Food and Agriculture Organization of the United Nations

Climate change, drought and agriculture in Small Island Developing States

Risks and adaptation options

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Foreword

Drought is a multifaceted hazard that affects regions across the globe and occurs under highly variable climatic regimes. Understanding drought is essential to distinguish it from other related concepts, such as aridity and scarcity, and to better recognize its impacts and implications. Over time, various global bodies have provided comprehensive definitions of drought, emphasizing its different components and development stages. Such analyses are critical as they can help to comprehend the sequence of impacts and the cascading effects it has on the environment and human livelihoods.

In the agriculture sector, drought has played a significant role in shaping land and water management practices throughout history. Its various dimensions have influenced irrigation techniques, water supply systems, and technological advancements, which in turn have shaped societies and civilizations. In more recent decades, the increasing frequency and intensity of drought episodes have produced growingly devastating effects on agri-food systems worldwide, thus emphasizing the need for effective adaptation and mitigation measures. Land and water management practices, as well as governance mechanisms, play a vital role in these objectives by reducing risks in drought-prone regions and safeguarding food security.

Changes in agricultural and environmental practices can contribute to the emergence of agricultural drought conditions. Unsustainable land-use practices, such as soil degradation, deforestation, and the destruction of wetlands, can lead to decreased water availability and increased runoff. Additionally, certain agricultural practices like large-scale irrigation and the cultivation of water-intensive plant species can further deplete water resources, leaving less water available for other purposes and diminishing groundwater levels.

In Small Island Developing States (SIDS) such challenges can easily become critical vulnerabilities. Their remoteness and sensitive ecosystems enhance their exposure to natural hazards, while their limited access to resources and high import costs often leave them with limited opportunities for economic diversification.

Understanding the distinct characteristics and vulnerabilities of SIDS is crucial for developing effective strategies to address drought and its impacts on food production. Raising awareness about the complex realities faced by agriculture in SIDS and the need for targeted interventions for drought management is a common responsibility. Collaboration among nations, international organizations, development partners, and civil society organizations is essential to assist SIDS in building drought resilience, fostering sustainable agricultural production, and mitigating the impacts of climate change. By recognizing and addressing the unique circumstances of SIDS, we can strive toward a more equitable and food-secure future for these vulnerable island nations.

The report, a result of the collaboration between FAO and IIED, sheds light on the critical challenges of the agriculture sector in SIDS and provides insightful recommendations stemming from the broad consultations carried out in selected countries. It identifies key areas for policy interventions and technical approaches and supports stakeholders in defining effective measures for drought risk resilience through improved land and water management.

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Abbreviations

APCP	Australian Pacific Climate Partnership
CIS	Climate information services
CRAs	Climate risk assessments
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
NGO	Non-governmental organizations
PHAMA	Pacific Horticulture and Agricultural Market Access Plus Program
RWH	Rainwater harvesting
SIDS	Small Island Developing States
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO-IHP	United Nations Educational, Scientific and Cultural Organization -Intergovernmental Hydrological Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island
UN CRT	United States - Climate Resilience Toolkit
USAID	United States Agency for International Development

Units

°C	Celsius degree
ft^2	square feet
km^2	square kilometre
mm	millimetre

Executive summary

This report focuses on the impacts of drought on agriculture in Small Island Developing States (SIDS) and provides key insights, findings, and policy recommendations based on comprehensive research, analysis, and broad consultative processes.

The concept of drought and its relationship to climate change and agriculture in SIDS is illustrated in the Introduction. Emphasis is drawn on the unique challenges faced by these vulnerable regions and on the need for effective adaptation strategies. The assessment of drought risks and vulnerability in SIDS are addressed, highlighting the challenges involved and presenting a methodology for the development of a drought vulnerability index.

The section on "Drought risks in SIDS" focuses on the complexity of assessing drought vulnerability in SIDS due to their diverse geography, climate, and socioeconomic factors. It recognizes the limits of existing composite index techniques and the need for tailored approaches that consider the unique features of such contexts. The chapter, hence, introduces the drought vulnerability index for SIDS, a modified framework that incorporates relevant indicators to comprehensively measure exposure and provide a nuanced understanding. A step-by-step approach is presented to facilitate cross-SIDS comparisons, and the employment of geospatial observations to identify vulnerable regions within SIDS.

The chapter "Results from the drought vulnerability index for SIDS" presents the results from the application of the drought vulnerability index, providing a comprehensive understanding of both the regional and subnational levels. Key indicators are investigated, and the index shows that smaller, poorer, and more isolated SIDS are highly susceptible to drought. Geographic size frequently correlates with socioeconomic drought, aridity, and crop water deficit. Mapping and analyzing drought exposure enable targeted strategies for mitigating impacts and enhancing resilience in vulnerable regions. The case studies of Grenada, Jamaica, and Trinidad and Tobago are presented as relevant examples of SIDS to demonstrate the findings of the drought vulnerability index.

The "Contextual analysis of drought vulnerability in selected SIDS" delves further into the applied method to demonstrate the effective application of the SIDS drought vulnerability index. To capture the diverse geographic and socioeconomic challenges faced by SIDS, the section fosters the need to go beyond standard methodologies based on composite weighted indicator approaches. Results of the national-level index presented are in line with relevant literature and indicate that smaller, poorer, and more isolated SIDS are more vulnerable, while outcomes of the regional consultations complement the message and indicate the Pacific region as the most vulnerable one. The sub-national mapping in selected countries, furthermore, provides a contextual picture of identified vulnerabilities, such as limited arable land, urban development constraints, and exposure of plantations to drought and social vulnerability.

"Drivers of drought risks for smallholders in SIDS" are explored in the following chapter. Recognizing the multidimensional nature of risks, the report acknowledges that drought vulnerability stems not only from increased meteorological events but also from structural factors, impacting marginalized and impoverished communities disproportionately. Factors such as poverty, education, water availability, compounding impacts, land tenure, demographics, and policy and governance are analyzed as key challenges to be tackled to inform effective mitigation strategies.

Building on the thorough analysis of SIDS contexts, the final chapters of the report outline technical and policy options to effectively address drought risks. In the section on "Adaptation options" water-based methods, agricultural interventions, livelihood diversification, risk assessment and communication, and monitoring and early warning systems are examined as potential strategies for building resilience. The benefits and constraints of proposed solutions are individually examined taking into account the specific features of SIDS.

The report concludes by highlighting comprehensive policy recommendations, underscoring the necessity for a holistic and participatory approach to drought risk management. Decision makers are urged to adopt a multifaceted strategy that goes beyond traditional methods, acknowledging the interconnectedness of various factors in mitigating drought impacts and fostering resilience among smallholder farmers. To address gender disparities in the face of climate change, a gender-responsive adaptation is crucial, necessitating the implementation of gender-transformative strategies tailored to the specific challenges faced by women in agriculture.

Furthermore, there is a pressing need to promote and operationalize financial solutions, including innovative insurance and grant products, ensuring that these mechanisms reach the ground and provide affordable and accessible social protection for all farmers. Culturally sensitive approaches are essential, as cultural factors significantly influence farmers' participation in drought management initiatives. Therefore, comprehensive education and training programs should be established to ensure the success of participatory approaches, empowering local communities.

Organizations such as farmers' groups and communities of practice are identified as pivotal players in socioeconomic development. Encouraging their establishment and supporting their activities not only fosters knowledge exchange but also contributes to inclusive development. In SIDS, where land and water re*source*s are limited, coordinated management is paramount. This should be rooted in participatory processes involving civil society and institutions to address the unique challenges faced by these vulnerable regions.

Finally, recognizing the importance of traditional and indigenous knowledge is crucial. This knowledge should be integrated into planning processes to enhance ownership, promote long-term sustainability, and ensure socially impactful outcomes. The report underscores the need for a collaborative approach involving non-governmental organizations (NGOs), civil society, and institutions, emphasizing that action-oriented research is pivotal to inform practice, programs, and policy.

The findings and insights presented in this report aim to inform policymakers, researchers, and stakeholders about the critical issues related to drought, agriculture, and adaptation in SIDS. By implementing the recommended policies and interventions, SIDS can enhance their resilience and mitigate the adverse effects of drought on agriculture and livelihoods.

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1 Introduction

1.1. Understanding drought

Drought is a phenomenon that affects regions at every latitude. It occurs under highly different climatic regimes, regardless of the intensity of precipitation. It is a temporary event spawned by water shortage, which should be distinguished from aridity, a permanent condition of certain climates with low rainfall, and scarcity, an imbalance between water supply and demand.

Several comprehensive definitions, with a common reference to its climate variability component, have been elaborated by relevant global bodies to define this multifaceted hazard, including:

- United Nations Convention to Combat Desertification (UNCCD): "the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land re*Source* production systems";
- Intergovernmental Panel on Climate Change (IPCC): "a period of abnormally dry weather long enough to cause a serious hydrological imbalance"; and
- World Meteorological Organization (WMO): "a hazard characterized by lower than expected or lower than normal precipitation that, when extended over a season or longer period of time, is insufficient to meet the demands of human activities and the environment".

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Along its development, different "progression stages" of a drought are commonly identified:

- meteorological drought, when precipitation departs from the long-term average in the region;
- agricultural drought, when soil water results insufficient to meet standard crop requirements due to precipitation deficits and water shortage;
- hydrological drought, when surface and subsurface water supply records below-than-normal levels; and
- socioeconomic drought, when physical water shortage impacts human activities.

In more recent years, a fifth stage of drought has been recognized, which takes into account the consequences of drought on ecosystems, hence identifying:

- ecological drought, when "an episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedback in natural and/or human systems" (Crausbay *et al.*, 2017).

When analyzing an unfolding drought event along its stages, a sequential pattern generally emerges, from meteorological to agricultural, ecological, and hydrological drought, which generates increasing socioeconomic impacts on livelihoods.

Although traditionally termed as a "natural" hazard, the "human effect" on the occurrence of drought events is nowadays largely acknowledged. Drought is associated not only with climatic variations but to climate change. Climate change mitigation efforts are increasingly directed to reduce its direct and indirect drivers and reverse the need for drought impact mitigation.

1.2. Climate change, drought and agriculture in Small Island Developing States

In the agriculture sector, the different dimensions of drought have molded land and water management practices throughout history and have steered irrigation and water supply techniques to cope with the effects. Drought has driven technological developments that shaped societies and, in so doing, contributed to the collapse or the progress of civilizations over the centuries.

Conditions of agricultural and hydrological drought may be produced as a result of changes in agricultural and environmental practices. New types of land use may degrade and compact soils, destroy vegetation, and leave wetlands dry and uplands without forests. Such practices can greatly increase rates of runoff while decreasing rates of infiltration so that levels of available surface, soil and, groundwater decline dramatically. Agricultural practices, such as large-scale irrigation, intensive production, or the cultivation of thirsty exotic plant species may remove large quantities of water from the water system, decreasing the amount of water available for other uses or rapidly reducing the levels of groundwater available in a local aquifer.

Drought impacts are devastating for agriculture, especially in developing countries where over 80 percent of drought-related losses are recorded by the sector. The vulnerability of rural livelihoods to drought, however, is a complex indicator accounting for both the socioeconomic practices of the populations living in the watersheds and the decision-making capacity towards drought impact mitigation.

Acknowledging this component of drought is necessary to address it and identify the most effective actions to be undertaken by governments, development organizations, and civil society organizations for the mitigation of drought impact on agricultural systems. In agriculture, land and water management and governance practices are instrumental to reducing risks in drought-prone regions and limiting the most negative consequences on food security. At the same time, understanding and assessing the vulnerability of ecosystems is conditional to the formulation of integrated policies for drought management that consider all sectors of relevance (energy, urban development, land planning).

Climate change is exacerbating the intensity and frequency of drought. Mitigating the occurrence of this hazard needs global efforts to reduce emissions that alter climate, with harmful consequences on agricultural systems and beyond. Nevertheless, mitigating the impacts of drought on ecosystems, and rural livelihoods in particular, can be achieved through planned actions at scale. Given that drought management requires the coordination of multiple social, economic, political, and ecological processes, efforts to address the impacts on agriculture will only succeed if they tackle the systematic barriers to the mitigation measures.

1.3. Climate change, drought and agriculture in Small Island Developing States

Small Island Developing States (SIDS)[1] are a highly diverse group of island nations located mainly in the tropical latitudes of Latin America and the Caribbean, Africa and the Indian Ocean, Asia and the Pacific. They comprise a wide range of geographies, ecologies, and socioeconomic characteristics that vary depending on their location, size, topography, ecology, demography, levels of development, and colonial histories.

Despite their diversity, SIDS share some unique features. These include remoteness and geographical isolation, small but rapidly growing populations, small economies, small land area, sensitive ecosystems, susceptibility to natural hazards, emigration of an active population, high import costs, limited water supply, limited natural resources, limited access to technology (Dev, 2021; Leal Filho *et al.*, 2021; UNDP, 2019a). SIDS are also sensitive to global economic shocks such as COVID-19 and the 2008 financial crisis, and limited opportunities for economic diversification.

[1] The Food and Agriculture Organization of the United Nations (FAO) generally characterizes SIDS by their remoteness, small and dispersed geographies, populations, and economies, as well as their high exposure and vulnerability to natural disasters linked to climate change, dependence on imported foods and tourism, and a high incidence of non-communicable diseases (NCDs). The FAO also notes SIDS particular vulnerability to the impacts of climate change due to their small geographical area, isolation, and limited natural resources. FAO has a long history of partnership with SIDS, providing policy advice, analysis and technical assistance in agriculture, livestock, fisheries, forestry, natural resources management and food security in its commitment to support resilient livelihoods and enhance food security. In building climate resilience within their agricultural and food systems, FAO has provided policy support, capacity building, technical assistance, and knowledge sharing. For a more comprehensive list of FAO activities in SIDS refer to: https://www.fao.org/sids-solutions/en

SIDS face high levels of exposure and vulnerability to natural hazards (including drought) and climate change (IPCC, 2007, 2021, 2022). The susceptibility of SIDS to cyclones and droughts prevents sectors, such as agriculture and water-dependent manufacturing, from operating at optimum levels, while limited size creates intense competition for land use (Waite, 2012).

It is important to note that Pacific SIDS hold particular geographic attributes that affect their vulnerability to climate change. For one, the Pacific is unique compared to other regions of the world in that it is defined by large expanses of ocean over five times the size of Europe, with scattered and isolated areas of land of varying size (Hunter, 2007). This so-called "tyranny of distance" has presented considerable complexities and challenges in the dissemination of information and services and the transportation of material and goods(Hunter, 2007). Pacific island nations are comprised of sometimes hundreds of islands constituting unique cultures and customs as well as topography.

1.3.1. Climate change in Small Island Developing States

Broadly speaking, SIDS are highly vulnerable to extreme weather events and anthropogenic climate change (UNDP, 2019a; UNESCO-IHP and UNEP, 2016; UNFCCC, 2007; Gheuens, Nagabhatla and Perera, 2019; Thomas *et al.*, 2020). This is largely due to their geographical location and the strong influence of the oceanic circulation system on their individual climates. Owing to their remote oceanic locations, the climates of SIDS are greatly influenced by large ocean-atmosphere interactions such as trade winds, El Niño/La Niña and the monsoons. They are also disproportionately exposed to climate-related hazards such as tropical cyclones, hurricanes, flooding, and droughts.

In recent decades, anthropogenic climate change has increased the frequency and intensity, which made such hazards more intense and more frequent, exacerbating the negative impacts that extreme weather events are having on SIDS. As the atmosphere heats up, the intensity and frequency of such extreme weather events will likely continue to increase, exposing the populations, environments, and economies of SIDS to ever more devastating impacts (IPCC, 2021, 2022).

In addition, climate change is driving slow-onset processes, such as sea-level rise, salt-water intrusion, coastal erosion, and biodiversity loss in SIDS (Thomas *et al.*, 2020; Martyr-Koller *et al.*, 2021; IPCC, 2022). These processes are already causing negative impacts that are in turn undermining the resilience and increasing the vulnerabilities of ecosystems, households, communities, and national economies to the compounding impacts of extreme weather events in the future. For some low-lying SIDS, these impacts (including drought and desertification) pose an existential threat, as islands may become uninhabitable, potentially prompting mass migration and relocation in search of more sustainable life chances (Handmer and Nalau, 2019; Gheuens, Nagabhatla and Perera, 2019).

The actual and potential impacts of climate change on SIDS include drought and rising temperatures, excessive precipitation and flooding, sea-level rise and salt-water intrusion, coastal erosion, loss of agricultural crops, degradation of coral reefs due to bleaching, increased instances of pests and diseases, and unpredictable storms and weather events.

These not only affect the environment and resilience of natural ecosystems but also have cascading impacts on every sector of the economy and society, including economic stability, agriculture and food security, water access and sanitation, health and well-being, education, tourism, and livelihoods (UNDP, 2019a).

The threats posed by climate change interact with a variety of social, economic, and political factors that render SIDS vulnerable to the hazards they face. For instance, many SIDS are characterized by high levels of unemployment, poverty, and income inequality. They also struggle with fragile economies that are dependent on imports, exposed to the impacts of external shocks in trade and financial networks, and affected by low levels of labour availability (UNDP 2019a, 2019b; Quak, 2019). It is important to note that while SIDS have a multidimensional poverty rate of 45 percent (UNDP, 2018), this masks a very wide range of results for individual SIDS. For instance, while SIDS, such as Madagascar and Guinea-Bissau, have multidimensional poverty rates of 77.8 and 67.4 percent respectively, those, such as Trinidad and Tobago and the Maldives, enjoy rates as low as 0.6 and 1.9 percent respectively.

SIDS' economies rely upon a narrow range of industries, many of which are dependent on natural re*Source* exploitation (e.g. mining and forestry) or vulnerable to climatic conditions (e.g. rainfed agriculture and fisheries). The natural resources and ecosystems of SIDS that are now more exposed to rising climate risks have already suffered due to other pressures, such as overexploitation, over-harvesting, pollution, deforestation, and degradation, which render them more vulnerable to climate change and related shocks such as drought.

As a result, many SIDS and their populations do not have adequate domestic resources to combat climate change on their own and require significant support from other stakeholders, including financial and technical assistance. The losses and damages that will be caused by climate change through the degradation of natural resources, ecosystems, human and social capital, and physical infrastructure will only serve to increase poverty, hunger, and economic and social inequalities over time, thereby limiting the ability of many SIDS to achieve sustainable development (UNDP, 2019a).

1.3.2. Climate change and drought in Small Island Developing States

SIDS are among the most water-scarce countries in the world and face particular challenges due to their low levels of freshwater availability (UNCTAD, 2021). According to UN data from 2016, almost three-quarters of SIDS (71 percent) face a risk of water shortage, a figure that increases to 91 percent in low-altitude SIDS (UNESCO-IHP and UNEP, 2016).

For many SIDS, reliable, safe, sustainable, and affordable access to potable water remains a critical issue. Typical sources of potable water for SIDS' communities include groundwater and surface water, which are commonly recharged during the wetter season of the year (UN-OHRLLS, 2015). But in many SIDS, sea-level rise, storm surges, and precipitation changes have already affected these sources, leading to increased stress on freshwater availability. Several SIDS have also experienced serious meteorological droughts and now have lengthier dry seasons with conversely shorter rainy seasons, and increased temperatures (Monnereau and Oxenford, 2017; Stennett-Brown, Stephenson and Taylor, 2019).

Most SIDS have low levels of groundwater availability and are highly dependent on rainfall to meet their needs. This renders them extremely vulnerable to variations in the quantity and distribution of precipitation. Low rainfall levels reduce the amount of water that can be harvested, reduce river flows, and slow the rate of groundwater recharge, and may result in prolonged and serious droughts (UNFCCC, 2007). This can seriously impact the availability of surface water to meet the requirements of households, farms, communities, and ecosystems.

Although all islands are vulnerable to saltwater intrusion, which is exacerbated by climate change, drought, and land degradation, SIDS that are reliant on small coastal aquifers are at particularly high risk of saltwater contamination from sea-level rise and storm surges (UNESCO-IHP and UNEP, 2016). This contamination can radically reduce the amount of water available for human and agricultural use – especially when combined with an increase in the incidence of meteorological drought due to climate change.

According to the UNFCCC and the IPCC, drought is likely to become more frequent and more intense in SIDS as a result of global heating (UNFCCC, 2007; IPCC, 2021, 2022). Projected increases in drought events, atmospheric temperature, and precipitation variability are expected to result in a decrease in the availability of fresh water in SIDS. This is likely to result in high levels of water stress, especially when considered in line with increases in population size and water demand (Gheuens, Nagabhatla and Perera, 2019; Karnauskas *et al.*, 2018). For instance, increasing drought risk is projected for Caribbean SIDS over the next 100 years, with moderate to extreme drought conditions projected for increases in global temperatures at or above 1.5°C (Hoegh-Guldberg *et al.*, 2019).

Freshwater systems on small islands are highly exposed to dynamic climate impacts, including droughts, and are among the most threatened on the planet (IPCC, 2022). According to United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2020), drought now accounts for 20 percent of the Pacific SIDS' "risk-scape", with agricultural drought-related losses contributing 20 percent of the total average annual losses in the region in 2019 (217.3 million USD). For instance, the El Niño-related 2015-16 drought in Vanuatu led households to rely on small amounts of contaminated water left at the bottom of domestic tanks for their household needs.

In Puerto Rico, between 2014 and 2016, the island experienced 80 consecutive weeks of moderate drought, 48 weeks of severe drought and 33 weeks of extreme drought conditions. Increasing drought trends are apparent across the Caribbean, with the region-wide drought of 2013-16 being the most severe drought event recorded in the 66-year period between 1950 and 2016 (IPCC, 2022). Drought risk projections for Caribbean SIDS, aligned with observations from the Shared Socioeconomic Pathway scenario 2, indicate that a 1°C increase in temperature (from 1.7°C to 2.7°C) could result in a 60 percent increase in the number of people projected to experience severe water resources stress from 2043 to 2071 (IPCC, 2022).

It is important to emphasize that the use and management of land and water resources by people, governments, and industries in SIDS have a significant impact on the availability of freshwater to meet human uses and contribute to the increasing incidence of drought. Population growth in recent decades has resulted in rising demands for freshwater of various kinds, while the acceleration of natural re*Source* exploitation (terrestrial and marine) has caused environmental degradation that amplifies the impact of meteorological drought in the landscape.

Increased groundwater extraction, deforestation, urbanization, infrastructure building, conversion of land to agriculture, mining, and other forms of economic activity have redirected water from the landscape for human use, as well as increasing levels of runoff, reducing rates of groundwater recharge and interrupting surface water availability. Many SIDS are, for example, heavily reliant on tourism as a revenue *Source* (Leal Filho *et al.*, 2021). Tourism requires a high quantity of water to service hotels and related facilities and the high tourist season often coincides with dry periods of the year in many SIDS (Waite, 2012).

