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Security of Water and Food Resources on Small Pacific Islands

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The approximately 10,000 small Pacific islands (i.e., Oceania, exclusive of Australia and the large islands of New Zealand, Papua New Guinea, and Hawaii) are home to nearly four million residents. Despite marked cultural, linguistic, and societal differences, the peoples of these tiny protuberances from the vast ocean share common challenges related to their vital food and fresh water resources: small land area, limited groundwater and aquifer capacities, and high dependence on rainfall.

Water Security

As growing plant-based foods is inherently dependent on the supply of fresh water, we will consider water issues first. Islands vary in their fresh water resources largely related to their elevation above sea level, and are generally classified as either low or high islands.

Water issues for low islands

Low islands, often lined up on roughly circular reefs referred to as atolls, are narrow, low-lying strips of coral rubble and sand. These remnants of rims of long-submerged volcanoes are particularly fresh water stressed. With their highest elevations a few meters above sea level, they possess extremely limited hydrogeological capacities. Their fresh groundwater is constrained to thin, shallow 'lenses,' so called as they are thicker in the center and thinner at their outer edges. These lenses result from the fact that fresh water is less dense than is salt water, and so, especially when confined in small spaces among the grains of sand that inhibit mixing, floats on top of the seawater that permeates the porous underpinnings of atoll islands.

Fresh water wells on low islands can often be easily created by simply digging a shallow pit in the loose, coarse sand that comprises the surface of low islands. The 'trick' is not to dig too deeply; if the pit extends below the bottom of the fresh water lens, salt water will intrude. However, given the shallow position of the lens and the permeability of the sediments in which it sits, the lens is easily contaminated by wastes such as oil drained onto the ground from a car's crankcase or any other pollutant carelessly discarded.

Equally, and increasingly frequently, the lenses of low islands become salinized from oceanic over-wash. With sea levels rising, king tides and spring tides – high tides that occur when the Earth, Moon, and Sun are in close alignment – may flood across an atoll island from ocean-side to lagoon-side. Likewise, storm surges can inundate low-lying areas with seawater. Such events have forced evacuation of islands.[1]

Surface freshwater sources are virtually non-existent on low islands. The atoll nation of Kiribati has but a single freshwater lake; similarly, among the 35 atolls and lone islands (~1,100 islands in all) of the Marshall Islands, only a few small freshwater ponds exist. Even when they exist, these limited surface freshwater sources are subject to salinization from storm surges or king tides.

Therefore, low islands are virtually entirely dependent on rain for their fresh water needs. Residents of atoll islands routinely employ rainwater catchment systems (RWCSs) to meet their needs for potable water, usually on the scale of individual residences, groups of houses, or at community centers such as schools and churches.

Even where infrastructure supports large-scale, centralized RWCSs to provide potable water, such municipal water sources often are unreliable and/or may be contaminated; leaks and illegal 'bootlegged' connections both allow untreated water to mix with treated. Furthermore, water from municipal systems in many places may be available for a few hours per day, a few days per week; the lack of continuous positive pressure in such systems commonly enables contamination, rendering their water

1 Yeo S. 2014, Marshall Islands face evacuations as sea swamps capital. Climate Home News. https://www.climatechangenews.com/2014/03/04/marshall-islands-face-evacuations-as-sea-swamps-capital/

unpotable. In general, on Pacific atolls, including urban centers such as Majuro and Tarawa, no resident can count on turning on a tap in their home and receiving water ready to drink.

Many in the region routinely buy bottled water for drinking and food preparation; but for many others, that luxury is not an option due to lack of funds and/or local availability of bottled water, especially on the smaller, more remote islands. Emergency desalinization, and even regular desalinization, is becoming more important in places such as Kiribati, Tuvalu, and the Marshall Islands.

Beyond the aforementioned rising sea levels and concomitant more frequent flooding, climate change increasingly wreaks havoc on low islands through drought. While Pacific islands have typically experienced regular shifts between and rainier and less rainy seasons, now much more extended droughts are becoming the norm.[2] While, historically, the residents have adapted to this variation via water conservation methods that are practiced more rigorously during drier times, droughts are now more extended and severe than was the case previously. Recent examples of serious reduction in rainfall - 55%, Aug 2015 – Nov 2016 in Port Vila, Vanuatu; 57%, Nov 1997 - Nov 1998 in Nadi, Samoa; and 60%, Dec 1997 – Jun 1998 in Majuro, RMI - include deficits of more than half of normal rainfall for periods of a year or more.[3]

Water Issues For High Islands

Residents of high islands – where remnants of a volcanic cone may rise hundreds of meters from the sea – in contrast, often have surface freshwater sources such as ponds, rivers, streams, or springs, in addition to more substantial groundwater in thicker lenses and aquifers. High islands often cause orographic precipitation, where the warm, moist air is forced to rise upon encountering the windward side of the slope; as it rises and cools, water condenses out of the vapor into the liquid state and falls as

