Research for Action on Climate Change and Health in the Caribbean:
A Public, Private, People's and Planetary Agenda

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Suggested citation: Allen CF, West RM, Gordon-Strachan G, Hassan S, McFarlane S, Polson-Edwards K, Thomas A, Hospedales CJ, Dubrow R. Research for Action on Climate Change and Health in the Caribbean: A Public, Private, People's and Planetary Agenda. Research for Action on Climate Change and Health in the Caribbean Project, 2024.

12. AGRICULTURE AND FOOD SAFETY AND SECURITY

12.1. WHAT IS HAPPENING?

Agriculture and greenhouse gas emissions

Agriculture is both a contributor to and threatened by climate change (Gordon-Strachan, 2021). By various estimates, farms emit around one-eighth of global emissions of greenhouse gases (United States Environmental Protection Agency, 2021; World Resources Institute, 2014). Most farm-related emissions come in the form of methane and nitrous oxide; both gases are many times more potent than carbon dioxide in their global warming effects but last in the atmosphere for far less time than carbon dioxide. For instance, methane has 84 times the 20-year global warming potential of carbon dioxide, but it stays in the atmosphere for an average of about 10 years compared with 300–1000 years for carbon dioxide (Climate Change Connection, 2020). Methane is produced by livestock during digestion due to enteric fermentation and is released via belches. Beef and dairy cattle produce large amounts of methane; pigs and poultry produce smaller amounts (Friel et al., 2009). Nitrous oxide emissions are an indirect product of organic and mineral nitrogen fertilisers (United States Environmental Protection Agency, 2021). Cattle belching and the addition of natural or synthetic fertilisers and wastes to soils represent the largest sources of emissions, making up 65% of agricultural emissions globally. Smaller sources include manure management, rice cultivation, field burning of crop residues and fuel use on farms (World Resources Institute, 2014). The Caribbean has only small-scale cattle farming, with most of its beef and milk products being imported, so Caribbean agriculture makes little contribution to total global methane emissions from cattle. However, beef and milk are major import items. The extent of emissions of nitrous oxide from Caribbean agriculture does not seem to have been the subject of research.

Climate drivers and food insecurity

Climate change also threatens and damages agriculture, and therefore food safety and security, in various ways. Climate change impacts such as hurricanes, extreme precipitation, increasing temperatures and sea level rise all affect agricultural production locally and globally (USGCRP, 2016). Given the region's high import dependency, when food import costs increase because of climate change influences on the agricultural sector globally, the risks of poor nutrition in the Caribbean are amplified. Climate change, combined with an abundance of highly processed foods, contributes to reduced access to nutritious and fresh foods (Baldeosingh-Arjune, 2022; Buenfil, 2021; Bueno et al., 2008; CARICOM, 2020; Dubrow, 2021; FAO, 2008; Gordon-Strachan, 2021; UN-OHRLLS, 2015). People tend to be anxious at the start of the hurricane season for many reasons, including the possibility of food insecurity (R4ACCHC, 2022a).

In 2020, the Food and Agriculture Organization of the United Nations (FAO) reported that the Caribbean[1] had a 32.1% prevalence of moderate food insecurity and a 39.2% prevalence of severe food insecurity[2] (i.e. 31 million people facing moderate or severe food insecurity) compared with a global prevalence of moderate insecurity of 18.5% and of severe food insecurity of 11.9% (FAO et al., 2021). The Caribbean islands are challenged with regard

[1]The countries included in the 2020 estimate for the Caribbean subregion are the Dominican Republic, Grenada, Haiti, Jamaica, Saint Lucia, and Saint Vincent and the Grenadines, which together represent 58.8% of the Caribbean population (FAO et al., 2021).

[2]Moderate food insecurity describes the situation when individuals face uncertainties about their ability to obtain food and have been forced to reduce, at times during the year, the quality and/or quantity of food they consume because of a lack of money or other resources. Severe food insecurity refers to situations when individuals are likely to have run out of food, experienced hunger and, at the most extreme, gone for days without eating, putting their health and well-being at serious risk (FAO et al., 2021).

to food production. Some of these challenges include the small size of the islands, the fact that less than 40% of the land is suitable for agriculture, the diminishing supply of fish (Chapter 14, "Marine resources and health", provides explanations for the shrinking supply of fish in Caribbean waters), the small areas of land with limited catchment basins[3] and the fact that agriculture is mainly small scale with low productivity and insufficient market access (Buenfil, 2021). Food insecurity may be exacerbated by the limited local workforce available for food production. Encouraging young people to be interested in agriculture as a form of employment or income is challenging (R4ACCHC, 2022b). In 2019, 3.3% of the workforce in countries belonging to the Caribbean Regional Fisheries Mechanism[4] were employed in the fisheries sector (Headley, 2021).

Partly because of these challenges and for historical reasons, Caribbean countries are highly dependent on imports of food and agricultural products. It has been estimated that more than 60% of food is imported (Gordon-Strachan, 2021). Challenges for food security include the relatively low nutritional value of the imported food and its high cost:

- Much of the imported food is cheaper than food produced locally but highly processed and therefore less healthy (Buenfil, 2021).
- Between 2018 and 2020, the region's imported food bill was USD 13.8 billion[5] (CARICOM, 2022).
- There was a 36% increase in the region's imported food bill from 2016 to 2020 (CARICOM, 2022).

The Caribbean is also challenged by food price inflation, which affects both imported and local food prices (Bueno et al., 2008). In 2020, in response to the region's high food bill, the Caribbean Community (CARICOM) introduced the "25 in 5" initiative, aimed at reducing the Caribbean imported food bill by 25% in five years (CARICOM, 2020).