1.3.3. Agriculture and food security in Small Island Developing States

Agriculture is a mainstay of the economy for many SIDS and remains the primary *Source* of food security and livelihood for large segments of their populations, many of whom depend on agriculture for their subsistence (UNFCCC, 2007). For instance, in the Pacific region, more than 60 percent of the population is employed in agriculture, which contributes to over 30 percent of total exports in Fiji, Papua New Guinea, and the Solomon Islands, and to more than 60 percent in Samoa, Tonga and Vanuatu (UNESCAP, 2020). Nevertheless, SIDS exhibit wide variations in the extent to which populations are dependent upon agriculture – for instance, in countries, such as Palau and Samoa, the percentage of people employed in agriculture is less than 3 percent (UNESCAP, 2020).

Despite recent trends towards modernization and urbanization, the majority of SIDS' populations live in rural areas and agriculture and fishing remain their primary livelihood activities (Connell *et al.*, 2020). Subsistence-based economies have lasted longer in SIDS than in many other parts of the world, especially in the Pacific, and survive best in the Melanesian SIDS of the Solomon Islands and Vanuatu (Connell *et al.*, 2020).

Cash crop agriculture is also critically important to SIDS' economies and to the livelihoods of farmers and farm workers. Built upon a long history of plantation agriculture, many SIDS are large-scale producers of cash crops for export, such as sugar, coconut, coffee, cocoa, copra, rubber, and palm oil. Such crops contribute a significant proportion (sometimes the entirety) of export revenues in most SIDS, allowing them to participate in international trade, as well as supporting local market activity and contributing to local incomes, food security, and nutrition. However, arable land for cash crop agriculture is in short supply in SIDS. Land and water access, therefore, impose limitations on the extent to which commercial agriculture can support increased levels of economic development to combat climate change.

Yet, despite the importance of agriculture to subsistence and national revenues, levels of food insecurity, hunger, and undernourishment are worse in SIDS than globally. According to the UN's 2023 report on the State of Food Security and Nutrition in the World, prevalence of undernourishment in the total population in SIDS between 2020 and 2022 are 15.3 percent compared to a global average of 9.2 percent (FAO *et al*, 2023).

This difference can be attributed to two factors: first, the limited availability of local food in SIDS which results from the scarce availability and degraded nature of land used for subsistence agriculture; and second, the high vulnerability of local food systems to weather-related shocks (FAO, 2014). These factors have resulted in high levels of dependence on imported foods.

1.3.4. Impacts of climate change and drought on agriculture in Small Island Developing States

The impacts of climate change and the rising incidence of drought events pose serious risks to agriculture, food security, and nutrition in many SIDS.

There is strong evidence that under most climate change scenarios, water resources are likely to be seriously compromised in SIDS (UNFCCC, 2007; Hunter, 2007; IPCC, 2021, 2022), and both subsistence and commercial agriculture will likely be adversely affected (IPCC, 2007). Multiple studies confirm that the most climate-vulnerable sectors in SIDS include water, agriculture and food security, and terrestrial ecosystems and coastal zones (IPCC, 2007; UNFCCC, 2005, 2007).

Projected impacts of climate change include extended periods of drought, loss of soil fertility, and declining availability of freshwater resources, with negative impacts on agriculture, biodiversity, and the ecosystems upon which they depend. As climate change intensifies, the production of subsistence crops is likely to be negatively affected by heat stress and changes in soil moisture and evapotranspiration, which will cause both short-term crop failures and a long-term decline in yields (Nelson *et al.*, 2009; Stern, 2006).

Extreme weather events cause irreparable damage to food crops on which small island populations depend. Extended droughts often cause damage to crops, resulting in low exports and high imports, the latter usually resulting in a huge burden on foreign exchange earnings.

Much of the prime agricultural land in SIDS is located on coastal plains which are threatened by sea-level rise. This rise, with accompanying salinization, is likely to have major impacts on crop production, especially in low islands and atolls in the Pacific, where all the crop agriculture is found on or near the coast.

Generally speaking, climate change is projected to result in increasing levels of aridity across SIDS, which will contribute to increased food and water insecurity in many places (FAO, 2014; Karnauskas *et al.*, 2018; IPCC, 2022). For instance, in the Caribbean, the IPCC projects that additional warming by 0.2°-1.0°C will cause the region to become predominantly drier (5-15 percent less rain than present day), with a greater occurrence of droughts (IPCC, 2022). This in turn could lead to associated negative impacts on agricultural production and a reduction in the variety of crops that farmers are able to grow.

Unless effective adaptation measures are taken to make agriculture resilient to climate change and drought, the negative impacts on people living in SIDS will be far-reaching. Risks include changes to crop yields and crop failures that will lead to instability of the food supply (IPCC, 2019).

Declining agricultural productivity caused by climate change will result in economic losses that will impact gross domestic product and undermine poverty alleviation and food security (UNFCCC, 2007). Impacts on agricultural yields will result in lower levels of food availability at the household level and reduced volumes of cash crops for export. In response, SIDS will need to increase food imports, which often result in a huge burden on foreign exchange earnings. The relative magnitude of these losses will, however, differ among SIDS.

It is important to note that though farmers are vulnerable, they are not passive in the face of adversity; they try to adapt and cope with changing conditions – experimenting and improvising with particular techniques (Barker, 2012) as well as utilizing traditional knowledge. For example, while the Pacific Islands are often described as highly vulnerable to climate change and lacking adaptation options, such descriptions disregard how Pacific islanders are leading climate action and combining their systems of knowledge with western science to implement locally relevant climate solutions (McLeod *et al.*, 2019).

Key insights

Droughts are commonly identified as meteorological drought, agricultural drought, hydrological drought, and socioeconomic drought. In more recent years, ecological drought has been recognized, which takes into account the consequences of drought on ecosystems, hence identifying.

Although traditionally termed as a “natural” hazard, the “human effect” on the occurrence of drought events is nowadays largely acknowledged. Drought is associated not only with climatic variations but to climate change.

The vulnerability of people and places to drought is driven by social and economic practices, especially the decisions of powerful elites and institutions. Efforts to address its impacts will only succeed if the structural drivers of the drought conditions that affect people and the vulnerabilities of those people to different forms of drought are tackled.

Most SIDS face similar challenges, such as remoteness, few local resources, rapidly growing populations, dependence on international trade, limited opportunities for economic diversification, and high transportation, communication, and infrastructure costs. Many have fragile economies, with high levels of unemployment, poverty, and income inequality – factors that render SIDS vulnerable to the hazards they face.

SIDS are disproportionately exposed to climate-related hazards, such as tropical cyclones, hurricanes, flooding, and droughts. Climate change is also driving sea-level rise, salinization, coastal erosion, and biodiversity loss.

These hazards impact every sector of the economy and society, causing negative impacts that undermine resilience to future extreme weather events.

According to UN data from 2016, 71 percent of SIDS face a risk of water shortage, rising to 91 percent in low-altitude SIDS. For many SIDS, reliable, sustainable, and affordable access to potable water is a critical issue. Increases in droughts, temperatures, and precipitation variability are expected to increase levels of water stress, especially considering growth in populations and water demand.

Agriculture is a mainstay of the economy for many SIDS and remains the primary *Source* of food security and subsistence livelihoods for large segments of the population, especially in the Pacific region.

The impacts of climate change pose serious risks to agriculture, food security, nutrition, and freshwater supplies in many SIDS. Unless effective adaptation measures are taken to make agriculture more resilient, the negative impacts will include reduced food availability and cash crops for export, putting a huge burden on foreign exchange earnings to pay for imported food.

2 Drought risks in Small Island Developing States

2.1. Challenges in assessing drought risks and vulnerability in Small Island Developing States

SIDS are a highly diverse set of countries, geographically, climatically, and socioeconomically. They span the central and eastern Pacific, the southern and eastern Atlantic, the Indian Ocean, the Caribbean, and the South China Sea. They range from tiny atoll states like Tuvalu to dispersed archipelagos such as Micronesia, from rural large island countries like Papua New Guinea to city-states like Singapore (Barnett and Waters, 2016).

Economic sectors within SIDS vary widely from fisheries and agriculture to mining, forestry, tourism, financial services, and water re*Source* management (Robinson, 2020). Agriculturally, SIDS produce a wide variety of cash and food crops (e.g. coconut, cocoa, coffee, sugar, tobacco, taro, cassava, yam, sweet potato, breadfruit, banana/plantain) and livestock (e.g. cattle, pigs, goats, sheep, chickens and other poultry), depending on the particularities of their geographical location, size, socioeconomic structure, level of development and colonial history (FAO, 2014).

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However, such variety does not fit well with a standard methodology to assess climate or drought vulnerability, because considerable economic and geographic variability means that levels of exposure, sensitivity, and adaptive capacity vary markedly both between and within SIDS (Duvat *et al.*, 2017).

Climate hazards in SIDS include drought, as well as erratic precipitation and consequent run-off, hurricanes and storms (i.e. cyclones and monsoons), extreme temperatures and humidity, storm surges, coastal inundation, and floods (Robinson, 2017). Many small-scale or individual state-level vulnerability assessments have been conducted (Daly *et al.*, 2010; Ferdinand, Haynes, and Richards, 2014; Stennett-Brown, Stephenson and Taylor, 2019), but similar large-scale SIDS-wide studies are less common (Guillaumont and Wagner, 2021).

Recent attempts constructed a climate vulnerability score for a range of SIDS (33 of them) using composite index techniques that aggregate categories and weights according to impact on the overall outcome of vulnerability (Scandurra *et al.*, 2018). Another exercise assesses the vulnerability of SIDS in the Indian and eastern Atlantic Oceans by aggregating maps of geospatial data on sea-level rise, temperature, hurricanes/cyclones, natural resources, and diversity in flora and fauna (Mills and Hancock, 2005).

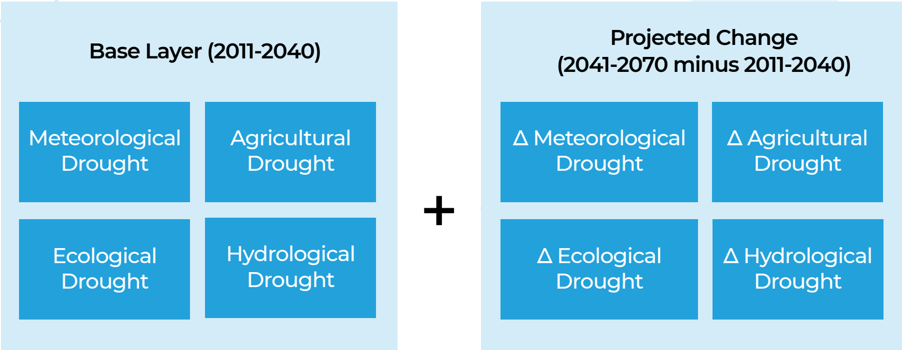
Assessing drought vulnerability is a significant challenge over such varied climates, geographies, ecosystems, and socioeconomic circumstances – particularly geographic size (for example, Papua New Guinea's area measures 462 000 km^2 compared to Tuvalu's 26 km^2) and socioeconomic drivers of sensitivity and adaptive capacity (e.g. low income to high income). We are yet to find such an exercise undertaken for all SIDS. The composite weighted indicator approach seems to be not suitable in such diverse circumstances and could compromise the validity of the results. Simply put, circumstances vary to the extent that clusters of indicators could be shown to matter in a model of drought vulnerability overall, and in certain locations, but have little to no traction in others. This challenge of context was illustrated by a straightforward preliminary analysis of drought thresholds of rice yields, which failed to uncover any coherent pattern across SIDS.

2.2. A methodology for drought vulnerability index in SIDS

The drought vulnerability index for SIDS adapts the standard framework for conceptualizing and measuring climate vulnerability to account for drought exposure. Figure 1 shows the basic format of the methodology to assess drought exposure in SIDS. The base layer is a parsimonious set of indicators that represent each component of drought – meteorological, agricultural, hydrological, and ecological:

- physical climate indicators, such as mean annual precipitation, in addition to the Fournier Index (i.e. rainfall distribution), show meteorological drought;
- agricultural indicators linked to scarcity of moisture, such as crop water deficit and the Aridity Index, illustrate agricultural drought;
- indicators of water bodies and groundwater, such as proximity to major hydrological basins or water collecting sites, show hydrological drought; and
- indicators of natural resources depletion, such as interactions between the Normalized Difference Vegetation Index and livestock density, show ecological drought in situations of livestock.

Figure 1. Impact-horizon categorization of drought financial instruments



Source: Authors' own elaboration.

In terms of timelines, certain drought exposure indicators have a forward-looking dynamic. The base layer focuses on 2011-2040 data and is developed using the spatial variation in each of the components of drought. The 2011-2040 is a projection from FAO's Global Agro Ecological Zoning data that runs from 1981-2010. This means the timeline for assessing the projected change in drought exposure is between two projected periods: 2011-2040 (considered the present base layer) and 2041-2070 (the future projected change layer).

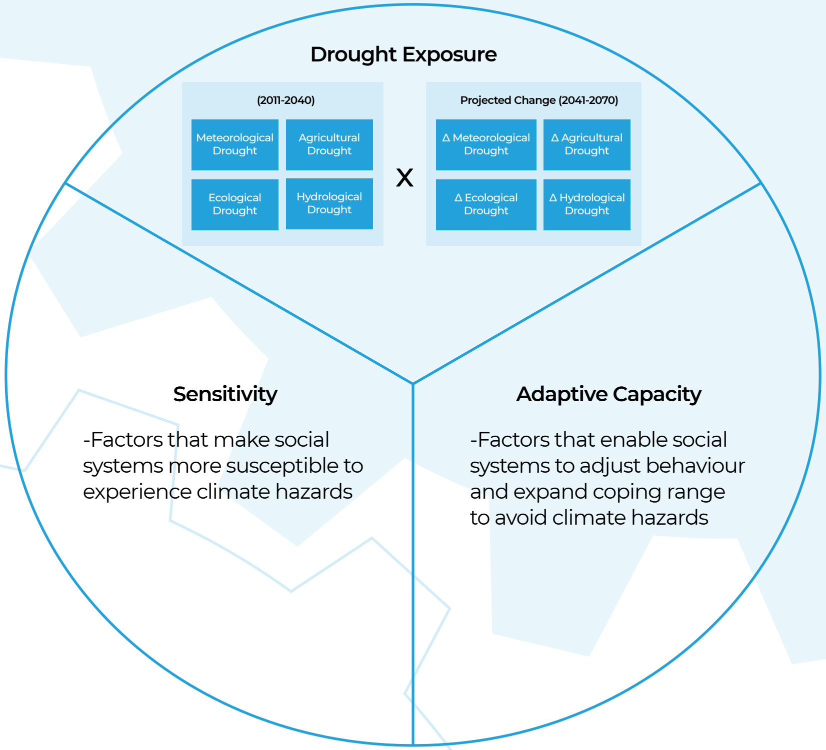
Using the 2011-2040 base layer and 2041-2070 projected change layer, forward-looking key exposure indicators for the national drought vulnerability index are calculated. This enabled a subnational hotspot calculation for each drought component with time-varying data. The merit of a subnational hotspot assessment is that the contextual and situational factors within each SIDS are partially adapted to levels of drought associated with climate variability, but the magnitude of change in future drought exposure shows where SIDS are yet to adapt, and whereby actions are essential to maintain future productivity, food security and wellbeing. This future drought exposure is calculated and interpreted in terms of the given SIDS, rather than a macro comparison.

Where a forward-looking component of an indicator is present, these are calculated as follows:

1. calculating the difference between 2041-2070 and 2011-2040 (i.e. change over time); and
2. overlaying this difference on top of the 2011-2040 base layer and summing the two values.

The measure of drought exposure for SIDS is integrated with socioeconomic factors that represent climate sensitivity and adaptive capacity. Figure 2 shows the widely recognized and applied climate vulnerability framework adapted to drought vulnerability within SIDS. Similar to the conception of drought exposure, sensitivity and adaptive capacity have been contextualized as much as possible to SIDS.

Figure 2. Drought vulnerability in SIDS: drought exposure, sensitivity and adaptive



Source: Authors' own elaboration.

Table 1 shows a breakdown of sensitivity and adaptive capacity indicators, often adapted to the unique settings of SIDS. Climate sensitivity typically focuses on indicators of population development, as well as livelihood sensitivity and options. SIDS are particularly sensitive in terms of agri-culture and fisheries livelihoods, but greater tourism opens up new and less climate-sensitive livelihood options. In terms of adaptive capacity, measures of infrastructure, institutional, and personal capacity matter moSt

SIDS are often best able to adapt when they are larger, more developed, and less remote factors which determine the depth and quality of infrastructure available to deal with drought.

Table 1. Indicators for sensitivity and adaptive capacity in Small Island Developing States

Sensitivity	Adaptive Capacity	Drought Exposure
Agriculture as % GDP[1]	Poverty headcount[1, 2, 3]	Annual Mean Precipitation Interaction (Meteorological)
Fisheries production[1]	Energy Consumption[2]	Annual Mean Temperature Interaction (Meteorological)
Liner shipping connectivity index[2]	Electricity access (proportion)[3, 4]	Fournier Index (Meteorological)
Rural Population[3, 4]	Literacy Rate[2, 7, 8]	Crop Water Deficit Interaction (Agricultural)
Life Expectancy [2, 4]	Agricultural Irrigation[3, 9]	Aridity Index Interaction (Agricultural)
Population Aged Between 15-64[3, 6, 1]	Access to Drinking Water[1]	Water Collection Sites (Hydrological)
Population density[5, 3]	Road Density[10]	Water Stress Index (Hydrological)
	Geographic Size[2]	Livestock-NDVI Interaction (Ecological)

[1] Ludena, C., and Yoon, Sang. 2015. Local Vulnerability Indicators and Adaptation to Climate Change: A Survey. Inter-American Development Bank Report, pp. 1.51.

[2] Scandurra, G., Romano, A.A., Ronghi, M. and Carfora, A., 2018. On the vulnerability of Small Island Developing States: A dynamic analysis. Ecological Indicators 84, pp.382-392.

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[6] Stennett-Brown, R.K., Stephenson, T.S. and Taylor, M.A., 2019. Caribbean climate change vulnerability: Lessons from an aggregate index approach. PloS one 14, pp. 1-19.

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[10] Birkmann, J., Jamshed, A., McMillan, J.M., Feldmeyer, D., Totin, E., Solecki, W., Ibrahim, Z.Z., Roberts, D., Kerr, R.B., Poertner, H.O. and Pelling, M., 2022. Understanding human vulnerability to climate change: A global perspective on index validation for adaptation planning. Science of The Total Environment 803, pp. 1-11.

2.2.1. Calculating drought vulnerability index for SIDS

The calculations started with the indicators for the drought vulnerability index.

Step 1: due to the extremely small size of many SIDS, mapping analysis was not suitable. Therefore, these data were summarized and extracted from GIS at the level of SIDS (i.e. national - admin level '0') to be used in other applications.

Step 2: normalization was conducted on each indicator to reduce the range of values. This process of normalization reduces the range of indicators to facilitate easier comparison across SIDS while keeping identical scale differences on the indicators.

Step 3: for each aspect (sensitivity, adaptive capacity, and exposure) of drought vulnerability, principal component analysis (PCA) was conducted. PCA reduced the number of indicators down to three "principal components" that best capture how the indicators move as a group. It is a particularly useful calculation to make when a large group of correlated indicators in one group are to be compared with another group or groups of indicators.

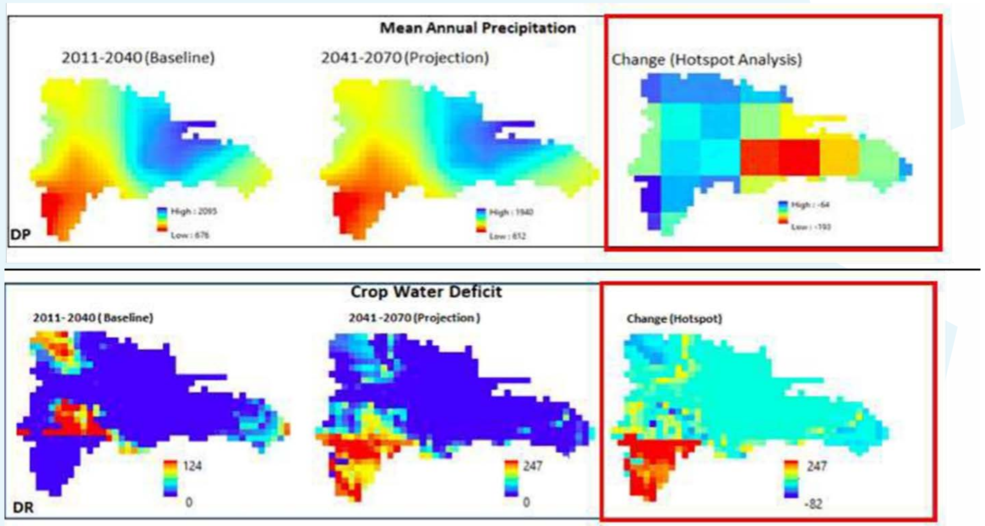
Step 4: the three principal components for each of the main parts of drought vulnerability were then added together to arrive at an aggregated value for: a) sensitivity; b) adaptive capacity; and c) drought exposure.

Step 5: the values for aggregated sensitivity, adaptive capacity, and drought exposure were then added together to arrive at an aggregated value for overall drought vulnerability within SIDS.

2.2.2. Conducting drought vulnerability hotspot analysis for individual SIDS

In terms of map analysis, overlaying the base layer and projected change, and re-calculating the overall metric, is the final process for establishing regions within SIDS that show the highest drought vulnerability (see step-by-step explanation of how this is calculated above).

Figure 3. Indicators for sensitivity and adaptive capacity in SIDS



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 12 September 2023]. http://www.fao.org/gaez/

Figure 3 uses the example of the Dominican Republic to illustrate the calculations of geospatial data made to construct the drought exposure components. The legends from the maps at the top of Figure 3 show the distribution of mean annual precipitation (mm). From 2011-2040, the highest values for mean annual precipitation are 2 095 mm, represented with deep blue, while 676 mm represents the lowest in red. While the change map on the right highlights that, even though the whole country is projected to experience a reduction in annual precipitation, the reduction is most acute in the central south eastern regions.

The legends from the maps at the bottom of Figure 3 show crop water deficit (mm). These legends are inverted to illustrate that a higher crop water deficit represents a shortage of moisture for growing crops and a greater proclivity for agricultural drought. The lowest value in crop water deficit in mm is represented as dark blue, while the highest value is red (247 mm), with light blue in between. The maps show that the southwest corner of the Dominican Republic is projected to experience a significant exacerbation of crop water deficit between 2011-2040 and 2041-2070, while the remainder of the country is projected to witness moderate negative change or improvement in some areas.

Key insights

Assessing drought vulnerability in SIDS is challenging due to their significant diversity in terms of geography, climate, and socioeconomic factors. Such variability, within and among SIDS, makes it difficult to apply a standard methodology for assessing climate or drought vulnerability.

The existing composite index techniques used for vulnerability assessments may not be suitable. Comprehensive SIDS-wide studies on drought vulnerability are still limited, and there is a need for tailored approaches that consider the unique contextual factors of each SIDS to obtain more accurate and meaningful results.

The drought vulnerability index for SIDS utilizes a modified framework to assess and measure drought exposure, incorporating indicators related to the different drought dimensions, to provide a comprehensive understanding of drought vulnerability. This approach acknowledges the unique contextual factors and specific challenges of SIDS and provides a more nuanced understanding of their vulnerability.

