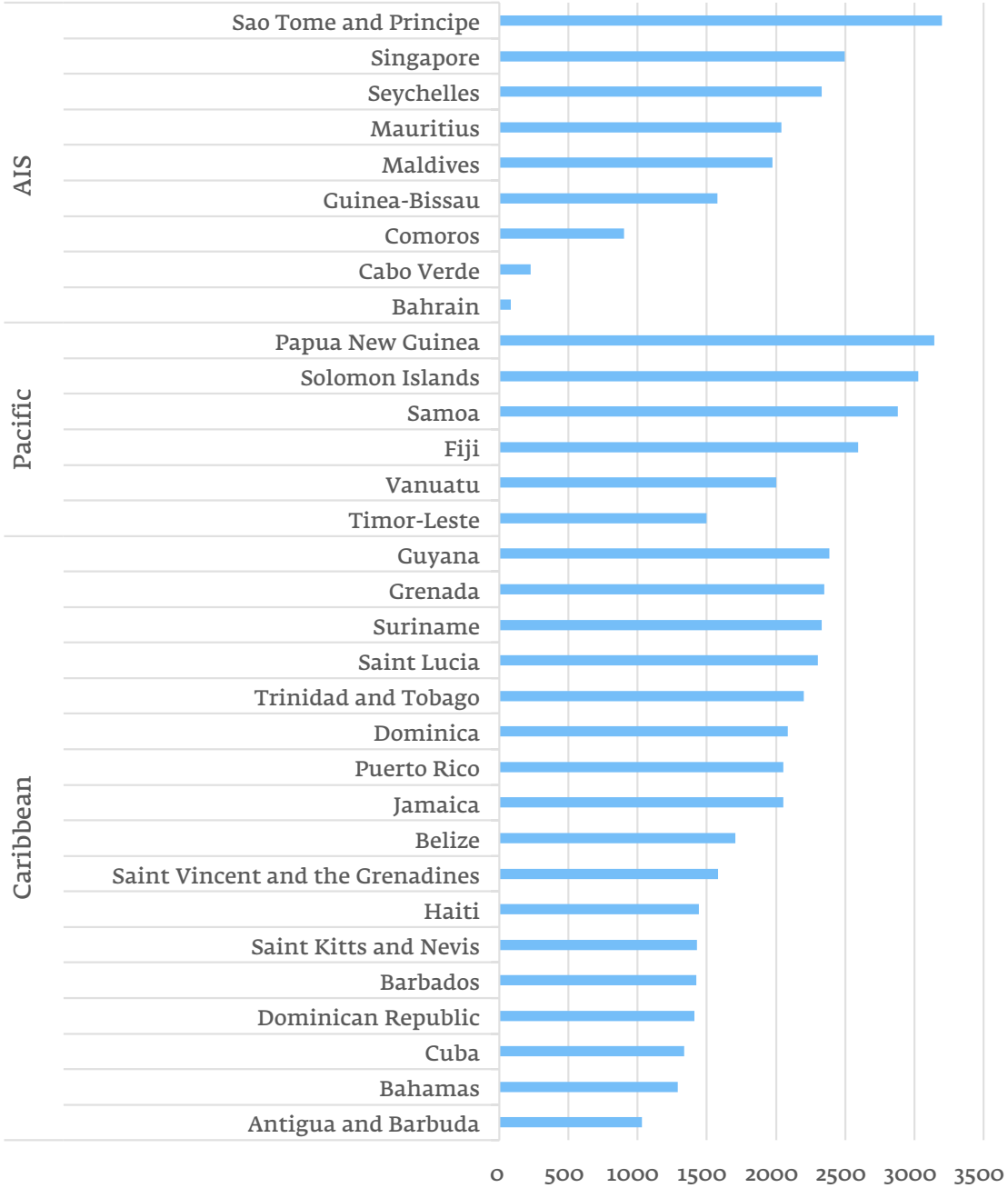
TABLE A.3.1. GENERAL PHYSIOGRAPHICAL CHARACTERISTICS OF THE SIDS

Region	Country	Islands by geology Source: Dahl, 1991	Terrain geology description Source: UNEP, 2004; UNESCO_IHP/ UNEP, 2016; FAO, 2019d; BGS, 2019	Terrain
Caribbean	Antigua and Barbuda	raised coral islands/volcanic	low-lying limestone and coral islands	mix
	Bahamas	low coral islands/raised coral islands	long, flat coral formations	low/medium
	Barbados	raised coral islands/ volcanic	flat central highlands	mix
	Bermuda	raised coral islands	no data	medium
	Aruba	no data	karstic limestone/igneous rocks/limestone	low
	Belize	atoll/Low coral islands/located at continent	no data	low
	Cayman Islands	raised coral islands	no data	medium
	Cuba	continental islands	terraced plains, small hills, mountains	high
	Dominica	volcanic	rugged mountains of volcanic origin	high
	Dominican Republic	continental islands	mountainous	high
	Grenada	volcanic	volcanic in origin, central mountains	high
	Guadeloupe	raised coral islands/volcanic	no data	medium/high
	Guyana	volcanic/ located at continent	low	low
	Haiti	continental islands	mountainous	high
	Jamaica	low coral islands	narrow coastal plains, mountains	high
	Martinique	volcanic	no data	high
	Montserrat	volcanic	no data	high
	Puerto Rico	no data	no data	mix
	St Kitts and Nevis	atoll/volcanic	volcanic, mountainous interiors	mix
	St Lucia 156 000	volcanic	volcanic, mountainous with broad valleys	high
	St Vincent and the Grenadines	volcanic	volcanic, mountainous	high
	Suriname	located at continent	low	low
	Trinidad and Tobago	volcanic	flat, hilly, mountainous	high
	Turks and Caicos Islands	low coral islands	no data	low
	British Virgin Islands	raised coral islands/volcanic	hilly volcanic islands and flat coral islands	medium/high
	United States Virgin Islands	no data	hilly, rugged, mountainous	high
	Anguilla	raised coral islands	flat low-lying coral and limestone	medium
	Curacao	volcanic	hilly, volcanic interiors	medium/high
	Sint Maarten	volcanic	hilly, volcanic interiors	medium/high

Pacific	American Samoa	atoll/volcanic	volcanic with two atolls	mix
	Solomon Islands	atoll/raised coral islands/volcanic	low coral atolls, rugged mountains	mix
	Cook Islands	atoll/low coral islands/volcanic	low coral atolls, volcanic, hilly	mix
	Fiji	atoll/raised coral islands/volcanic	mountainous, of volcanic origin, coral atolls	high
	French Polynesia	atoll/low coral islands/raised coral islands	no data	low
	Kiribati	atoll/low coral islands/raised coral islands	low-lying coral atolls	low/medium
	Guam	raised coral islands	no data	Medium/High
	Marshall Islands	atoll/low coral islands	low coral, limestone and sand islands	low
	Micronesia (Federated States o	atoll/low coral islands/raised coral islands/volcanic	low coral atolls, volcanic, mountainous	mix
	Nauru	raised coral islands	sandy beach, coral reefs, phosphate plateau	medium
	New Caledonia	atoll/low coral islands/raised coral islands	metamorphic and sedimentary	low/medium
	Vanuatu	atoll/raised coral islands/volcanic	narrow coastal plains, mountains of volcanic origin	mix
	Niue	raised coral islands	limestone cliffs, central plateau	medium
	Northern Mariana Islands	raised coral islands/volcanic	S: limestone and reefs, N: volcanic	medium/high
	Papua New Guinea	atoll/raised coral islands/volcanic	coastal lowlands, mountains	mix
	Timor-Leste	mountainous	narrow plain coast central mountain	high
	Palau	atoll/low coral islands/raised coral islands/volcanic	low coral islands, mountainous	mix
	Tonga	raised coral islands/volcanic	coral formation, volcanic	medium/high
	Tuvalu	atoll/low coral islands	low-lying and narrow coral atolls	low
	Samoa	volcanic	narrow coastal plains, interior mountains	high
AIS	Bahrain	no data	low lying. Limestone bedrock slopes rise	low
	Cabo Verde	volcanic	rugged, rock, volcanic	high
	Comoros	volcanic	volcanic islands	high
	Maldives	atoll	flat	low
	Mauritius	low coral islands/volcanic	small coastal plain, central plateau	mix
	Guinea-Bissau	located at continent	low	low
	São Tomé and Príncipe	volcanic	no data	high
	Seychelles	low coral islands	narrow coastal strip, coral, flat	low
	Singapore	continental islands	lowland, undulating central plateau	low

Figure A.3.1

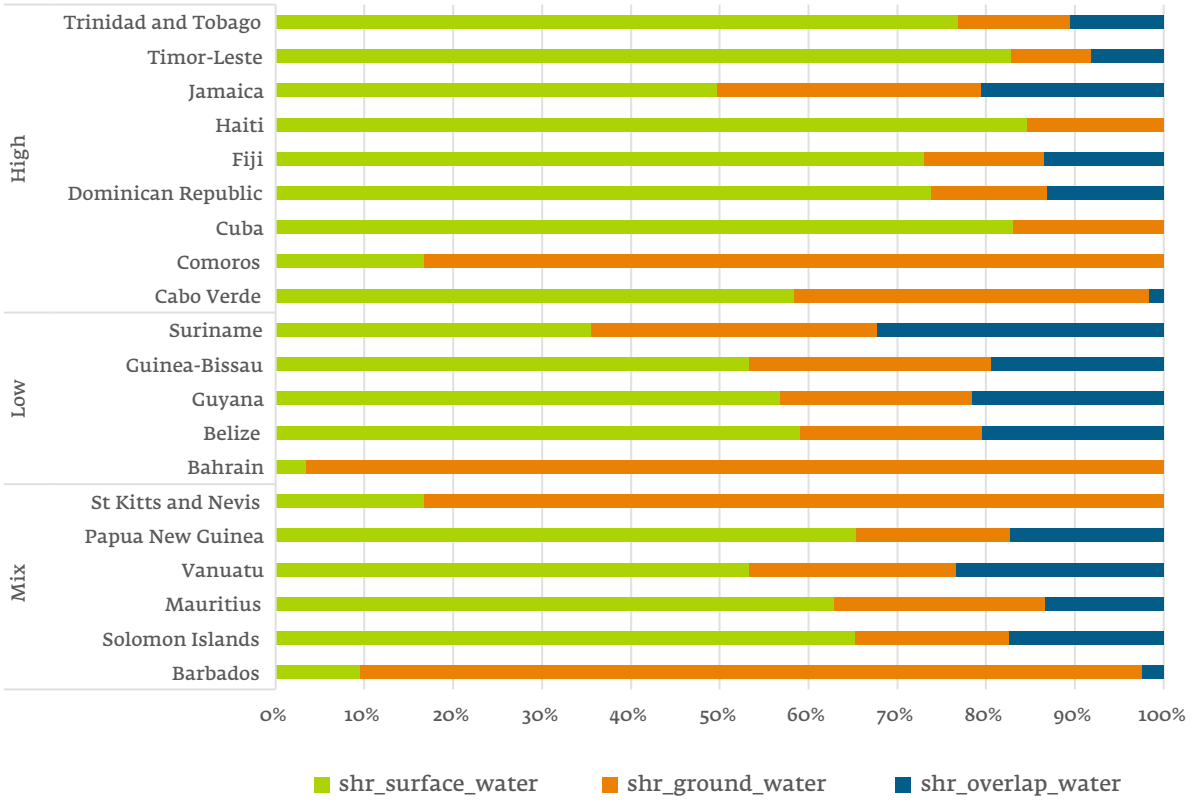
Average annual precipitation in mm per year (1985-2015)



Source FAO, 2020a

Figure A.3.2

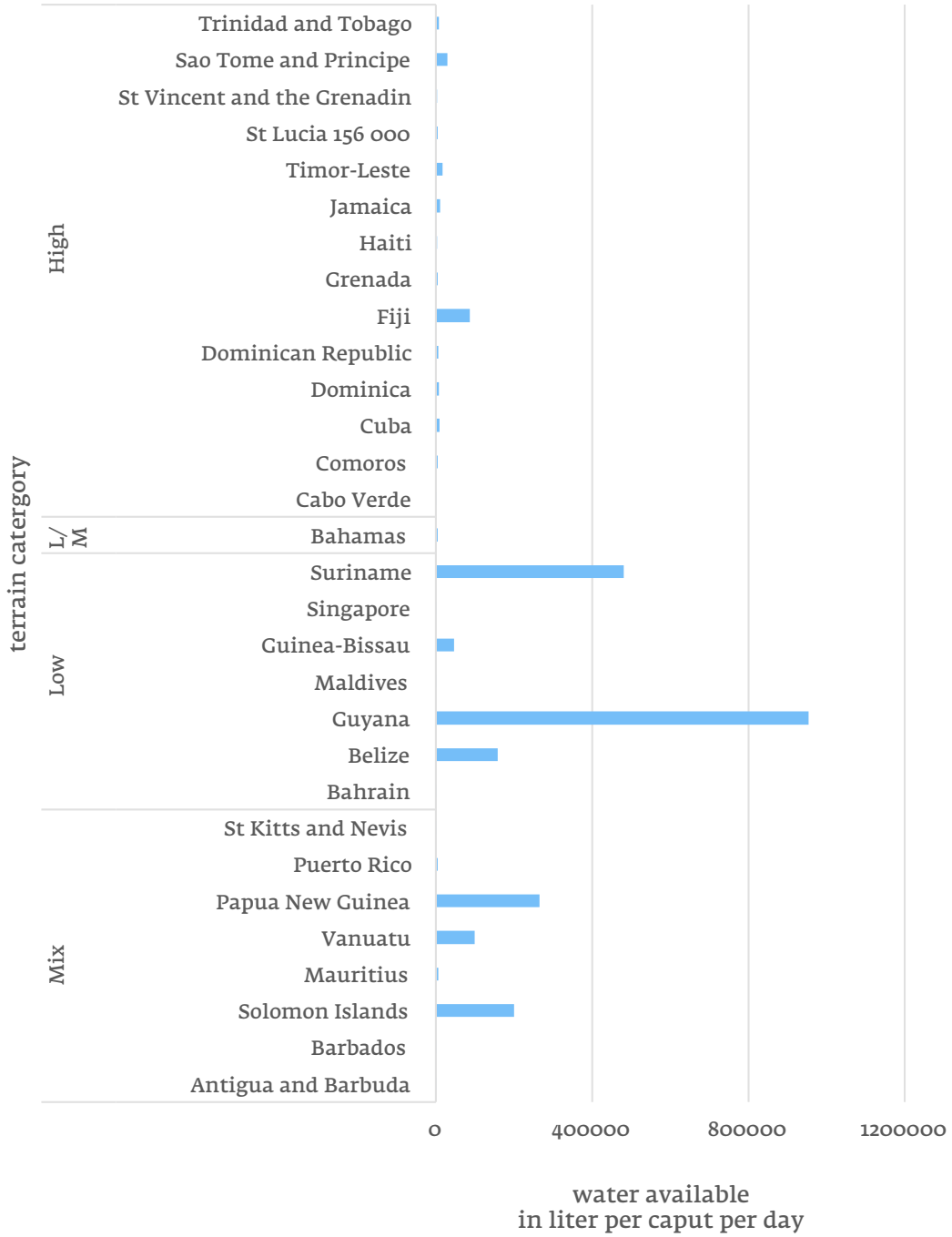
Share of renewable water resources: surface water, groundwater and overlap by terrain characteristic