Vulnerable groups

A consistent supply of nutritious food is necessary for physical and mental health and well-being throughout the life course, from before birth to old age. Climate change and climate variability affect the production, availability and accessibility of agricultural crops, livestock and fisheries and thus the consistent supply of safe and nutritious food. Food insecurity affects vulnerable groups disproportionately, including indigenous groups, women, children, older people and those from lower socioeconomic groups. Food insecurity and loss of income can increase anxiety and depression, particularly among indigenous communities and smallholder farmers (Buenfil, 2021; Cashman, 2021; R4ACCHC, 2022c; Vreedzaam and de Kom, 2021). See Chapter 7, "Mental health".

Indigenous populations that depend on locally obtained food from land and sea are especially at risk of either undernutrition or overnutrition (the latter due to dependence on processed food when crops or fisheries fail). In Suriname, pineapples and cassava are examples of crops on which the indigenous communities depend. The planting and harvesting of these crops are affected by the weather and animal behaviour[6] and they take a long time to grow; furthermore, they are not irrigated and depend on rainwater. Flooding renders these crops inedible. It also contaminates the drinking water wells, and access to food and health care are further reduced

[3]Catchment basins provide humans with water for drinking and other domestic purposes. They are also used for agricultural purposes for irrigation and drinking water for farm animals.

[4]The member states of the Caribbean Regional Fisheries Mechanism are Anguilla, Antigua and Barbuda, the Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, and Turks and Caicos.

[5]The top five importing countries based on key commodities – rice, water, sugar, maize, wheat, poultry meat, dairy products, meat (sheep, goat, beef, swine), edible vegetables and roots, fish, fresh fruits, and ginger and turmeric – were Haiti (USD 3.1 billion), Jamaica (USD 1.2 billion), Trinidad and Tobago (USD 1.1 billion), the Bahamas (USD 556 million) and Barbados (USD 408 million).

[6]Some bird songs are more prominent in the rainy season and others in the dry season. Indigenous communities often use these natural world patterns to determine when to plant and harvest their crops.

when flooding renders the airstrips inaccessible. The extreme floods and heavy rains caused by climate change have affected not only the indigenous populations of Suriname but also the population of the capital city, Paramaribo (Vreedzaam and de Kom, 2021).

Under- and overnutrition and food insecurity

Food insecurity may be associated with undernutrition or overnutrition, especially among children. The prevalence of overweight among children under 5 years old is 7.0% in the Caribbean, which is above the global average of 5.6% (Gordon-Strachan, 2021). Overweight and obesity have been linked to high levels of consumption of processed foods in the Caribbean, where people are overly reliant on high-calorie, energy-dense, nutrient-poor, imported processed foods (CARPHA, 2018; Dubrow, 2021; Gordon-Strachan, 2021). A major risk for noncommunicable diseases (NCDs) and their complications is from high levels of consumption of processed foods, inadequate consumption of micronutrients and insufficient daily intake of fruit and vegetables. After hurricanes, fresh foods, especially fruit and vegetables, are usually in short supply and what is available tends to be highly processed, increasing the risk of onset of new NCDs and exacerbating existing NCDs (CARPHA, 2018; Flemming, 2021). See Chapter 4, “Noncommunicable diseases and risk factors”, for more information.

However, research suggests that the relationship between food insecurity and the prevalence of overweight and obesity is inconsistent across country income groups, regions and genders. In a global study, a link was noted between obesity and food insecurity, particularly among women in high-income countries, while it was almost absent in men. In children the results were mixed. In middle- and high-income countries, the evidence that food insecurity is associated with an increased risk of being overweight was more pronounced in girls than boys (Maitra, 2018). Evidence from the Caribbean indicates, however, that the positive correlation found globally in some groups between food insecurity and the prevalence of overweight may not hold in this region. The 2007 Jamaica Youth Risk and Resiliency Behaviour Survey of 1674 children aged 10–11 years found that 11% of children in the sample were overweight. Children living in a food-insecure household had significantly lower odds of being overweight than those living in a food-secure household. In this analysis there was no difference between boys and girls in the relationship between food insecurity and overweight (Dubois et al., 2011).

Globally, food insecurity is associated with an increased risk of low-birthweight babies and anaemia in women (Maitra, 2018). Pregnant women and their developing foetuses may also be affected by a possible lack of folic acid in their diets, which causes neural tube defects. In the 10–18 months following Hurricane Gilbert in Jamaica in 1988, a sharp increase in the number babies born with such defects was noted. It was found that these babies were born to mothers who had significantly less folate in their diet during the periconceptional period (Watson-Duff and Cooper, 1994). It should also be noted that men, women, children and older people have different nutritional needs, and these may be amplified by gendered norms, differences in access to information and resources, and power differentials (CARPHA, 2018; FAO et al., 2018; IPCC, 2019).

Effects of climate change on agriculture and food security

Increases in the frequency and intensity of hurricanes, landslides and floods (Figure 1) have the potential to destroy crops and livestock, through waterlogged fields and soil erosion along slopes; contaminate clean water; damage fishing boats; and reduce fish stocks (Dubrow, 2021; R4ACCHC, 2022a,c,d, 2023a). There will also be loss of agricultural land on the coasts because of coastal flooding and erosion (Buenfil, 2021). Between 1990 and 2018, there were 119 flooding events recorded in the Caribbean (Fontes de Meira and Phillips, 2019). Increasingly heavy rainfall and floods cause contamination of pastures with enteric microbes (e.g. *Salmonella*) that can enter the human food chain (CARPHA, 2018). See Chapter 1, "Health impacts of extreme weather events", for further information.

Figure 1: Flood in Trinidad and Tobago, 2018

Source: Trinidad Express Newspapers (2018) (https://trinidadexpress.com/news/local/national-disaster-declared/article_16ff68d4-d47a-11e8-9e2f-e3a80bd3c43c.html).