2 Iese V, Kiem AS, Mariner A, Malsale P, Tofaeono T, Kirono DGC, Round V, Heady C, Tigona R, Veisa F, Posanau K, Aiono F, Haruhiru A, Daphne A, Vainikolo V, Iona N. 2021, "Historical and future drought impacts in the Pacific islands and atolls". Climatic Change volume 166, Article number: 19 (2021), https://doi.org/10.1007/s10584-021-03112-1

3 Ibid.

rain that ultimately collects in aquifers. These aquifers, if above sea level, can feed and replenish high-islands' streams and ponds.

Even in these better-supplied locales, however, fresh water for drinking is a limited resource, as river or stream flow usually varies in synchrony with rainfall, whose patterns are increasingly erratic, with more extensive droughts becoming ever-more common. And, similar to low islands, coastal freshwater lenses are subject to contamination and salinization, and the limited surface water sources easily polluted. On these high islands, residents rely on RWCSs, and/or surface water, and/or groundwater, depending on a number of factors.

Similar to low islands, also, many high island municipal water systems are not well maintained. Leaks from such systems both wastewater and allow microbial (viral, bacterial, fungal, protozoan, etc.) and chemical contaminants degrade water quality.

Water Decontamination

So for many residents of small Pacific islands, collecting and storing drinking water from rain or local surface sources is an ongoing individual, family, and/or community task. Groundwater, surface water, and rainwater are subject to microbial contamination if in contact with organic debris. Besides salt, such microorganisms are the major contaminants of fresh water in Pacific islands, while metal, mineral, pesticide, or other chemical contamination are generally much less of an issue. Many such microbes can induce illness. Processes for ridding water of such 'bugs,' therefore, are critically important for maintaining the health of residents across the region.

Both geographic isolation and limited technical support capacities constrain the use of reverse osmosis and ultraviolet (UV) light decontamination systems on small remote islands. These technologically sophisticated systems are appropriate only where and when replacement parts can be obtained reasonably quickly, and trained knowledgeable personnel are available; neither circumstance is common across much of the Pacific Ocean expanse.

Various less technologically sophisticated options for decontamination, all coming with certain costs and benefits, are well known. Boiling water, for example, is not particularly technologically challenging but entails investments of time and considerable energy resources, rendering this a somewhat costly method. Simply placing a bottle of water in direct sunlight throughout a day will, through heating and UV exposure, kill the vast majority of microbes; this method is difficult to scale up, and its efficacy depends heavily on strong, direct sunlight.

The use of iodine crystals, on the other hand, is relatively simple and not time or energy-intensive, but (a) such crystals are not always available, (b) this method is unsuitable for pregnant women due to potential maternal-fetal health issues, and (c) the aftertaste of iodine is unpalatable to many.

Chlorine tends to be more readily available than iodine, but brings with it issues of taste; furthermore, as chlorine volatilizes readily, its protection is transient and thus achieving the proper dosage (enough to kill microbes but not enough to taste) and timing (enough time for it to take effect, but not so much that the antimicrobial effects wane) is problematic.

The antimicrobial use of silver has been long recognized. Recently, however, a broadly practical decontamination process based on silver's lethality to microbes has been developed. MadiDrops ™ are silver-infused, porous ceramic cakes that, placed in a five-gallon water dispenser, will knock out virtually all microbes overnight. A single MadiDrop can be used daily for a year, decontaminating more than 1,500 gallons of water.[4] This technology hits a 'sweet spot' for isolated small Pacific islands, inexpensive and requiring neither replacement parts nor technological sophistication nor electrical power.

Filtering is another traditional option for microbial decontamination. The technologies for filtering out microbes are changing rapidly, with rising effectiveness and decreasing costs. Examples of three relatively new simple microbial filters suitable for application on small Pacific islands follow:

- Folia Water makes coffee-filter type filters infused with silver nanoparticles. The Folia system comes with a filter holder that screws onto standard plastic water bottles, enabling simple decontamination and filtering of a half-gallon of water in about 10 minutes. Each filter can provide a week of germ-free water for a family.[5]

4 https://madidrop.com/

5 https://www.foliawater.com/

- Aqus filters are an inexpensive, multi-layered filter based on progressively finer and finer nanofibers. These small, simple devices can filter up >300 gallons per day and remove bacteria, fungi, and most other microbes, except viruses.[6]
- LifeStraw™ is a thick, plastic straw containing filters, along with decontaminating iodine crystals and carbon. This device enables a single consumer to drink safely, directly from a contaminated source.[7]

Desalinization

While small Pacific islands typically have very limited supplies of fresh water, they are all surrounded by a vast ocean of salt water. Emulating the natural water cycle of evaporation to condensation and back, various distillation technologies enable the extraction of fresh water from seawater.