Source: Authors' computations based on FAO, 2019a

Figure A.3.3

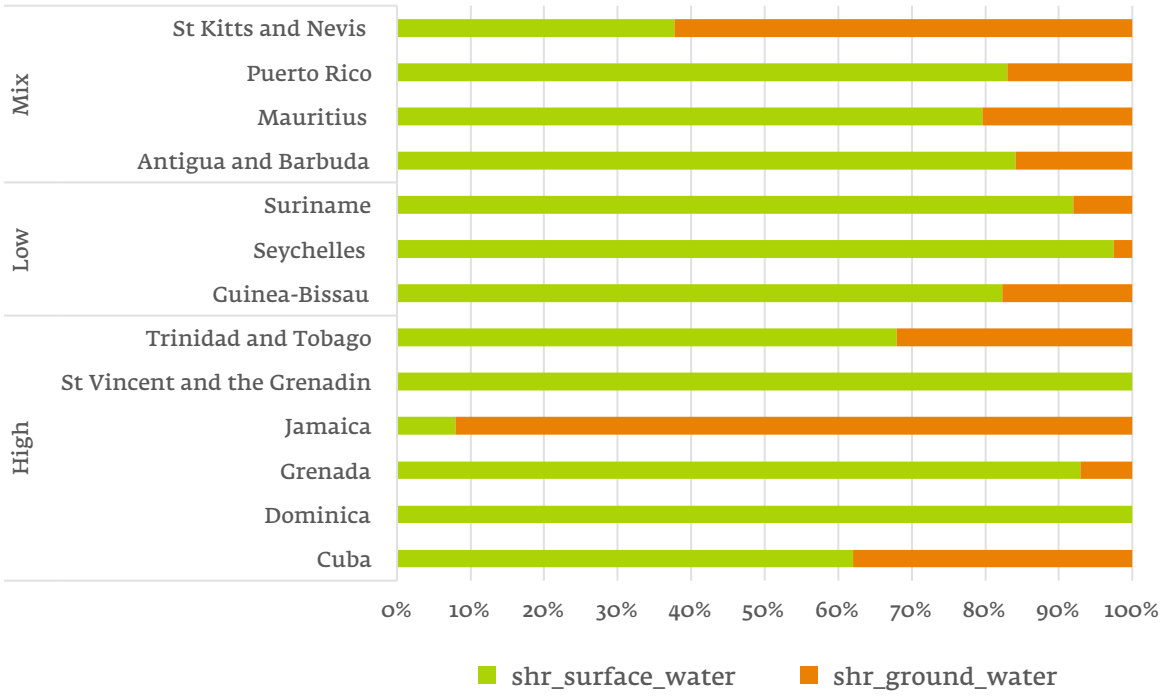
Water from renewable sources in liters per capita per day by island physiography



Source: Authors' computations based on FAO, 2019e

Figure A.3.4

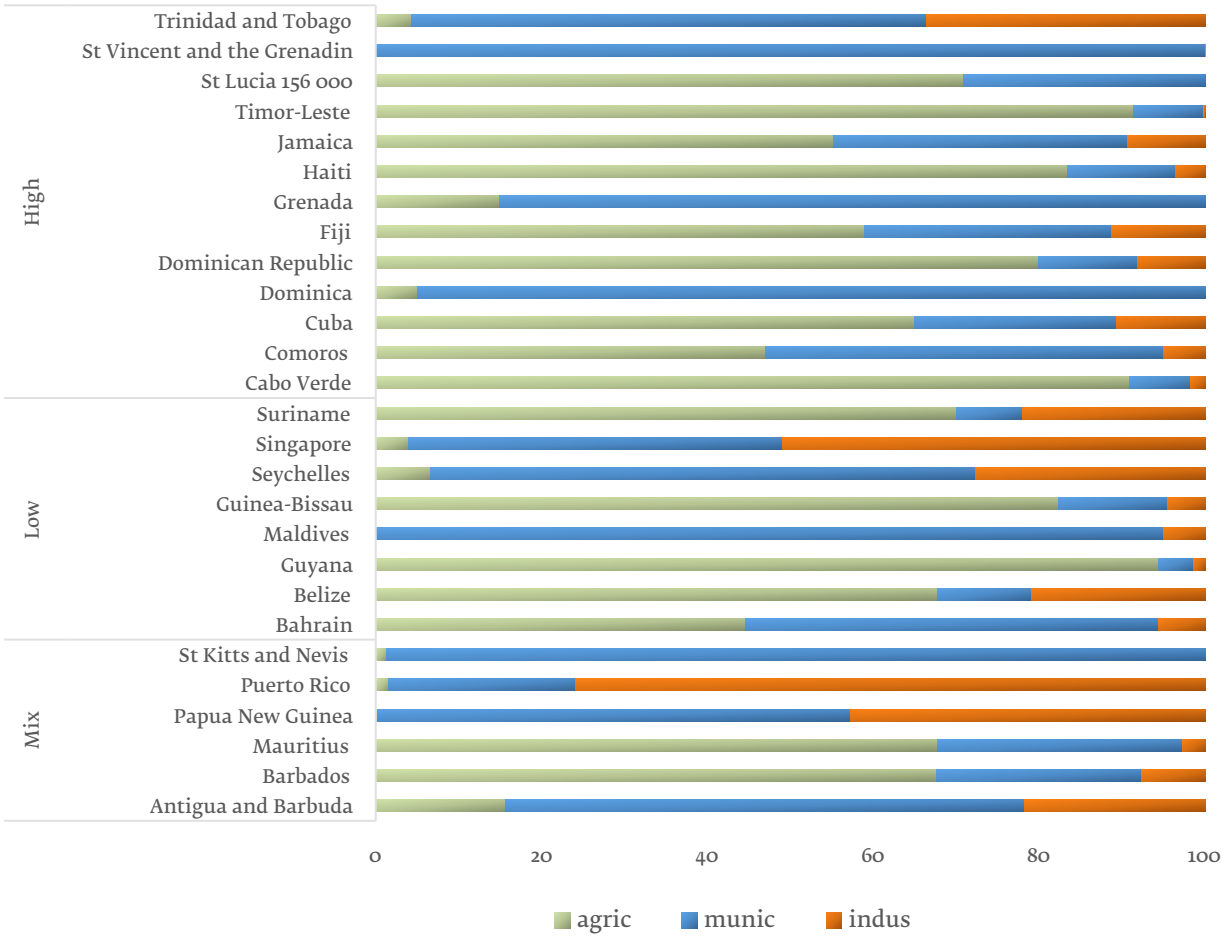
Extraction shares from surface and groundwater by island category



Source: Authors' computations based on FAO, 2019b

Figure A.3.5

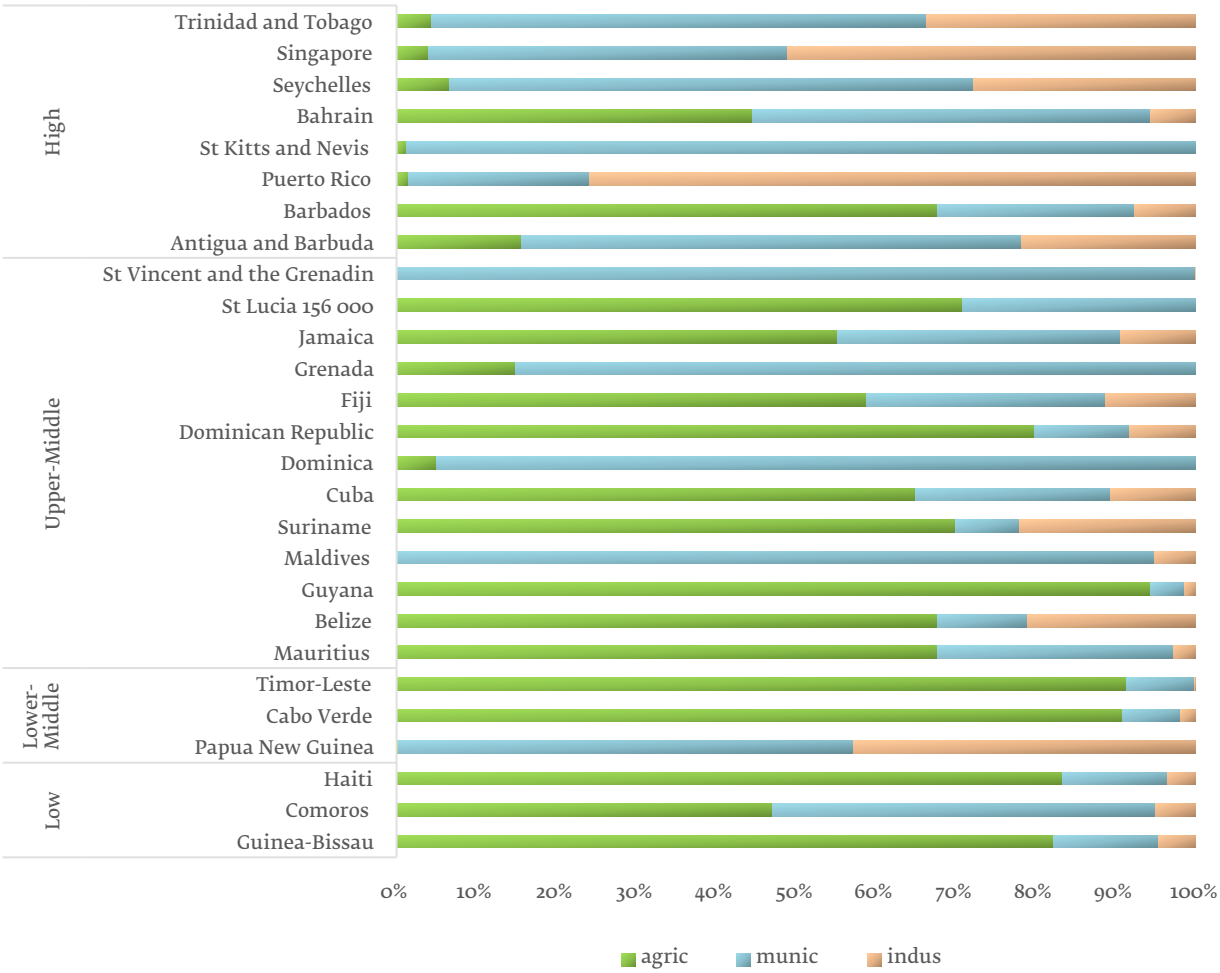
Water withdrawal by sector, grouped by terrain indicators



Source: Authors' computations based on FAO, 2018a

Figure A.3.6

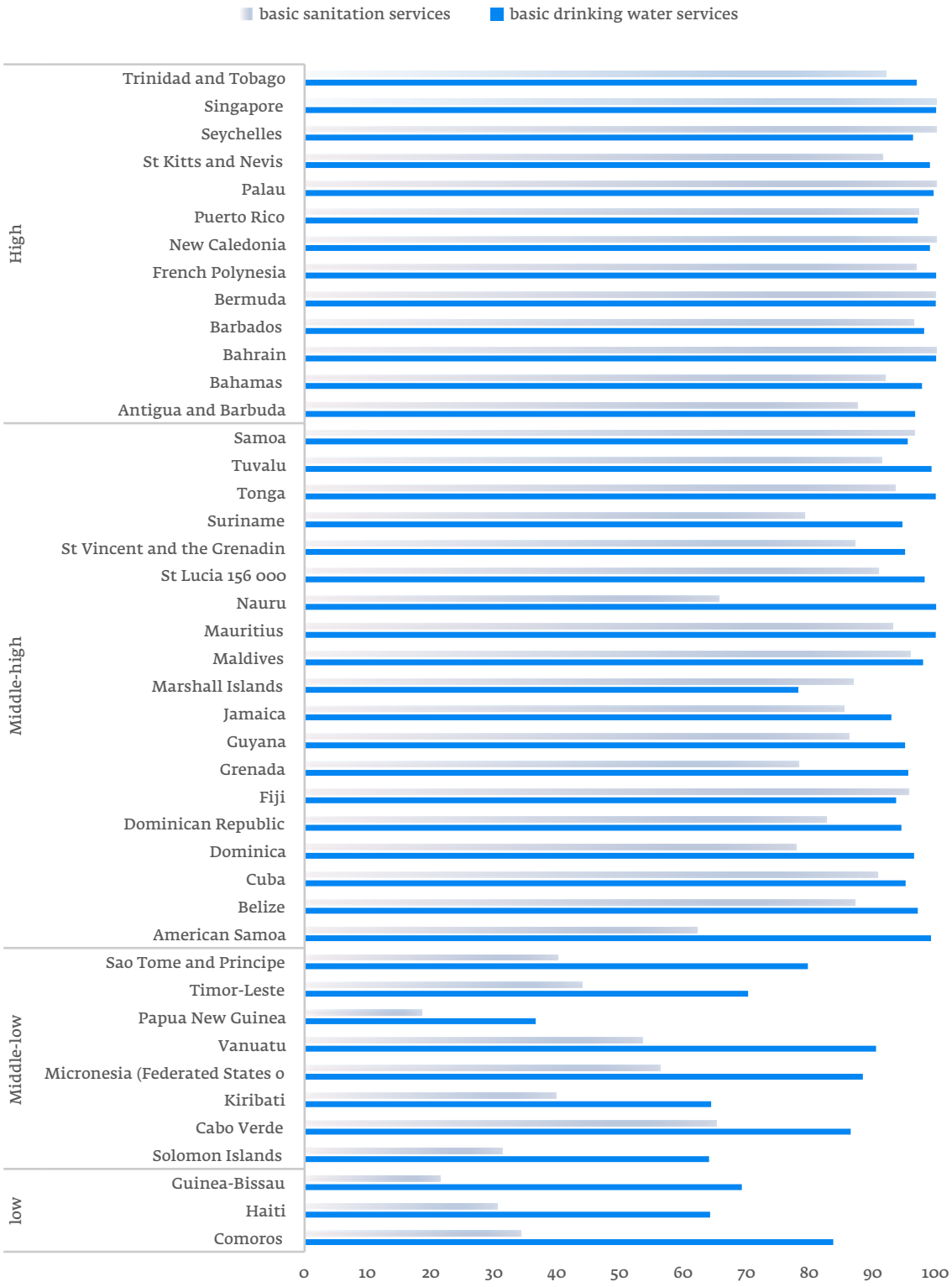
Percentage of the cultivated area equipped for irrigation with the year of reporting between brackets