In 2017, 100% of Dominica's agricultural crops were destroyed by Hurricane Maria. In addition, 90% of the poultry, 65% of the rabbits and 50% of the cattle and small ruminants were lost. The infrastructure for the fishing industry (e.g. fishing boats and equipment) and fish stocks were damaged. Moreover, food shops were destroyed or damaged. Power outages and the destruction of most of the secondary roads necessary to transport labour and agricultural products to markets and ports also contributed to food shortages (CARPHA, 2017; International Medical Corps, 2017). Likewise, in the Bahamas following Hurricane Dorian in 2019, food security was threatened (R4ACCHC, 2022e).

The findings above suggest the need to increase agricultural production in the Caribbean. However, it should be noted that dedicating more land to agriculture may modify natural landscape features such as river courses which may provide protection from environmental impacts of climate change such as flooding. Andrewin et al. (2015) found a positive association between the percentage of agricultural land and the number of deaths due to floods and storms during 2000–2012, suggesting that the amount of land dedicated to agriculture determines the lethality of floods and storms in the Caribbean.

In the Caribbean, water scarcity has been increasing because of the intensive use of water in the agricultural sector, among other factors, some of which are climate related (CIMH and FAO, 2016; Cashman, 2021; IPCC, 2014a; R4ACCHC, 2022c, 2023a; Trotman et al., 2017). Low availability of clean water compromises food safety (R4ACCHC, 2023a). In addition, ocean saltwater intrusion due to rising sea levels could affect both agriculture and water security (Dubrow, 2021). In the low-lying islands of the Bahamas, it was found that, during periods of reduced rainfall, groundwater catchment areas shrank, and rising sea levels allowed ocean saltwater to penetrate further inland into the terrestrial ecosystem, resulting in water scarcity and damage to agriculture (Greaver and Sternberg, 2010; R4ACCHC, 2022a).

After a hurricane, food can easily spoil when there are power outages and damage to storage facilities. The availability of clean water declines because of contamination, partly from damaged sewage infrastructure and saltwater intrusion (Buenfil, 2021; CARPHA, 2018; Dubrow, 2021). (See Chapter 1, "Health impacts of extreme weather events", for more information on the impacts of hurricanes and Chapter 3, "Water, sanitation and

hygiene", for more information on water security). Degradation and spoilage of products in storage and transport can also result from changes in humidity and temperature, notably from microbial decay but also from potential changes in the population dynamics of stored product pests (e.g. mites, beetles, moths) (Moses et al., 2015).

In the last two decades, the Caribbean experienced two intense periods of droughts – 2009–2010 and 2014–2016 – with 2015 being the driest year on record in several Caribbean islands including Antigua, Barbados, Jamaica, Saint Lucia and Tobago, (Trotman et al., 2017). In Haiti, the 2015–2016 drought affected food security when 70% of the local agriculture production was lost (WFP, 2021). The regional drought of 2009–2010 reduced agricultural crop production in several countries, including Antigua and Barbuda (onions and tomatoes), Dominica (bananas) and Guyana (rice). Saint Vincent and the Grenadines was able to produce only cucumbers, pumpkins and sweet potatoes. The 2005 drought in Jamaica resulted in agricultural losses of JMD 300 million (Gordon-Strachan, 2021). Drought also affects food security through increased food prices (R4ACCHC, 2022a,c; Trotman et al., 2017). Less intense wet seasons followed by more intense dry seasons can lead to an increase in bush fires. Such fires can cause destruction of agricultural crops and related infrastructure. In addition, after the land has been damaged by fire, when the wet season comes, flooding and land slippage can occur (Farrell et al., 2010). See Chapter 1, "Health impacts of extreme weather events", for more information on the impacts of droughts and wildfires.

The increased temperatures associated with climate change threaten food security by increasing the risk of crop failure and potential loss of livestock. For example, root crops and vegetables are likely to be affected by heat stress and changes in soil moisture and evapotranspiration. Additional causes of food insecurity due to hot temperatures include agricultural workers' reduced capacity for outdoor work and the increased spread of plant and animal pests (Buenfil, 2021; Dubrow, 2021; Parker et al., 2022; R4ACCHC, 2022a; UNFCCC, 2005). In 2020 the Caribbean experienced a record-breaking hot season; new air temperature records were set in Cuba, Dominica, Grenada and Puerto Rico (WMO, 2021).

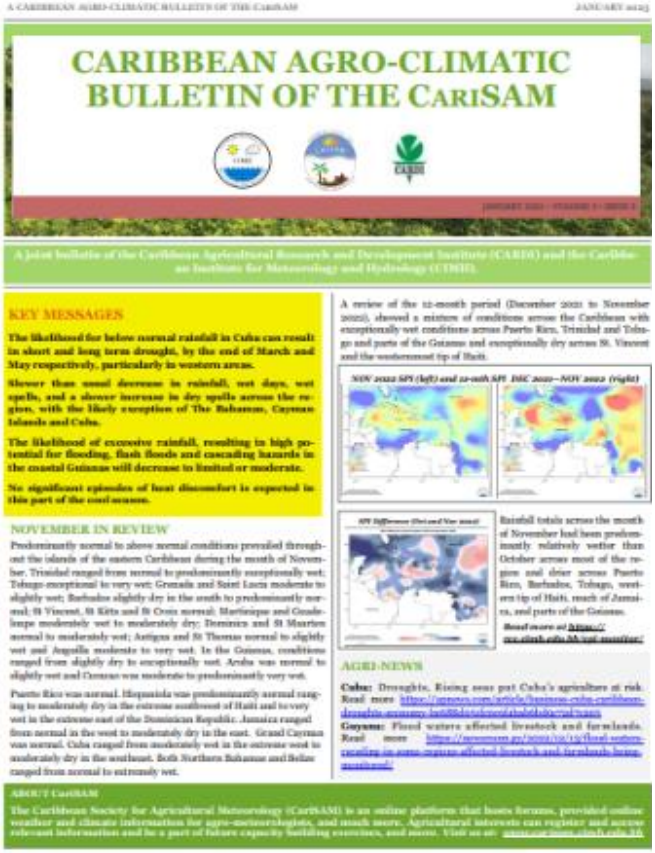
Effects of climate change on fisheries and food security