A step-by-step methodology can be employed to estimate drought vulnerability based on clear indicators. This methodology enables the assessment and comparison across SIDS, contributing to a better understanding of their overall vulnerability to drought events.

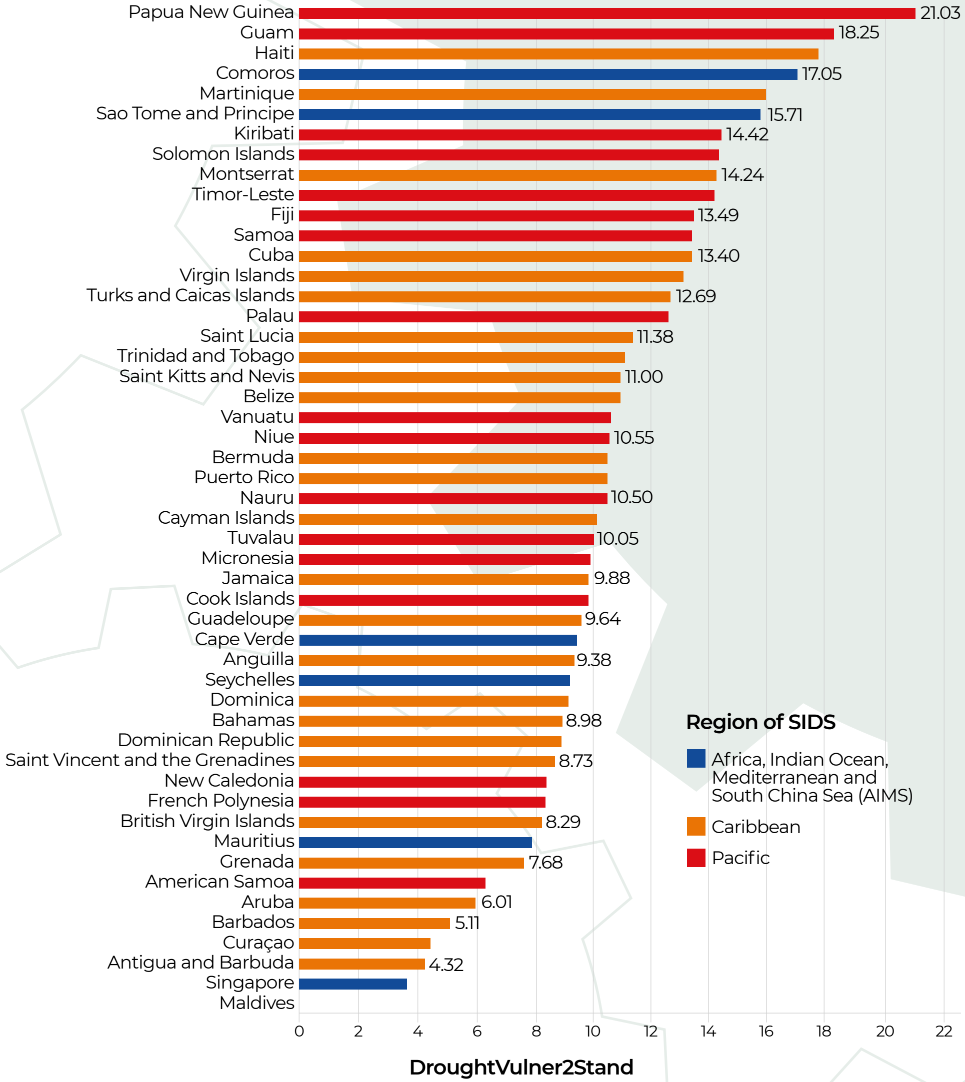
Geospatial observations can support the identification of the most vulnerable regions. The application of the drought vulnerability index can assess drought exposure components, helping to understand the spatial distribution of drought vulnerability within SIDS.

3 Results from the drought vulnerability index for Small Island Developing States

3.1. Drought vulnerability in SIDS and by region

The results from the drought vulnerability index broadly run in accordance with the understanding of climate vulnerability of SIDS within the literature (Figure 4). The immediate broad trend is that the smaller, poorer, and more isolated SIDS are the most vulnerable to drought. Most of the top 10 drought-vulnerable SIDS broadly fit this trend, apart from the larger, but acutely underdeveloped, SIDS of Haiti and Papua New Guinea.

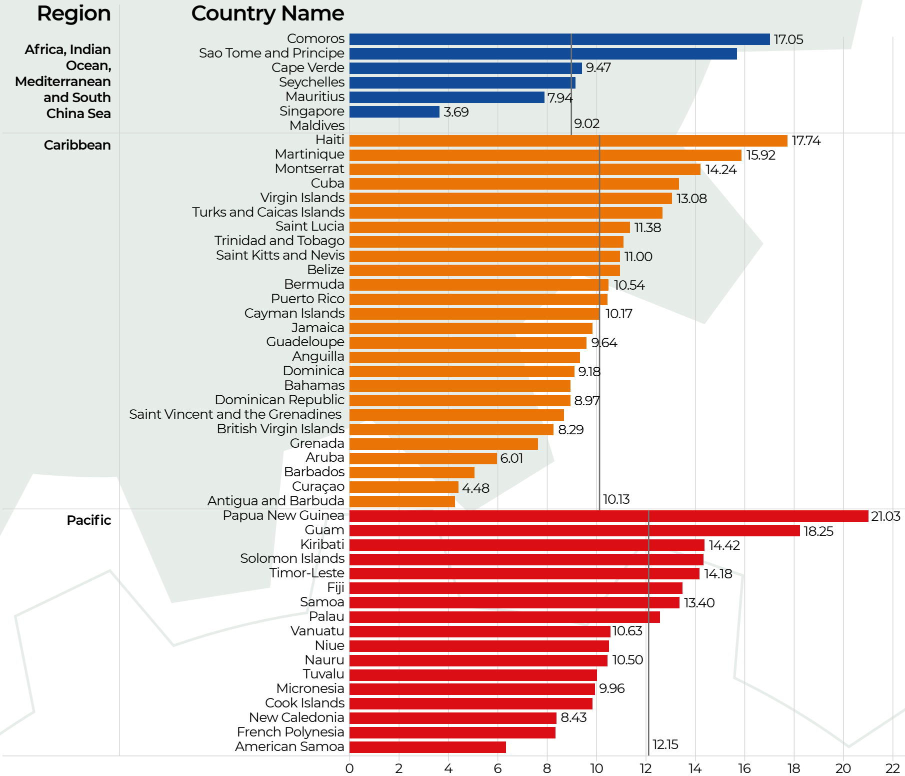
Figure 4. Drought vulnerability of SIDS



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 27 July 2023]. http://www.fao.org/gaez/

Figure 5 provides a clearer regional breakdown of drought vulnerability within SIDS. It illustrates better that those smaller and more remote SIDS, particularly around the Pacific, have significant challenges about drought vulnerability. Overall, the Pacific region is the most drought vulnerable with a mean score of 12.15, which is to be understood relatively in terms of Africa, Indian Ocean, Mediterranean and South China Sea (AIMS) (9.02), and the Caribbean (10.13).

Figure 5. Drought vulnerability index of SIDS clustered by region



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 27 August 2023]. http://www.fao.org/gaez/

3.2. Investigation into key indicators

Table 2 sets out the correlations between geographic size and many of the other predictors for drought vulnerability. Correlation is a calculation that shows how two indicators move together – '0' would suggest there is no overlap in how they move together, '1' suggests they move in the same way, while a correlation of +0.30 is generally considered to be an instance where there is some discernible pattern between the movements of the two indicators. When necessary, indicators are sometimes inverted to show that higher values represent higher vulnerability.

The findings suggest that geographic size is a key determinant for a range of socioeconomic drought vulnerability indicators and is strongly correlated to aridity and crop water deficit. The smaller geographic size was associated with key infrastructure components like inadequate access to drinking water, lower literacy rates, and lower road density.

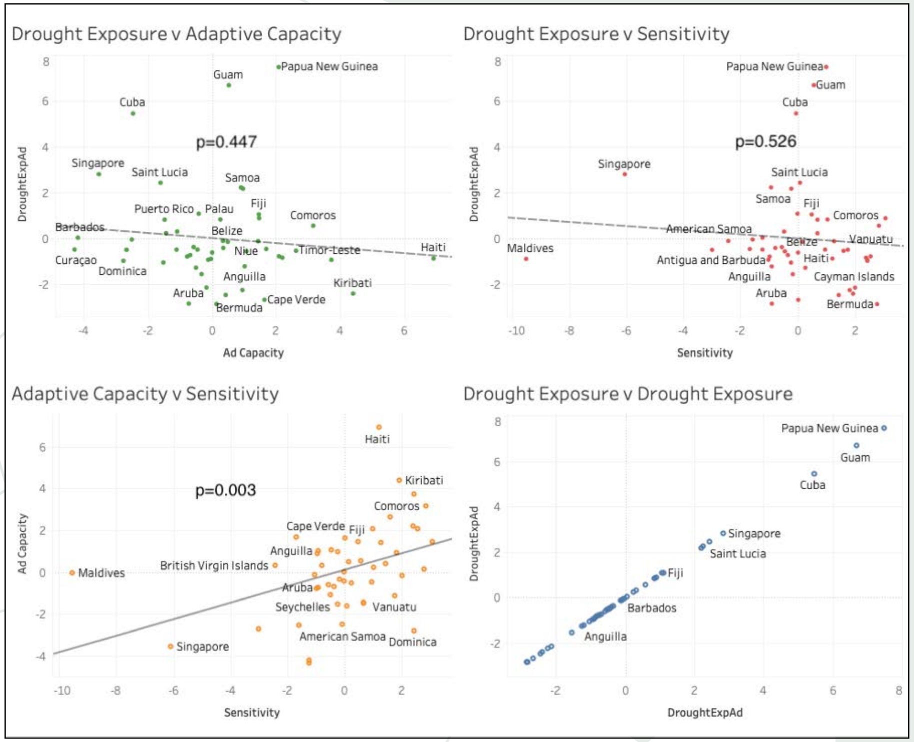
At the same time, geographic size is a determinant of overall poverty and life expectancy, interestingly for the assessment of drought vulnerability, aridity is also strongly associated (0.86) with the geographic size of SIDS. But as may be expected, geographic size doesn't influence many other indicators that are not or only partially related to the exposure, except for agricultural drought where small SIDS tend to have less crop water deficit.

Table 2. Examples of correlations with geographic size as a driver of multiple drought vulnerability indicators

Road density	Rural population	Life expectation	Poverty rate	Literacy rate	Access to drinking water	Aridity index	Crop water deficit
0.2198	0.3052	03167	01912	0.2341	0.5207	0.8643	0.4114

Figure 6 provides a bivariate illustration of the relationship between the final principal components that were calculated for sensitivity, adaptive capacity, and drought exposure. The first thing to note is that there is little relationship between drought exposure and either sensitivity or adaptive capacity. This is recognizable through the flat trend line across the two charts located at the top of Figure 6. This is to be expected, due to many indicators – such as rainfall and temperature – having no link to people, their institutions, and development status. The second key finding is that, reassuringly, there is a strong positive relationship between the principal components of sensitivity and adaptive capacity. Finally, the bottom right chart shows the perfect correlation and thus distribution of drought exposure. Papua New Guinea, Guam, and Cuba feature here as outliers with very high drought exposure. When looking back at the data, these islands scored the highest on the interconnected drought indicators of the Fournier index (i.e. rainfall distribution), water stress, and one of the highest on precipitation and the aridity index, which are naturally all related.

Figure 6. Drought vulnerability of SIDS clustered by region

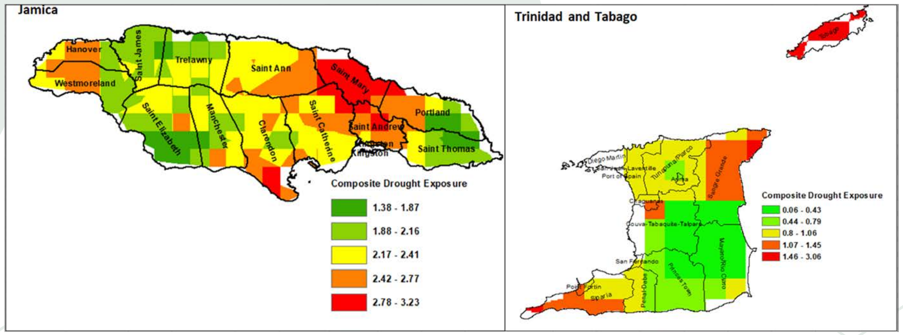


Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 15 June 2023]. URL: http://www.fao.org/gaez/ and World Bank Group. Climate Change Knowledge Portal. [Accessed on 15 June 2023]. https://climateknowledgeportal.worldbank.org/

3.3. Subnational mapping – Jamaica, and Trinidad and Tobago

The composite drought exposure map is prepared based on six disaggregated drought exposure indicators – three meteorological drought indicators, two agricultural drought indicators, and an ecological drought indicator (Figure 7). The meteorological drought indicators are annual mean precipitation, annual mean temperature, and the Fournier index; agricultural drought indicators are crop water deficit and the aridity index; while ecological drought is captured through the Normalized Difference Vegetation Index. The composite drought exposure map is prepared by combining these six indicators according to the projected change methodology described in section 2 above. Figure 7 shows that St Mary Parish and southern St Catherine in Jamaica have the highest drought exposure, while north western Sangre Grande and Tobago Island itself have the highest drought exposure in Trinidad and Tobago.

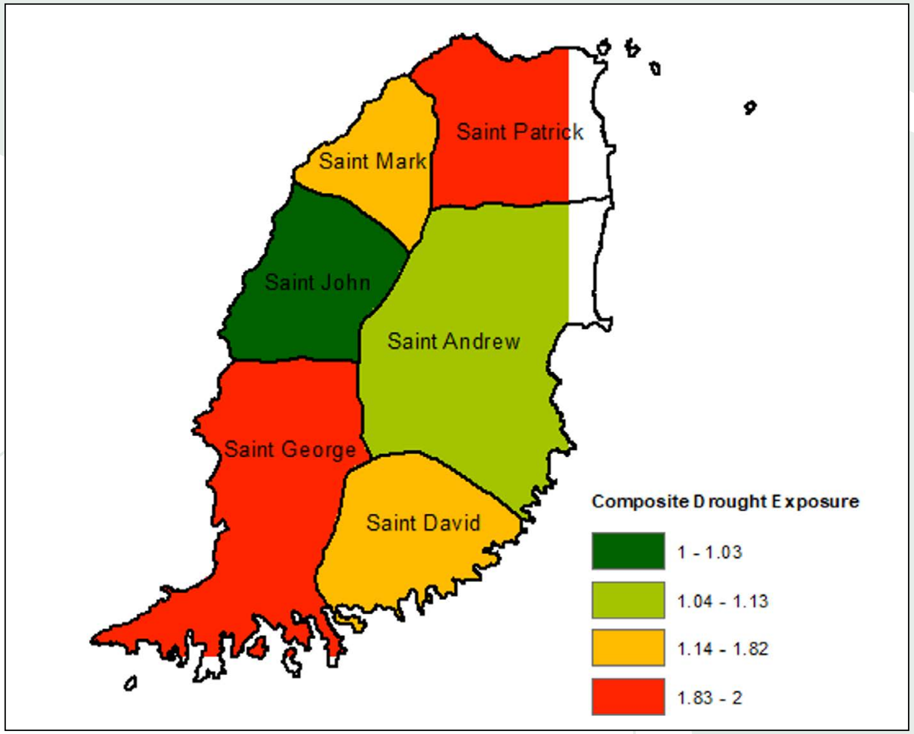
Figure 7. Jamaica, and Trinidad and Tobago hotspot drought exposure



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 02 June 2023]. http://www.fao.org/gaez/

Figure 8 shows the drought exposure map for the island of Grenada. The data quality decreased considerably for this SIDS. Specifically, there was no subnational variation available for the indicators of precipitation, temperature, and the Fourier index. The map, thus, shows the combined subnational variation of crop water deficit hotspot calculation and the aridity index. It illustrates that Saint Patrick and Saint George have notable relative drought exposure.

Figure 8. Grenada hotspot drought exposure map



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 02 June 2023]. http://www.fao.org/gaez/

Key insights

The application of the drought vulnerability index confirms literature findings and indicates that the smaller, poorer, and more isolated SIDS are the most vulnerable to drought.

The geographic size can directly determine conditions of socioeconomic drought, and it is highly correlated to aridity and crop water deficit.

At the same time, geographic size does not appear to influence other indicators that are not or only partially related to the exposure, except for agricultural drought whereby small SIDS tend to have less crop water deficit.

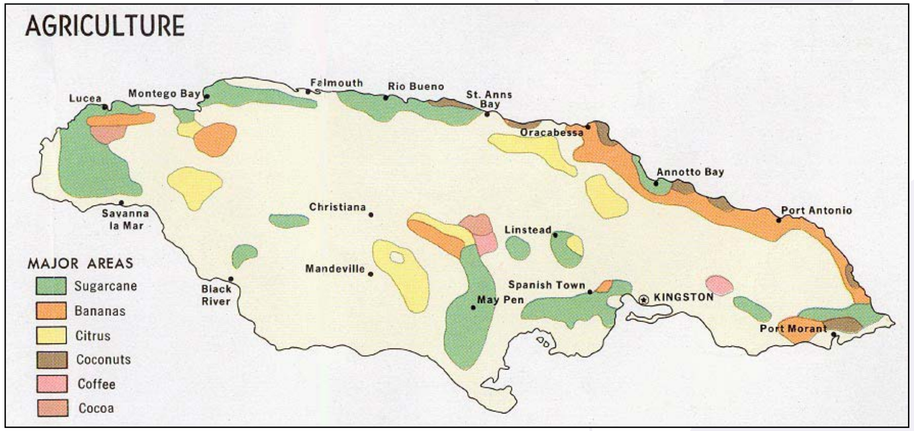
The mapping and analysis of drought exposure allows not only the identification of areas particularly susceptible to drought. It also enables targeted actions and strategies to mitigate the impacts of drought and enhance resilience in these regions.

4 Contextual analysis of drought vulnerability in selected Small Island Developing States

4.1. Jamaica

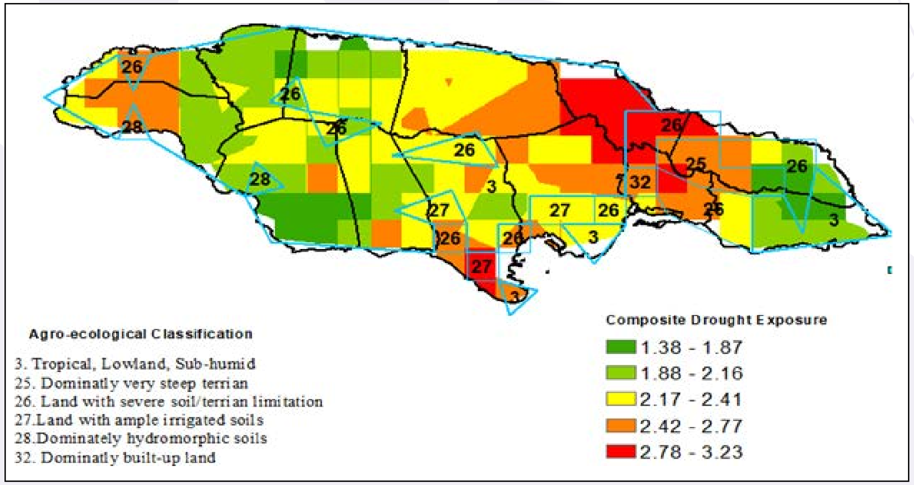
Largely due to historical factors, Jamaica's agricultural sector is structured for sugarcane production and sugar production. Other prominent export crops include bananas, cocoa, coffee coconuts, pimientos, citrus fruits, ginger, tobacco, yams, papayas, dasheens, peppers, melon, pumpkin, carrot, cabbage, tomato, callaloo, cucumber and cut flowers (see Figure 9). Crops for domestic consumption are primarily grown by small cultivators, including tubers such as sweet potatoes, cassava, yams, and dasheens, and also legumes, fruits, and cereals, such as tomatoes, beans, rice, and potatoes.

Figure 9. Jamaican agriculture



Source: The University of Texas at Austin. [Accessed on 05 June 2023]. https://maps.lib.utexas.edu/maps/jamaica.html

Figure 10. Jamaica drought exposure and agro ecological classification



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 05 June 2023]. http://www.fao.org/gaez/

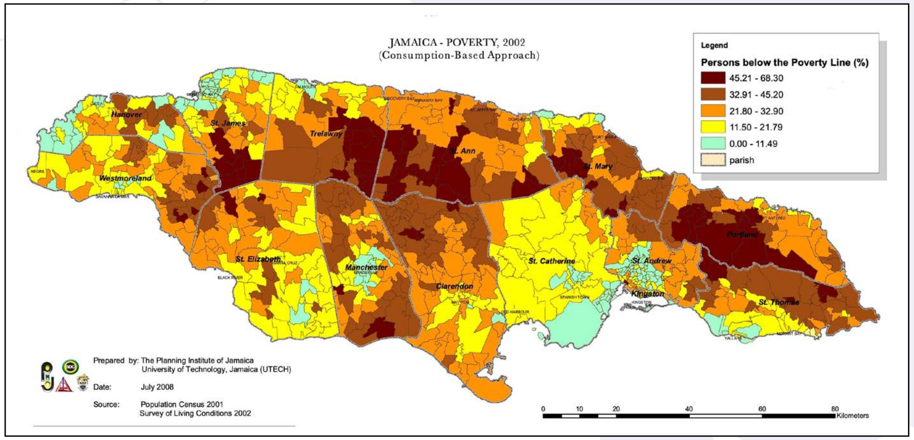
The majority of land in Jamaica is not optimal for crop production (see tropical, lowland, sub-humid agroecological classification in Figure 10), with the largest belt of low-potential land located inland within the northern parishes of St James, Trelawny, St Ann and St Mary. Some cropland to the immediate west of Kingston (St Catherine and Clarendon parish) is of moderate suitability (see the land with ample irrigated soils in Figure 10), which has typically been used for sugarcane production, and to a lesser extent, bananas, citrus fruits, and coconuts. The western and north western parts (the parishes of Westmoreland, Hanover, and St James), especially along the coast, are suitable for sugarcane, bananas, citrus fruits, and coffee. In the northern coastal parts of St Ann, St Mary, Portland, and St Thomas, there is a long belt of banana production, along with some citrus fruits and coconuts (see land with ample irrigated soils in Figure 10). It is along the north western and western coasts where Jamaica's highest potential agricultural land is located.

The hotspot map of Jamaica suggests greater drought exposure in the areas of St Mary, and to a lesser degree, West Portland, St Ann, and the western parishes of Westmoreland and Hanover (see Figures 7 and 10). This suggests increased physical drought pressures in some of the high-potential areas along the north western coasts where bananas, citrus fruits, and coconuts are grown, as well as moderate physical drought pressure in Westmoreland and Hanover parishes with significant sugarcane production.