Source: FAO, 2018c

Figure A.3.7

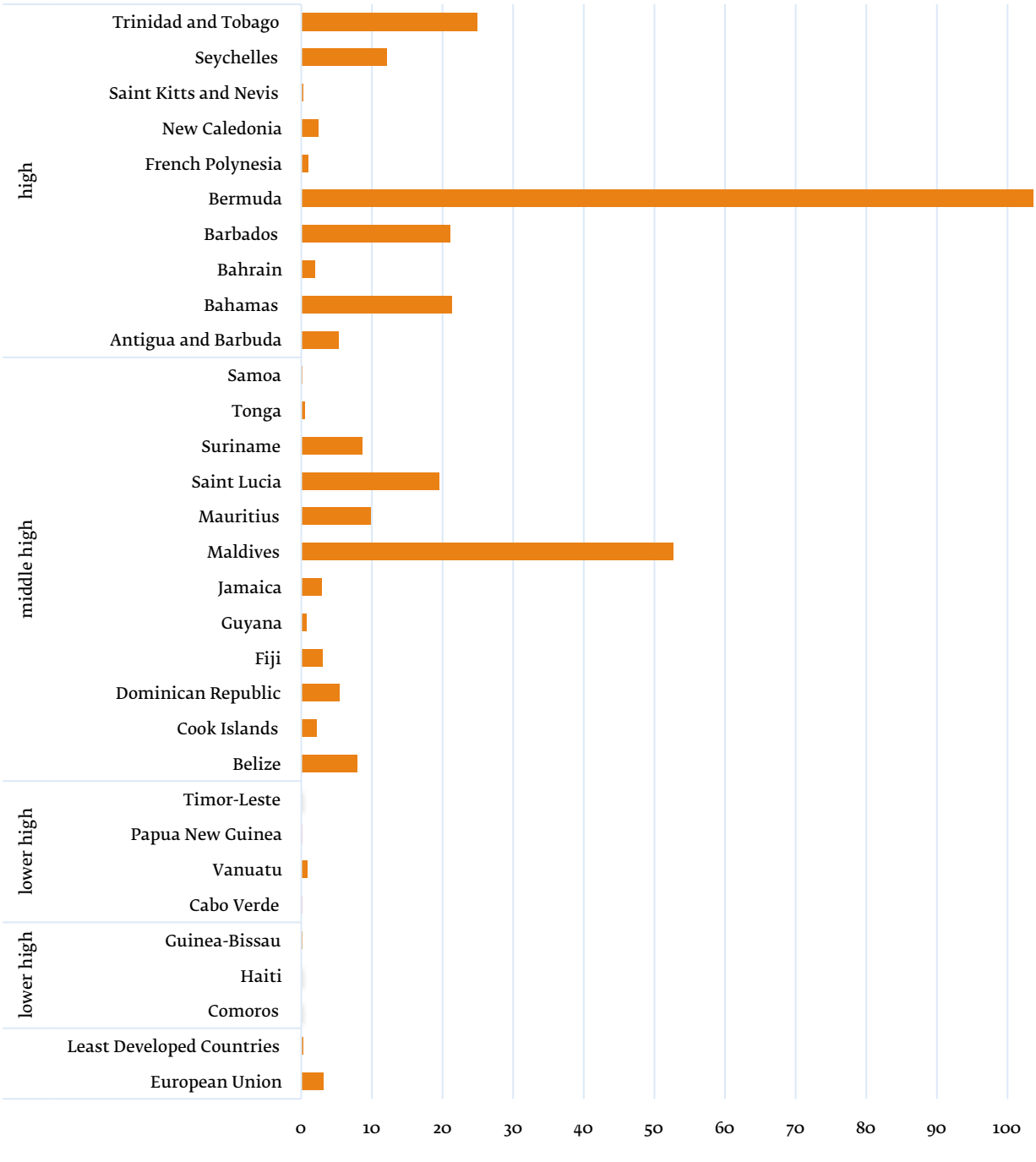
Access to drinking water and sanitation services by country and income group



Source: Authors' computations based on FAO, 2018b

Figure A.3.8

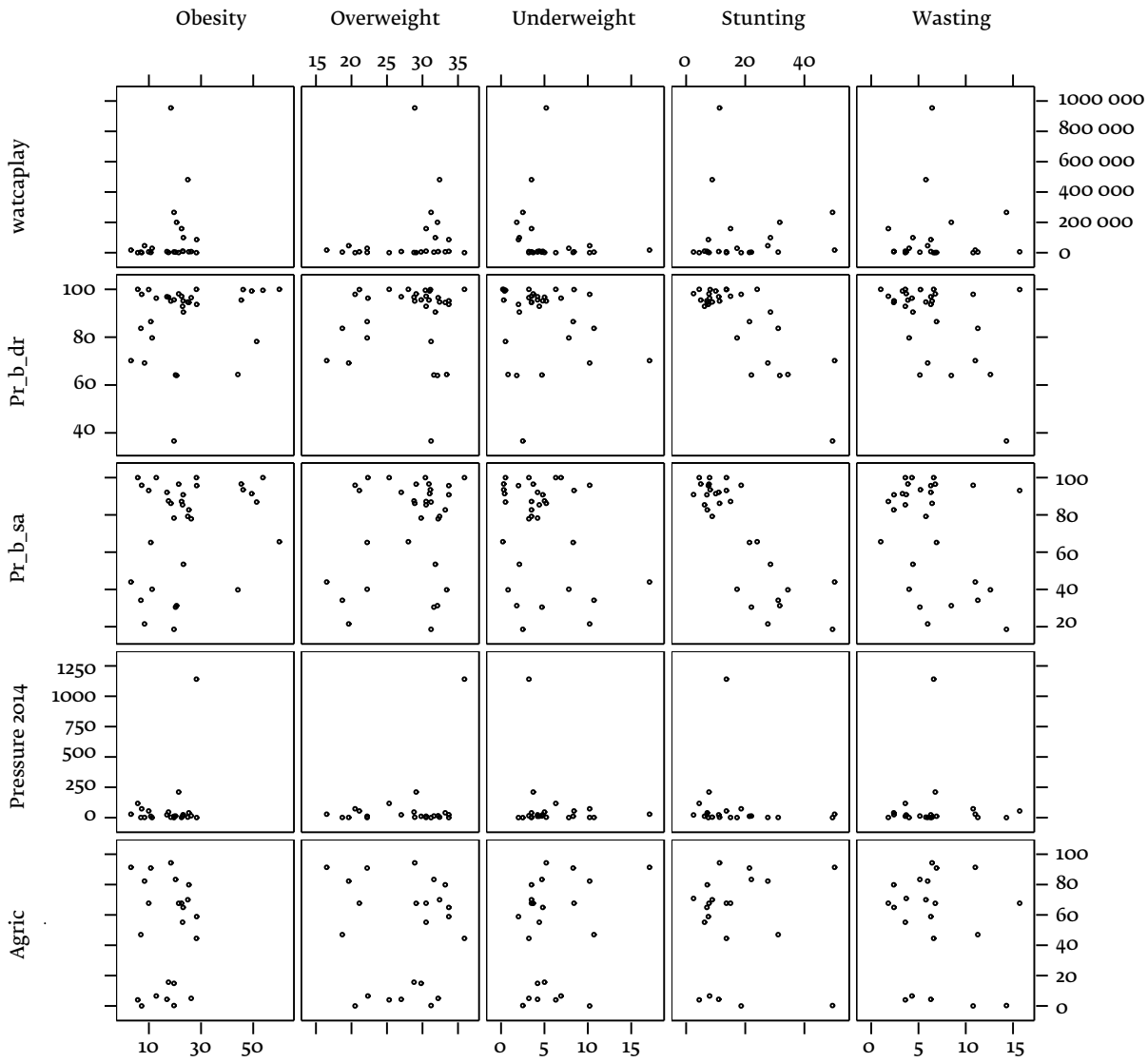
Pesticide use in tonnes per 1 000 ha by country for main geographical regions, using the EU and least developed countries as reference



Source: Authors' computations based on FAO, 2020b and FAO, 2020c

Figure A.3.9

Scatterplots between nutritional indicators and water characteristics on the SIDS



Source: Authors' computations based on results of Section 2.2 and Sections 3.2 and 3.3

Annex 5.1. Supplementary material for Section 5

THE SURVEY

A study of sustainable management and use of freshwater resources for food security and nutrition in Small Island Development States

A Basic information			
A1	Which SIDS country are you representing?		
A2	Who is your employer?	2.1	Others, please specify

B Water governance	
B1	Who is formally entrusted with leadership on water management?
B2	What is the quality of the political leadership concerning water?
B3	Do responsible agencies have sufficient capacities, budget support, and knowledge?
B4	At which levels are agencies involved in water affairs (multiple answers possible)
B5	Is there a water law/act?
	If answer is 'yes' go to B5.1, if answer is 'no' go to B6
B5.1	Is the water law/act appropriately executed
B5.2	Are there legal binding consequences in case of misconduct
B5.3	Are there incentive structures to reward good management
B6	Is there any ruling water policy?
	If answer is 'yes' go to B6.1, if answer is 'no' go to C1
B6.1	Are the water policies appropriately executed?
B6.2	Are there legal binding consequences in case of misconduct
B6.3	Are there incentive structures to reward good management
B7	How is the water policy coherence (linkage with other sectors)

C. Constraints	allocation	scarcity	pollution	over-exploit. aquifer	flooding	data paucity
C1	Which issues are perceived as water governance challenges?					
	if 'yes' go to C2	if 'yes' go to C3.1	if 'yes' go to C4.1	if 'yes' go to C5.1	if 'yes' go to C6.1	if 'yes' go to C7.1
C2.1	What water allocation problems do you perceive?					
C2.2	Is the water infrastructure of a sufficient quality to allocate the water at the desired place?					

C2.3	Is the water allocation also used to preserve the quality of the eco-systems?				
		Very serious	Serious	Moderate	No problem
C3.1	Does water scarcity directly affect the development of the agricultural sector in your country?				
C3.2	Does water scarcity directly affect the Food security and Nutrition in your country?				
C3.3	Does water scarcity directly affect the Sanitation and Hygiene conditions in your country?				
C3.4	Does water scarcity directly affect the ecosystems and eco-services in your country?				
C3.5	Does water scarcity directly affect the tourist sector in your country?				
C4.1	Is the treatment satisfactory?				
C4.2	Is the treated water reused for agriculture?				
C4.3	Is the treated water reused for municipal objectives?				
C4.4	Is the treated water discharged in the sea?				
C4.5	Is the treated water reused for other purposes?				
if C4.5 is yes, please indicate the other purposes.					
C4.6	Is untreated water reused for agriculture?				
C4.7	Is untreated water reused for municipal objectives?				
C4.8	Is untreated water discharged in the sea?				
C4.9	Is untreated water reused for other purposes?				
if 4.9 is yes, please indicate the other purposes.					
C5.1	Is there any regulation concerning the exploitation of groundwater?				
C5.2	If C5.1 is positive, what kind of regulation is in place?				
C5.3	If C5.1 is positive, are the regulations supervised and controlled?				
C5.4	If C5.1 is negative, is it to your opinion necessary to regulate the groundwater exploitation?				

C5.5	If C5.1 is negative, is groundwater exploitation largely practiced?

C6.1	Is flooding a problem in your country?
C6.2	If C6.1 is positive, is there an emergency plan to address the problems related to flooding?
C6.3	If C6.1 is positive, is there an early warning system for flooding?
C6.4	If C6.1 is negative, do you expect that flooding becomes a problem in your country because of climate change effects?

C7.1	Is data paucity and lack of information on water management a problem in your country?
C7.2	If C7.1 is negative, for which purpose do you need the information?
C7.3	If C7.1 is negative, what kind of data and information are needed to your opinion? (multiple answers possible)
C7.4	If C7.1 is negative, should the country spend more resources to meet the data demands for water management?

Table A.5.1

Who is your employer?

	Frequency	Percent
Government official	26	42.6
NGO	9	14.8
Regional government	5	8.2
Local government official	3	4.9
Water authority	3	4.9
International organization	4	6.6
Private sector	4	6.6
Regional association of water utilities/water utility	2	3.3
Others	5	8.2

Table A.5.2

Institutes involved in water governance by SIDS region

	Caribbean	Pacific	AIS	Total
National government	30.48	25.97	50	28.8
Specialized agency	25.71	7.79	0	17.9
Ministry of water	18.1	15.58	50	17.4

Local government	7.62	11.69	0	9.2
NGO	2.86	11.69	0	6.5
Local community leaders	1.9	11.69	0	6
Water users association	2.86	6.49	0	4.3
Farmer associations	2.86	2.6	0	2.7
Regional government	1.9	2.6	0	2.2
Public utilities authority	0.95	0	0	0.5
Ministry of Health	0	1.3	0	0.5
Private companies e.g. UNELCO	0	1.3	0	0.5
Semi-autonomous agency	0	1.3	0	0.5
Water resource management agency	0.95	0	0	0.5
Water utility	0.95	0	0	0.5
Water and sewage company	2.85	0	0	1.5

Table A.5.3

What are the most important tasks for the local government?

	Caribbean	Pacific	Total
Control of abuse	6.25	21.42	15.90
Law-making	6.25	10.71	9.09
Water distribution to agricultural sector	25	17.86	20.46
Water distribution to households	25	17.86	20.46
Water distribution to industry	18.75	10.71	13.63
Overall supervision	0	7.14	4.54
Water treatment/water purification	18.75	14.28	15.91
Total	16	28	44

Table A.5.4

What are the most important tasks for NGOs?