Coral reefs are important for the supply of most edible seafood and fish (Burke et al., 2011; Dubrow, 2021; IPCC, 2014b). By 2030, 90% of Caribbean reefs will be at risk because of thermal stress and ocean acidification, and by 2050 this will have increased to 100% (Burke et al., 2011). Virtually no species, including commercially important fishery species, is expected to be spared from climate change-related damage. Suitable habitats for these species are projected to decline across most of the Caribbean region, resulting in high levels of extinction locally and declining fishery catches. In the Caribbean the most vulnerable species to climate change are high-value species, such as groupers, snappers and parrotfish. By 2050 it is expected that there will be a 10–30% decline in catch availability across species in a scenario of low greenhouse gas emissions or a 20–60% decline in a high-emissions scenario. Snapper and grouper populations will decline by 50–100% in both low- and high-emissions scenarios (Grant, 2021; Headley, 2021; Maximay, 2021).

Biodiversity, on land and sea, is affected by climate change. Warming oceans also affect the growth of *Sargassum* and harmful algal blooms. The latter produce phycotoxins – notably ciguatera toxin produced by dinoflagellate algae, which causes ciguatera fish poisoning in people who have eaten fish that have accumulated the toxin (CARPHA, 2018). Excess *Sargassum* reduces access to fish, clogs boat propellers, damages boats and fishing gear, and forces fisherfolk to travel longer distances (Dubrow, 2021). See Chapter 14, "Marine resources and health".

Regional and national interventions and studies

Figure 2: Caribbean Agro-Climatic Bulletin of the CariSAM (January 2023 issue)



Source: Caribbean Regional Climate Center (2023) (https://rcc.cimh.edu.bb/carisam-bulletin-vol-6-issue-8-january-2023/).

The bulletin of the Caribbean Society for Agricultural Meteorology (CariSAM) is prepared by the Caribbean Institute for Meteorology and Hydrology in collaboration with the Caribbean Agricultural Research and Development Institute. Each issue of the CariSAM bulletin reviews the climate of the previous month, highlighting any agricultural impacts. It also provides climate-smart agricultural information. Figure 2 shows the front page of the January 2023 issue (CIMH, n.d.; Flemming, 2021).

There have been regional post-hurricane disaster assessments. For example, in Dominica, following Hurricanes Irma and Maria, an assessment was conducted of the impact of these hurricanes on the health of the local population and its response to them. It was found that fruit and vegetables were destroyed, livestock were killed or injured, and fish stocks and fishing boats were damaged. Food safety was compromised because of damaged infrastructure and lack of water. Power outages increased food spoilage. In the aftermath of the hurricanes, the government focused on providing agricultural supplies and fishing equipment to farmers and fisherfolk. It also reconstructed the water infrastructure and delivered water to citizens. This was accompanied by a major public health campaign on drinking water, food preparation and hand washing (Caribbean Public Health Agency, 2018). There are, however, limited regional data relating to climate change, agriculture and food insecurity and their impacts on health (Buenfil, 2021).

In 2019, the United Nations Economic Commission for Latin America and the Caribbean undertook a study of riverine flooding in Jamaica (2012, 2017) and Trinidad and Tobago (2018). In Trinidad, several areas and approximately 150,000 people in 4100 households were affected: Saint Helena, Kelly Village, Santa Monica, Madras, Vega de Oropouche and North Oropouche. Seventy-five per cent of local farmers were severely affected through loss of crops and livestock, harvesters, tractors and other equipment. The damage to the agricultural sector was the result of the destruction of the actual and/or potential production capacity of the soil (e.g. erosion, sedimentation or salinisation); destruction of infrastructure including roads, farm property, storage buildings, irrigation systems, pens, corrals, farming machinery and equipment; and the need to replant permanent crops. In Jamaica, in the parish of Saint Mary where the study was focused, agricultural losses were estimated at JMD 225 million (2012) over 415 hectares of farmland and 5500 affected farmers. In 2017 the agricultural impacts were related to flooding and land slippage from excessive rainfall, which was exacerbated by slow runoff of persistent rainfall over several days (Fontes de Meira and Phillips, 2019).

Research has demonstrated a decline in the number and abundance of fish species, with potential fishery catches projected to decline as the ocean temperature increases (Grant, 2021). Other research has examined

water flows associated with maize production and trade in the Caribbean to explore the implications of import substitution for sustainable water use and food security (Yawson, 2022).

One study examined adaptation and coping strategies employed by farmers to reduce damage to their farming systems before and during the immediate aftermath of Hurricane Dean in 2007. Strategies before the arrival of the hurricane included the protection of nurseries (e.g. covering with roof sheeting or taking seedling trays indoors), re-transplanting (e.g. lifting tomato plants, putting them in a box, spraying the leaves and bringing them indoors to be replanted later), cutting trenches to channel water away from crops, spraying with leaf fertiliser or fungicide to enhance the resilience of the crops to extreme rainfall, and harvesting and storage, which generally ensured that the crops fetched a good price after the disaster, as fresh food was in short supply (Campbell and Beckford, 2009).

Strategies after the hurricane had passed included post-hurricane harvesting of marketable produce; restoring plants to salvage crops and mitigate losses (e.g. weeding, moulding, mulching, fertilising and manuring, spraying and watering); relocating farm plots, especially those previously on hillsides, to the foot of the hill, where topsoil and fertilisers had accumulated; and the scaling down of production in terms of both land area and number of crops planted (Campbell and Beckford, 2009).