The mapped illustrations of Jamaica have shown cropping patterns and physical drought exposure across Jamaica. To accompany these indicators of drought vulnerability, drought sensitivity, and adaptive capacity are illustrated in Figure 11 through the proxy indicator of subnational poverty distribution. Figure 11 illustrates that the drought exposure hotspot of St

Mary Parish, with its focus on banana production, does have a high incidence of poverty within the population. Meanwhile, the western parishes of Westmoreland and Hanover are relatively wealthy areas, thus suggesting lower drought sensitivity and higher adaptive capacity.

Figure 11. Jamaica poverty index



Source: The Fiwi Roots Project. [Accessed on 03 June 2023]. https://fiwiroots.com/poverty-distribution.html

In terms of livestock and fisheries, the primary climate hazards for livestock are floods and hurricanes, while naturally, fisheries are not subject to drought. Livestock includes cows, pigs, sheep, goats, and poultry. The livestock sector has tripled since 1970, helped by an import substitution strategy that has supported the price received by national producers. In terms of aquaculture, the industry is clustered in St Catherine and Clarendon, although it has reduced significantly in the past two decades. The food fish subsector is made up of red hybrid tilapia, crustaceans (*Penaeus vannamei* or marine shrimp and *Macrobrachium rosenbergii* or freshwater shrimp) and mollusks (*Crassostrea rhizophorae* or mangrove oyster). The ornamental fish subsector produces a variety of ornamental fish species such as P*terophyllum scalare* and *Crassius auratus* for export. In terms of fisheries, there are roughly 18 000 registered fishers in the Jamaica Seascape area. Fishers reside on and fish from the Pedro Cays, fish on Pedro Bank from the mainland, and fish on the South Shelf.

4.2. Trinidad and Tobago

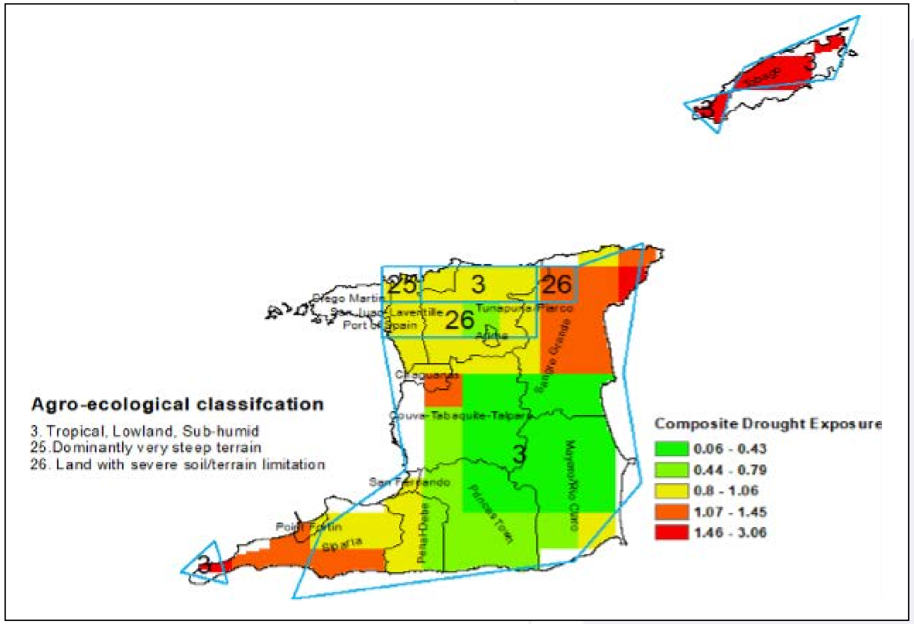
Agriculture is made up of large estate plantations in Trinidad, along with small farms cultivated by individual owners and families on both islands. Small farms produce mainly for domestic production, including corn, rice, pigeon peas, peanuts, beans, potatoes, cassava, and citrus fruits. Small farmers have in places embraced technologies to boost high-quality protected vegetable production, intensifying yields relative to the previous open-field productive systems. Such farmers tend to focus on sweet pepper, tomatoes, pak choi, lettuce, cucumbers, shado beni, cauliflower, beans, carali, chive, and hot pepper.

Plantations mainly grow crops for commercial export, with some export crops produced by small farms. Sugarcane grown on large plantations is the main commercial crop, which is supplemented by small farmers. Cocoa is the second major export crop, cultivated mainly within plantations in areas of elevation. Small farmers tend to intercrop bananas, coffee, and cocoa, also in elevated areas, but in much smaller quantities. Ornamental flowers are cultivated for export, but in small quantities.

About 28 percent of the total land in Trinidad and Tobago is considered arable, with the most suitable land comprising around 15 percent (see tropical, lowland, sub-humid classifications in Figure 12, and agricultural areas in

Figure 13). Agricultural land in Trinidad and Tobago is constrained in two ways. First, in Trinidad, by forest cover over the western, north, and southern areas. Second, for both Trinidad and Tobago, urban and residential development has been significant in recent decades, often situated in agricultural areas.

Figure 12. Trinidad and Tobago drought exposure and agroecological classification



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 12 June 2023]Accessed DATE. http://www.fao.org/gaez/

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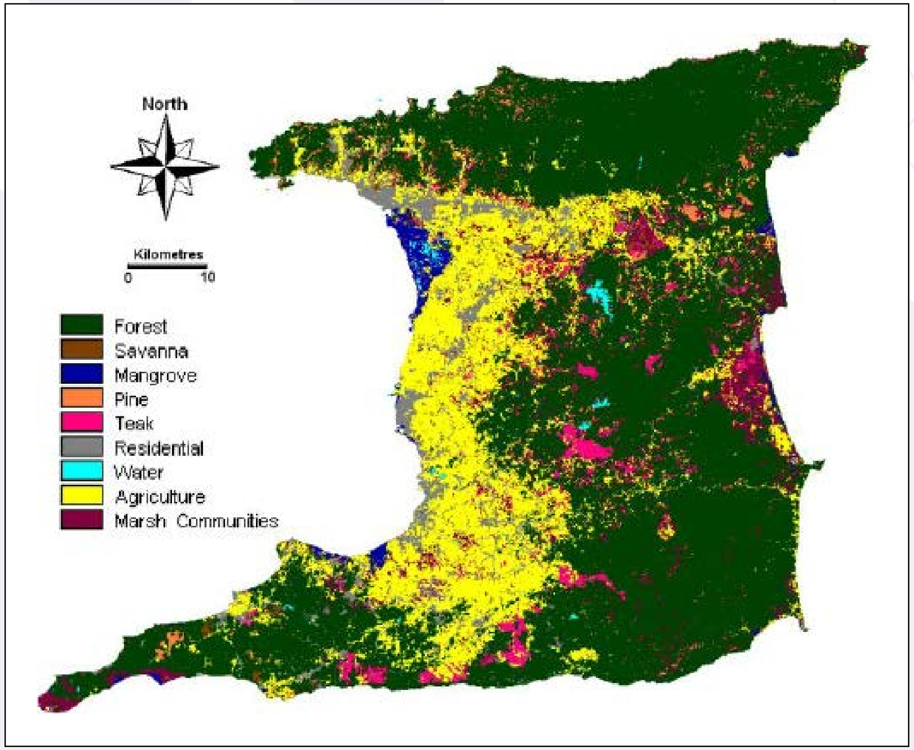
Figure 13. Trinidad (top) and Tobago (bottom) – land use

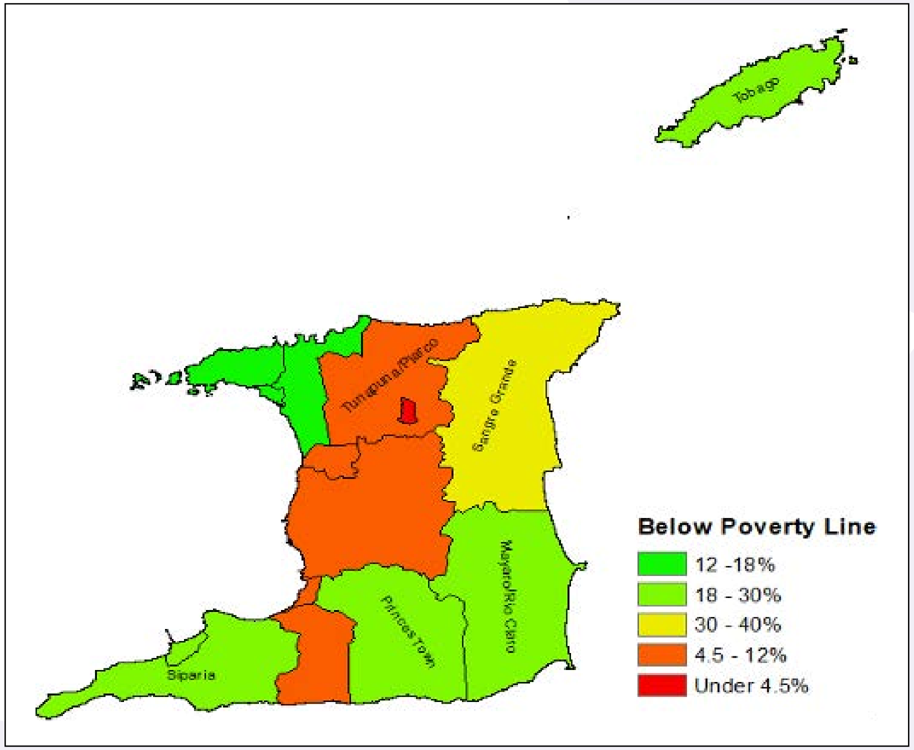


Source: **Baban, S.M., Ramsewak, D. and Canisius, F.**, 2009. Mapping and detecting land use/cover change in Tobago using remote sensing and GIS. *Caribbean Journal of Earth Science*, 40(3), pp.1-13.

High drought exposure overlaps with agriculturally productive areas mainly in Trinidad and only in the County of Caroni. There are pockets of high drought exposure in the northeast and moderate exposure in the north, both of which have some agriculture. However, the whole of Tobago has high drought exposure, indicating that drought as a physical phenomenon is a challenge, and will likely worsen in the coming decades. There are indications that rising physical drought exposure will impact agriculture in some areas.

Furthermore, deteriorating drought conditions need to be understood in terms of climate sensitivity and adaptive capacity. Figure 14 shows the variability in poverty rates across Trinidad and Tobago. The County of Caroni has a relatively small proportion of people below the poverty line, but there is moderate to high poverty in north eastern and south western Trinidad, where drought exposure is highest Meanwhile, Tobago sees an alignment of all factors – high drought exposure and high poverty rates in agriculturally productive areas.

Figure 14. Trinidad and Tobago poverty rates



Source: **Alkire, S., Kanagaratnam, U. and Suppa, N.** 2021. *The Global Multidimensional Poverty Index (MPI)* 2021, OPHI MPI Methodological Notes 51, pp. 1-23.

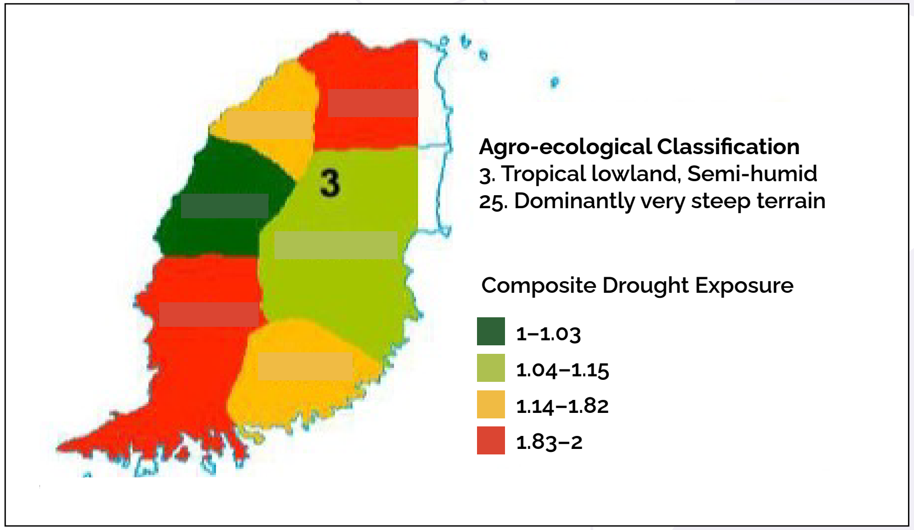
In terms of livestock and fisheries, the primary climate hazards for livestock are rising temperatures and erratic precipitation, with some susceptibility of livestock value chains to drought, while naturally, fisheries are not subject to drought. Livestock includes cows, pigs, sheep, goats, and poultry. The livestock sector includes poultry, cattle, goats, hogs, sheep, and water buffalo. Fishery activities include gillnet fishing, trolling, shrimp trawling, fish pot fishing, and industrial longline fishing. Inland fisheries include hand collections for crabs, oysters, brackish water species, and shellfish, as well as aquaculture via the use of tank-based, modified seawater water recirculation for the production of high-value marine fish species.

4.3. Grenada

Grenada is the second largest exporter of the spice nutmeg (it is known as the "spice island") and together with mace, it is the main export crop. Other export crops include cocoa, citrus fruits, bananas, cloves, and cinnamon. Food crops more for domestic consumption include yams, sweet potatoes, corn, peas, and beans.

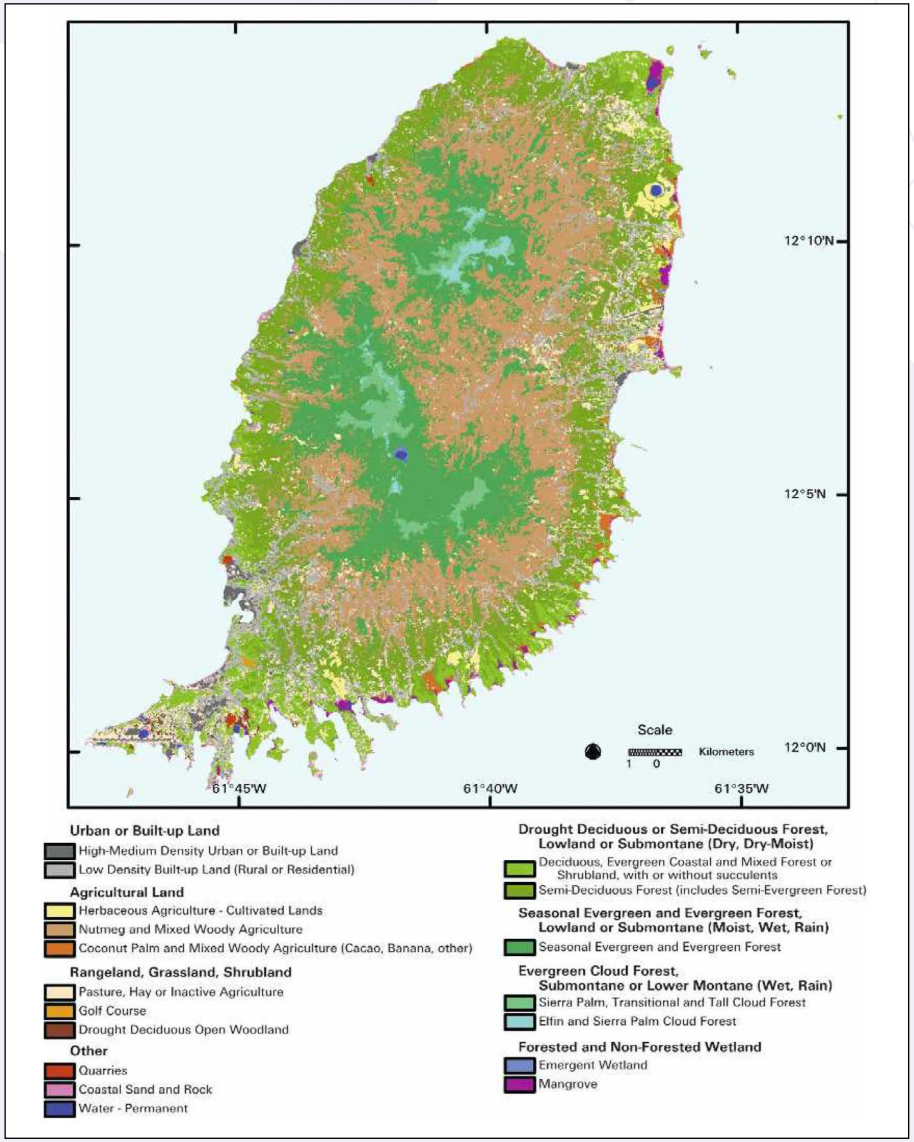
The amount of agricultural land has fallen significantly over the past 50 years, from around 65 to 23 percent. Furthermore, agriculture has become less important to Grenada's increasingly diversified economy, falling from 17.7 percent in 1975 to 4.9 percent in 2020 (see Figures 15 and 16). The land use map for Grenada (Figure 16) illustrates the striking pattern of nutmeg, coconut, cocoa, and banana cultivation. Almost in a figure of eight, around two elevated cloud forests, the majority of agricultural land is situated away from both the elevated areas and the coast. A small amount of herbaceous agriculture is concentrated in the north east of the island, as well as sporadic micro-cultivation sites around the coastal regions. While the majority of the land is shrub-land, evergreen, and deciduous forest, the whole island is classified as tropical lowland and semi-humid (Figure 15).

Figure 15. Grenada hotspot drought exposure map



Source: FAO and IIASA. Global Agro Ecological Zones version 4 (GAEZ v4). [Accessed on 16 June 2023]. http://www.fao.org/gaez/

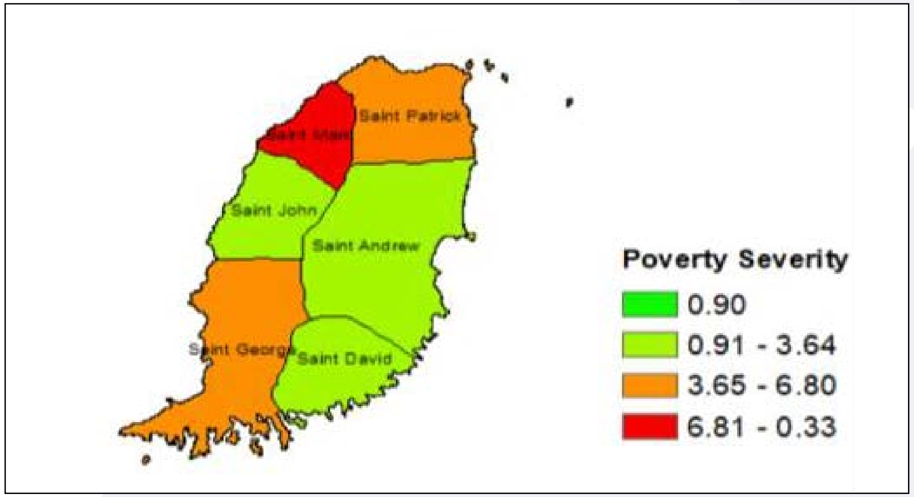
Figure 16. Grenada land use map



Source: **Helmer, E.H., Kennaway, T.A., Pedreros, D.H., Clark, M.L., Marcano-Vega, H., Tieszen, L.L., Ruzycki, T.R., Schill, S.R. and Carrington, C.S.**, 2008. Land cover and forest formation distributions for St. Kitts, Nevis, St. Eustatius, Grenada and Barbados from decision tree classification of cloud-cleared satellite imagery. *Caribbean Journal of Science*, 44(2), pp.175-198.

As the distribution of agricultural production is evenly spatially distributed around Grenada, physical drought exposure interacts with agricultural production in the locations where it is highest – namely St Patrick in the north west where nutmeg and herbaceous agriculture are situated, and St George in the south west where cultivation of nutmeg, coconut palm and other types of agriculture takes place. To accompany the situation assessment of crop production and drought exposure, Figure 17 shows drought sensitivity and adaptive capacity, through the proxy indicator of subnational poverty severity distribution. This demonstrates that not only are St Patrick and St George focused on agriculture and experience or will experience high drought exposure, but they also have moderate to high rates of poverty that are associated with high drought sensitivity and low adaptive capacity.

Figure 17. Grenada poverty severity map



Source: Authors' own elaboration based on Carribean Development Bank. 2010. *Poverty Assessment Report: Grenada, Carriacou and Petit Martinique*. National Assessment Team Publication, pp. 1-149.

In terms of livestock and fisheries, the primary climate hazards for livestock are rising temperatures and erratic precipitation, with some susceptibility of livestock value chains to drought, while naturally, fisheries are not subject to drought. Livestock include cows, pigs, sheep, goats, and poultry. The livestock sector includes poultry, cattle, goats, hogs, sheep, and water buffalo. Fishery activities include gillnet fishing, trolling, shrimp trawling, fish pot fishing, and industrial longline fishing. Inland fisheries include hand collections for crabs, oysters, brackish water species and shellfish, as well as aquaculture via the use of tank-based, modified seawater recirculation for the production of high-value marine fish species.

Key insights

SIDS are highly diverse geographically, climatically, and socioeconomically – but this variety does not fit well with a standard methodology to assess climate or drought vulnerability.

A composite weighted indicator approach is not suitable in such diverse circumstances and could compromise the validity of the results. Circumstances vary so much that indicators considered relevant in a model of drought vulnerability, either overall or in certain locations, may have little to no traction in other locations.

The presented national-level drought vulnerability index of SIDS broadly mirrors findings in the literature – i.e. the smaller, poorer, and more isolated SIDS are, the more vulnerable they are to drought. Most of the top-10 drought-vulnerable SIDS fit this trend, apart from the larger but acutely underdeveloped SIDS of Haiti and Papua New Guinea.

When presented regionally, the index better illustrates how smaller and more remote SIDS have significant challenges in relation to drought vulnerability. Overall, the Pacific region is the most drought-vulnerable.

Subnational drought vulnerability mapping pilot in Jamaica, Trinidad and Tobago, and Grenada used six meteorological, agricultural and ecological drought indicators. The maps illustrate, that: Jamaica has limited arable land and drought vulnerability in high-potential cash-crop areas; in Trinidad and Tobago, arable land is increasingly constrained by urban development; and Grenada's nutmeg and coconut plantations are exposed to high levels of drought and social vulnerability.

5 Drivers of drought risk for smallholders in Small Island Developing States

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5.1. Drought risks are multidimensional

Vulnerability in human systems and communities can also impact food security (Lowitt *et al.*, 2015; Schnitter *et al.*, 2019; Shah and Dulal, 2015). Although farmers are observing changes in rainfall and precipitation patterns, other factors affect their ability to cope and adapt (Rhiney, Eitzinger and Farrell, 2016). Research in Jamaica found that only 15 percent of cocoa farmers had adapted their farming practices in response to observed changes in climate (Rhiney, Eitzinger and Farrell, 2016). Similarly, only around 20 percent of farmers surveyed in Trinidad and Tobago indicated that they had made some form of adjustment to their farming practices in response to observed changes in rainfall.

Adaptation to extreme climate conditions such as drought is not isolated from decisions related to socioeconomic factors. The capacity to adapt is dynamic and is influenced by a society's productive base, including natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance, national income, health, and technology. It is also affected by development policy and multiple climatic and non-climatic stresses (Campbell, Barker and McGregor, 2010). In a poll conducted at the Caribbean Regional Dialogue, 87 percent of participants agreed with the statement that "certain farming communities within the country that I live/operate are more vulnerable to drought compared to others" (Regional Dialogue, 2022).