	Caribbean	Pacific	Total
Control of abuse	33.34	13.05	17.25
Law-making	0	4.35	3.45
Overall supervision	16.67	4.35	6.90
Water distribution to agricultural sector	16.67	13.05	13.80
Water distribution to households	16.67	26.09	24.14
Water distribution to industry	0	17.39	13.79
Water treatment/water purification	16.67	21.74	20.69
Total	6	23	29

Table A.5.5

Are water users associations politically influential?

	Caribbean	Pacific	AIS	Total
Very strong	0.0	40.0	0	21.1
Moderately strong	37.5	30.0	100	36.8
Not very strong	50.0	20.0	0	31.6
Not at all	12.5	10.0	0	10.5
Total	8	10	1	19

Table A.5.6

Is there a water law, by-law or act at national and local community levels?

	Caribbean	Pacific	AIS	Total
No	10.26	17.39	100	14.3
Yes	89.74	82.61	0	85.7
Total	39	23	1	63

Table A.5.7

Is the water infrastructure of a sufficient quality to allocate water to the desired place?

Q19	Frequency	Percent
No	32	72.7
Yes	12	27.3

Table A.5.8

Is water allocation also used to preserve the quality of the ecosystem?

Q20	Frequency	Percent
No	28	63.6
Yes	16	36.4

Table A.5.9

Is the treatment of polluted water satisfactory?

Q25	Frequency	Percent
No	33	78.6
Yes	9	21.4

Table A.5.10

Are there regulations concerning the exploitation of groundwater? Are the regulations supervised and controlled?

Q32	Frequency	Percent
No	17	41.5
Yes	24	58.5

Table A.5.11

Are the regulations supervised and controlled?

Q33	Frequency	Percent
No	10	41.7
Yes	14	58.3

Table A.5.12

In your opinion, is it necessary to regulate groundwater exploitation?

Q34	Frequency	Percent
No	4	9.3
Yes	39	90.7

Table A.5.13

Is there an emergency plan to address problems related to flooding?

Q37	Frequency	Percent
No	16	27.6
Yes	42	72.4

Table A.5.14

Is there an early warning system for flooding?

Q38	Frequency	Percent
No	23	41.8
Yes	32	58.2

The following Table (A.5.15) collects the original answers of the respondents verbatim, without further editing or synthesizing.

Table A.5.15

For which purpose do you need more and better information? What kind of data and information are needed in your opinion?

Q41: For which purpose?	Q42: What kind of data and information?
Research	Statistical monthly data
In order to develop strategies and systems; in order to effect adequate water management controls, policies and infrastructure; in order to direct serious focus to the island's water issues.	Although rainfall data is available when requested, all stakeholders in the water industry should receive regular and consistent data of actual and forecasted rainfall figures. Groundwater data and water pumped should also be readily available and shared among the agencies which have a particular interest in these statistics. The amount of water being lost through surface runoff, drainage canals, roadways and gullies should be known. This water usually flows out to sea. However, if the quantities lost are known, water capture infrastructure can be designed and implemented in order to provide irrigation water to the agricultural sector. This will mitigate the effects of climate change and lower annual rainfall averages, which have been plaguing the island for the past several years.
To build better policies and control mechanisms	Seasons, local historical, availability
To improve management of the resource	Hydro-meteorological data
Conservation of water sources, access rights, better water reticulation systems for farms etc.	Clear guidelines stemming from regulation, policies, etc. about rights of access, ownership, allocation, water use, reticulation systems for rural communities and farms.
	Number of water cuts, flooding measures
Efficient water use	How much to use for different purposes
For agricultural purposes and balancing that with other demands.	Water recycling case studies, opportunities of water on communal landowner land and better managing water ex ante and ex post natural disasters.
Awareness and advocacy purposes	Understanding that the problem of shortage of water in one area is different in another. Monitor the different sectors that use water and why. Industries and households are paying the same rate per milliliters of water whereas there should be a different rate charged to industries that uses water as a raw material to their production services.
Better management of water resources	Use and treatment of water
	Polluted water treatment at the village level for safe reintroduction into the environment. This is important for water management at the community level.
The information can be used in the teaching and learning process in the Fiji National University.	Actually the water bye-laws, standards on treatment, non-revenue water management, and since the water fitters licenses have been stopped by the government and the students graduating from the university with the plumbing trade finding difficulties to perform in the industries without the licenses.
New system	Save for human consumption
Household planning	Schedule maintenance
To know how safe the water is to consume	Water quality testing and availability

Personal development	all
Planning and decision making	Historic data
For farming, and engineering	Historical data, scientific real time data
Our major problem is lack of adequate storage and distribution so a great deal of water goes to waste. This is not really tracked	We lose a great deal of water because storage is inadequate and because pipes are old and leak. Both major reservoirs in the capital are silted up and no action has been taken. Data on water lost and cost involved might inspire better planning and action
More accurate estimation of expected water demand and supply to guide decisions on water use regulation	Estimates on expected water demand and supply (seasonally/ quarterly/annually)
Decision-making, network planning, tackling the issue of non-revenue water	GIS data on company assets, flow data from surface water sources, demand data from customer classes
Information is needed for modelling and rating curves.	Real-time river stage and discharge measurements. Filling and reducing gaps in rainfall data. High resolution LIDAR data for river profile dimensions. Soil moisture data.
Water demand forecasting and disaster risk management	Hydro-meteorological information, demographic info, water demand - consumption by households, industry, agriculture, tourism; abstraction rates from water sources; reports of water audits, etc.
Research and project implementation	
Resource management	flood and drought forecast
Planning and infrastructural	Hydro-logical
Sea level rise	Baseline information on rivers and freshwater ways
Forecasting trends and information on availability and status of water sources	Ultimately need a water management information system
Health and nutrition purposes	Whether our drinking water is clean or our beaches clean
Information is needed for proper water balances, watershed characterisation and modelling. Real time river discharge data are also lacking and there is insufficient budget to cover equipment maintenance costs.	Real time or daily river discharge data, peak discharge data, regular water quality data
To quantify water resources and project availability; For flood modeling purposes	Mostly continuous discharge data
Management	All data
Planning to alleviate floods, build resilience.	1. rainfall, 2. historical flood impacts, 3. topography, 4. soil types
Analysis	High temporal frequency hydrologic and meteorological data, high resolution DEM, recent LULCF layer (NRCS Curve numbers or equivalent), channel x-sections, data on water consumption and abstraction

To determine periods of water deficit based on consumption and use vs rainfall and storage.	Meteorological data. Water consumption patterns / trends
To manage water abstractions	Quality and quantity data
For the purpose of providing the correct response	Updated data on people who are affected by the water issue/ problem
Legislation and regulation	Water sources, types, access to water,
Agriculture	Weather forecasting
Technical decision	Pollution
Detailed record keeping	More official rain gauge locations
To better understand the challenges faced	How much actual water use per community
Agricultural forecasting, estimates, etc.	Volume of run-off water / area
To make sure that people are aware of the good use of water and whether it is safe	Level of chemical used to make the water pure to use
To be able to easily locate water in areas where there is insufficient water for household	Data to track or locate water basins to be able to supply in a large scale
For development of other policy papers; for advice to other agencies on water usage in the country	Types of water sources being used in country, volume of water used in certain areas during certain periods, number of people using water sources in an area, etc.
Where to find water	Groundwater assessments, national water plan
For decision making purposes by different users	Water quality data, water quantity data
To anticipate our activities	Precise weather information

Annex 6.1. Guidelines for project evaluation

Table A.6.1

Rubrics for project evaluation

ode	Transdisciplinarity	Multidisciplinarity	Institutional collaboration	funding	Social impact	ecosystem changes	Delivery	Success/failure	Sustainability
--	Absence of transdisciplinary approach	Monodisciplinarity	No collaboration	No funding	Very negative	Degradation of ecosystems	No delivery or of a very poor quality	Social and ecological objectives were not achieved	Sustainable
-	Transdisciplinary approach present but implementation unsuccessful	Monodisciplinarity with consultations of other disciplines	Some collaboration	Ad hoc funding	Negative	Light degradation of ecosystems, functions no recovery	Delivery but insufficient and a poor quality	Either social or ecological objective of interventions was achieved	
-+	Transdisciplinary approach present with some results	More than one discipline involved	Collaboration established with minor results	Funding beyond project time	Negative/ positive	Light degradation of ecosystems, functions can be recovered	Delivery but either insufficient or poor quality	Part of the social and ecological objectives of interventions were achieved	Moderately sustainable
+	Transdisciplinary approach successful; clear involvement of transcendence stakeholder	Multidisciplinary approach without integration	Collaboration successful; alignment of activities	Revolving fund; during project phase	Positive	Ecosystems not affected; eco-services in function	Delivery sufficient and of a moderate to good quality	Social and ecological objectives of interventions were achieved successfully	
++	Transdisciplinary approach very successful; stakeholders of transcendent disciplines fully participate in NBS process from design to implementation	Multidisciplinary approach with full integration	Collaboration very successful; alignment activities and establishment of sustainable relationships	Revolving fund; proven operational beyond project phase	Very positive	Ecosystems improved; eco-services function better as before project	Delivery sufficient and of a good quality	Social and ecological objectives of interventions were achieved successfully and mutually strengthen each other	Sustainable

Annex 6.2. Questions for in-depth interviews

1. WATER GOVERNANCE

Concerning water governance, we hope to make an inventory of political priorities concerning water management with a special focus on agriculture and food security. We aim to organize meetings with institutes involved in water governance, e.g.:

- FAO team
- governmental institutions
- non-governmental institutions
- private sector companies

The questions below have been formulated to gain information on a) water governance, b) agricultural water governance and c) health issues related to agriculture and water. The interviews are open-ended and the questions merely serve to prompt discussions on relevant topics. Please, read the guidelines for interviews found at the Annex of this TOR.

1.1 Proposed questions on water governance

Objective questions

1. How is water policy established? Is there an active role for the parliament or other stakeholders (what is the legislation institute)?
2. What kind of programmes were established that relate to water management, agriculture and food security?
3. How are responsibilities for agricultural water management delegated? At which level?
4. Is municipal wastewater collected and treated for reuse?
5. Is treated wastewater used for agriculture?
6. Is untreated wastewater used for agriculture?
7. Is there an incidence of water-borne diseases?
8. Are there any statistics on the incidence of diarrhea?

9. Any rain harvesting at the household level?

Reflective questions

1. Do you agree with the political priorities for the water governance of the island?
2. What is the best feature of the current water policies?
3. What do you like the least about the policies?
4. Was the indicated implementation of the policy a success? Please explain.

Interpretive questions

1. What were the major challenges involved in establishing the current water policies?
2. What are the lessons learned, or what should have been done differently?
3. What were the major 'wins'?
4. Were there any unintended impacts or consequences - either positive and/or negative?

Decisional questions

1. What needs to be done now to improve water management?
2. What needs to be done in the future to improve water management?
3. Is there a message for our study on water management?
4. Did you miss a topic or do you want to add something that didn't come up in the interview?

1.2 Questions on water governance and agriculture

Objective questions

1. Which institute is responsible for agricultural water management?
2. How are the responsibilities of agricultural water management delegated? At which level?
3. Is municipal wastewater collected and treated for reuse?
4. Is treated wastewater used for agriculture?
5. Is untreated wastewater used for agriculture?

Reflective questions

1. Do you agree with the priorities on agricultural water management?
2. In your opinion, what is the best feature of agricultural water management?
3. What do you like the least about agricultural water management?
4. Is there any direct communication between the farmer and the legislation institute?
5. Are farmers organized in a cooperation or institution?

Interpretive questions

1. Was the indicated implementation of the policy on agricultural water management a success? Please, explain.
2. What were the major challenges involved in establishing the current policy on agricultural water management?

a. What are the lessons learned, or what should have been done differently?

b. What were the major 'wins'?

c. Were there any unintended impacts or consequences – either positive and/or negative?

Decisional questions

1. What needs to be done now to improve agricultural water management?
2. What needs to be done in the future to improve agricultural water management?
3. Is there a message for our study on agricultural water management?
4. Did you miss a topic or do you want to add something that didn't come up in the interview?

1.3 Questions on agriculture and health

Objective questions

1. Is the agricultural sector satisfied with current water policies?
2. Does the agricultural sector to contribute to food diversity?
3. How are responsibilities for food diversity delegated?
4. Is municipal water collected and treated for reuse in the agricultural sector?

5. Are there policies in place to promote food diversity?

Reflective questions

1. Do you agree with the priorities concerning diversity of food consumption?
2. In your opinion, what is the best policy for the diversity of food consumption?
3. In your opinion, what is the major constraint to diversity food consumption?
4. Do you think cultural preferences play a big role in food habits?

Interpretive questions

1. How could improved water management serve food diversity?
2. What are the lessons learned, or what should have been done differently?
3. What were the major 'wins'?
4. Does income play an important role in access to food diversity?

Decisional questions

1. What needs to be done now to improve food diversity?
2. What needs to be done in the future to improve food diversity?
3. Is there a message for our study concerning food diversity?
4. Did you miss a topic or do you want to add something that didn't come up in the interview?

Annex 6.3. Guidelines for the interview

1. **Before the interview**

    a. Determine the role that each team member will play during the interview; nominate one leader of the interview who orchestrates the setting.

    b. Note name, function and institute of the interviewee.

2. **Start of the interview**

    a. The meeting starts with a respectful greeting.

    b. Exchange of name cards.

    c. Building trust. After the greeting, we convey

        i. the purpose of our visit

        ii. the context of our study

        iii. emphasise the importance of the respondents' participation.

        iv. emphasise that the interview is voluntary and that the interviewee can stop any moment of the interview

        v. what we are going to do with the results of the interview and

        vi. what we are going to do with the study

    d. Avoid the creation of false pretenses; the respondent might be sensitive if promises are made that cannot be realized.

    e. Guarantee anonymity. No reference will be made to the names of respondents.

    f. Ask if the respondent agrees to a digital recording of the interview.

    g. The length of the interview is approximately 30 minutes.

3. During the interview

a. Ask the respondent if he/she wants to make an opening statement on the topic (e.g., water governance).

b. If no, start with the questions posed in the TOR.

c. Read the questions carefully.

d. If the respondent starts a storyline do not interrupt and wait until he/she finishes; then pick up again.

e. Take a break when needed or indicated by the respondent.

f. Let respondent feel that their answers matter.