The Asociación Cubana de Técnicos Agrícolas y Forestales in Cuba has undertaken research to explore the mitigation, adaptation and resilience aspects of agriculture. Areas of study included (Vasquez, 2021):

- The vulnerability of the main types of agricultural production systems (2012–2015);
- The sensitivity of production components (e.g. soil, crops, irrigation pest control systems) to drought and tropical cyclones on farms (2012–2016);
- The resilience of farms in terms of agroecological transformation (2016–2021);
- The main resilience functions identified in farm design and management (2016–2017).

12.2. WHAT SHOULD BE DONE?

Individual and community actions and how to support them

Promote backyard and community gardening

The Caribbean imported USD 1.4 billion in processed foods in 2018–2020. The high levels (> 60%) of imported foods and an estimated 50% rise in the region's food bill from 2000 to 2020 increase the looming threat of food insecurity (Gordon-Strachan, 2021). Climate change threatens food security further. Backyard gardens can provide fruits, vegetables and herbs that can contribute to a healthy, nutritious, low-cost diet. In addition, gardening is known to improve mood and encourage physical activity (R4ACCHC, 2023b). Every household has the power to help change the way we produce and consume food in the Caribbean, thus contributing to a more sustainable regional food security system, especially if sustainable farming methods are used such as rainwater harvesting and aquaponics (Healthy Caribbean Coalition, 2020, n.d.a).

The Healthy Caribbean Coalition in partnership with the action team of its childhood obesity prevention civil society organisation has launched a backyard gardening initiative, which aims to promote this practice by providing helpful tips and a platform to showcase backyard gardening initiatives from civil society organisations across the region (Healthy Caribbean Coalition, n.d.b). To date there have been backyard gardening initiatives in several Caribbean countries including Antigua and Barbuda, Barbados, Bermuda, the British Virgin Islands, Guyana, Jamaica, Saint Kitts and Nevis, and Saint Lucia (Healthy Caribbean Coalition, n.d.b). Backyard gardening can provide small agricultural business opportunities, with produce marketed through community farmer markets and channelled into school food programmes (Buenfil, 2021; R4ACCHC, 2023b,c). Box 1 presents a case study of a small business that produces vegetables and fish using sustainable methods in Saint Lucia.

Box 1: Case study on using aquaponics and rainwater harvesting to support healthy eating

Alex Happy Greens (AHG) provides organic fresh produce to communities in Saint Lucia, including vulnerable populations such as people living with NCDs and disabilities. AHG uses both rainwater harvesting and aquaponics. Rainwater is a natural and free source of water that can be used to irrigate plants. After filtration, the water is salt, pathogen and pesticide free, the final point being key for organic farming. Rainwater can be harvested at home, where rain runs from the roof into a downspout containing filters and is collected in a barrel. No chemicals are needed for water treatment.

AHG has also invested in aquaponics, a combination of aquaculture, which is growing fish and other aquatic animals under controlled conditions, and hydroponics, which is growing vegetable crops in water without soil. AHG uses aquaponics to raise tilapia fish, the most widely raised warm water aquaponics crop product in the world. In aquaponics, plants are fed the fish waste and in return clean the water for the fish. Beneficial bacteria gather in the spaces between the roots of the plants and convert the fish waste into nutrients that the plants use for growth. The result is a good collaboration between aquaculture and gardening.

Source: Healthy Caribbean Coalition (2020); photo by Andrew Felix.

Structural/governmental and private sector actions

Build knowledge and awareness of climate change impacts on agriculture and food safety and security

Climate change adversely impacts on food security, in terms of the availability of fresh and nutrient-rich crops and livestock products, and on food safety. It is important to improve understanding of these impacts to motivate effective action on food security and safety. This awareness-raising can be at the population level using social media as well as traditional communication channels such as newspapers, radio and television.

The basics of nutrition, agriculture, and food safety and insecurity should be taught in schools. For example, at the primary level it is important to impress on children the importance of healthy eating, including fruit and vegetables, and washing hands and raw foods before eating. At secondary schools, concepts such as climate change pathways and impacts, as well as mitigation and adaptation, can be taught. For example, the relationship between climate change and increasing ocean temperatures and acidification, causing a reduction in fish supplies, can be taught, thus raising awareness of the importance of individuals reducing their carbon footprint.

How to grow your own food and the hazardous effects of climate change on food availability can also be taught in schools. This will build capacity in technical agricultural areas, potentially encourage students to pursue careers in agriculture and may stimulate agri-entrepreneurship (R4ACCHC, 2023b).

Schools can also assist through nutrition policies that ban the sale of sugar-sweetened beverages (SSBs) and encourage the provision of healthy meals using locally sourced ingredients (R4ACCHC, 2023d). Proper nutritional advice and guidelines for pregnant women and newborns should be stressed at pre- and postnatal clinics.

It is also necessary to build awareness in the agriculture and health sectors, among farmers and healthcare practitioners alike, as well as among policymakers. There needs to be further research into how this information should be disseminated to the different levels of society and the different sectors that are primarily affected by the impact of climate change on agriculture and food safety and security (Gordon-Strachan, 2021).

Ensure sufficient numbers of trained health inspectors to ensure food safety at all eating establishments

It is important that all establishments serving food, including those in hotels and guest houses, and people handling food in public domains, for example street vendors, meet minimum basic food hygiene standards. Each country needs to have sufficient numbers of skilled personnel to provide training and conduct inspections. Food vendors who have received such training and dining establishments that have passed minimum standards should be provided with certification that is clearly displayed. The Caribbean Public Health Agency (CARPHA) provides an advanced food safety and certification train-the-trainer course for health and hospitality stakeholders through its Tourism Health Programme. Training is conducted by certified experts using the globally recognised SERVSAFE food safety material adapted for the Caribbean context (CARPHA, n.d.).