It is important to note that though farmers are vulnerable, they are not passive in the face of adversity. They try to adapt and cope with changing conditions, experimenting and improvising with particular techniques as well as utilizing traditional knowledge (Barker, 2012). For example, while the Pacific Islands are often described as highly vulnerable to climate change and lacking adaptation options, such descriptions disregard how Pacific islanders are leading climate action and combining their systems of knowledge with western science to implement locally relevant climate solutions (McLeod *et al.*, 2019).

While some farmers may be impacted by all or certain critical factors, they should not be considered a homogenous group. Different farmers and their households will be affected differently by different sets of factors, depending on the intersectional characteristics of their everyday lives within the context where they live. Factors such as gender, age, physical ability, social class, livelihood group, levels of wealth/income/asset ownership, geographical location, ethnicity, and language group will all affect the extent to which the factors elaborated below influence levels of smallholder vulnerability and capacity to adapt to increasing levels of drought risk.

When considering the vulnerability of different farmers, agricultural communities, and producer groups, it is important to bear in mind that drought risks are multidimensional in nature. All programmes to address these risks must therefore take multidimensionality into account and ensure that interventions consider the variety of ways in which particular types of drought shock will affect different individuals and social groups differently.

5.2. Poverty and inequality

Although the experience of the poorest in society is unique to their context, poverty in general has a major influence on levels of vulnerability to climate change. Marginalized groups and people living in poverty are more severely impacted by climate shocks and stresses owing to their experience of social exclusion and the inequitable distribution of power and resources (Addison *et al.*, 2022). These factors result in such groups having lower levels of asset ownership; less access to resources and public services; less support from government, civil society organizations and the private sector; and less access to information, training, and decision-making processes, compared to other members of society (Addison *et al.*, 2022).

Across SIDS, the majority of farming is small scale (FAO, 2014). In Grenada, for example, over 80 percent of farmers in the fruits, vegetables, and roots and tubers subsectors are considered small-scale, that is to say, farming on less than half an acre or 0.2 hectares (World Bank *et al.*, 2015). In Papua New Guinea, 85 percent of the population are rural-based subsistence farmers engaged in the cultivation of crops or the keeping of livestock (Regional Dialogue, 2022).

Smallholder and subsistence farmers throughout SIDS rely on low income and have little to no cash reserves. Smallholders also have difficulty accessing loans (Ramona, O'Connor and Cox, 2020). This limited financial capital inhibits farmers from investing in certain adaptation strategies and technologies and limits their ability to absorb climate change-related shocks (Taylor, McGregor and Dawson, 2016). Often, farmers might be fully aware of what will help their crops and increase their resilience to drought conditions (such as thicker mulch or capital-intensive measures like drip irrigation), but they lack the capital to adopt these strategies.

As well as owning few assets (e.g. land, physical plant) and lacking financial savings, smallholder farmers also have limited access to services, information, and technology (Ramona, O'Connor and Cox, 2020). Numerous studies have shown that the amount and diversity of assets held by a household or community determine the levels of vulnerability to climate change and to drought (e.g. Moser and Ekstrom, 2010). Research from across the Global South has shown that households and communities that lack assets or access to them often find they cannot raise the resources needed to cope with a shock, such as a drought. This can lead drought-affected households to engage in negative coping strategies to survive, such as selling the few assets they do own, eroding their savings to cover essential costs, taking out loans at prohibitive rates of interest, removing children from school, distress migration, and placing members of the family or community into modern slavery (Addison *et al.*, 2022).

Such strategies mean that – in their efforts to cope with a short-term shock – poorer members of society may undermine their long-term resilience to future shocks. Efforts to address drought risks in smallholder farming communities must therefore not only aim to improve the drought resilience of agricultural production but also include interventions to increase the resilience of households to cope with shocks and bounce back.

It is also important to recognize that poverty and a lack of financial capital are linked to social inequalities, which are rooted in relations of power. When droughts occur, farmers who are more economically endowed may be able to take advantage of the shortfall of supply during a drought and end up better off than poorer farmers in the same community (Campbell, Barker and McGregor, 2010). They may also be able to adopt complex and costly adaptation methods, such as new irrigation techniques, that make them more resilient to droughts than their poorer neighbors (Lenderking *et al.*, 2020), and they are likely to more easily access "matching grants" and loans that can help them cope with or adapt to drought-related adversities.

5.3. Education, training and access to information

A majority of farmers in the Caribbean have no formal education in agriculture. For instance, one survey conducted in Trinidad and Jamaica found that 92 percent of farmers lacked formal education (Rhiney, Etzinger and Farrell, 2016). This lack of formal education or training means that farmers may not know which agricultural practices they should use to address the challenges they face and can even result in farmers employing practices that increase their vulnerability to drought.

The situation is similar in other regions. For example, the Australian Pacific Climate Partnership (APCP) and the Pacific Horticulture and Agricultural Market Access Plus Program (PHAMA plus) undertook a participatory process in which farmers in all four root-crop growing regions of Fiji completed a self-assessment of their level of knowledge on climate change. The vast majority of farmers rated their level of knowledge as "little" or "some" (APCP and PHAMA plus 2020). In Papua New Guinea, one respondent stated that a "general lack of knowledge of the impacts of climate change locally and globally and a lack of knowing what the future holds for them" acts as a barrier for smallholder farmers in building their resilience and adapting to climate change (Regional Dialogue, 2022).

The lack of formal education in agriculture among farmers is not relieved by the provision of effective, drought-risk informed agricultural extension services, whether by government authorities or private service providers. Of particular concern are:

- The poor quality and reach of government extension services to smallholders, meaning that the most vulnerable farmers do not have access to advice and support – especially in marginal areas; and
- The lack of up-to-date understanding among extension services of the climate and drought risks that affect farmers or of the kinds of agricultural practices that farmers should use to address those risks.

This issue is further exacerbated by the fact that agricultural extension services and other government services display a limited level of skilled knowledge around drought, climate change, sustainable agriculture, and adaptation measures (Regional Dialogue, 2022). Many of these issues are influenced more by a lack of capacity and funding within these government sectors than by a lack of interest or attention.

These concerns suggest that governments and other stakeholders could contribute significantly to farmers' resilience by improving their access to good quality information, advice, and technical support on drought-resilient agricultural practices.

While the effects of climate change are becoming apparent in most SIDS, the review of the literature and consultation process indicated that the majority of smallholder farmers in the Caribbean and Pacific do not have adequate knowledge or awareness of climate change, its effects on rainfall patterns and the risks it poses to agricultural production. The literature and consultation process also revealed that many farmers, in fact, continue to plant according to their experience of historical precipitation patterns, and do not consider the fact that rainfall patterns have changed and become more variable.

However, where farmers are aware of climate change and its impacts, they often lack access to information and training on the adaptation methods best suited to minimize the impact of drought and are therefore unable to do much with the climate information they do have.

It is important to note that farmers have a plethora of traditional knowledge that is context-specific, innovative, and effective in the face of drought. For example, traditional farming systems are used throughout the Pacific islands (e.g. agroforestry, multi-crop garden systems, mulching, organic compost) that have provided resilience against external shocks and helped to maintain food security (McGregor *et al.*, 2008; Taylor, McGregor and Dawson, 2016; Regional Dialogue, 2022).

While these traditional farming methods have their limitations in the face of changing precipitation patterns due to climate change (e.g. unprecedented length and severity of the dry season), it is still imperative that any intervention strategy integrates and acknowledges these practices.

5.4. Reliance on rainfed agriculture and water availability

The majority of farmers in the Caribbean and Pacific Ocean SIDS still depend on precipitation to irrigate their crops. In Jamaica, as many as 80 percent of farmers practice rainfed agriculture (Buckland and Campbell, 2021). A survey in Trinidad and Jamaica found that the majority of cocoa farmers had no form of supplementary irrigation on their farms (Rhiney, Eitzinger and Farrell, 2016). The same is true for the Pacific (Regional Dialogue, 2022).

This reliance on rainfall compounds the exposure-sensitivity of farmers in SIDS to climatic extremes (Buckland and Campbell, 2021). As rainfall in SIDS becomes more variable in distribution – both temporally and geographically – and as SIDS become more exposed to drought events, rainfed agriculture is becoming increasingly susceptible to water stress.

Reliance on rainfall for agriculture can be mitigated easily through the use of irrigation technologies. Most subsistence and smallholder farmers in the Caribbean and Pacific, however, lack access to either irrigation technology or water services (e.g. water tanks), largely due to a lack of financial resources to purchase the equipment required. In the Pacific, farmers lack access to even the most basic types of irrigation (Regional Dialogue, 2022). Furthermore, care must be taken when implementing irrigation in drought-prone regions, as high temperatures and dry conditions expedite evapotraspiration, leading to increased soil salinity.

In addition to this, the majority of participants in the Caribbean Regional Dialogue stated limited water resources as a major factor making SIDS particularly vulnerable to drought.

5.5. Compounding risks and impacts

Climate change risks are complex, and drought does not happen in a vacuum. As atmospheric temperatures increase, the impacts of climate change-related shocks and stresses are escalating with such intensity and frequency that they are now occurring increasingly consecutively. This has a compounding effect on populations and ecosystems and leaves residual risks of future losses and damages in their wake (Mechler *et al.*, 2020; IPCC, 2022; Addison *et al.*, 2022).

Farmers throughout the Caribbean and Pacific not only face more frequent and intense droughts due to climate change but are also experiencing the negative impacts of other climate change-related shocks and stresses. These include a greater incidence of extreme weather events (e.g. hurricanes), flooding due to changing precipitation patterns, increases in temperature, saline intrusion, sea-level rise, and increasing infestation of insects. Consultation in Cabo Verde revealed saline intrusion as a major issue facing farmers in an already water-stressed region.

As seen in Jamaica, the tendency towards longer and deeper drought periods since the 1990s has been compounded by increasing temperatures and more incidents of extreme weather events. In fact, droughts are presumed by most farmers to be less disastrous in terms of crop loss than hurricanes (Campbell, Barker and McGregor, 2010).

The prevalence of other climate change impacts and the related risks that farmers face mean that although measures can be undertaken by farmers to mitigate the impact of drought, such as setting up rainwater harvesting and irrigation systems, these measures can be physically wiped out by a hurricane. Farmers are then using their limited savings and assets to recuperate from the losses and damage incurred by the hurricane and may not be able to reinvest in drought adaptation measures. In Grenada, for example, the nutmeg sector has still not recovered from hurricanes that hit the island in 2004 and 2005.

These findings show that programmes to address drought risks in agriculture should not consider drought in isolation from other types of risk. Drought risks to smallholder farmers must be considered in relation to how they interact with other types of climate hazards, as well as with socioeconomic and ecological processes that are dynamic and evolve over time.

Programmes should be designed in a robust manner to address two sets of risks:

1. existing vulnerabilities to drought, based on an understanding of past drought incidence; and
2. future climate change-related shocks that may be more frequent, intense, and compounded, based on the best available climate projections.

Ideally, these risks should be considered in relation to models of socio-economic and agricultural vulnerabilities to different climate futures for different agro ecological zones and geographical locations over different time horizons.

5.6. Land tenure and land rights

Land tenure and land rights are major issues in determining the levels of drought vulnerability and adaptive capacity of smallholder and subsistence farmers in SIDS. These issues are closely related to those of poverty and inequality and should be considered important factors in the design of effective programmes to tackle drought risk in agricultural systems in small island nations.

5.6.1. The Caribbean

Issues related to land tenure exist across the Caribbean. Countries, such as Jamaica, St Lucia, Trinidad and Tobago, Grenada, and Dominica face issues related to the unequal distribution of land, absentee owners, landlessness or squatting, insecure tenure, predominantly short-term leases and/or restrictive leases. These issues and how they influence the vulnerability and adaptive capacity of smallholder farmers arose in the majority of the regional dialogue conducted within the framework of this analysis. Agriculture in Grenada, for example, is carried out mainly on small-scale, family-run farms, many of which sit on untitled, informally occupied land (World Bank *et al.*, 2015).

In Jamaica, both private and state-owned land exist. Jamaica, however, suffers from an unequal distribution of agricultural land, with high-quality arable land concentrated among a small number of large farms and only 22 percent of the land being state-owned (USAID, n.d.). In the 1970s, fewer than 1 percent of farms occupied approximately 57 percent of cultivable acreage, while 81 percent of farms (under 2.5 hectares each) occupied approximately 16 percent of the land (USAID, n.d.). These privately owned family farms are a form of freehold tenure, where rights are shared by an entire kinship group and are passed down on the basis of inheritance. They can be retained by absentee owners who perennially reserve the right to return and claim their share of the plot.

In Jamaica, both private and state land can be leased for agricultural purposes, with a maximum lease period of 49 years for state land (USAID, n.d.). However, Jamaica's rural population suffers from insecure tenure, with few rural landholders holding documentation of their rights to the land. Although 49-year leases are available, few leases are set up for this amount of time, with some as low as two years (Regional Dialogue, 2022).

Where formal documentation is available, it can come with very restrictive lease conditions, for example: within three months of signing, improvements must be seen in the field or farmers will be kicked off the land; or, whatever is produced must be sold at a price that is determined by the contract holder; or, no buildings may be erected on the land; or, no crops other than the ones specified are to be planted (Regional Dialogue, 2022).

Squatting (or captured land) is another form of land tenure in Jamaica that has become institutionalized. Squatters may acquire rights of possession over private land after 12 years and rights over state land after 60 years, although the rate of formalization of squatter rights is unknown. Over the last few decades, the government in Jamaica has tried to enact land titling; however, it has faced pushback from landholders because of the fees required (USAID, n.d.).

The issue of restrictive lease conditions is also seen in Trinidad and Tobago where, after sugar production was discontinued, the land became state-owned. This land was then leased, but the lease came with a number of restrictions – around irrigation, the building of houses, and the types of crops that could be grown (e.g. only short-rotation crops).

Several reasons revealed why land tenure is critically important for drought resilience:

1. insecurity of tenure tends to discourage long-term investment (also see Potter *et al.*, 2004). This means many farmers might not want to invest in certain adaptation measures, because of high set-up costs (e.g. for drip irrigation) or the long-term investment required to realize a return (e.g. conservation agriculture).
2. without proof of land tenure, farmers may not be able to access loans, subsidies, grants, and other forms of government support. In Trinidad and Tobago, for example, to access farming schemes you often need a farmer's badge, which you only get when you have tenure.
3. if farmers lack tenure, they might not be registered with the appropriate government bodies, potentially impacting the effectiveness of the work of government agencies, including agricultural extension services, relief efforts, and meteorological services such as early warning systems.

5.6.2. The Pacific

The Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Papua New Guinea all have enduring systems of customary land tenure (Boydell, 2010) that follow traditional or tribal governance structures (McLeod *et al.*, 2019).

While these systems of ownership, land use, and tenure vary greatly across the Pacific region and between islands and cultures, generally land is mostly vested in groups based on common descent, place of residence, and participation in social and economic activities (Taylor, McGregor and Dawson, 2016). The elders of the community typically manage the cultivation and traditional bush-fallow practices. These elders, who are responsible for relatively large tracts of land, distribute the land to community members according to their needs and status. In this system, although land meets the subsistence requirements of the individual and the community, it also has a symbolic value through identification with a family, clan, or lineage (Taylor, McGregor and Dawson, 2016).

These systems of customary land tenure that follow traditional or tribal governance systems can conflict with western judicial laws and processes. This can deter large international organizations from providing climate financing, as they require stringent contract-based agreements such as land transfers and easements for protected areas (McLeod *et al.*, 2019).

Although the pro-privatization literature correctly recognizes problems with the quality of property rights in many developing countries, its claim that privatization and individualization of title are the best or only practical alternatives to these customary rights is hardly proven (Boydell, 2010). Traditional tenure and knowledge systems can, in some cases, inform sustainable adaptation strategies (McLeod *et al.*, 2019).

Registered freehold is not seen as the preferred or ultimate type of tenure but is rather one of several appropriate and legitimate forms of tenure available (customary, leasehold, group tenure, and others). The most appropriate form/s depends on context. Tenure types that best suit both the social, cultural, and economic needs of local communities and the needs of responsible land administration authorities at a particular time are advocated.

For the Pacific, then, the design of adaptation policies must consider these traditional tenure and knowledge systems (McLeod *et al.*, 2019), while the encouragement of leasehold solutions should be sensitive to customary ownership and attempt to strike a balance between communal and individualized property rights that is agreeable to citizens and that promotes principles of legitimacy, accountability, participation and fairness (Boydell, 2010).

5.7. Demographic and intersectional factors

Climate change interacts with diverse social, economic, and political processes that affect how climate hazards impact different people, households, and communities (Addison *et al.*, 2022; Carthy and Addison, 2022). More specifically, social, cultural, physical, and political factors shape people's lives and the environment in which they live (PreventionWeb, 2020).

This means that some groups are more vulnerable to climate change impacts, including drought, than others. The poorest and most marginalized people are affected first and worst by the impacts of climate change. These include women and children, people living with disabilities, elderly people, LGBTQI+ people, ethnic and linguistic minorities, and Indigenous Peoples (Addison *et al.*, 2022).

Age, gender, poverty, and education are factors that contribute to drought vulnerability in Caribbean and Pacific SIDS. However, this list should not be seen as exhaustive as there may be other factors that contribute to drought vulnerability, such as indigenous identity.

5.7.1. Age

Across the Caribbean, the population actively engaged in farming is aging rapidly. In Grenada, for example, young people are choosing not to become farmers (World Bank *et al.*, 2015). Older people have limited mobility, they are more vulnerable to heat stress, and they tend to be less "tech-savvy", often lacking access to the internet.

Older farmers may be less adaptable than younger farmers, due to their deep experience of practices that are no longer appropriate to the evolving climatic conditions and their resistance to change. They may be disorientated by unprecedented changes in climatic patterns that leave them feeling unable to adopt the new farming practices that are required to adapt to new conditions.

5.7.2. Gender

Women-led households are some of the poorest in SIDS. For example, in Jamaica, few women own land legally – even though they can legally own land, they are equally entitled to inherit family land, they can put land solely in their name, and they can be documented as joint or individual landowners (USAID, n.d.).

In Grenada, many households led by women are single-headed households. Although many projects and programmes over the years have been designed to target women, many policies are not gender-sensitive (Regional Dialogue, 2022).

In the Pacific, gender norms mean that women's roles in agriculture are largely invisible (APCP and PHAMA, 2020). Only male heads of household are counted as farmers in official data and come forward for training or other agricultural development opportunities. In addition, rural women in the Pacific face great development challenges, often lacking access to basic services and infrastructure such as water and sanitation, electricity, health, and education, while suffering a higher risk of domestic violence (Pacific Farmer Organizations, 2019).

In many rural areas of Capo Verde, the role of women can be different from island to island (Regional Dialogue, 2022). On some islands, women have no role in on-farm decision-making processes, on other islands, women are more empowered. In addition to this, in certain locations, men are in control of the non-truck related distribution of water, which makes it difficult for women to get access to water in certain rural areas.

5.7.3. Poverty and education

An analysis of climate impacts on food security at the household level in Trinidad and Tobago argues that one of the key factors influencing food security in the face of climate change is the household's socio-demographic profile. In particular, households in which the head does not have a primary school education are more vulnerable to food insecurity (Shah and Dulal, 2015).

Programmes to address drought risks in SIDS must ensure that the multidimensional and intersectional vulnerabilities and adaptive capacities of particular people, households, communities, and social groups are considered and that interventions are designed in ways that target the specific resilience deficits of the most vulnerable people.

5.8. Policy and governance

The impacts that drought has on agricultural systems, farmers, their households and the communities and landscapes that they live in are mediated to a significant degree by the policies and governance systems that prevail in any given small island state. Governance has a major influence on the type and extent of impact that natural disasters have in SIDS.

Concerns associated with policy and governance that were raised in the consultation process across Caribbean SIDS include the following:

- national agricultural policies that do not integrate drought or climate change management adequately, and that do not provide guidance on how to manage climate and drought risks effectively in the agricultural sector;
- policy decisions that are made without meaningful consultation with farmers on their needs and priorities – resulting in top-down policy-making that reflects the interests and concerns of national policy-makers and often imposes on farmers inappropriate technical solutions that do not support drought resilience;
- lack of coordination between levels of government;
- lack of adequate or appropriate training of agricultural extension workers to ensure that they understand how to address drought risks and can advise farmers appropriately; along with a lack of resources invested in extension services;
- lack of investment in the delivery of appropriate agricultural inputs to smallholder farmers to enable them to adopt new practices or crops; and
- failure to adopt policies to deliver social protection to farmers in the event of drought or other climatic shocks, or to help farmers increase their resilience by adopting drought- and climate-resilient livelihoods options.

These findings suggest that any programme designed to address drought risks affecting agriculture in SIDS must not simply deliver technical interventions targeting the farm level. The overarching policy environment and systems of governance that shape how and what decisions are made on agricultural policy must also be addressed. Programmes should be based on a robust analysis of the political economy of decision-making in the agriculture sector. Obstacles to effective policy-making and programme delivery must be identified and solutions developed, in collaboration with farmers, their representatives and business partners, and local authorities.

Key insights

The vulnerability to drought of smallholder farmers is not solely due to increasing exposure to more intense and frequent meteorological drought events. Vulnerability is the result of structural factors that render communities less capable to cope with and adapt to such events.

Marginalized groups and people living in poverty are more severely impacted by climate shocks, due to social exclusion and inequitable distribution of power and resources. They have fewer assets and savings, less support from civil society or the private sector, and less access to loans, government services, information or training than other members of society.

Most smallholder farmers in SIDS have no formal education in agriculture, although many possess traditional knowledge that is context-specific, innovative and effective in the face of drought (e.g. agroforestry, multi-crop garden systems, mulching, and organic compost).

Government extension services are considered difficult for smallholders to access, and they lack an up-to-date understanding of drought risks or the agricultural practices needed to address them.

Most farmers in Pacific and Caribbean SIDS (80 percent in Jamaica) still practice rainfed agriculture. As rainfall becomes more variable and droughts more frequent, rainfed agriculture is increasingly susceptible to water stress. This can be mitigated through irrigation, but for most smallholders these technologies are unaffordable.

As temperatures rise, climate shocks are occurring increasingly consecutively, with a compounding effect on populations and ecosystems. Programmes should not address drought in isolation but tackle two broad sets of risks: 1) existing vulnerabilities to drought, based on past drought incidence, and 2) future climate shocks that may be more frequent, intense and compounded, based on climate projections.

Land tenure is a major issue in determining drought vulnerability and adaptive capacity. Insecurity of tenure discourages farmers from investing in adaptation measures. And without proof of land tenure, farmers may not be able to access loans, subsidies, grants and other forms of government support including extension services.

Demographic factors such as age, gender, poverty and education also affect vulnerability to climate impacts. Older people are more sensitive to heat stress and tend to be less “tech-savvy” or adaptable than younger farmers. Women-led households are some of the poorest in SIDS and often struggle to access loans, basic services or training opportunities. Research shows that households whose heads lack a primary school education are more vulnerable to food insecurity.