4. Possible problems

a. Respondent does not want to cooperate with the interview:

   i. Try to convince the respondent that collaboration is useful for water governance and agricultural development on the island.

   ii. If the respondent continues to refuse to cooperate, respect their decision, pay a courteous farewell and locate the next respondent.

   iii. A special note of this occurrence should be made in the final report of the survey.

b. Answers of a respondent are not consistent

   i. Carefully confront the respondent with the inconsistency.

   ii. If an inconsistency is detected after the interview, repeat visits to the respondent and try to elicit the correct information.

   iii. If the visit cannot be repeated, a special note of this occurrence should be made in the final report of the survey.

c. Respondent does not or cannot give straightforward answers

   i. If one has the impression that the respondent does not answer the interviewer to the best of their knowledge stop the interview with a courteous farewell.

   ii. A special note of this occurrence should be made in the final report of the survey.

d. Interruptions

   i. If the interview is interrupted, the respondent should be asked if the interview can be continued at another time.

   ii. If this is not possible, the answers to the interrupted interview are kept. Yet the interview is not counted as complete and should be replaced by another complete interview.

   iii. A special note of this incident should be made in the final report of the survey.

e. Different answers are given by respondents

   i. Do not confront respondents with different answers that are given by other respondents

   ii. Different answers are dealt with in the processing stage.

5. After the interview

a. After the interview, the conversation is transcribed and analysed in a session with the team.

b. Keep hard copies of the conversation for later checks.

c. If errors are detected during this stage, revisit the respondent to obtain the correct information.

Annex 6.4. Interviews in Barbados

James Paul, Director of the Barbados Agriculture Society

Paul is a former parliamentarian and the current director of the Barbados Agriculture Society (BAS), an umbrella organization established in 1845. BAS represents nine commodity groups and has 500 farmer members. The highlights of the interview follow.

Various challenges for the agricultural sector concerning water management were discussed with Paul. He stated that maintaining environmental health is of utmost importance for the country. However, the water supply for households, agriculture and industry must be central to water governance. The main challenge for the water sector in Barbados is to develop a comprehensive water policy that can be applied through regulation and policy enforcement.

According to Paul, the management of water resources in Barbados should be based on political decisions: "...the Parliament should have a say on the legalisation of water policies, knowing that it is difficult to amend the policy or law which can compromise our water resources."

Yet social interdependence and fear of retaliation make it difficult to enforce rulings and regulations: "Law enforcement is quite hard in Barbados: as we are in a small island, everybody knows each other [and] no one will harm another person."

The interviewers expressed concern about the pollution of surface and groundwater in Barbados due to high concentrations of pesticides and herbicides. The concern was acknowledged by Paul: "Also, we are developing programmes that disseminate and push for the use of best practices on the individual farms by applying natural fertilizer and prevent[ing] the overuse of regulated pests and pesticides."

Paul acknowledged that data on water quantity and quality as well as information on chemicals used in agriculture should be improved by involving all stakeholders in data collection, including the private sector. Such information should be freely available. Paul observed that poorly treated wastewater discharged from tourist hotels to the sea has affected marine ecosystems, with dire consequences for coral reefs. To combat water pollution, BAS tries to promote the use of organic fertilizer as an efficient and environmentally friendly alternative to chemical fertilizers. Farmers are increasingly using fertigation in drip irrigation systems; this increases the application efficiency and reduces fertilizer losses. BAS is also actively promoting sound water management by training farmers and stimulating the adoption of best practices. Paul believes that higher water efficiencies can be attained by teaching farmers about drip irrigation, fertigation, hydroponic farms, water harvesting techniques and water scarcity in the country.

Paul indicated that there are many conflicts between farmers in upper catchments and downstream areas concerning quality of released water. Yet there is no clear authority that can intervene in such conflicts.

Fulfilling the government's political agenda of expanding urban areas with the related increase in water demand will require using treated wastewater (TWW) facilities to treat water. The reuse of water for certain purposes (e.g., irrigation of lawns) should be considered.

On the political role of BAS, Paul indicates that his organization has a voice. His position in the previous government ensures that there are active political contacts. Importantly, He is confident that the objectives of BAS have government support.

In response to questions about the success of water management in Barbados, Paul pointed to the successful efforts to raise awareness around the importance of water efficiency. He cited the adoption of water harvesting practices for nurseries and the introduction of drip irrigation as examples. He also pointed to the active role of the private sector: "[It] will be good to [engage] farmers ... in the process of the development of water policy and understanding the importance of rain harvesting."

Paul expressed his concerns on changing climatic conditions and the overexploitation of groundwater reserves. He gave the example newly built houses that drill illegal wells. He is also concerned about policies that are prepared by bureaucrats without proper analysis or consideration of the needs of the population. Politicians should play a more active role in the process of formulating water management programmes. Pricing water could be an instrument to increase the efficiency of water use of water. In the end, it is the political will is necessary to control water use, improve the water quality and to take the measures necessary to address climate change: "....are we actually seizing all the opportunities for water management?"

Nicole Austin, Alex Ifill and Jaime Paul, Barbados Water Authority (BWA)

The interviewees provided an overview of their mandate and main tasks. BWA was established in 1980 and charged with supplying Barbados with potable water, as well as providing wastewater treatment and disposal services to the sewered areas of Bridgetown and the South Coast. BWA is responsible for monitoring, assessment, control and protection of water resources. Currently, supplies over 100 000 customers with water, operates two wastewater treatment plants and a desalination plant. Sewage treatment and disposal services are provided to 4 400 customers. A planned third wastewater treatment plant should cater to 6 000 customers. Various water acts give BWA control over surface and underground water reserves in Barbados. Most of the acts date from the colonial period and cover the main water sources used for irrigation and recreational purposes. Water mainly comes from groundwater reserves (80 percent), and from streams and springs; 20 percent of the drinking water comes from the Spring Garden desalinization plant: "Only three streams deliver some (surface) water; each has its own act."

BWA is currently working on developing a new act: ".... the new act should account for the current water stress [and] also look [at] the reuse of water, rainwater harvesting and groundwater extraction policies."

There is a new regulation for major hotels to have their own TWW plants. These plants are regulated by the Environmental Protection Department (EPD). The EPD has the specific responsibility to monitor possible marine pollution: "All hotels by law have to be connected to the sewage system. The Environmental Protection Department monitors and regulates…what they can discharge and where they can discharge."

Smaller hotels are given three years to organize a water treatment protocol; they are not allowed to discharge septic tanks into the sea without first treating the water.

The Marine Pollution Control Act of 1998 clearly states that discharges are illegal and, in principle, can result in fines. Nevertheless, the interviewees indicate that the population is accustomed to the discharge of untreated wastewater: "Discharges in the sea [have existed] from time immemorial, but I know that the Environmental Protection Department and the Coastal Zone Management Unit can monitor and enforce rules based on discharges in the sea, which cause water pollution."

The BWA licenses wells and monitors their extraction rates and water quality. Extraction rates are based on long-term recharge volumes by catchment area. Yet the monitoring of extracted water volumes is not an easy task:

Right now, we're reviewing the entire system because you are not charged at all for over extracting. We do request that farmers put working meters in place. But of course, you know that comes with its own issues because if they don't have it in place… what are we going to do really about that?

Licenses are based on farm size and the potential recharge of that catchment in an average year; it does not consider crop composition: "Farmers are considered regular customers and are charged a commercial rate, which is a lot cheaper compared to household rates."

The BADMC is responsible for its own wells but reports on extraction rates to the BWA on a monthly basis.

High nitrogen concentrations due to agricultural practices are a major concern for the BWA. Pesticide concentrations in groundwater are below the thresholds indicated by WHO: "In principle, …[BWA] monitor[s] for primary pollutants monthly, every four months for pesticides and [every year we conduct in-depth research on] all pollutant elements that can be traced."

This might change in future as agriculture is moving towards more intensified farming practices, such as the cultivation of cash crops and seasonal vegetable farming, which requires heavy doses of pesticides and herbicides multiple times a year:

The government has banned the import, not the use of herbicides. So…the trend has been [going] down and [in now] below the detection limit. The only fertilizer that we see [of significance] is nitrogen, as well as nitrates, [which], are monitored on a weekly basis.

The main challenge for BWA policy is to manage the increasing demand for water and to regulate the fierce competition between the various water uses:

"As a regulator and major consumer BWA has a clear-cut conflict of interests with farmers who demand their water."

"..... But how do you balance the demand of farmers and the golf course?"

Another challenge is the cultural barrier to reusing water. Currently, treated wastewater is only used for irrigating golf courses. Barbados also lacks the necessary infrastructure for treating water: the two existing treatment plants are near the coast, which makes water pumping and transport costly.

"We have an international society that is very litigious. So, then children play. They pick a pathogen and they hear that they're actually using renovated water [treated wastewater] to irrigate. Then you get these [law]suits coming in."

The downstream problems caused by water pollution in the upper catchment are recognised by the BWA: "... we don't control [downstream flows]. I mean we only monitor at the source... We only control the wells"... "Technically it can fall on the act [the act provides a legal mandate to control the quality of upstream water flows]. But we never had the manpower."

Lack of staff and the absence of a clear mandate means that upstream pollution is only recognised after complaints by downstream farmers.

Rainwater harvesting is not a custom in Barbados, unlike on other Caribbean Islands (e.g., St. Kitts, the Virgin Islands) where water is being harvested at the level of households: "... regarding rainwater harvesting we even have a challenge to get people to install tanks connected to our system. ... [i]n case the water goes off as a backup they don't have tanks [if people are cut-off from the water system, there is no backup system of water storage when there are no tanks]."

The following is an example of a good practice that might help to promote rainwater harvesting:

My parents grew up in St. Vincent in a Catholic country where they were responsible for their own water collection. She takes the water from the tank and she would use it to bathe ... to cook ... [O]thers don't have that history. [I]f they don't have that understanding, that culture they will never ever know.

Rainwater harvesting will be an approach under climate change conditions that are likely to bring erratic and concentrated showers and extended dry spells. Currently, the use of rainwater harvesting is limited by law. There are several examples of lawsuits in tourism areas due to the use of harvested rainwater, which resulted in water-borne diseases.

Damian Coppin, Suzette Edey-Babb, Robert Saul, Leslie Sealy, Glenn Marshall, Jamekal Andwele, Gennia Oxley, Beverly Wood, Ministry of Agriculture; Stephen Alleyne (National Programm Consultant Carrebian office, FAO C).

The mission statement of the Barbados Ministry of Agriculture (MoA) affirms its aim is to create a competitive agricultural sector that contributes to the socio-economic development and food security of the country. The efficient and sustainable use of the natural resource base should be assured through the adoption of appropriate technology

While water management and irrigation falls under the BWA, the MoA's BADMC controls 50 to 60 percent of the water supply from 600 active irrigation stations in different districts. Other farmers receive water directly from the BWA.

According to the Ministry: "...We monitor the water pumps... individual farmers provide pump data. from there we can measure the amount of water used per pump." Yet there is no exact figure for the division of water supply between BWA and BADMC. All farmers under BADMC pay commercial rates for the water supplied. Some of the farmers and land users receiving water from BWA pay commercial rates while others pay drinking water rates. Indeed, it is not clear how much water is used by these farmers for household purposes and how much is used for farming. Moreover, agricultural land is increasingly being converted to build-up areas or golf courses, further complicating the water accounting. Lastly, there are plantation farmers who possess their own wells based on traditional water rights.

The MoA acknowledges the current stress on water resources and intends to increase the efficiency of water use through subsidies that can be used to purchase drip irrigation and desalinise groundwater. BADMC rations water supply during dry spells, so that a sustainable water supply can be guaranteed over the long term.

There is, as yet, no MoA research programme concerned with creating higher water use efficiency. BADMC is looking at ways to increase productivity by new technologies, such as hydroponic farming.

Some people collect rainwater to store in a water tank, yet, few use the stored water for their homes or gardens. One problem is that people do not trust the quality of the water stored in the tanks.

The MoA does not actively promote the reuse of water in agriculture. The interviewees think that this practice should increase. However, the existing water treatment plants are located in urban zones, far from agricultural areas.

The MoA has an interest in playing a prominent role in drafting the new BWA water act: "The data [that can support and substantiate the formulation of a new water act] is something that MoA should have to look for. You have to have a policy if you want to come up to such a level. " The Ministry is currently not involved in this important water policy act and the division of water resources between sectors is unclear:

It is not clear which type of water supply is being used for which [purpose].... It is important to specify the use of water so that in a government policy, agricultural water is used for agricultural purposes only and not for industrial purposes.

The MoA plays an active role in the government's National Food security and Nutrition Plan (Government of Barbados/FAO, 2013), which addresses unhealthy diets and aims to reach poor and socially-excluded groups in the society: "About 60 percent of the local produce from the farmers is paid for by the government, collected in distribution centers and sen[t] to the feeding programmes in schools, hospitals and other places."

The MoA wants to extend the four commodities (potatoes, cabbages, beans and peppers) that are currently distributed to the food programme to include more diverse and healthier foods.

The Ministry of Agriculture and Food Security recently embarked on the ambitious Farmers' Empowerment and Enfranchisement Drive (FEED) programme. FEED aims to achieve savings on foreign exchange by 2022 by reducing agricultural imports while improving the country's national Food security and Nutrition. This will be achieved through appropriate technology and sound management of the entire value chain to deliver internationally marketable crops that can compete with the imported food items.

The source of water for home gardens and school farms is domestic net water or tap water from the BADMC wells. The use of net water carries the high domestic use tariff even if the water is for gardening/farming.

Many people have home gardens to support family income. The home gardens are usually irrigated with tap water rather than harvested rainwater even if the latter is available in tanks. The MoA interviewees indicated that laws and cultural acceptance constrain the use of harvested rainwater.

The MoA develops policies to help farmers achieve the prime minister's goals to increase national food production and reduce the export food bill. The MoA manages a subsidy programme to incentivise farmers to use drip irrigation and is involved in several food programmes that aim to improve food diversity and nutrition among targeted groups.

MoA has had various promotional programmes focused on young children "... because most of them don't know where their food is coming from." Ministry staff have worked with schools to raise awareness around agricultural activities and food production. Teachers have been trained to grow and use the produce. A nutritional officer has taught students how to prepare healthy foods, "... for example, teaching them [to use] pumpkin instead of ... cheese in a recipe ...."

The programme lasted three years before it was unfortunately closed down. However, the Ministry continues to promote the use of fresh foods. Recently, the target group has been changed to office workers at the prime minister's request.