Include food safety and security in national disaster preparedness and recovery plans

Immediately following climate-related or natural disasters such as hurricanes, earthquakes or volcanic eruptions, there is a high potential for food insecurity and threats to food safety. These especially affect vulnerable communities such as indigenous groups, women – especially pregnant women – children, older people, those from lower socioeconomic groups and people living with NCDs. Because of the damage to local food production, there may be increased reliance on high-calorie, energy-dense, nutrient-poor, imported processed foods. Therefore, food safety and access to nutritious food should be included in national disaster preparedness and recovery plans, with a focus on vulnerable communities.

Damage to utilities and infrastructure can threaten food safety. Planning for such hazards must be built into disaster preparedness and recovery plans. For example, prior to the region's hurricane season (July–December),

food storage facilities, with back-up generators, should be assigned and located in each country's urban and rural areas, the drainage infrastructure should be cleared to prevent flooding that could damage agriculture, and sewage and sanitation structures should be inspected for any potential damage.

Encourage climate-smart agriculture, adaptation and resilience-building, more local agricultural production and the use of appropriate technology

Climate-smart agriculture (CSA) solutions assist with adaptation to the impacts of climate change on agriculture and food insecurity. Agricultural technologies and practices are considered CSA if they enhance food security while addressing at least one of the three other objectives of CSA (sustainably increasing agricultural productivity and farmers' incomes, adapting and building resilience to climate change, and reducing and/or removing greenhouse gas emissions) (CIAT and World Bank, 2018). CSA includes growing high yielding varieties of crops and breeding animals that are resilient to heat, drought, pests and diseases. Also encouraged are the use of climate-proof irrigation systems, drainage and sustainable land management (World Bank, 2022). CSA has been proposed and is already being implemented by some Caribbean countries such as Antigua and Barbuda, Belize, Dominica, Grenada, Saint Vincent and the Grenadines, Saint Kitts and Nevis, Saint Lucia and Suriname (CIAT and World Bank, 2018; Gordon-Strachan, 2021; IICA, 2017; Itoewaki, 2021).

The implementation of CSA will incur costs for retrofitting and reorganising agricultural practices in line with climate mitigation and adaptation. Governments must develop policies for CSA and consider providing incentives and possibly compensation to farmers implementing CSA practices. Such incentives will help with promoting compliance and will build sustainability into CSA initiatives (Buenfil, 2021; Dubrow, 2021; Gordon-Strachan, 2021; R4ACCHC, 2023b). Box 2 demonstrates an example of CSA in Belize. The World Bank has agreed to provide additional funding for CSA in Belize.

Encourage the production and consumption of plant-based foods

Moving away from meat and dairy (especially cattle) and fish production and consumption towards fruit, vegetable, bean and grain production and consumption can reduce greenhouse gas emissions and help to mitigate climate change, while also reducing import dependency and the region's food import bill. Moving away from fish can also help compensate for reductions in fish stocks associated with climate change and reduce the challenges for marine biodiversity caused by overfishing, but this would also mean less consumption of this nutritious, protein-rich food. There are substantial health benefits in increasing the proportion of plant-based foods in people's diets if managed with due attention to the balance of nutrients. For example, the risks of developing NCDs associated with meat consumption would be reduced (Friel et al., 2009).

In the Caribbean, some cultural groups already have a plant-based diet, including many Hindus and Rastafarians. Some vegetarian food items, such as callaloo, ackee, stewed peas, roti and doubles, are very popular. However, most people appear to regard meat and fish as dietary staples. Plant food products designed to taste like meat and fish are mostly imported and expensive. Governments should provide incentives to local food manufacturers to increase the development and marketing of local plant-based alternatives to meat, fish and dairy products. Health promotion should highlight the health benefits of increasing the proportion of plant-based food in the Caribbean diet and emphasise that this change is important for climate change adaptation and mitigation.

Box 2: Case study on building resilient communities in Belize through climate-smart agricultural practices

Ya'axché Conservation Trust is a Belizean conservation organisation founded in 1997, whose mission is to maintain a healthy environment with empowered communities by fostering sustainable livelihoods, protected area management, biodiversity conservation and environmental education in the Maya Golden Landscape (MGL) of southern Belize. Ya'axché's geographical focus area, the MGL, is a 311,850-hectare mosaic landscape of globally important protected areas, communities, private land and state land covering a diverse range of ecosystems. Within this landscape, Ya'axché works with eight local communities made up of mostly Mopan and Q'eqchi' Mayas and Hispanic members under its Community Outreach and Livelihoods Programme. This programme focuses on empowering communities in conservation through environmental education; capacity-building; training in leadership, governance and microenterprises; and ongoing extension support to mentor farmers in implementing sustainable agriculture.

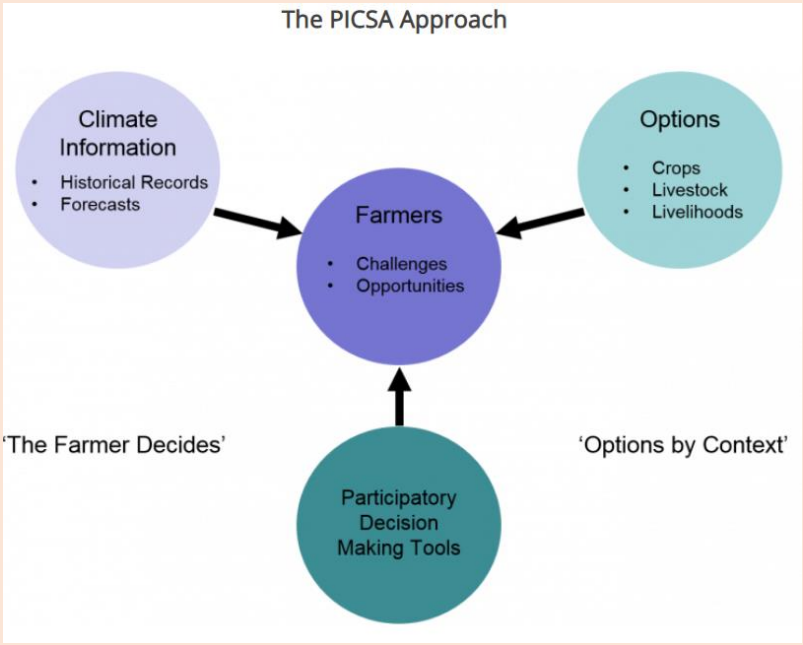
Ya'axché promotes the adoption of sustainable agricultural practices, namely cacao agroforestry, *Inga* alley cropping (growing of crops between rows of *Inga* trees) and beekeeping with agroforestry to improve the economic and food security of disadvantaged farmers and improve wildlife connections between fragmented forests. Farmers are provided with materials, equipment, training and technical support to shift to environmentally friendly farming techniques. A 0.4-hectare demonstration plot of *Inga* alley cropping is located in a 380-hectare plot of community agroforestry concession land in the MGL. This plot is used to restore the degraded soil and as a platform for promoting peer-to-peer learning among farmers. Farmers learn from each other about agroecology and alternatives for conserving soil in this innovative way. As of 2017, 31 farmers from the Trio Farmers Cacao Growers Association had converted 18% of the concession land into cacao-based agroforestry farms.