Policy and governance have a major influence on the impacts drought has on agricultural communities. Concerns raised across Caribbean and Pacific SIDS include lack of policy guidance on managing climate risks, top-down policy-making that fails to consult with farmers or local authorities, resistance to innovation due to vested interests or ignorance, lack of drought-relevant extension services, lack of investment in agricultural inputs for smallholders, and failure to deliver social protection or livelihoods options to farmers.

6 Adaptation options

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6.1. Water-based interventions

6.1.1. Rainwater harvesting

Description and benefits

Rainwater harvesting (RWH) is an ancient, low-risk, and proven technology that involves the collection and storage of rainwater (Waite, 2012). Techniques include the use of farm ponds and rainwater catchments. Rainwater harvesting can be used for both domestic and agricultural purposes during periods of drought.

Throughout the consultation process, RWH was brought up as an adaptation strategy that is effective, affordable, and easily understood by farmers. It is being undertaken in countries such as Jamaica, St Vincent and the Grenadines, Grenada, Trinidad and Tobago, and Barbados (Regional Dialogue, 2022). It has the following benefits (Waite, 2012):

- it is easily deployable, given the fact that materials are found locally and there is a basic familiarity with the technology.
- it empowers households and communities through decentralized implementation.
- it can be encouraged through mandates and tax benefits.
- it brings people closer to the water *Source*, thereby limiting wastage and encouraging water savings.

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In recent decades, the governments of Cambodia, Haiti, China, Thailand, India, and Brazil have all deployed RWH systems for households and industries to ease rural droughts and urban water shortages (Green and Nibbs, 2018). RWH has been implemented and set up in Jamaica under the Government of Jamaica's 2011 Adaptation Fund programme (Adaptation Fund, 2011). Across various rural farming communities in Trinidad and Tobago, pilot projects for RWH systems have been implemented in the last eight years (Regional Dialogue, 2022).

RWH has also been supported in an Adaptation Fund project in the Maldives. In Kiribati, an island facing insufficient freshwater supplies, along with saline intrusion and freshwater contamination, the village councils from five communities – Bonnano, Mauanako, Kaue, St Patrick, and Te Roti – embarked on adaptation projects to rehabilitate their community rainwater catchment systems (UNDP, 2019b).

In St Kitts and Nevis, the Nevis Physical Planning Department passed and implemented the Nevis Physical Planning and Development Control Regulations 2021 which requires a building, intended for human habitation, to be provided with a cistern or rainwater catchment and a storage facility having a minimum capacity of 1000 gallons per 100 ft2 of roof catchment area where there is no public supply and a minimum of 500 gallons per 100 ft.2 where there is a public supply.

Challenges, obstacles, and considerations

Although households might already be adopting RWH strategies for multiple uses, there is still a large scope to make existing RWH methods more efficient, safe, and effective. Having said that, very few Caribbean countries have taken action to implement RWH on any significant scale. RWH, for example, is underdeveloped in national policy in Jamaica (Waite, 2012).

While RWH is relatively cheap to implement, there are initial costs such as those for plastic liners. Farmers might therefore require assistance with start-up costs.

SIDS are faced with limited water supply – whether for domestic, commercial, or agricultural uses. For this reason, RWH should be considered not just for irrigation, but also for domestic and commercial use. Building codes, for example, should be revised to increase opportunities for rainwater catchment and storage.

The long-term implications of climate change must be taken into consideration. SIDS' dependency on rainfall increases the vulnerability of small islands to future changes in the volume and distribution of rainfall. Low rainfall can lead to a reduction in the amount of water that can be harvested, a fall in river flows, and a slower recharge of freshwater lenses, which can result in prolonged droughts. Since most of the islands are dependent on surface water catchments for their water supply, it is likely that demand cannot be met during periods of low rainfall.

6.1.2. Drip irrigation

Description and benefits

Drip or trickle irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The purpose is to place water directly into the root zone and minimize the negative impacts of evaporation, such as the risk of soil salinization and decreased crop yield due to low available water. Plant roots can easily extract water from the subsurface, which remains constantly wet, while the soil moisture content at the top can remain dry (decreasing evaporation losses). Though targeting crop roots minimizes the risk of salinization associated with irrigation, further measures are often required to protect dry soils when implementing drip irrigation. Soil moisture monitoring and water quality monitoring can ensure appropriate levels of water without high levels of salts or contaminants are being applied through irrigation.

Drip irrigation was promoted and invested in as part of Jamaica's Adaptation Fund programme. Subsurface drip irrigation (SDI) technology was also used in a successful water-reuse pilot project in Cape Verde.

Challenges, obstacles, and considerations

- **Costs:** the initial cost of drip irrigation is relatively high and may not be an affordable option for most farmers in the Caribbean (Campbell, Barker and McGregor, 2010), without subsidies or local modifications. The promotion of schemes equipped with drip irrigation may even exacerbate existing social inequalities between different groups of farmers – with small-scale farmers being the least likely to benefit (Rhiney, Eitzinger and Farrell, 2016). The same argument holds for other adaptation strategies that tend to be capital-intensive, such as greenhouse cultivation. Subsidies or funding programmes that support the set-up costs of these kinds of technologies should be accessible and prioritize smallholder farmers. In addition, there may be scope to make drip irrigation more affordable to smallholders, by using locally *Source*d materials or less technically complex methods that achieve the same outcome.
- **Technical skills:** in addition to high start-up costs, drip irrigation systems need to be installed properly, inspected regularly, and maintained, with certain parts such as pipes likely needing replacement at some point. For many farmers, this process can be costly and technically complex, requiring proper training, technical support, access to parts, and the capital to purchase new parts. The difficulty in obtaining imported irrigation equipment is a major limiting factor for small producers (World Bank *et al.*, 2015). In the Pacific, logistical, technological, and weather-related obstacles are common in remote islands, causing delays to material-dependent projects (McLeod *et al.*, 2019).
- **Resistance to new technology:** although drip irrigation systems are highly effective, imposing this new technology on farmers without adequate information can be met with resistance. Farmers need to receive as much information as possible to understand how the technology works and what it can and cannot do. In particular, farmers need to know that drip irrigation is more effective than hand watering, why it is more effective (e.g. showing how it works on a technical level through visual representations and demonstrations), and that the system can be used in a variety of ways, especially on seedlings. Additionally, further training for farmers to maximize the impact of irrigation and minimize risks of salinity could protect drought-prone soils. Techniques such as mulching aid in preventing evapotranspiration, reducing the amount of water needed, and with training in soil moisture monitoring, farmers can appropriately manage water resources.

6.1.3. Greywater use

Description and benefits

Greywater is domestic wastewater generated in households (apart from toilet waste). It requires less treatment than "black water" (wastewater from toilets) because it has less microbial presence (Gorgich *et al.*, 2020). In Jamaica, some farmers have undertaken greywater purification in which water goes into a pond and is then used for irrigation (Regional Dialogue 2022). In one study, algal wastewater treatment of grey water was shown to be a low-cost, energy-efficient way to reclaim water of sufficient quality for use in agriculture (Delanka-Pedige *et al.*, 2020).

Challenges, obstacles, and considerations

- perceptions. Public perceptions about the safety of reclaimed water were a major impediment to water recycling until recent years. However, several pioneers of water recycling have demonstrated that these attitudes are ephemeral and can be changed with proper outreach, demonstration, and education (Sheick *et al.*, 2018).

6.2. Agricultural interventions

6.2.1. Drought-resistant crop varieties

Description and benefits

Due to the difference in the capacity of crop varieties to withstand longer-term changes in climate, the impacts of stressors such as drought on crops will not be uniform. Perennial crops (e.g. cocoa and coffee) take a longer time to mature, leaving them more exposed to climate- induced shocks and stresses. Tree crops, on the other hand, have a built-in resilience to climate fluctuations due to their established root systems, energy stores, and more hardy woody tissue (Rhiney, Eitzinger and Farrell, 2016).

Certain crops are naturally more drought-resistant and tolerant to dry spells (e.g. scallion, beetroot, sweet potato, cassava). In the Pacific, farmers have historically adapted their food production systems to extremes of climate variability, by planting staple food crops such as banana, sweet potato, and aroids that are relatively resilient to changes in climatic conditions (Taylor, McGregor and Dawson, 2016). This process is increasing in countries such as Papua New Guinea with recommendations from organizations like the National Agriculture Research Institute, which encourages the planting of more drought-tolerant varieties of sweet potato, cassava and rice (Regional Dialogue, 2022).

In some cases, crops are engineered to be more drought-resistant. For example, research centers in Cuba have developed varieties of crops that are more resistant to extreme weather, including tomato, onion, garlic, chili, banana, sweet potato, and taro (UNDP, 2019b).

Challenges, obstacles, and considerations

Many farmers choose which crops to grow based on market demand or tradition. Asking farmers to shift towards more drought-tolerant varieties must take this into consideration. For example, on Bellona Island in the Solomon Islands, the cultivation of yam gardens is closely linked to identity, status, and prestige (Reenberg *et al.*, 2008).

In some cases, farmers will require technical and financial assistance to diversify into new drought-resistant crop varieties in response to erratic crop yields and weather patterns (Rhiney, Eitzinger and Farrell, 2016). Access to new drought-resistant seeds, when created, might be limited for many farmers. Farmers may also be unaware of what types are best suited to their soil and climate conditions. In this case, extension support can greatly help with selecting the right types of crops and offer guidance on nurturing. The selection of seeds must be based on farmer needs, i.e. what farmers are able to grow or what seeds work for local market demand.

It is important to communicate to farmers the scientific findings around the impacts of drought on crops. For example, cassava is a crop that will yield well under drought situations, but studies have shown that the cyanide concentration found in tubers and leaves increases under water stress (Taylor, McGregor and Dawson, 2016). This high cyanogen concentration can be reduced to safe levels through processing operations such as fermentation, boiling/cooking, and drying (Bolarinwa *et al.*, 2016).

Drought can be accompanied by high temperatures. Plants that can genetically handle drought may not be able to handle a combination of drought and heat stress, as these are genetically distinct attributes (Taylor, McGregor and Dawson, 2016). For example, the cocoa plant has a wide temperature range. So, while a warmer climate does not affect it, the projected reductions in annual precipitation and inter-seasonal variation in rainfall distribution will lower its yield (Rhiney, Eitzinger and Farrell, 2016).

Finally, it is important that farmers are well-informed about drought-vulnerable crop varieties and have access to adequate drought-warning systems so they can make planting decisions early enough.

6.2.2. Mixed cropping and intercropping

Description and benefits

Mixed cropping involves the growing of two or more crop cultivars in the same field during one growing season in close proximity or, in the case of intercropping, simultaneously in particular patterns. Intercropping improves crop resilience. It can promote climate resilience through higher plant re*Source* efficiency (space, nutrients, and water) and the natural suppression of insect pests, pathogens, and weeds.

One study found that mixing cassava with a diverse group of intercrops benefited five key ecosystem services, including pest suppression, disease control, soil and water services, and land productivity, with the effects being detected across very different locations and farming systems (Romero, 2017).

Mixed cropping and intercropping can also act as a safety net, ensuring better yields in case of poor returns from the main culture, especially when some crop types are more heat- and drought-resistant than others. A study in Papua New Guinea from 2010-12 found that intercropping coffee with food crops benefitted women by enhancing their food security and cash incomes – this trend holds more generally for the Pacific region (Georgeou *et al.*, 2022). In countries such as Uganda, it is found that when farmers experience severe environmental conditions, they increase the number of crop species to reduce the risk of crop loss and maintain the livelihoods of farming families (Antonelli, Coromaldi and Pallante, 2022).

Policies aimed at providing farmers with better access to a diversity of crops and varieties can strengthen their capacity to adapt to climate change.

Challenges, obstacles, and considerations

Despite its benefits, intercropping has perceived risks and challenges, including decreased crop yield, increased management complexity, and a steep learning curve for successful management (Huss, Holmes and Blubaugh, 2022). This means that, while in some cases mixed cropping is a traditional practice, where monocropping is the dominant form of agriculture or where farmers are shifting away from monocropping practices, farmers will need training, education, technical assistance, and guidance.

6.2.3. Mulching

Description and benefits

Mulching is a process by which a layer of material is applied to the surface of the soil to conserve soil moisture. This can be done using a variety of readily available organic matter such as guinea grass, old hay, fresh-cut forage, chipped brush, wood shavings, tree leaves, etc. This protective layer of mulch shield soil from heat and light, preventing evaporation of available water in the soil. Mulching also improves soil fertility, health, and moisture retention through increasing soil organic matter (Ngosong *et al.*, 2019). Soil organic matter has been shown to have a positive relationship with soil moisture retention, boosting plant resilience to drought (Lal, 2020). Mulching as a technique is recommended in climate-smart agriculture and conservation agriculture (FAO, 2021).

Mulching is a process practiced throughout the Caribbean and Pacific to regulate soil moisture loss during dry periods (Rhiney, Eitzinger and Farrell, 2016; Regional Dialogue, 2022). In Jamaica, farmers' knowledge and skills underpin livelihood strategies, even though their financial resources are extremely limited (Barker, 2012). As such, a key aspect of farming systems in southern St Elizabeth Parish is the use of mulching techniques as an adaptation to dry conditions (Barker, 2012).

Mulching is central to farmers' traditional knowledge, skills, and re*Source*fulness in coping with hazard vulnerability (Barker, 2012). Some of the literature recommends "thicker mulching" during droughts, which involves applying a second layer of mulch.

Challenges, obstacles, and considerations

Guinea grass, which is often used for mulching in the Caribbean, must be purchased and can be quite costly. Some farmers may struggle to buy guinea grass for mulching a single layer, let alone a second layer. For many farmers, purchasing water takes precedence. Mulching is also associated with harboring pests, which are attracted to the moisture at the base of the crop. This may inhibit growth or result in crop failure.

6.2.4. Improved livestock production

Description and benefits

Livestock can be very severely affected by drought and diminished access to drinking water. Drought is often paired with heat, threatening the health of livestock and further exacerbating their need for water.

Indigenous, locally adapted breeds can be more resilient to heat and water availability, while introduced breeds may be more vulnerable (Bell *et al.*, 2016). As such, the use of indigenous breeds and those bred to be more drought- and heat-tolerant is encouraged.

Livestock management is a key consideration for promoting resilience of drought-prone agricultural systems. Proper manure and livestock management can facilitate increase soil moisture and fertility (Qin *et al.*, 2019), while overgrazing of livestock, particularly in dry conditions, can lead to loss of plant life, decreased yield, and loss of soil fertility (Horn, Hart, and Paisley, 2016). Therefore, careful consideration of stocking rate, livestock feed sources, distribution of manure, and duration of grazing per location should be considered when raising livestock in drought-prone areas.

To keep livestock cool, proper housing is crucial. Housing with elevated floors, high roofs, and ventilator fans can create micro-climates that manage heat stress in animals.

Water harvesting systems can also be utilized to ensure livestock have access to drinking water during periods of drought (Regional Dialogue, 2022).

Challenges, obstacles, and considerations

Proper housing for livestock might be cost-intensive.

6.2.5. Organic farming

Description and benefits

Organic farming has been shown to make farms more resilient to climate impacts (Regional Dialogue, 2022). Organic production aims to foster healthy soils, which have good structure, allowing them to absorb and hold moisture, drain well, maintain adequate aeration, and foster deep, healthy crop root systems (OFRF, 2023). Such soils sustain crops through dry spells, require less irrigation water, and undergo less ponding, runoff, and erosion during heavy rains (OFRF, 2023; Regional Dialogues, 2022).

Organic farming aims to foster this healthy soil through practices such as crop rotations, intercropping, symbiotic associations, cover crops, organic fertilizers, and minimum tillage (FAO, 2023). Certification of organic cocoa field practices, for example, requires cocoa to be grown under the shade canopy of tall forest trees or food trees. This contributes to livelihood diversification by providing an additional *Source* of income to cocoa farmers.

Organic farming also requires the use of organic fertilizers. On Tarawa, located in the Marshall Islands, the "banana circle" initiative successfully composts existing organic material to increase soil fertility and grow crops – a low-maintenance, low-cost, and culturally acceptable system that provides families with saleable products (Georgeou *et al.*, 2022).

In the Dominican Republic and the eastern Caribbean, institutions and farmer groups are promoting fairly-traded and organic produce to take advantage of new opportunities in niche markets overseas, thereby sustaining agricultural exports and enhancing rural livelihoods (Barker, 2012).

Challenges, obstacles, and considerations

As with many other labor-intensive and transformational adaptation processes, farmers will require training, and technical and financial assistance to shift over to organic farming. Effective implementation of organic farming requires site-specific knowledge of crops most adapted to local conditions, and awareness of the impacts of organic fertilizers and amendments. Organic amendments, if applied improperly, can damage soil through overfertilization, lead to nutrient imbalance and compromise soil health.

Understanding farmers' concerns (e.g. those around pests and diseases) will be important to address. This engagement would also include support in engagements with certification boards and entry into value chains, which is often complex and expensive.

6.2.6. Agroforestry

Description and benefits

Agroforestry is a process by which trees are deliberately combined with agriculture on the same piece of land. This process can also be called edging or perimeter planting and is a soil moisture-loss strategy in which the cultivation of taller, more bushy plants around the perimeter of a farm plot interrupts the flow of wind over the plot and can shade certain crops.

Agroforestry systems buffer crops from large fluctuations in temperature, keeping crops closer to optimal growing conditions. Shade trees protect crops from lower precipitation and reduced soil water availability through evaporation and improve soil water infiltration. Such agroforestry systems also help protect crops from extreme storm events. Finally, the trees chosen also provide tree crops, which can be turned into another *Source* of income and food.

Challenges, obstacles, and considerations

Cultural perceptions around the value of cleared land may prove an obstacle to agroforestry. Consultations revealed that in countries such as Grenada, land clearing is an ingrained cultural practice. For example, if a piece of land is surrounded by woods or hedges, a farmer will cut down the trees and clear the land, because of the engrained belief that the vegetation on the land is not of value and that "clear land is good land" (Regional Dialogue, 2022). Furthermore, appropriate species must be selected for the local conditions. While some species may provide shade sooner than others, this is typically a long-term investment due to the time and labor required to establish mature trees.

6.2.7. Agroecology, conservation and regenerative agriculture, traditional farming practices

Description and benefits

Agroecology is when ecological processes are applied to agricultural production systems. Agroecological systems are highly diverse. From a biological perspective, agroecological systems optimize the diversity of species and genetic resources in different ways. For example, agroecological systems organize crops, shrubs, and trees of different heights and shapes at different levels or strata, increasing vertical diversity (FAO, 2018).

Conservation agriculture is used to combat declining soil health and encompasses the use of three key farming practices (Ramona, O'Connor and Cox, 2020):

1. minimal mechanical soil disturbance (zero tillage);
2. maintenance of carbon-rich organic matter covering the soil or mulch to feed the soil; and
3. rotations or sequences of crops including trees.

Regenerative agriculture also includes the use of practices designed to rebuild soil quality and organic matter but does so in a manner that explicitly aims to produce food and biomass whilst also building functional biodiversity, improving water retention, and sequestering soil carbon as a means of mitigating climate change. Regenerative farming is an ecosystem-based approach to agriculture that requires a shift in the way that farmers think about agriculture and their farm, by considering both as functional elements within the landscape and the surrounding ecosystem.

Practices such as edging, mulching, intercropping, and water recycling are included as approaches in agroecology, conservation agriculture, and regenerative agriculture. These practices can lead to a more resilient farm.

Traditional farming practices: A lot of the practices found in regenerative agriculture, agroecology, or climate-smart agriculture are utilized as part of the traditional farming practices undertaken by some farmers in SIDS, particularly those in the Pacific. Central to how farmers negotiate complex agricultural problems is the concept of local or indigenous knowledge (Campbell, Barker and McGregor, 2010). For example, in the Caribbean island of Saint Croix, agriculture both on the slopes of the mountains and on lower ground is dominated by mixed cropping on small land holdings (Campbell, Barker and McGregor, 2010). In the Pacific, farmers' traditional agriculture practices involve a number of measures that make their farms more resilient to drought (Tikai and Kama, 2004; Taylor, McGregor and Dawson, 2016; Regional Dialogue, 2022).

Traditional food production in the Pacific is based on tubers in garden plots, often using shifting cultivation and linked to agroforestry (Taylor, McGregor and Dawson, 2016; Georgeou *et al.*, 2022). These multi-crop garden systems are protected by trees, with palm leaves used to shade crops and seaweed utilized as compost (Taylor, McGregor and Dawson, 2016).

As stated in the document:

> *"It is clear that the Pacific traditional system of production can provide a significant level of resilience to climate variability. It would seem sensible therefore, when considering how to reduce vulnerability and enhance resilience, to consider this system closely and see how it can be further strengthened, how it can be used as the foundation on which to develop commercial production, and what are the key components of the system imparting resilience that should be promoted (Taylor, McGregor and Dawson, 2016, p209.)."*

Challenges, obstacles and considerations

- Long-term investment: this transformational process can take a long time to yield results (Regional Dialogue, 2022). Up to seven years may be required in some cases to realize the maximum benefits of conservation agriculture (Ramona, O'Connor and Cox, 2020). It is also quite labour-intensive to set up and certain interventions may require specific types of equipment (Ramona, O'Connor and Cox, 2020). Where land tenure is not secure or where savings and income are limited, farmers may be reluctant to invest labour, time, and money to implement long-term strategies and may instead favor shorter-term solutions.

- Complex and costly: while these approaches may offer higher levels of on-farm and household drought resilience, farmers may still prefer to use monocropping approaches, especially if they are in a state of financial insecurity. This is often because farmers already understand how to implement such systems, they are less complex to set up, and they provide a higher yield of starchy crops for consumption and sale in good seasons.
- On many Pacific islands, for example, there has been a move away from more resilient traditional practices and agro-ecosystems into cash cropping. The degree to which traditional farming systems are retained varies throughout the region (Taylor, McGregor and Dawson, 2016).
- Nevertheless, in periods of drought, farms that use agroecological systems are likely to enjoy better yields and returns. Understored crops will receive some protection from drying winds and excessive heat and, due to the complementary architecture of the plants, the total return to the farmer is likely to be higher in times of stress.
- Lack of awareness. Many farmers in the Pacific do not use these traditional methods to actively become more resilient to drought. In fact, much of what farmers ordinarily do they may do without being aware of its specific benefits. For example, farms may produce and use organic compost simply because access to fertilizers and pesticides is limited and expensive. Tillage may not be practiced on farms not because farmers are aware of its negative impacts on soil, but because they cannot afford to own or hire a plough and till. It is important, therefore, that farmers are made aware of why certain practices work well to build resilience against drought compared to others – this includes supporting them in any of their existing practices, which already improve their resilience.