School Feeding Programme

Jean Fransen, Food Security and Rural Development Officer, FAO Sub-Regional Office for the Caribbean; Dawn Browne, Manager, School Meals Department, Ministry of Education

The School Feeding Programme (SFP) is fully funded by the Government of Barbados. The primary school serves a meal to all children; the secondary school only serves children with financial challenges at home.

The objective of the SFP is to reduce the consumption of processed foods and fat intake and to increase the consumption of fruits and vegetables. The programme has recently changed its focus from sufficient calorie intake to a combination of calorie and essential nutrients. Currently, an average meal contains vegetables, starch and protein, often complemented with fruits. Food quantities follow dietary guidelines.

Locally-produced crops are preferred by the SFP. This choice brings various challenges. First, suppliers might provide imported food only, for example, when the availability of local foods is limited and can be sold at higher prices elsewhere. The school meal programme has limited negotiating power due to limited resources. Another serious challenge is the lack of constant supply by small farmers.

Nevertheless, there are opportunities for the SFP to incorporate local produce into school meals. The SFP and the FEED programme had a successful collaboration, which started in September 2019. The FEED programme provides SFP with locally produced commodities (e.g., sweet potato and peppers). Moreover, the BADMC contributes fresh and healthy food from their own producers and storehouses to enhance the quality and diversity of school meals.

The BADMC aims to increase the number of commodities used in the school food programme. Collaboration with other stakeholders has started, however, a further expansion of the ministries involved (e.g., BWA, the Ministry of Environment and Ministry of Education) would secure the sustainability of the food supply for the programme.

The objective of using local foods in school menus is also being pursued at the regional level, where there are similar challenges. A constraint is that small farmers prefer to sell their produce at markets, rather than to the school feed programmes, because of delayed payments by governments. Barbados is an exception and pays the farmers within two weeks. Other countries aim to reduce the delays.

The SFPs have not been explicitly included in national policy. However, since the arrival of a new Minister of MoA in 2018, there has been greater commitment; this is manifested by the fact that schools now have the ability to make changes to the menu. Furthermore, MoA promotes SFP in the parliament as an efficient tool against hunger and malnutrition.

The interviewees held that school meals should be included in formal policy-making processes to assure that menus include local products and are aligned with food dietary guidelines. Nutrition centres, which develop dietary guidelines, recently started to collaborate with the school meal programme although the collaboration is still in its infancy.

At the regional level, there seems to be a political desire to strengthen SFPs, however, few countries have managed to improve school meal policies. The particular challenges are that few people advocate SFP and the considerable time needed to institutionalise SFP policies. In addition, the role of the civil society in promoting SFPs could be stronger.:

In my opinion, it takes so long because the civil society [and] the population, we are not following up. We are not saying, you say you will be doing that, why you are not doing it? So, civil society is not demanding that much.

The interviewees pointed to the opportunities to exchange strategies with other countries on the SFPs. Currently, Guyana and Trinidad and Tobago are exchanging their experiences at a formal level. Respondents indicated that the exchange of information and experiences urgently needs to be expanded.

Drinking water was promoted in nursery schools but was quickly replaced with sugary beverages after the promotion ended. The taxation of such beverages does not seem to have an effect on its consumption in schools. The option to ban sugary beverages at schools seems to be more effective: "I don't know that [the tax] had much effect, particularly in schools because I think children are drawn to [sweet drinks] and if they want it, they're going to get it."

Widespread opportunities to buy bad quality food challenge the best intentions. Junk food can be found in school cafeterias and vendors sell snack foods around school areas.

The interviewees indicated various opportunities to diversify the SFPs. Following dietary guidelines, information about the appropriate amount of food per food group could be provided to the school kitchens. Furthermore, the SFP could capitalise on the collaboration between the nutrition centre and BADMC to create recipes that follow the guidelines. In general, a trend towards more healthy diets can be observed when comparing recipes from the 1970s with current school meals. Some SFP meals are not appreciated by students and parents are asked by the school masters to encourage their children to participate. Furthermore, school meals are now a subject of the educational programme: "We need to stop just looking at it as that you're providing a meal for these children and try to incorporate it as an educational opportunity to teach these children...why is this better for you."

School gardens in Barbados are not common, nor are the gardens that exist linked to the SFP. The Prime Minister has pushed for clear links between healthy food production and the SFPs. However, these intentions have yet to be realized.

The promotion of healthy foods still faces a raft of challenges. First, there is no clear policy to follow dietary guidelines in determining the composition of school meals. Second, the cultural preferences of the younger generation are heavily weighted to fast food chains. Third, fortification programmes are largely absent despite widespread micronutrient deficiencies that can cause serious health problems. It is worth mentioning that there have been some discussions about the fortification of sweet potatoes in some countries in the region.

The interviewees emphasised the importance of increasing dietary diversity, promoting collaboration between ministries and departments and finding more money to support the SFP: "It makes no sense ...[to have] dietary guidelines...[without input]input from the persons who actually put them together to make sure that we are on the right track [with school meals] and that type of thing."

Hugh Sealy, Lecturer, University of West Indies, Advisor to the Prime Minister

Sealy observed that the lack of data on water resources seriously affects decision-making processes around water-related economic development programmes in Barbados. He noted discrepancies between FAO's AQUASAT and data used by the BWA. For example, BWA data holds that approximately 25 percent of freshwater resources being used for agricultural use, while FAO claims 60-70 percent. Sealy emphasised that this discrepancy is due to the lack of transparency and verifiable protocols and agreements between institutions: "Somebody has the authority to give those numbers [from BWA to FAO] [yet, the numbers are not transferred] ... ([hence], they operate on totally different numbers."

Sealy indicated that this [absence of numbers] may be due to the lack of meters at the production wells and the use of indirect methods (pumping curves) to approximate water production. Besides, measuring at the source of the public supply wells after the water has been chlorinated does not reflect the raw water quality.

Concerning water stress, "...we are very close to abstracting all of our freshwater resources in an average year of precipitation. And in a one in 15-year drought year, which is becoming more frequent, we have a deficit."

Sealy referred to the large share of non-revenue water, which can be around 49 percent on average: "...we're pumping twice as much water as we get actually to the consumer. "

Sealy indicated that water demand has increased over the years, as about sixty years ago only one-third of the current amount of water was pumped compared. Also, outdated information makes it difficult to assess current crop water demands.

Historically, freshwater resources have been undervalued. Better data could support informed decisions on water distribution between households, economic sectors and ecological flows.

Sealy observed that agriculture's contribution to the economy has been decreasing. However, current government policy places agriculture more prominent on the agenda. There is an opportunity to expand agricultural development by producing biofuels, such as the cultivation of sugar cane used to manufacture ethanol. This aligns with the government's vision for a fossil fuel free economy by 2030. However, to produce enough ethanol to serve the transport sector alone would require historical production figures of around 1 million tonnes of sugar cane per year. Biofuels may also be in demand to produce electricity, with between 300 – 600 acres of a biofuel crop required for every megawatt (MW) of generating capacity. These production levels can only be obtained when water demand is fine-tuned with seasonal variation where rain-fed periods are combined with additional irrigation.

Sealy has been instructed by the cabinet to upgrade the two existing wastewater treatment plants for managed recharge of groundwater aquifers and, possibly, to irrigate non-food crops and crops that are not eaten raw. This should result in an additional four million imperial gallons per day (MGD) of reclaimed water; 1.5 MGD from Bridgetown and 2.5 MGD from the South Coast. A major concern for Sealy is the reduction of infiltration rates due to the lack of maintenance of agricultural drainage wells and the inherent lack of storage capacity, especially given emerging climate change scenarios. A data paucity problem prevails here as well since the current climate change models use a coarse resolution that is not applicable to Barbados. Sealy indicated that the general message is that Barbados could receive 20 percent less precipitation [usually these statements refer to a horizon of 30 years when climate change becomes fully in force].

There are no plans to build additional sewage collection networks in Barbados. Currently, 110000 homes discharge domestic wastewater into septic tanks or directly into a suck well; creates water quality problems and affects the ecology of the island. Dumping untreated wastewater has affected 40 percent of the coral reefs around Barbados. Sealy estimates that 50 percent of the nitrogen in the wastewater comes from agriculture and 50 percent from human and animal waste. Of the nitrogen load that reaches the nearshore, 85 percent comes from groundwater and 15 percent from surface runoff: "... [W]e thought agriculture was this benign thing; we were only worried about human waste .. yet then we've got these nitrate concentrations in our groundwater....[It] is going to impact on the coasts."

Sealy recommended an institutional reform that would split the regulatory and operational responsibilities of the BWA. The idea would be to strengthen the independent monitoring of water quality and quantity.

Sealy does not expect that adding an additional 5 000 hotel beds on top of the current 6 000 will significantly affect water scarcity; it should increase water use by half a million to a million gallons. To expand agricultural production, however, Barbados needs better planning processes, based on the type of cultivated crops.

Sealy advocates integrated, nature-based solutions that draw on the traditional knowledge base, together with modern data, to support the balanced use of abstraction wells, water reuse and rainwater harvesting to increase water use efficiency. Desalination is likely to play a larger role in the provision of potable water in future.

Annex 6.5. Hydrological data used for SHLLP water availability assessment

Table A.6.2

Monthly precipitation and evapotranspiration data and kc values for three crop rotation schemes in SHLLP

Month	Precipitation	ETo[1]	Crop rotation_1	kc_1	ETxkc_12	Crop rotation_2	kc_23	ETxkc_2	Crop rotation_3	kc_3	ETxkc_3
Jan	68	179	cassava	0,3	54	sweet potato	0,65	116	sweet potato	0,5	90
Feb	45	208	cassava	0,3	62	bare soil	0,2	42	sweet potato	0,82	170
Mar	36	201	bare soil	0,1	20	bare soil	0,2	40	sweet potato	1,15	231
Apr	61	144	squash	0,5	72	beans	0,4	57	sweet potato	1,15	165
May	82	180	squash	0,5	90	beans	0,73	131	sweet potato	0,65	117
Jun	112	178	squash	0,95	169	beans	1,15	204	bare soil	0,2	36
Jul	130	194	squash	0,75	146	beans	0,35	68	bare soil	0,2	39
Aug	156	178	cassava	0,3	53	bare soil	0,1	18	beans	0,4	71
Sep	166	134	cassava	0,3	40	sweet potato	0,5	67	beans	0,73	98
Oct	144	116	cassava	0,8	93	sweet potato	0,82	95	beans	1,15	133
Nov	203	155	cassava	0,8	124	sweet potato	1,15	178	beans	0,35	54
Dec	112	163	cassava	0,8	131	sweet potato	1,15	188	bare soil	0,1	16

[1]Potential evapotranspiration; [2]crop coefficient initial phase, [3]crop coefficient development phase; [3]crop coefficient final phase.

Source: Precipitation and ETO, BADMC, 2020a. Source , Kc coefficients, Allen et al., 1990.

Annex 6.6. Interviews in Mauritius

Central Water Authority

Chandrasen Matadeen, Agriculture General Manager; Harish Lobind, Agriculture Chief Engineer (Operations Division); Dineshswar Lutchmun, Chief Engineer (Project Management Office); Mitradev Lobin, Agriculture Chief Engineer (Project Management Office); Sewkumarsing Dinassing, Agriculture Chief Engineer (WR/OSS); Druv Sungkur, Commercial Director; Houmesh Benee, Higher Clerical Officer (Management Information Unit); Atish Soobroydoo, Economist-Analyst

The Central Water Authority (CWA) was established in 1971 and operates under the aegis of the Ministry of Energy and Public Utilities. When the Water Resources Unit (WRU) took over the responsibility of water resources administration in May 1993, the CWA became mainly responsible for the treatment and distribution of potable water for domestic, commercial and industrial uses. Mauritius has two main sources of water: surface water (contributing 52% of the water supply) and groundwater (contributing 48%). There are 104 service reservoirs and about 440 boreholes on the island; 195 of the boreholes are under CWA authority and are monitored daily during the dry season. Licenses are issued to private owners and are renewable. About 850 000 m^3 of water are treated per day. Highlights from the interviews follow.

One of the main challenges for CWA is to reach its water supply targets: "So, one of the problems of the moment is 24/7 supply of water because we have nearly...65 percent which receives 24/7 and our target is 100 percent."

The interviewees explained that this problem stems from inadequate funding, low water tariffs and inadequate running water:

The problem also is we have a tariff of water which is very low compared to countries of Africa. If you compare, you see it is very low. But the problem also is our level of non-revenue water, it is nearly 55 percent, therefore, for half of the water we are injecting it is not attainable [50% of the pumped water is lost].

Further information on the water tariff is available on the CWA website (http://cwa.govmu.org/Pages/Services/Charges%20fees%20tariff/watertariff.aspx). On average the domestic rate for water supply is 6 rupees per m^3.

The CWA staff noted that recycled treated wastewater is billed separately from potable water and wastewater. Some of the treated wastewater is mixed with groundwater and used for irrigation. CWA acknowledged that several hotels reuse grey water for irrigating lawns and golf courses and there is a policy supporting the use of treated water for irrigation but this happens rarely: "There is a policy to use the treated water for irrigation, but what I mention is the mentality of the people is that [they] don't accept."

The interviewees explained that the water authority reuses 20 percent of the wastewater collects. The remaining 80 percent goes into septic tanks and pits and ends up in the sea with dire consequences for the ecology, as CWA acknowledges.

Licenses issued to operate private boreholes usually have an exploitation limit dictated by their position relative to CWA's borehole. Borehole drilling is done under the supervision of the WRU. Sporadic checks are conducted to check water abstractions:

[N]ormally when [people apply to operate a] borehole they have to apply for the entitlement of water, ...then we decide whether we can give them that much...water because it will, of course, affect our own borehole, [so] depending on our abstraction we give them an entitlement.

CWA mentioned that they mainly rely on collected data rather than on models for monitoring. They monitor all of their 195 boreholes and the WRU has observation wells to for an overall assessment of groundwater balances.

Responding to a question on borehole owners, CWA staff answered that the main boreholes are drilled by factories and big sugar cane plantations, mostly for irrigation and hydroelectric power generation. CWA explained that the extracted water is chlorinated, put in reservoirs and then supplied to consumers. There are daily quality checks, including the amount of residual chlorine. These checks are assessed against WHO criteria. The water quality tests are done at CWA's laboratories. A water quality committee at the ministerial level monitors effluent discharge: "So we are we have our laboratory here self [CWA has its own laboratories] .. what is certified and they carry out water quality tests."