Source: CIAT and World Bank (2018).

Promote Participatory Integrated Climate Services for Agriculture

Participatory Integrated Climate Services for Agriculture (PICSA) is a participatory approach for climate services and agricultural extension, developed by researchers at the University of Reading, United Kingdom. PICSA aims to support smallholder farmers to make informed decisions under variable and changing climatic conditions. It does this through combining accurate, locally specific weather information; locally relevant crop, livestock and livelihood options; and participatory decision-making tools. PICSA places the farmers at the centre of its approach and helps them to address issues of rainfall variability, extreme temperatures, seasonal changes and extreme conditions such as droughts and floods (Flemming, 2021; University of Reading, n.d.) (Figure 3).

Figure 3: The PICSA approach



Source: Clarkson et al. (2019).

Encourage hospitals to grow their own food for their patients and staff

In 2021, the South-West Regional Health Authority (SWRHA) in Trinidad and Tobago, through its largest health facility, the San Fernando General Hospital, created its own culinary medicine food park to supplement patients' nutritional needs. The primary goal of this farm-to-hospital initiative is to promote the sustainable production of fresh, safe and nutritious food while ensuring a consistent and varied supply for its patients. Overseen by nutrition aides, the first crops – fine thyme, pak choi, lettuce and chives – were ready just five weeks after setting up the hydroponic system. The hospital, the first in the country to grow its own food, joins Cancer Treatment Centers of America in Phoenix, Arizona, and the Hawaii State Hospital, which have all improved their nutrition offerings with food from their onsite farms (see Figure 4). The plan is to have farms set up at other health facilities in the SWRHA area. This initiative forms part of the Trinidad and Tobago Health Services Programme, funded by the Inter-American Development Bank, to support healthy lifestyles to address NCDs (Felmine, 2021).

Figure 4: Culinary medicine food park at San Fernando General Hospital, Trinidad and Tobago

Source: Felmine (2021), with permission from Guardian Media Limited.

Such an initiative can be used as a model for other hospitals and health facilities throughout the Caribbean. The farmland does not necessarily have to be on the health facility's grounds nor be managed directly by it; off-site

communal grounds for several health facilities can be negotiated with ministries of local government and/or agriculture. This can also provide employment opportunities (R4ACCHC, 2023b).

Develop nutritional and agricultural polices to improve the health of the population

Regional food security policies for the Caribbean region include the Regional Food and Nutrition Security Policy and Action Plan, the CARICOM Common Fisheries Policy and the CARICOM COVID-19 Agri-food Plan. The main pillars of the action plan are food availability and food access; food utilisation/nutritional adequacy; and stability of food supply (CARICOM, 2020).

With the decline in fish availability, it is estimated that more than 10% of the global population could face micronutrient and fatty acid deficiencies. It is important to encourage sustainable fishery practices in the Caribbean (R4ACCHC, 2022a,e). The Third Strategic Plan of the Caribbean Regional Fisheries Mechanism, 2022–2030, which considers regional policies such as the CARICOM Common Fisheries Policy, has the following as its strategic objective 3.2: promote improved access to and consumption of nutritious fish and seafood. At the national and regional levels, it is important to consider fish availability in nutrition-sensitive policies (CRFM, 2021; Grant, 2021).

A tax of at least 20% on SSBs is one of many evidence-based interventions put forward by the Pan American Health Organization and World Health Organization for the prevention and control of NCDs. Taxation of SSBs is supported by the regionally endorsed CARPHA Six Point Policy Package. In Barbados, a 10% tax contributed to a 4% reduction in SSB consumption. Bermuda's 75% tax on sugary soft drinks, sweets, pure sugar and cocoa products raised USD 5.4 million in the 14 months post implementation, which funded health and wellness initiatives. Policymakers in the Caribbean have noted this evidence, and both Antigua and Barbuda and Saint Kitts and Nevis announced commitments to tax SSBs in 2022 (Healthy Caribbean Coalition, 2022; R4ACCHC, 2022b, 2023b). Associated with SSB policies is the use of mandatory front-of-packaging warning labels to warn consumers when foods are high in sugar and unhealthy fats (Healthy Caribbean Coalition, 2021; R4ACCHC, 2022b). Other important policies include school-related policies that target childhood obesity. This includes regulating the availability and marketing of unhealthy food and drink close to schools (R4ACCHC, 2022b, 2023b).