6.2.8. Innovative technological solutions

Description and benefits

- Automated irrigation systems. These can include sprinklers controlled via mobile devices during wet and dry seasons (FAO, 2021). As droughts increase, improving water use efficiency in irrigated agriculture is crucial for sustainable agricultural production (Bwambale *et al.*, 2022). There is potential to improve water use efficiency through smart irrigation systems, especially with the advent of wireless communication technologies, monitoring systems, and advanced control strategies for optimal irrigation scheduling (FAO, 2021).
- Aquaponics. A food production system that couples aquaculture (raising aquatic animals such as fish, crayfish, snails, or prawns in tanks) with hydroponics (cultivating plants in water), whereby the nutrient-rich aquaculture water is fed to hydroponically grown plants, where nitrifying bacteria convert ammonia into nitrates. Plants that do well in aquaponic systems include lettuce, chives, basil, spinach, peppers, cucumbers, shallots, tomatoes, capsicum, red salad onions, and snow peas. Aquaponic systems do not typically discharge or exchange water under normal operation, but instead recirculate and reuse water very effectively. This makes aquaponics especially effective in locations with limited water availability (and limited availability of fertile land). Aquaponics was brought up in the consultation process as an agricultural practice being undertaken by younger (and often more educated) farmers (Regional Dialogue 2022).
- Stone drains. Stone drains manage the flow of water into the soil (allowing it to penetrate slower and deeper) while the rocks used for drainage absorb the heat from sunlight more than other materials like mulch.

Challenges, obstacles, and considerations

Fertigation systems can cause uneven nutrient distribution when the irrigation system is faulty. This leads to over-fertilization or leaching of nutrients when excess water is applied to crops.

Aquaponic systems are costly to set up and maintain and must be installed professionally and properly maintained. They consume a lot of electricity, although they can be set up to be energy-efficient. While careful design can minimize the risk, aquaponics systems can have multiple "single points of failure", where problems such as an electrical failure or a pipe blockage can lead to a complete loss of fish stock.

6.3. Livelihood diversification

Description and benefits

The diversification of a household's non-farm income sources is a well-known means for farmers to insure themselves against risk (Antonelli, Coromaldi and Pallante, 2022) and is a valuable adaptation method and strategy to manage erratic irregularities of rainfall and temperature patterns (Lenderking *et al.*, 2020) as well as fluctuations in the price of agricultural products (Antonelli, Coromaldi and Pallante, 2022). The ability of farmers to cope with or adapt to droughts is fundamentally determined by their livelihood assets.

Generally, the more stable and diverse the asset base, the better equipped farmers will be to respond to atypical climatic conditions (Campbell, Barker and McGregor, 2010). This also pertains to a variety of crops being planted. For example, beekeeping can be practiced on lands occupied by forests and perennial crops (World Bank *et al.*, 2015).

Challenges, obstacles, and considerations

Poorer farming households may lack access to human capital, education, labour, and social capital for successful diversification, meaning that more economically endowed farming households might be more capable of adopting diversification as an adaptation measure (Antonelli, Coromaldi and Pallante, 2022).

6.4. Risk assessment and communication

6.4.1. Climate risk assessments

Climate risk assessments (CRAs) can be an essential tool to help decision-makers increase their understanding of climate risks and assess uncertainty. CRAs can be national, top-down, data-driven, cross-sectoral assessments or they can be locally led, sectoral, participatory, process-driven assessments (Adaptation Research Alliance, 2021). CRAs identify the likelihood of future climate hazards and their potential impacts on different communities (C40 Communities, 2018).

CRAs can aid a country or community in understanding potential risks and risk scenarios (e.g. location, severity, frequency), the likelihood that different hazards will occur, and the impact they might have. Armed with this information, decision-makers can ensure that adaptation, response, and risk-reduction mechanisms are risk-informed.

In Saint Lucia, for example, farms were mapped according to their soils and their exposure to landslides, floods, and other hazards. This process helped guide farmers in their decisions as to what commodities to plant based on farms' susceptibility to floods and landslides.

6.4.2. Vulnerability mapping

Understanding where vulnerabilities lie helps guide responses and inform decision-making on how to manage climate change risks effectively. Vulnerability mapping, which maps exposure, sensitivity, and coping capacity can provide crucial information for local governments and non-governmental agencies when developing prevention and preparedness plans and identifying gaps in or opportunities for resilience building (Mohanty and Wadhawan, 2021). Vulnerability mapping can also help determine who the less affluent farmers are and the location of isolated fringe farms that have less access to resources and climate information services.

6.4.3. Data

Data is a critical component of risk assessments and vulnerability mapping. Although the Caribbean fairs better than the Pacific in this regard, access to high-quality and context-specific data is still limited. At the national level in Jamaica, for example, although national damage assessments are routinely conducted and compiled in the aftermath of hurricanes, there is generally an absence of data on the impact of drought on agricultural production (Barker, 2012).

6.4.4. Risk communication

Risk communication is the intentional effort on the part of one or more sources to provide information about hazards and their potential impacts to motivate recipients to use the information and take appropriate action (Martínez *et al.*, 2012). Climate risk communication is important for all climate hazards. CRAs are fruitless if the appropriate communication of climate risks does not flow readily from forecasters to decision-makers to the people who need it the most (Bharadwaj *et al.*, 2021).

Smallholder farmers, for a variety of reasons such as age, location, and education may not have information on the risks that they face because of drought. It is critical, therefore, that the processes chosen to enhance the communication of risk are prioritized and adequately re*Sourced*.

Over the past decade, the Global Framework on Climate Services has facilitated the development of tailored climate information services (CIS) internationally, with the distinct aims of improving climate risk management, increasing resilience, and enhancing developmental outcomes (WMO, 2011). The provision of these services is partly built on the assumption that improved awareness of and access to climate services can strengthen farmers' responses to climatic extremes.

Consequently, tailored CIS has gained significant traction across the Caribbean, as a strategy to manage climate risks and associated societal impacts (Buckland and Campbell, 2021). In the Caribbean, tailored CIS for the agriculture sector has been actively integrated into local meteorological operations since the inception of the Caribbean Agro-Meteorological Initiative in 2010.

As one participant from Trinidad and Tobago stated in the regional dialogue:

> *"[The] issue with drought too is simply…[that]…people don't know how bad it's going to get despite the outlooks. Outlooks are useful but many people don't understand how to read them and what it means for them. You may not know how much less rainfall you're talking about. [We therefore have a] need for translating [the] information we have to [the] farmers themselves."*

6.5. Monitoring and early warning

When households and communities receive ample warning of droughts, they are better able to respond and make informed decisions that protect their lives, assets and livelihoods. Given this, early warning systems are exceedingly important. Early warning systems include a process or system for linking early warning information to effective decision-making: as soon as meteorological stations and monitoring systems detect oncoming events, this information is disseminated and communicated promptly through a variety of accessible channels to the people who need it most (Climate-ADAPT, 2019).

The anticipatory actions that smallholder farmers undertake to combat drought often depend on the type of information that they have. With early warning, farmers might choose, for example, to alter what they plant (Regional Dialogue, 2022). Given this, it is crucial that early warning systems information are disseminated to those who need the information most, including decision-makers and local communities.

Throughout the Caribbean and Pacific, farmers experience both a "rainy" and "dry" season, with tropical storms a common occurrence in the rainy months. Many farmers rely on traditional weather-predicting techniques as well as anticipated weather patterns to dictate their farming practices. In certain inherently dry regions in Jamaica, where there is an inefficient water supply system, farmers have tailored their farming practices to rainfall and drought patterns, which has resulted in the development of traditional weather-predicting techniques that include relying on clouds, winds, stars, the moon and the behavior of certain animals or insects to predict when it will rain (Campbell, Barker and McGregor, 2010).

However, with climate change increasing the intensity and frequency of impacts causing droughts unprecedented in both severity and length, and with shifting precipitation patterns causing changes in rainfall that are affecting both the dry and rainy seasons, these traditional forms of forecasting are becoming unreliable.

Successful forecasts of specific drought events have been reported in Jamaica (USAID, 2015). In fact, Jamaica was the first country in the Caribbean region to develop drought forecasts.

6.5.1. Data

As with risk assessments, data is a critical part of well-functioning early warning systems. Weather experts rely on meteorological measurements to determine when a drought is occurring. In some situations, where these resources are limited, local residents and local observations can play a critical role in relaying important information (US CRT, 2019). Due to Jamaica's lack of automated systems, for example, the met office relies on human observers. The national weather service of the Marshall Islands has observation stations on only eight out of its 24 atolls (US CRT, 2019). Residents on the outer atolls depend on rainwater to refill their water tanks and recharge their aquifers; if residents report lower-than-usual tank levels and increasingly brackish groundwater, those observations can point to drought even before it is observed in meteorological data (US CRT, 2019). This real-time on-the-ground information can be more timely in some cases and might be an effective strategy for data collection for islands that lack the capacity to install automated systems. In addition to this, it enhances ownership of the monitoring and early warning system by local residents.

6.5.2. Climate information services

Weather warnings such as drought warnings in Jamaica are communicated by the Jamaican Meteorological Service in four ways: 1) via TV and radio alerts, 2) via text message to local met office database contacts, 3) via national agro met farmer bulletins found online, and 4) via community-specific forecasts found online (Buckland and Campbell, 2021). These weather bulletins, however, do not come with advice on what to do (Regional Dialogue, 2022).

In 2021, Buckland and Campbell explored how well these climate services are taken up and how they shape drought management strategies and decisions, by surveying 356 farmers across Clarendon Parish, Jamaica. In their survey, over 98 percent of the farmers indicated that they are aware of the weather forecasts and drought warnings via TV and radio and have access to both media.

However, only a third changed their farming practices based on these forecasts (Buckland and Campbell, 2021). Furthermore, 80 percent of the farmers interviewed lack awareness of or access to the Jamaican Meteorological Service's community-specific climate information which is disseminated online.

To assess the impacts of CIS on management outcomes, a comparative approach was used. This tested the hypothesis of whether farmers who were aware of, had access to, or used CIS had contextually better management practices and outcomes than farmers with limited knowledge of or interaction with CIS. Compared to their counterparts who used CIS information in their farm decisions, the limited use of CIS by farmers was associated with increased spending following drought events, inability to reinvest in their farms, and complete exhaustion of savings in past drought events. Similarly, an association was found between farmers who had limited awareness of CIS and increased financial loss, as compared to counterparts who were more aware that climate services exist.

Age tends to play a factor in awareness of these services, with younger farmers (below the age of 40) being more aware of online services. In addition to this, farmers learn of the services provided by the met office by attending farmer field schools run by Jamaica's Rural Agricultural Development Authority, where they discover how to use the weather forecast information provided and give feedback (Regional Dialogue, 2022). However, due to a lack of resources, currently only 120 000 farmers are registered with Jamaica's Rural Agricultural Development Authority (Regional Dialogue, 2022).

6.5.3. Emergency response and relief efforts

Early warning systems and vulnerability mapping can also be used to trigger anticipatory cash transfers and well-organized, adequately financed relief efforts. In Jamaica, more than 90 percent of farmers said that they did not receive any assistance from the government following the 2008 drought (Campbell, Barker and McGregor, 2010). While relief efforts scarcely build resilience, it is difficult to overstate their importance in accelerating the recovery process in the immediate aftermath of a disaster.

Disaster relief is important because farmers in Jamaica, for example, said it took them up to six months to recover from the hurricane events of 2004 and 2005, while others said recovery took more than a year. When drought occurs in Papua New Guinea, farmers are unable to replant until the next sowing season or until the rains return, amounting to at least six months to a year until crops return to normal, with root crops taking up to two years to fully recover (Caritas, 2015). Anticipatory cash transfers and adequately financed relief efforts can help farmers absorb shocks and not dive deeper into poverty during recovery.

Local community members are the first responders in any disaster situation. In Tuvalu, a study found that drought was the hazard communities felt least prepared for, compared to typhoons, for which people generally felt better prepared, through reliable early warning systems. Given this, precedence should be given to plans that integrate climate information services and people-centered, multi-hazard early warning systems, through better climate information, community preparedness, response, and resilience (Sengupta, 2022).

Given their proximity to the risks, and their local knowledge and skills, communities can play a critical role in reducing risk and boosting recovery by being the first responders in the event of drought. As such, community-based early warning and early action, community-based disaster risk reduction, and community-level disaster management planning and coordination can dramatically increase the capacity of communities to respond to climate hazards.

Key insights

Rainwater harvesting (RWH) is an ancient, low-risk and proven technology that smallholders in SIDS reported as effective, cheap and easily understood. It is easy to deploy, using local materials and technology. It empowers communities through decentralized implementation. It can be encouraged through mandates and tax benefits. And it brings people closer to the water *Source*, limiting wastage and encouraging water savings. Yet very few Caribbean countries have implemented it at scale. RWH should also be considered for homes and commercial use, with building codes revised accordingly.

Drip irrigation can be more efficient than surface irrigation. However, set-up costs of drip irrigation can be high and technical skills are required for installation and maintenance. More affordable and less technically complex methods should be explored where necessary. Access to spare parts may be challenging for far-flung islands.

Some crops like cassava and sweet potato are naturally more drought-resistant. Equitable access to seeds of more drought-resilient crops is important, while cultural factors attached to particular crops must be considered.

Farmers should seek to diversify their livelihoods through, for example, mixed cropping, beekeeping or selling tree crops.

Mixed cropping and intercropping are good strategies to promote crop resilience and diversification. For example, mixing cassava with intercrops has been found to benefit pest suppression, disease control, soil and water services, and land productivity. However, while mixed cropping can be a traditional practice, where monocropping is dominant, farmers will need training, education, technical assistance and guidance.

Organic farming has been shown to make farms more resilient to climate impacts. Soil-improvement practices such as crop rotations, intercropping, symbiotic associations, cover crops, organic fertilizers and minimum tillage create healthy soils that can absorb and retain more moisture and sustain crops through dry spells.

Similar agroecological approaches, such as conservation and regenerative agriculture, prioritize boosting soil health, through zero tillage, carbon-rich organic mulching and crop rotation. However, these approaches are complex, costly and labor-intensive to set up and may take years to deliver returns.

Agroforestry, in which trees and tall bushes are planted around the perimeters of farm plots, shades crops and protects them from storms and temperature fluctuations. Tree crops can also be harvested as another *Source* of income.

The traditional farming systems of Pacific islanders provide significant resilience to climate variability. Their practice of multi-crop garden plots – using shifting cultivation, protected by trees, with palm leaves as shade and seaweed as compost – merits further study as a potential foundation on which to develop commercial production.

Risk assessment, early warning and communication are vital to help farmers prepare for incoming weather hazards, such as drought. Climate risk assessments and soil mapping can help guide farmers in what to plant. Vulnerability mapping can identify opportunities for governments to boost resilience. Climate information services have gained significant traction across the Caribbean, but it is essential to ensure that early warnings actually reach vulnerable communities through accessible media in time for them to act and that they come with advice on what to do.

Overcoming engrained behavior is a challenge. Farmers often tailor their practices to traditional weather patterns, but with climate change disrupting these patterns, accurate forecasting and effective early warning are becoming more important. A survey in Jamaica in 2021 found that while 98 percent of farmers had access to weather forecasts and warnings, just a third changed their farming practices accordingly.

In terms of post-disaster aid, while relief efforts scarcely build resilience, they are essential to speed up the recovery process, which enables communities to prepare quicker for the next disaster event. In Papua New Guinea, for example, root crops can take two years to fully recover from a drought. Anticipatory cash transfers and well-financed relief efforts can help farmers absorb shocks and not dive deeper into poverty following disaster.

7 Policy recommendations

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7.1. Take a comprehensive approach

Farmers throughout the Caribbean and Pacific face not only the increasing intensity and frequency of drought due to climate change, but also other climate change impacts such as worsening extreme weather events (e.g. hurricanes), changes in precipitation, flooding, increase in temperatures, saline intrusion, sea-level rise and worsening infestations of insects. The occurrence of a hurricane, for example, causes smallholder farmers to experience loss and damage. Then, in attempting to rebuild and recover after these experiences of loss and damage, farmers may be pushed further into poverty and forced to consume all remaining assets and savings (Nisi and Addison, 2022). This makes them less able to cope with future shocks, such as drought as well as ongoing slow-onset processes such as saline intrusion.

It is, therefore, critical for decision-makers to consider the landscape of risks, both long- and short-term, that smallholder farmers face. For example, in flood-prone areas where flooding is causing severe issues as well as drought, measures to retain soil moisture that work to mitigate the risk of drought must be paired with flood control measures such as the construction of drainage systems, diversion channels, weirs, cut-off channels, and retarding basins. Certain measures, such as agroforestry, have been promoted for their ability not only to mitigate against the impacts of drought but also to protect crops during extreme weather events such as hurricanes.

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7.2. Be gender transformative

Women, women-headed households, and gender minorities tend to be more vulnerable to the impacts of climate change and the consequent losses and damages. This is because social, cultural, political, and economic forms of marginalization and exclusion hamper their access to economic resources, assets, decision-making power, and political influence (Addison *et al.*, 2022).

In the Caribbean, women-led households are some of the poorest. In the Pacific, women play a pivotal role in agricultural activities at the household and community levels and have the potential to act as agents of change and contribute to livelihood strategies adapted to changing environmental conditions (APCP and Phama Plus, 2020). However, gender norms mean that women's role in agriculture is largely invisible. Only male heads of household in Pacific SIDS are counted as farmers in official data and it is only they who come forward for training or other agricultural development opportunities. While there are some modest programmes targeting women's farming of niche products, there is little focus on supporting women engaged with men in smallholder agriculture.

It is important that adaptation processes are gender-responsive. Rather than seeing gender as a tick-box exercise that simply denotes the number of women engaged in a particular activity, programmes should where possible challenge and address context-specific issues around inequity, power, and agency in relation to gender. In this regard, it is also important to understand context-specific gender dimensions, as these issues are not homogenous and are determined by a variety of factors.

7.3. Promote education, awareness and training, and ensure long-term capacity building

7.3.1. Education, awareness, and training

- many farmers would benefit from access to education, awareness, and training to improve their understanding on:
- the impacts of climate change and drought on agricultural systems in the short- and long-term;
- changes and trends in local weather patterns due to climate change;
- the adaptation measures best suited to build their resilience and manage drought risks in their particular context and geographic region;
- why and how these particular adaptation measures work;
- how to implement these measures and, where necessary, how to maintain them; and
- which practices are maladaptive and why.

This information is critical as it builds adaptive capacity, equips farmers with the skills and information necessary to plan productively, and empowers them in their decision-making processes. The consultation process revealed that there is considerable interest among smallholders in this kind of information. In Grenada, for example, farmers have requested training on maintaining irrigation systems and pumps as well as understanding how to water their plants properly (Regional Dialogue, 2022).

Training initiatives already in place can offer guidance at the national and regional levels. In Jamaica, an irrigation curriculum for small-scale farmers has been developed. Known as "Surviving the Drought: An Irrigation

Curriculum for Jamaica's Small-Scale Farmers", it utilizes a knowledge transfer curriculum that focuses on water management strategies. The project employs the farmer field school approach to deliver the curriculum. The manual section includes agro ecosystem analysis, which aims to guide farmers in conducting regular observation and analysis of their farms to become decision-making experts.

Education, awareness raising, and training programmes must be geared towards long-term sustainability. Adaptation projects tend to focus on delivering one-off activities such as training and workshops that work to fill an immediate knowledge deficit (Rokitzki and Hofemeier, 2021). However, holding simple one-off workshops has shown to be ineffective in both delivering capacity building and disseminating scientific information (Bernedo Del Carpio and Alpizar, 2021). Workshops and training may still be effective, but only if they move beyond ad-hoc activities towards increasing empowerment over the long term.

Education, awareness-raising, and training programmes must be designed in a bottom-up, inclusive, and participatory manner. For example, an irrigation project in Jamaica designed training classes using pictures and games, to ensure that all members of the farming community were included, including those who were illiterate. Meanwhile, the farmer field school approach developed by FAO centers on problem-solving and discovery-based learning. Its interactive and participatory techniques provide avenues for farmers to increase their knowledge and adaptive capacity through various problem-identification and problem-solving activities. Following farmer field schools and farmer-to-farmer training programs, continued support, monitoring, and adaptation, as promoted by the FAO RECSoil initiative, is optimal for tailoring drought-resilient management practices to a specific area. Indicators such as soil moisture, yield, and consultations with farmers should inform the ongoing land management planning process.

7.3.2. Capacity building

Planners must focus on bottom-up and top-down capacity building, at sectoral and community levels (Lenderking *et al.*, 2020). The literature and consultation process identified a lack of capacity at both government and farm levels as an obstacle or challenge in adapting to drought. Within the climate development community, capacity development is seen as "the process by which individuals, organizations, and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time" (Rokitzki and Hofemeier, 2021). Capacity development is, therefore, seen as an outcome where institutions, organizations, and communities have gained the skills, abilities, knowledge, and tools to adapt and respond to climate risks in the long term.

Top-down capacity building is important. Samoa's national adaptation programme of action identifies the lack of technical knowledge at the sectoral level on climate change and its future implications as a possible barrier to the formulation of relevant and effective policies, strategies, and activities. Top-down capacity building involves increasing the number of agricultural scientists and agricultural policy analysts (Lenderking *et al.*, 2020), as well as building the knowledge, resources, and skills of extension officers and other key stakeholders within ministries of agriculture. In the consultation process, a need to move away from the reliance on external experts was mentioned (Regional Dialogue, 2022). This means that rather than relying on the knowledge and skills of external or foreign experts, research processes must focus on building the capacity of local practitioners and researchers who are then able to support communities to adapt and respond to climate risks long after a particular project has ended Fiji, for example, suffers from a lack of professional and sub-professional staff that include the qualified personnel required to plan, design, observe, monitor, supervise and inspect before, during and after the implementation of adaptation measures (Lenderking *et al.*, 2020). In the Pacific, the Papua New Guinea National Agricultural Research Institute has called for capacity building in research, science, and technology with a focus on climate change modelling and prediction, climate change policy research and development, climate change mitigation research, weather forecasting, early warning systems and other climate change-related disciplines and focus areas.

7.4. Increase access to social protection, insurance, and grants

7.4.1. Social protection

Social protection is a set of policies and programmes aimed at protecting all people against poverty and vulnerability throughout their lifecycles. This can include labour market interventions, social welfare programmes, social safety nets, and social insurance (Addison *et al.*, 2022). Social protection measures include an array of policies and interventions that are not only aimed at providing safety nets in the event of climate shocks but are also designed to reduce poverty, address underlying vulnerability, and build climate resilience (Aleksandrova and Costella, 2021). Shock-responsive social protection can scale up welfare support either before, during, or after a climate shock occurs (Addison *et al.*, 2022). Shah and Dulal (2015) call for social protection programmes in Trinidad and Tobago. The Productive Safety Net Programme of Ethiopia and India's Mahatma Gandhi National Rural Employment Guarantee Scheme are good examples of social protection programmes.

7.4.2. Insurance

Insurance is a risk transfer mechanism that can provide quick liquidity after an insured climate shock or disaster occurs. By releasing a payout, microinsurance schemes can help vulnerable and poor households reduce harmful coping strategies, such as using savings, selling assets, taking children out of school, or using seed stock.

Crop insurance can support farmers in facing the risk of reductions in yields due to climate change. Weather index-based insurance has been introduced in recent years in many countries. It allows individual smallholder farmers to hedge against agricultural production risks, such as droughts or floods. The product pays out on events that are triggered by a publicly observable index, such as rainfall recorded on a local rain gauge. This approach means that payouts can be calculated and disbursed quickly and automatically without the need for households to formally file a claim (Dev, 2011). It is important to note, however, that the costs of insurance are high and can be unaffordable, especially for those living in poverty.