CWA pointed out that Mauritius has reached the peak of its groundwater resources exploitation; and that the government has now embarked on increasing surface water exploitation. A groundwater licensing committee, working together with CWA, must check the abstraction level before any new boreholes are drilled: "Groundwater, I think we have reached the maximum. We can increase the surface, for example, the government has planned to build a new dam ...."

Regarding the recent trend of conversion of agricultural land to cities, CWA commented that this can be attributed to the incentives involved [the higher value of built-up areas]. CWA added that the conversion of agricultural land from sugar cane to other crops has created water problems: big sugar cane planters have water licenses and water rights but small farms do not. These small farms are obliged to apply for the licenses and rights and this has put a strain on CWA's potable water supply network. The strain has been amplified by the drilling of boreholes by small farmers for irrigation and potable water supply. This is illegal as only CWA is permitted to supply potable water:

And they will diversify their activity...you have a case here where the applicant is far from their own network and [they apply] for the authorising to drill the borehole [closer to the homestead][and use it] for bottling. And sometime later [they] change it to another purpose.

CWA noted that most of the hotels outside of their supply zone use desalinisation plants for their water supply, although desalinisation poses environmental problems. The plants are powered by solar and fossil fuels.

CWA is highly concerned about water abstraction from boreholes and it is actively seeking other water sources. Some institutions, such as schools and colleges, are exploring rainwater harvesting. CWA pointed out that it is working with banks to provide incentives, such as loans, to encourage rainwater harvesting.

The Water Resources Monitoring Committee draws its members from all public stakeholders (CWA, WRU, the Food and Agricultural Research and Extension Institute (see sections below), the Irrigation Authority (see sections below), and the Wastewater Management Authority in the water sector.

Food and Agricultural Research and Extension Institute

Ganeshan Seelavarn, Chief Executive Officer; Gungadurdoss Mala, Assistant Director (Crops); Goolaub Shri Swami A M, Assistant Director (Crops)

The Food and Agricultural Research and Extension Institute (FAREI) was established in 2014 to combine the functions of the former Food and Agricultural Research Council and the Agricultural Research and Extension Unit. FAREI operates under the Ministry of Agro-Industry and Food Security and is responsible for research and extension services for non-sugar crops, livestock and forestry to ensure that consumers have sufficient and healthy foods. FAREI employs 545 staff.

FAREI's mandate is based on the fact that production costs of sugar cane (labour costs and unfavourable prices) are rising, causing a decrease in production:

... [T]he issues ...[are] that the ...price of sugar is going down and the costs of production are up, so people are abandoning the cane land, and that is where we want to encourage growers to go into other crops. Other crops where they will be able to get to make some profit.

Land formerly occupied by sugar cane is usually converted to sites for universities, golf courses or diversified to other crops (e.g., macadamia and other nuts, cocoa, potatoes, and onions). The most important staple crops (wheat and cereal) are largely imported. Vegetables produced locally can meet the demand and are only imported when circumstances are dire. In some cases, frozen and fresh vegetables are imported by the hotel industry when high-quality products are needed:

Seventy percent of the food is imported. ... we can't produce rice and wheat here, because of climate conditions .... In terms of vegetables, we are more or less self-sufficient, except in terms of calamities ... [when] we have to import.

FAREI noted that the Agricultural Marketing Board authorises imports of strategic crops (e.g., potato, onions and garlic). For other crops, importers go the Plant Protection Office to request

import permits. The Plant Protection Office consults with FAREI before issuing any permits.

FAREI encourages people to adopt sheltered farming (greenhouses) to protect plants against increased rainfall intensity due to climate change. Sheltered farming has become popular because it reduces the costs of fertilizer and pesticide inputs: "When you talk about figures, 20 years ago we had only six units and now it is more than 1 000 units."

According to FAREI, there are different grant schemes for sheltered farming, rainwater harvesting and the purchase of agricultural equipment. Household surveys are conducted every decade by statisticians to evaluate FAREI's efforts to help people adapt better and healthier foods.

A Pesticide Regulatory Office oversees pesticide use, but FAREI is also concerned with sampling at the farm gate to assess the quality of pesticides used by farmers. Acknowledging that Mauritius uses large amounts of herbicides (5 kg per hectare), FAREI argued that: "... [W]e have 50 000 hectares [of] sugar cane and ... sugar cane [uses] a lot of herbicides ...."

Some 80 percent of the non-sugar sector in Mauritius is irrigated. The remaining 20 percent is located in rain-fed areas Due to several periods of drought and rainfall, FAREI has developed a scheme to encourage people to harvest rainwater for irrigation. For this scheme, FAREI developed groundwater-fed and gravity-driven drip irrigation systems for groups of farmers. These large scale projects require a form of cooperation. Yet even though most Mauritius farmers belong to cooperative associations, they tend to be deeply individualistic and non-cooperative. FAREI noted that it is difficult for people to work together.

The tension between water use for agriculture and for other purposes can be basically attributed to water rights, according to FAREI. Big corporate firms have water rights that they use for golf courses and tourism, leaving small growers with little access: "... small growers don't get access to river waters for example because they don't have water rights. That's the issue we see very often."

FAREI explained its intention to establish drainage systems and practice contour ploughing in sloping areas as protection against flash floods. However, these uncommon practices have been difficult to implement.

Considering the possibility that the agriculture sector would reuse water, FAREI held that this would be highly unlikely: "People won't really go for reused, recycled water in agriculture. Except maybe some in hydroponics...."

The FAREI staff observed that agriculture has a lower priority than other sectors (e.g., industry and tourism) during times of drought, and this usually adversely affects farmers: "For example, when drought is on, the water for irrigation is cut first. Agriculture [don't] have... a priority compared to the other sectors, so the industrial sector, hotel sector, they are a priority for water."

FAREI has 16 crop extension officers on the island and eight concerned with the livestock sector. That means that there are 800 – 1 000 planters for each extension officer. FAREI

has an extension office in each region and suboffices that operate five days a week. The extension officers usually oversee field group activities in the morning and conduct training in the afternoon. Large-scale farmers often have their own agronomists, who work with the extension officers.

Livestock health is overseen by the Division of Veterinarian Service. In general, livestock rearing in declines as people moves to other types of work. The small size of the island has also contributed to this decline:

Then gradually the tendency for the population...has changed, there is more [literacy] and more people going for other types of work and at the time it was the women who are the most [engaged] with the general activities of the livestock-keeping while the men were handling... food collection and transport.

The FAREI representatives explained that pig and goat rearing has stabilised despite management and cultural challenges (most Mauritians are of Hindu and Muslim origin and do not consume pork). Deer meat is considered high quality and is hunted in forest lands. The island imports very little poultry; meanwhile, the dairy sector cannot compete with imports.

Responding to a question on the need for additional water reservoirs, FAREI answered that more water is needed for agriculture. They believe that there is a need to look at the water rights as reservoirs can be disruptive: "Reservoirs will disrupt...biodiversity...and then you have certain areas which get flooded, [while in others the] level of water will decrease."

Reservoirs are managed by the Central Water Authority and the Water Resource Unit manages water rights.

In closing remarks, FAREI asked: "... should we introduce... more efficient water systems [for small farmers] or should we revise the water act that gives so much water to the sugar cane sector?"

Visit to Wooton Crop Research Station

The Wooton Crop Research Station, which falls under the auspices of FAREI, carries out research on crop production, agro-processing, ornamentals and fruits. The station offers training to entrepreneurs on food processing and provides assistance to growers at the Farmers' Training School. During a recent visit, the acting manager of the station explained that the government encourages farmers to shift from traditional open-field cultivation to sheltered farming systems. The system change anticipates growing adverse climatic conditions while enabling the improvement of production capacity and quality of farm produce. Through FAREI, the government provides grants of 50 percent of investment costs to stimulate the transition (up to a maximum of MUR 400 000, approximately USD 11 175). The modernisation of the farms should also attract a new generation to address the labour shortage in the agricultural sector.

The research programme aims to introduce and test innovative water saving techniques for sheltered farms and to produce guidelines and manuals for farmers wanting to shift to sheltered farming (e.g., guidelines for hydroponics).

Mauritius Cane Industry Authority

RajKamal Soniah, CEO; Balmick Sanjay Molaye, Chief Financial Officer

The Mauritius Cane Industry Authority (MCIA) was established in 2011. Its mission is to promote the development of the sugar cane sector through innovative and efficient services, research and development. Currently, MCIA is fully funded by the government (three or four years ago when sugar cane fetched good prices, it was funded by the sugar cane industry). Today, the sugar cane industry directly employs about 20 000 people.

The interviewees indicated that two sectors are the main water users in Mauritius: the corporate sector, which historically has water rights, and smallholders, who receive water resources through the irrigation authority. A small group of smallholders has its own irrigation systems and uses water against payments. Yet most farmers don't really have to look for water rights since everything is managed by the Irrigation Authority, for a fee.

The Water Resource Unit (WRU) oversees water extraction, monitoring and allocation for agricultural and other uses. From current water balance assessments, it has been deduced that Mauritius is a water-stressed country. [According to the MCIA], the WRU has no concrete plans to improve the water situation in the irrigation sector.

Respondents noted that MCIA supports deficit irrigation using centre pivot sprinkler systems. Currently, the irrigated land area under sugar cane is 20 000 to 22 000 hectares, about 30 percent of what it was two and a half decades ago. Harvesting is about 50 percent mechanized; the other half is done by hand. The reduction in sugar cane production has led to large tracts of land being abandoned. In some cases, buildings have sprung up on former sugar cane lands. The MCIA representatives explained that a reduction in land area devoted to sugar cane production can be attributed to labour shortages and water constraints:

... [P]eople think with cane abandonment there will be land released to grow other crops, but I don't think this is really happening. It is abandoned because there is no labour or there are water constraints. Labour is a big issue, so in fact, there [has] been a little conversion of [abandoned] land for other crops so far.

MCIA contrasted its sugar cane industry to that in Indonesia and Malaysia. In Indonesia, small-scale farmers grow, cultivate and process sugar cane with very little efficiency. Mauritius has higher efficiency with a 10 percent percentage recovery of the sucrose. He added that some countries have a higher percentage of recovery because their cane is richer in sugar due to a favourable climate.

MCIA was asked about the dependence of sugar cane production on irrigation:

What I...understand that is we have different climatic zones. In the central block, we don't need irrigation. But in the coastal zones, north, west, east, it can be quite difficult to grow... rain-fed [crops]. That's where we really need irrigation water.

The respondents explained that sugar cane crops experience water stress between September and December. The lack of water is exacerbated by the fact that domestic water usage has priority over irrigation. Furthermore, farmers have to prioritise their irrigation needs according to the stage of the crops, e.g., recently planted fields require more water than mature fields.

When asked about the future of the sugar cane industry in Mauritius, MCIA has an optimistic view fueled by innovation, the diversity of sugar cane varieties grown and government investments. The main hurdles are the lack of guaranteed prices and limited water: "To be realistic, water is a very scarce resource. And with the development of the country in terms of smart cities, there is a need for water."

The respondents shared that Mauritius uses about 5 kg of inputs (mainly herbicides) per hectare, which is the maximum quantity allowed. Large-scale farmers use less than this amount. The herbicides applied in the fields are approved for use in Europe because the sugar is mainly sold in Europe.

Regarding the option of using wastewater for irrigation, respondents noted that, while technically this was possible, the local community was unlikely to accept it.

In closing remarks, MCIA talked about the changing climate, which has led to flooding in some areas, dryness in others, particularly in the coastal areas, and unpredictable rainfall. There is a need to review historical water rights. Water storage continues to be an important issue; the government has developed several dams (e.g., Bagatelle and Midlands) with plans of building a new one in the south.

Irrigation Authority

K.C.S. Kong Thoo Lin, Head of Operation and Maintenance Department; M. Lutchoomun, Principal Engineer; P.R. Dabeeah, Divisional Irrigation Operation Officer; S. Mooloo, Engineer; S. Kundhai, Irrigation Operation Officer; R. Ramburn, Irrigation Operation Officer; N. Sawmy, Irrigation Operation Officer; K. P. Ramdhun, Irrigation Operation Officer

The Irrigation Authority (IA) is a parastatal body established in 1978 and operating under the Ministry of Agro-Industry and Food Security. Its overall objectives are: i) to study the development of irrigation; ii) to implement and manage irrigation projects in every irrigation area; and iii) to undertake research on the optimum use of water. IA is responsible for issuing irrigation permits and manages around 2 500 hectares of irrigated land (the total irrigated area in Mauritania is about 17 000 hectares) It is not responsible for the private sector, which manages its own water sources and irrigation systems. IA receives water from the Central

Water Authority; water resources are managed by a water resource monitoring committee that is chaired by the Ministry of Energy. Irrigation is the fourth priority in terms of water use.-

In introductory remarks, the IA interviewees described their first project in the Northern Plains, which covered around 1 200 hectares and involved about 3 000 small farmers. Irrigation water was taken from the Collier Reservoir and distributed to the farmers. The pipeline conveyance and distribution system was replaced in 1995 during a dry period when water was rationed. A second project, commenced in 2000 but it was discontinued:

We...got financing from [the] African [Development Bank], unfortunately, [the] government decided to stop [the project]. One of the reasons [was] water availability and the second reason was planters; they [wanted] to develop the land [for uses] other than agriculture.

IA also shared information on other small irrigation projects they have carried out, next to the projects in the Northern Plains, around the island, e.g., at Talma, St. Philips and on the Western Coast; the latter was recently suspended due to bad water quality.

IA mostly promotes drip irrigation for sugar cane and vegetables. The irrigation system was modernised in 2000. The drip irrigation was not fully implemented in the NPP as IA ran into contractual problems. For other areas [where no drip irrigation is implemented we find] a mix of pivot and sprinkler systems. IA added that harvesting in these [drip] irrigation areas is done manually for planters and mechanically for large scale farmers [that practice the centre pivot and sprinkler irrigation system].

The respondents explained that IA works with about 5 000 farmers. About 80 percent of the land occupied by these farmers is under sugar cane. Due to the declining prices of sugar cane, there has been a clear shift from sugar cane to vegetables:

You know, the price of sugar goes down, and this has an impact on planters and...it is not profitable to plant [sugar cane]. They just leave it then. And sometimes we have...a shift from sugar cane to vegetables. This is a major issue, where we have estimated [that] some 600 arpents... have been left.