Research gaps and how to address them

Gain a better understanding of climate-smart agriculture and how it can benefit agriculture and food insecurity in the Caribbean

CSA has been proposed and is already being implemented by some Caribbean countries. It is necessary to understand more about its feasibility and effectiveness in the Caribbean context. Some questions include (Gordon-Strachan, 2021; Maximay, 2021):

- What is the current situation of climate-resilient or smart agriculture in the Caribbean?
    - What are the understanding of, attitudes toward and practice of CSA in the Caribbean among farmers and the general public?
- Which climate-smart practices (e.g. drought-resilient crops such as sweet potato) are best suited to the Caribbean region?
- How do we promote CSA, adaptation and resilience-building to improve local production?
- What technologies do we need for effective CSA, and do such technologies already exist?
- What is the cost–benefit ratio of developing CSA in the Caribbean?
- What are the links between soil and gut microbiomes under differing types of CSA operation?

Investigate the reasons for the overreliance on imported foods in the Caribbean and the extent to which this is driven by climate change effects on local fisheries and agriculture

The reasons for high levels of reliance on imported food include the limited availability of land, dumping of untreated wastewater into the sea, the limited size of catchment basins and a small agricultural economy (Buenfil, 2021). To reduce this overreliance on imported food it is necessary to identify factors that cause it (e.g. trade policies) and to what extent it is caused by climate change impacts (Dubrow, 2021; R4ACCHC, 2023b).

Explore the impact of food insecurity on vulnerable populations

Vulnerable populations are disproportionately affected by climate change effects on food security and safety. Studies should be conducted to establish the impact of climate change-related food insecurity in the Caribbean on vulnerable communities such as older people, children, pregnant women, people living with NCDs and indigenous populations.

Conduct research on the role of fish in providing nutrition to Caribbean people

Given the importance of fish and the marine environment for nutrition, potential research questions include (Dubrow, 2021; Grant, 2021):

- What raw materials are needed to develop innovative fish products with improved nutritional value?
- What raw, plant-based materials are needed to develop alternatives to fish, with similar or improved nutritional value?
- What is the nutritional value and consumption of fish by age group and sex? Which types of fish provide the optimal nutritional value for vulnerable communities such as pregnant women and children?
- What is the nutritional value of fish species that are resilient to climate change in the Caribbean?

Conduct studies to develop evidence-based strategies to reduce disruption to food availability in the event of a climate-induced disaster

To facilitate food safety and security, research questions include:

- How does a country ensure that there is adequate food after a natural disaster?
- What routes are used to transport fresh foods to vulnerable communities? Are these routes still passable after a hurricane, e.g. have the drains been cleared pre-hurricane season to prevent flooding, and have large trees been trimmed to prevent road blockages due to fallen branches?
- Are there emergency generators on hand to assist with preventing food spoilage?

Determine the effectiveness of actions at the individual, community, structural/government and private sector levels

Monitoring, evaluation and research questions include:

- What is the cost-effectiveness of backyard gardening in the Caribbean?
- Is there increased awareness of the impacts of climate change on food security among the general public, farmers and healthcare providers?
- What proportion of eating establishments have food safety certificates?
- What are the recommendations for incorporating food safety and security into national disaster preparedness and recovery plans?
- Have there been government incentives for the use of CSA? If so, what was the uptake of these incentives?
- Has the use of PICSA increased?

- How many health facilities are growing their own food for their patients?
- Are national nutritional and agricultural polices being implemented? Have their impact and cost-effectiveness been evaluated?

Surveillance gaps and how to address them

Monitor the association between climate change, extreme weather and food security

The relationship between climate, severe weather events and food security should be established and monitored. Potential research questions include (Dubrow, 2021; Gordon-Strachan, 2021; R4ACCHC, 2023b):

- How have food supplies changed following severe weather events?
- How have stocks of various commercially important fish species changed over time and before and after hurricanes?
- What are the effects of ocean warming and acidification on commercially important fish stocks?

Development of indicators for a monitoring and evaluation framework at the country level to evaluate the "25 in 5" CARICOM initiative

In 2020, in response to the region's high food bill, CARICOM introduced its "25 in 5" initiative, aimed at reducing the Caribbean imported food bill by 25% in five years (CARICOM, 2020). However, strategies to achieve this "25 in 5" goal must be grounded in a framework involving CARICOM, the private sector and international donor partners, supported by multilateral collaboration, particularly in the areas of policy intervention, institutional strengthening, investment and sector financing (CARICOM, 2020). The implementation of the CARICOM Agri-Food Systems Strategy in the Member States is expected to help achieve this target. This strategy will give special attention to priority crops and products such as poultry, maize, soya, meat (goat, sheep, beef), rice and niche vegetables, of which large amounts are imported in the region (CARICOM, 2022). Currently, national agricultural activities working towards achieving the targets set by the Special Ministerial Taskforce on Food Production and Food Security are reported through a template. In 2022, 10 CARICOM member states[7] reported using this template (CARICOM, 2022). However, to ensure that the "25 in 5" targets are met there needs to be an accompanying monitoring and evaluation framework against which progress can be monitored (Gordon-Strachan, 2021; R4ACCHC, 2023b).

Research and surveillance capacity-strengthening needs

To address the research and surveillance needs in relation to agricultural crops, livestock and fisheries and food safety and security, capacity must be built in implementation science, impact evaluation, qualitative and mixed methods research, and advanced statistical methodologies. The following additional specialist expertise is required: basic food production and management principles, such as hazard analysis critical control points and One Health (Maximay, 2021; Oura, 2021); integrated water resource management; geospatial and marine spatial technology (Grant, 2021); integrated crop–livestock systems; polyculture; the integration of auxiliary vegetational structures such as green roofs and facades; spatial and altitudinal structure of farm matrices (Vasquez, 2021); aquaculture and aquaponics; and PICSA.

[7]Antigua and Barbuda, the Bahamas, Barbados, Grenada, Guyana, Montserrat, Saint Lucia, Saint Vincent and the Grenadines, Suriname, and Trinidad and Tobago.

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