7.4.3. Grants

Grants can help farmers cover the set-up costs of certain adaptation measures and fund interventions that increase their resilience. They are available from institutions such as the African Development Bank and the Global Agriculture and Food Security Program.

Importantly, given that grants, unlike loans, are interest-free, they support farmers in covering these costs without making them incur future debt. However, grant application processes do require a lot of resources, information, and time. Given this, where possible, support systems should be put in place that help farmers in submitting applications as individuals or cooperatives. This support can be given by, for example, local NGOs or implementing agencies such as the FAO. In line with this, where possible, local-level capacity should be built to allow farmers (ensuring equitability) and farmer cooperatives to be able to apply directly. Where national grants are made available, application processes should be simplified.

7.5. Foster farmer associations, cooperatives and organizations

Due to their circumstances, rural smallholder farmers often lack the opportunities to negotiate better terms of trade for their agricultural products, as well as to hold government and non-government actors accountable, access resources and credit, demand and access services and public goods, or benefit from the exchange of knowledge and information.

Farmers associations, cooperatives, and organizations can aid farmers in overcoming these challenges. However, where these groups exist, participation is limited – especially in the Caribbean where, for example, a 2017 survey of farmers in Trinidad and Tobago found that fewer than 31 percent participated in farmers' organizations (Rhiney, Eitzinger and Farrell, 2016). This was reinforced throughout our consultation process, which suggests that the culture within farming communities in the Caribbean tends towards individualism and competitiveness. The Pacific, on the other hand, is said to have strong cultural traditions of mutual support between individuals and families in critical situations (Reenberg *et al.*, 2008; Taylor, McGregor and Dawson, 2016). These cultural differences should be taken into account as they may impact the ease with which individuals join such associations, cooperatives, and organizations. In Kiribati, there had been a 94 percent increase in the number of cooperatives in the last four decades with copra-farming and fisheries dominating the space. In Papua New Guinea, 6 000 registered co-operatives are in operation, with almost 60 percent in the coffee and copra-farming sectors. In Vanuatu, there are 356 active co-operatives in the country with a membership of 14 438 individuals. In Jamaica, 100 000 people are members of 39 agricultural cooperatives.

Farmers' associations, cooperatives, and organizations benefit farmers by creating opportunities for and improving performance on a wide range of important factors, detailed below.

7.5.1. Representation and bargaining power through leveraging collective action

Organized groups and communities are more likely to have their voices heard and their demands met. As such, farmer organizations and associations help increase the lobbying power of farmers, their capacity to negotiate better terms, their participation and influence in policy dialogues and agricultural development actions, and their ability to hold both state and non-state actors accountable.

These organizations can also help facilitate dialogue between smallholder farmers, governments, donors, and the private sector (IFAD, 2014).

The objectives of the Windward Farmers Association of St Vincent and the Grenadines, for example, are to:

- work in collaboration with farmers, farmers' organizations, and food producers to improve the socioeconomic well-being of farmers and to work towards the total eradication of poverty in rural communities;
- enable farmers and food producers in the Caribbean to play their part in directing the development of agriculture in the region by coordinating educational and research programmes and by disseminating information relevant to agricultural development;
- coordinate the efforts of farmers, farmers' organizations, and food producers in the Caribbean in launching united action to influence

policy decisions on matters affecting agriculture and general socioeconomic development;

- create and forge alliances and linkages between farmers' organizations and food producers' groups, and between those organizations and other national, regional, and international organizations and institutions concerned with agricultural and rural development;
- promote the democratic participation of farmers at all levels of the development process; and
- promote the building of awareness and solidarity among farming organizations and communities at the national, regional, and international levels.

7.5.2. Peer-to-peer learning, access to information and capacity building

Farmers often lack access to information on climate change, droughts, and solutions. Farmer organizations, associations, and cooperatives can create a forum for exchange and give farmers the opportunity to share important information and learn from each other. In some cases, information sharing can happen over modern platforms such as WhatsApp.

In addition to this, governments might be able to better assist in the dissemination of information. In Kiribati, for example, there has been an increase in the government's efforts to release contemporary training manuals for members of co-operatives.

Social cohesion among farmers fosters capacity building and learning (Regional Dialogue, 2022). Peer-to-peer learning allows farmers to see first-hand the benefits of adopting certain adaptation measures, incentivizing them to adopt similar measures. Building off this, the International Fund for Agricultural Development (IFAD) has utilized the "lead farmer model" in East Africa in which a lead farmer is tasked with piloting and passing on information about adaptation measures such as drip irrigation. In an irrigation project in Jamaica, certain farms were taught improved watering methods and soil moisture-retention techniques. When farmers from inside and outside the community witnessed increased benefits on these pilot farms, they requested assistance to do the same on their farms (Regional Dialogue, 2022). This also resulted in the formation of a farmers' community group, which was able to operate as a platform for knowledge transfer (Regional Dialogue, 2022).

In addition to creating a platform for sharing information about adaptation measures, farmer cooperatives, communities, and associations can play an important role in disseminating and sharing climate risk information through accessible channels. In St Lucia, for example, as part of an FAO-run project, a WhatsApp group was created to exchange information between regional and local stakeholders (FAO, 2021).

Capacity building can also include financial literacy and business management training.

7.5.3. Social networks and support

Smit and Wandel (2006) believe that the presence of bonds (strong kinship networks) can increase adaptive capacity by providing economic, managerial, and psychological help. The presence of bonds and ties within communities provides fertile ground for governmental intervention to facilitate the development of agrarian policies and rural programmes (Smit and Wandel, 2006).

In the Pacific, social capital was identified as a critical adaptive capacity determinant of communities across several Pacific Island countries (Taylor, McGregor and Dawson, 2016). The identified indicators of this were community diversity, leadership, collective action, support services and networks, and governance (Taylor, McGregor and Dawson, 2016).

In some cases, these groups can help individual farmers with the issue of theft (Regional Dialogues, 2022) and can support members in periods of crisis. For example, during the COVID-19 pandemic in the Caribbean when there was limited access to inputs, markets, and alternative revenues, farmers' organizations supported their members via social protection and solidarity funds.

7.5.4. Pooling resources

Pooling resources helps in, for example, sharing the cost of expensive technology (Regional Dialogues, 2022). In other cases, pooling resources results in jointly owned assets, such as equipment and machinery.

7.5.5. Access to grants and loans

Smallholder farmers often lack sufficient access to the financial services they need, including access to loans and credit. In Southeast Asia, for example, the risks involved in lending to newer, smaller, or agriculture-based enterprises are often too great for banks and other formal lenders to assume (USAID, 2023). These risks include inadequate financial infrastructure, limited forms of collateral, difficulty in enforcing contracts, a dearth of insurance products, and the particular risks faced by agriculture, such as seasonality, environmental disaster, and potential for spoilage.

Farmers' organizations and associations can assist members in accessing loans, as they may lack the resources to do this as individuals. The President of Cooperatives of the Americas has said: "This [the cooperative system] can offer many contributions, for example, inter-cooperation among savings and loan cooperatives that provide financing to farmers' cooperatives and to individual small farmers to get ahead and to stay afloat in this complex climate" (IICA, 2020).

In addition, rural cooperatives and other farmers' organizations can access a wide range of external grants and loans. With its international reach, IFAD is well-positioned to assist cooperatives through a wide range of loans and grants. In Lebanon, for example, a new IFAD project will benefit an estimated target group of around 250 000 rural people in 50 000 households and will include agricultural smallholders, the landless, smallholder rural entrepreneurs, rural women and fishermen. Most of them identified the lack of access to credit as the main obstacle to the betterment of their income. The lack of credit prevents the poor from engaging in productive activities, including small or medium on-farm and off-farm income-generating activities. They encounter great difficulties in access to banking and financial facilities. Programme beneficiaries are or will be members of rural producers' cooperatives or rural savings and credit cooperatives.

7.5.6. Access to services and non-financial inputs

Members of farmers' organizations and associations can leverage collective strength and bargaining power to access non-financial inputs, services, and appropriate technologies (Raju *et al.*, 2017). These might include training and education programmes, as well as raw materials, technology, seeds, and fertilizer. In Jamaica, the agricultural community in the post-World War II era was faced with challenges in the acquisition of agricultural equipment, seeds, and fertilizers. Agricultural cooperatives developed from these areas of need and farmers were then able to procure their farming requisites and market many of their crops through these organizations. In addition, the introduction of modern farming techniques was possible through the cooperatives.

7.5.7. Access to niche markets

Niche markets include, for example, fair trade and organic products. Farmers can partner with private entities on more equitable terms while reducing transaction costs and receiving adequate information on market information and trends.

7.5.8. Tracking underlying drivers of vulnerability and intersectional inequity

By their nature, cooperatives are socially inclusive. They reduce farmers' vulnerability and prevent them from falling into poverty, thus making them an important tool for challenging inequalities afflicting women and indigenous groups.

Women-only cooperatives help women developing their own businesses, reflecting their needs and realities, and help them overcome the biases that frequently limit their economic development.

7.6. Foster communities of practice

Climate change impacts manifest themselves differently in each country, district, and community. While each country is unique, there are standard good practices in addressing drought, which can be adapted to local realities. Given this, the sharing of good practices across countries and regions is important. Communities of practice are a means to share knowledge and lessons learned across social, professional, or geographic silos and boundaries. For example, Jamaica's early warning and drought forecasting systems is one of the most advanced in the region and there can be great benefit and opportunities for other countries to learn of what has worked or the challenges that have been faced.

Regional and national communities of practice can help countries, institutions, researchers, and practitioners share knowledge and experience to help implement best practices to address drought in agriculture. Lowitt *et al.* (2015) suggest enabling communities of practice with shared values, needs, and priorities, which could provide structures to foster social and collaborative relationships and collective action among smallholder farmers. The importance of sharing information both regionally and among SIDS on the opportunities, solutions, and challenges in building resilience in the agriculture sector was brought up by a number of participants in the Caribbean Regional Dialogue.

Learning can happen at the country level, among districts and provinces, or in cities. In Grenada, for example, the island of Karikoo is naturally dry with no access to freshwater sources, either above or below ground, and very limited rainfall (Regional Dialogue, 2022). Those living in Karikoo, therefore, have historically practiced water harvesting and conservation techniques, such as the use of water-holding tanks (cisterns) and manmade ponds. Interviewees from Grenada highlighted the benefit of learning from these communities.

The idea of "learning routes" was encouraged in one key informant interview – a process by which pilot countries might adopt certain strategies and encourage "exchange visits" from neighboring countries to foster cross-country learning (Regional Dialogue, 2022).

Of course, rather than reinventing the wheel, an investigation should be conducted into existing communities of practice or information-sharing platforms that can be supported and utilized. For example, at the Caribbean Regional Dialogue, one participant mentioned the SIDS Solution Forum. This forum seeks to promote the exchange of information that includes a series of dialogues such as the "Second global SIDS solutions dialogue building agricultural resilience in SIDS: now more critical than ever" (Regional Dialogue, 2022).

7.7. Improve off-farm water management

Given the limited water availability within SIDS, off-farm water management practices are crucial. This includes policies and processes around water use, management, and storage (UNFCCC 2007). Water-scarce countries in the Caribbean have already started adapting to climate change by revising water management approaches and policies (Mycoo, 2018) and regional efforts can be seen through initiatives such as the Caribbean water climate and development programme.

Several countries in the Caribbean have adopted integrated water resources management to protect water resources. The integrated water resources management process promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems (Mycoo, 2018).

Given that during times of drought in SIDS water must be shared across sectors (e.g. agriculture, domestic, and commercial), rainwater harvesting practices must be enforced and incentivized outside the farm level, for example with commercial and public buildings (Waite, 2012). In Barbados, the Town and Country Planning Department requires that all buildings, other than houses having a gross roof area of $93m^2$ or more, install a rainwater storage tank or cistern for secondary uses (Mycoo, 2018). It is also mandatory that hotels have on-site water-recycling facilities for golf courses and landscaped areas. In Saint Kitts and Nevis, the Nevis Physical Planning Department passed and implemented the Nevis Physical Planning and Development Control Regulations 2021 which require any building intended for human habitation to provide either a cistern or rainwater catchment, and a storage facility with a minimum of 500 gallons per 100 ft^2 if there is a public supply and 1 000 gallons per 100 ft^2 if there is no public supply.

As Waite (2012) points out, and mentioned during the consultation process, RWH cannot supply all water needs, especially as climate change worsens. Water management solutions must therefore include greater water efficiency across all industries, the use of reclaimed water to restore and conserve water resources, sustainable management of surface and groundwater, protection and restoration of watersheds, and the introduction of innovative technologies (McLeod et al., 2019; Waite, 2012).

Extracting clean water from seawater is becoming an increasingly integral part of the Caribbean's search for water security (White and Falkland, 2010). Although desalinization is not new to the region, it has enjoyed mixed success in small island settings, owing to operational costs.

7.8. Foster locally led adaptation

Greater focus on locally-led adaptation could lead to more information on the vulnerabilities, impacts, and adaptive capacities of communities; a better understanding of the gaps and limitations in existing programmes; and opportunities for empowering vulnerable groups such as women and youth (UNESCO, 2017). Community participation can also help generate insights into the social dimensions of resilience. Often resilience is only seen as the capacity of an ecosystem to withstand and recover from damage. This neglects resilience as a social process, which depends on the capability of communities to absorb shocks and changes (Gheuens, Nagabhatla and Perera, 2019).

It is vital that interventions are chosen and designed to meet the priorities and needs of affected communities. By adopting participatory processes that empower communities to engage meaningfully in the design, planning, and implementation of adaptation and resilience-building programmes, organizations can better assess local priorities and preferences while increasing a sense of ownership and ensuring the long-term sustainability of interventions (Addison et al., 2022). For example, in consultation with farmers in Fiji, the APCP and PHAMA plus found that the standout solutions that present real promise to enhance climate resilience across all four growing regions include: agroforestry, organic farming, and greater use of traditional farming practices (APCP and PHAMA, 2020).

However, this is not common practice. In their exploration of stakeholder engagement within the agri-food system in Saint Lucia, for example, Ville and colleagues found that collaboration processes were often top-down and lacked representation of smallholder farmers (Ville, Hickey, and Phillip, 2017).

Importantly, while participatory processes can foster a sense of ownership and trust, top-down processes can have the opposite effect, potentially fostering distrust (Ville, Hickey, and Phillip, 2017). Lowitt et al., (2015) found that the systemic lack of public services throughout the Caribbean was compounded by a "pervasive lack of trust reported between actors and institutions throughout the agricultural innovation system [...] in the Caribbean" (Lowitt et al., 2015).

Understanding local community structures, functions, and cultural and agricultural practices is important when implementing any policy or intervention. It is also important to understand the indigenous or traditional practices of farming communities, as well as the decision-making processes around why certain farming practices are undertaken. Regions, countries, districts, and communities are unique – and understanding these particularities produces more effective, long-term, socially impactful outcomes. Tikai and Kama (2004) have highlighted that understanding indigenous knowledge in the Pacific would produce a more efficient and cost-effective path to sustainability in the agricultural sector.

Below are some examples of traditional and local practices that should inform the planning and implementation of adaptation initiatives:

- in Samoa, Taro mulching is a common practice among local farming communities, while vegetable mulching is not practiced because it attracts the giant African land snail (Achatina fulica) and results in extensive vegetable losses (Ramona, O'Connor and Cox, 2020).
- in Bellona, in the Solomon Islands, the cultivation of yam gardens is closely linked to cultural identity, status, and prestige (Reenberg et al., 2008).
- in the three sub-regions of the Pacific, distinct differences in social organization and cultural practices exist (Lese *et al.*, 2021). For example, sharing information in Melanesia and parts of Micronesia is constrained by the diversity of languages and cultures, while in Polynesia and parts of Micronesia, sharing information is broad-based and systemic, involving government, villages, and church communities (Lese et al., 2021).
- in Kiribati, maneaba – a traditional community decision-making system symbolized by the maneaba or meeting house – plays a crucial role in getting support from community members at the start of the project (UNDP, 2019).

A soil health project in Samoa showcases the importance of bottom-up participatory processes. In a climate adaptation programme that focused on soil health in Samoa – undertaken by the Australian Centre for International Agriculture Research from 2010-2015 – inputs were garnered from the Samoan government and various institutions, agencies, and organizations outside of Samoa, while few inputs were sought from local farmers (Ramona, O'Connor and Cox, 2020). The programme was unaware that many Samoan farmers were already adopting climate adaptation practices because no participatory research had been conducted before the programme's implementation.

Conversations with Samoa's Ministry of Agriculture and Fisheries led the programme to identify mucuna as the ideal cover crop for farmers to improve soil health (Ramona, O'Connor and Cox, 2020). However, no farmers used Mucuna, and the few that did try it reported that it grew too fast and was not an effective cover crop. For farmers, dadap was the preferred cover crop.

Instead of top-down decisions made by foreign aid organizations, researchers, and high-level government officials – who appeared to conclude that

Samoan farmers were not using adaptation practices – a more reflective approach that investigated traditional knowledge might have produced more positive outcomes for the agricultural sector.

It is therefore critically important for global climate policy and national governments alike to recognize and support community efforts to build resilient communities and ecosystems through ecosystem-based adaptation strategies that are rooted in traditional knowledge and reinforced by climate science, traditional leadership structures, and sustainable climate solutions (McLeod *et al.*, 2019).

7.9. Utilize and support non-governmental organizations and civil society organizations

NGOs and civil society organizations play a critical role as trusted members of society who work closely with local communities and stakeholders, often representing them at local and national levels (Addison *et al.*, 2022; Regional Dialogue, 2022). They are often well-placed to work alongside governments to increase community resilience and reduce risk. NGOs and civil society organizations can work as champions and translators of climate information, run training and education programmes, set up demonstration farms, and coordinate disaster risk reduction programmes.

In Saint Vincent and the Grenadines, for example, non-profit civil society organizations such as Richmond Vale Academy work with communities on poverty reduction, environmental conservation, and climate change awareness, including creating organic demonstration farms and sustainable home gardens, and contributing to national initiatives (Guell *et al.*, 2022). In Fiji, local NGOs, most prominently the Foundation for Rural Integrated Enterprises and Development, encourage traditional, indigenous farming practices such as integrated cropping and promote a backyard gardening programme.

7.9.1. Government support

Technical and financial assistance from local and national-level governments is required to support smallholder farmers in adopting adaptation measures. Training and awareness programmes must come paired with the technical and financial support to implement these measures.

Relevant government sectors must be more engaged in establishing viable farm risk management programmes to support farmers in replacing lost revenues through indemnity and crop insurance, and other risk management programmes.

7.9.2. Action-oriented research

There is a need for more geographically focused research on the impacts of climate change and drought on agricultural systems throughout SIDS. This research, however, must strive to be action-orientated.

Action-orientated research is a methodological approach for conducting collaborative research with practitioners and community partners that can inform practice, programmes, community development, and policy while contributing to the scientific knowledge base (Small and Uttal, 2005). Regional research institutions and universities must conduct needs-driven research that can then be disseminated to extension officers and the agricultural sector (Regional Dialogue, 2022).

Action research is transboundary, meaning that it encompasses all forms of knowledge. Indigenous knowledge can help with devising innovative research for agricultural researchers, extension workers, and development practitioners for sustainable agriculture development (Tikai and Kama, 2004).

Key insights

Decision makers need to consider the broad landscape of risks. Specific measures can be applied not only to mitigate the impacts of drought but also to enhance farmers' capacity to cope with future shocks and adapt to slow-onsetting phenomena.

Gender-responsive adaptation processes need to go beyond the simple inclusion of women into activities. Context-specific challenges and dimensions have to be addressed to promote the capacity of women to be agents of change.

The level of participation in farmers' associations, cooperatives, and organizations is influenced by cultural factors. In some regions, individualism versus mutual support, for instance, can mark a significant difference in opportunities and improved performances. Recognizing and understanding these cultural differences is crucial for effectively promoting and establishing such groups in rural communities, as they play a vital role in addressing challenges faced by smallholder farmers.

While social protection programs, insurance schemes, and grants are essential for addressing poverty, vulnerability, and building climate resilience among smallholder farmers, challenges such as affordability and complex application processes can remain unaddressed. It is crucial to explore innovative and cost-effective approaches to ensure that these resources are accessible to farmers, including the use of technology, simplified application processes, and building local capacity to facilitate direct application by farmers and cooperatives.

Farmers' organizations provide a range of benefits to smallholder farmers, including increased representation, peer-to-peer learning and pooling of resources, access to services and financial inputs. Furthermore, these collective platforms foster knowledge exchange, social cohesion, and inclusive development, helping to address the specific needs of women and marginalized groups.

Notwithstanding the different impacts of climate change across regions, valuable good practices can be shared and adapted to local realities. Communities of practice, serve as platforms for knowledge sharing, collaboration, and collective action. Establishing information-sharing platforms and promoting exchanges between pilot and neighboring countries, as the SIDS Solution Forum sponsors, can foster cross-country learning.

Given the limited availability in SIDS, coordinated development and equitable management of water, land, and related resources is crucial. Comprehensive water management solutions should encompass water efficiency measures, reclaimed water use, sustainable management of surface and groundwater, watershed protection and restoration, and the adoption of innovative technologies. In certain regions, the extraction of clean water from seawater through desalination is gaining importance, although operational costs remain a challenge in small island settings.

Participatory processes that involve communities in the design and implementation of adaptation programs foster ownership, trust, and long-term sustainability. Traditional and local practices, including indigenous knowledge, must inform the planning and implementation of adaptation initiatives to achieve effective and socially impactful outcomes. The recognition and support of community efforts in building resilience through ecosystem-based adaptation strategies rooted in traditional knowledge and climate science are vital for global climate policy and national governments.

NGOs and civil society organizations, as trusted members of society, play a critical role in enhancing community resilience and reducing risk. Government support is crucial to facilitate the adoption of adaptation measures by smallholder farmers. Action-oriented research is needed to inform practice, programs, and policy. It should encompass diverse forms of knowledge, including indigenous knowledge, to foster sustainable agricultural development.

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Changes in agricultural and environmental practices can contribute to the emergence of agricultural drought conditions. Unsustainable land-use practices, such as soil degradation, deforestation, and the destruction of wetlands, can lead to decreased water availability and increased runoff. Additionally, certain agricultural practices like large-scale irrigation and the cultivation of water-intensive plant species can further deplete water resources, leaving less water available for other purposes and diminishing groundwater levels.

In Small Island Developing States (SIDS) such challenges can easily become critical vulnerabilities. Their remoteness and sensitive ecosystems enhance their exposure to natural hazards, while their limited access to resources and high import costs often leave them with limited opportunities for economic diversification.

The report, a result of the collaboration between FAO and IIED, sheds light on the critical challenges of the agriculture sector in SIDS and provides insightful recommendations stemming from the broad consultations carried out in selected countries. It identifies key areas for policy interventions and technical approaches and supports stakeholders in defining effective measures for drought risk resilience through improved land and water management.

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