The IA is responsible for promoting crop cultivation in dry areas, mainly in the northern and eastern parts of the island where annual rainfall is less than 1 000 mm. The lack of water availability for new projects in the northern part of Mauritius cannot necessarily not be addressed by groundwater pumping, due to the high cost of electricity. In addition:

The CWA has been exploiting all the underground water, so in the past, we have been building [..] reservoir [as an alternative] so they have been maintaining water underground. So now, thinking to start water from underground to do irrigation is almost [impossible], I mean [there is] no place available where we can dig [to] remove water.

IA argued that competition from the tourism sector and other industries, as well as the reduced contribution of agriculture to GDP, are major impediments.

With the decline in sugar prices, the government reduced its investments in irrigation. The IA mainly relies on government financing and receives only small amounts of money from planters. Other than that, they have no other source of income:

...[T]he government also is not injecting a lot of money in irrigation. And the costs planters pay for the service are highly subsidised....[W]e actually cover [10 to 30 percent of the cost of] in providing the system. So, it is huge spending [that] the government is making indirectly.

The respondents explained that irrigation fees include labour and water charges. Planters are charged based on their capacity to pay. Falling incomes and low rainfall have adversely impacted IA operations. Recently, IA received a grant from the European Union, which it is using to enable their system to accommodate more crops (mainly vegetables) in a three-year project (expected to be completed two years from the time of the interview). IA has also launched a consultancy service to provide guidance on climate change:

We are trying to modernise our system...trying to bring about some changes in the frequency of irrigation because it was designed mainly for sugar cane and we want a shift to vegetables.

IA explained that PVC (polyvinyl chloride) pipes are used in the new irrigation systems and losses are low. Initially, system efficiency was 60 percent, but it is now as high as 90 percent in some places. Furthermore, the theft of water is low due to a good monitoring system. Water theft mainly occurs when irrigation cycles take longer than ten days (the volume of theft is about 2 000 litres per day).

Previously, IA faced some challenges in controlling water pressures, but this is no longer a problem. IA's main drip irrigation systems cost around MUR 30 000 per acre (USD 756); the irrigation system is replaced every seven years.

The IA interviewees noted that water rights have been provided to the sugar estates for a long time. Some of the estates have been converted to other uses, and since water is no longer used for agriculture, the rights should be revoked.

IA noted that, unlike in other countries, the Mauritian government does not compensate farmers for water costs. Respondents pointed out that planters pay 1.5 cents per m3 for raw water, while the Wastewater Authority charges them 80 cents for the same amount. This makes it hard for IA to recover its costs from the farmers they supply with water.

Prior to 2000, IA rarely met with beneficiaries before starting a project. Now, they consult with beneficiaries, as advised by IFAD, to understand their needs. Even so, it is clear that future projects will face challenges around water availability, labour shortages (young people are not interested in agriculture) and ageing irrigation infrastructure. The labour shortage has compelled IA to source external workers during harvests.

While IA initially planned to work with planters through cooperative societies, the plan fell through: "It didn't work. Because you know, people won't work for free now. They want to have money." IA now works with the cooperatives through a committee that generally meets

every week. Operational costs are lower when the cooperatives are in charge. IA pays the cooperatives some money for project management.

IA insisted that an irrigation agreement should be in place prior to the initiation of any project; the agreement should take a bottom-up and holistic approach, outline the potential benefits of irrigation, and promote flexibility, engagement and cooperation with the planters.

IA commented that greenhouses and hydroponics are becoming popular in urban and peri-urban areas. About 2 years ago, an amendment was made to the law [the Local Government Amendment Act, 2018: http://extwprlegs1.fao.org/docs/pdf/mat182258.pdf] that allowed planters to establish greenhouses without applying for conversion from sugar cane to other crops. IA must ensure that the greenhouses are built in such a way that they do not infringe on irrigation activities. In some places, IA supplies water to greenhouses subject to availability. Respondents added that sheltered farming is being trialed and farmers trained in rainwater harvesting to complement available irrigation water.

Water Resources Unit

Lomush Juggoo, Director

The Water Resources Unit (WRU), established in May 1993, operates as a department of the Ministry of Energy and Public Utilities and is responsible for the assessment, development, management and conservation of water resources. A number of laws govern the management of water resources in Mauritius, such as the CWA Act (19 July 1971: http://cwa.govmu.org/Documents/CENTRALWATERAUTHORITY%20Act%20-%20Updated%20Version.pdf), the Rivers and Canals Act (1863: https://www.ecolex.org/details/legislation/rivers-and-canals-act-lex-faoc004943/), the Groundwater Act (30 April 2015: http://extwprlegs1.fao.org/docs/pdf/mat161254.pdf), etc. Under the CWA and Groundwater Acts, the CWA issues groundwater drilling permits and abstraction licenses. The WRU is the technical arm of the Ministry and is fully involved in the management of water resources in Mauritius together with CWA and other key stakeholders.

In introductory remarks, the WRU representative described the current constraints faced by Mauritius (e.g., water resources scarcity, poor water management) and the country's vulnerability to climate change. In the past years, the erratic rainfall with seasonal variations and long dry periods have prompted Mauritius to adapt to such climatic risks in order to ensure water security to protect its population, the environment and the economy.

The integrated management of water resources includes both the quantitative and qualitative aspects (water volumes and water quality aspects) within an overall governance framework. A focus on increasing water storage capacity should be an important part of a strategy for meeting increasing demand. The interviewee added that any strategy for sustainable development should take into consideration the key components of sustainability: "Any development should be in a sustainable way, that is, there should be a balance between the social component, the economic component and also the environmental component."

The government is making a massive investment to develop the water infrastructure in Mauritius to keep pace with development and meet increasing demands while alleviating poverty and ensuring food security. WRU pointed out that SIDS are vulnerable and particularly affected by climate-related challenges to the long-term sustainability of the water sector. For example, with sea level rise, the risks of sea water intrusion is exacerbated; the government has taken measures to protect sensitive zones and aquifers. To address such challenges, WRU believes that actions need to be taken at different levels through effective coordination of all the stakeholders. For example, the ministerial-level Water Resources Monitoring Committee takes stock of the water situation in the country, meeting at regular intervals and more frequently (on a weekly basis) during the dry season:

The committee...comprises...stakeholders who are involved in water resources management, water supply and the irrigation sector, which also represents some of the water syndics and other such stakeholders.

Huge investments are being channeled into water resources mobilisation, upgrading water supply systems and management of wastewater. A current project is rehabilitating old water infrastructures to enhance the safety and optimisation of water resources. A project is underway to rehabilitate the 100-year old La Ferme dam and increase its capacity.

WRU explained its plans for new dams (the most recent is the Bagatelle Dam). For such projects, it is mandatory to undertake environmental assessment studies to identify potential impacts (as well as mitigation measures to reduce the impact on the environment) that may be needed during the project's life cycle. The impact assessments are based on Mauritius's Environment Protection Act (2002) and related funding agency guidelines if required.

There have also been massive investments by the government to reduce non-revenue water losses in the water distribution network (which are about 50 percent). The Central Water Authority is investing in surface reservoirs. The National Sewage Master Plan is being implemented in the central urbanised part of the island in order to protect groundwater against pollution.

Wastewater treated at the tertiary level is used for irrigation purposes in dry parts of the island. Payment for wastewater is charged as a percentage of the volume of potable water and there are different tariffs for each category of use.

Licenses for water abstraction are issued and monitored by the CWA, while the WRU is involved in technical aspects of the decision-making process for each license application. For example, there is a two-stage application process for groundwater abstraction via a borehole. First, an application is made for a drilling permit (including personal details, proposed activities and volume of water to be abstracted, etc.); second, an application for a groundwater license is made and supported by a technical report indicating pumping rates, geology, levels, etc. The groundwater license is granted by CWA based on recommendations by the Groundwater Licensing Committee. The applicant has to abide by several conditions, including monthly returns on their abstractions, which is used for billing purposes and to monitor abstraction volumes. The applicant is obliged to do groundwater quality tests and remit the results to CWA/WRU.

Lomush Juggoo made the point that multiple approaches are needed to keep pace with the level of development required to meet increasing demands in a sustainable way. The water sector faces many challenges, including climate change, the high level of non-revenue water, and the [limited] availability of financing; these all affect water management. The government has prioritised investment in the water sector, with due consideration of social aspects and the special needs of vulnerable groups:

...[A]ddressing water problems are not limited only to [promoting adaptation in] the water sector. ...[T]o a great extent, it helps [if] adaptation measures [are implemented in other sectors also. Some policies have a considerable impact on society. For instance, there is a free 6 m^3 government water policy, which highly benefits the low-income and vulnerable groups.

Water users' associations are coordinated by the Water Resources Monitoring Committee, which also serves as a platform where they can express their requirements through their representatives. Whenever big water infrastructure developments are planned, stakeholder consultations are held to raise awareness of the project and consider the concerns and requirements of the key sectors such as irrigation, tourism, etc.

The WRU participates in working sessions and collaborates in specific projects where inputs from the water sector are needed. Consultations are also held with FAREI in planning their projects depending on specific requirements. The Mauritius National Water Policy of 2014, should, according to the prevailing national strategy, be adopted over time by the various stakeholders. This is coordinated at the level of the Ministry of Energy and Public Utilities. It was highlighted that, in general, small islands have small economies and cannot easily mobilise funds to implement their strategies. SIDS cover less than one percent of the world land area and population but are at the forefront of climate change impacts. The WRU recommended that at the global level, SIDS should be given a special consideration in funding.

Concerning how water policies could be improved in Mauritius, it was suggested that for new emerging sectors, like tourism, the policies should be adapted and take into account the participation of relevant stakeholders.

Wastewater Management Authority (unrecorded).

Navindranath Jowaheer, Officer In Charge; Jacques Alexis Radhay, Divisional Manager (Pollution Control Unit); Haidar Ally Kinoo, Divisional Manager (Project Management Unit)

The WMA, established in 2000, operates as an autonomous organization under the aegis of the Ministry of Energy and Public Utilities. Its core activities are the collection and treatment of domestic, commercial and industrial wastewater for disposal in an environmentally acceptable manner. The WMA employs about 495 persons.

The Mauritian public wastewater system consists of about 755 km of sewer network, 73 pumping stations and ten public wastewater treatment plants. There are four major and six minor wastewater treatment plants (WWTP). About 60 hotels have their own WWTP. The WMA has 89 000 customers and about 27 percent of the population are connected to the

sewage network. Forty-seven MCM of wastewater are treated every year, of which two MCM are used for irrigation, mainly of sugar cane.

The WMA generates revenue from domestic, non-domestic tariffs and wastewater services. The revenue collected covers 100 percent of operational costs.

Capital projects, identified under the National Sewerage Masterplan, are funded by the government through the Ministry of Energy and Public Utilities (MEPU). The WMA must submit its investment programme to the MEPU for approval. Industries are licensed under the Regulations (under the 'Wastewater Management Authority Act, 2020: https://www.wmamauritius.mu/wp-content/uploads/2020/01/Waste-Water-Licence-for-Discharge-of-Industrial-Effluent-into-a-Waste-Water-System-Regulations-2019.pdf) to discharge their effluents into public sewers and hotels are monitored under the Environmental Protection Act (2002). The Wastewater Laboratory, along with other governmental laboratories, takes part in an independent environmental audit to monitor the quality of different water bodies.

The part of the population that is not connected to a sewer system – 73 percent – uses on-site disposal systems consisting of cesspits and septic tanks. These are emptied by around 80 private wastewater tankers, which are registered with the WMA. These private tankers are allowed to discharge at wastewater pumping stations, which then pumps to a major WWTP where the wastewater undergoes preliminary treatment before disposal to the sea via a long sea outfall. Currently, all housing development requires a wastewater clearance. Building and land use permits for housing development are issued only when the wastewater clearance has been issued.

In line with the stated mission of the government to connect 50 percent of the population by 2030, the WMA is committed to meet the target through various projects. The western region is a priority because of the dense population of tourists and the potential degradation of the coastal zone.

Current constraints experienced by the WMA include the lack of certain expertise, like process engineers.

The interviewers remarked that water users were not part of the Water Resources Monitoring Committee. In response, WMA indicated that when building and land use permits are issued there are legal and binding procedures in place that enable members of the public and other stakeholders to express their opinions and contribute new ideas.

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Sustainable management of freshwater resources for
food security and nutrition in Small Island Developing States

Corrigendum

Updated on 21.12.2021

The following corrections were made to the PDF after it went to print.

Page	Location	Text in printed PDF	Text in corrected PDF
xvi	First paragraph	This publication was prepared by the FAO Land and Water Division with the technical direction of Sasha Koo-Oshima, Deputy Director of the FAO Land and Water Division, and Ms. Athifa Ali and Mr. Shengyao Tang, who kindly provided financial support from FAO's South-South and Triangular Cooperation. The publication also benefited from substantive contributions from FAO's regional offices in Barbados and Mauritius for their field assistance with water managers, researchers and farming stakeholder groups. Additionally, the authors would also like to acknowledge the technical contribution as well as review of the following FAO colleagues: Marlos DeSouza, Oxana Perminova, Eva Kohlschmid, Manuel Maria Flores Ruiz, Antoine Asselin Nguyen, George Akoko, Taimur 'Tai' Khan, and Bart van den Boom.	This publication was prepared by the FAO Land and Water Division with the technical direction of Sasha Koo-Oshima, Deputy Director of the FAO Land and Water Division. The authors are thankful to FAO's South-South and Triangular Cooperation Division (PST), represented by former division director Dr Shengyao Tang, his successor Mr Ye Anping and Ms Athifa who kindly supported this study and the missions to Barbados and Mauritius. PST jointly with the Land and Water Division (NSL) distributed the survey among water professionals in SIDS countries. Dr Amani Alfarra from the Land and Water Division provided technical assistance throughout the project. Also, we would like to thank FAO's regional offices in Barbados and Mauritius for their assistance and for organizing contacts with dedicated water managers, researchers and farmers, all of whom responded enthusiastically and without reservations to our in-depth interviews.

Sustainable management of freshwater resources for food security and nutrition in Small Island Developing States

This report examines the relationship between water governance and food insecurity in Small Island Developing States (SIDS). It starts by profiling the socio-economic and biophysical diversity in the SIDS, traces water flows on the islands in terms of volume and quality and identifies the factors that exert pressure on water resources. The report analyses 23 case studies to determine the factors for the success and failure of water policy interventions.
It appraises the findings of a survey of water professionals and presents detailed findings of two case studies. Finally, the report provides a road map and action plan for an approach to water governance that can support the food security and nutrition of SIDS.

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