Passive solar distillation to obtain fresh water is a very simple, low technology process. At its most basic, a hole is dug in the substrate, exposing previously buried soil. Freshly cut vegetation is sometimes added to the pit, to increase the amount of water. A sheet of plastic is laid across the hole, with its edges held firmly to the ground. A small weight is placed on the plastic over the hole, with a catchment container directly beneath. Water vapor from the soil and vegetation condenses on the plastic sheet, flows by gravity to the point beneath the weight, and drips into the catchment container.

This process, while useful in an emergency situation is very inefficient. Over the centuries, many improved distillation designs have been developed, but generally these have energy efficiency rates of ~30-40% limiting usefulness. Many other commercial distillation devices, on the other hand, are technologically complex, requiring specific replacement parts, and so are unsuitable for use in remote small islands.

One notable exception is a new company, Sunny Clean Water that has recently developed an extremely efficient process to obtain about five

6 http://www.aquswater.com/

7 https://www.lifestraw.com/

gallons of fresh water per day from a one-square-meter device.[8] These stills are being field-tested, and show considerable promise for availability in the near future. Their relative simplicity suggests ready application in remote island locales.

Extraction of Water from Air

Finally, technologies are being developed to extract and condense water vapor directly from the air. A company called Zero Mass Water has already commercialized a system melding state-of-the-art nano-structured materials together with a solar panel to produce a device that extracts and condenses water from the humidity in the air. However, the sophistication and need for special parts makes this option less useful for remote small-island sites.

On the emerging front in this realm, however, a group of researchers at Penn State University have recently developed a "slippery rough surface" whose nano-scaled textured surface is particularly efficient at passively condensing water vapor from air; prototype devices harvest 30 gallons per day per square meter of surface. At some point in the not-too-distant future, this might well lead to a broadly usable simple system requiring little technological sophistication that could meet drinking water needs on small Pacific islands.

Particularly with rising sea levels and the more frequent and extended droughts that accompany climate change, accessing adequate quantities of potable water on small Pacific islands is an increasing challenge. However, appropriate innovative technologies are helping meet this challenge, and are offering new ways for residents of these remote sites to enhance their drinking water security, resiliency, and self-sufficiency.

8 https://www.sunnycleanwater.com

Food Security

Food security is declining worldwide, at least in part due to the COVID-19 pandemic.[9] While not as prevalent as in Asia and Africa, moderate and severe food insecurity impact 12.9% and 3.4% of Oceania residents[10] respectively; the UN Sustainable Development Goals (SDG) indicator 2.1.1 – prevalence of undernourishment (POU) stands at 6.2% or 2.6M Oceania residents[11] (note that this figure includes citizens of Australia, New Zealand, and Papua New Guinea). This POU stands almost a full percentage point higher than what it was in 2010.[12]

Climate Change Impacts

Climate change is already decreasing food security in Oceania and this trend is accelerating over time. Virtually every aspect of climate change is having, and/or is projected to have, a negative impact on the self-sustainability of Oceania residents in terms of their food supplies.[13] Rising air, ground, and sea temperatures are disrupting traditional growth patterns of food crops and marine resources, triggering declining yields of the former and both reductions and migration of the latter. More extreme weather events, including more prolonged and severe droughts, more irregular and episodically heavier rainfall, and more intense tropical cyclones, are all damaging the subsistence agriculture and agroforestry commonly practiced in the region. Rising sea levels are salinizing freshwater lenses and aquifers and are causing more ocean inundation and flooding. All of these changes will place a heavier reliance on more expensive (and for many residents, unaffordable) and more heavily processed (and thus less healthful) foods, exacerbating the increasing POU noted above.

The severe and prolonged droughts had negative impacts on food security, killing off many of the agricultural staples and forcing residents to

9 FAO, IFAD, UNICEF, WFP and WHO. 2021, The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO. https://doi.org/10.4060/cb4474en

10 Ibid.

11 ibid.

12 In brief to The State of Food Security and Nutrition in the World 2021. http://www.fao.org/3/cb5409en/cb5409en.pdf

13 Salem S. 2020, Climate Change and Food Security in the Pacific. https://www.e-ir.info/2020/02/18/climate-change-and-food-security-in-the-pacific/

consume less palatable and less nutritious vegetables.[14] Of concern going forward, the duration, frequency, and intensity of droughts, and especially of severe droughts, is projected to increase over coming decades.[15]

Both salt tolerant and drought tolerant food plants exist in the Pacific islands, and new varieties of many of these are being developed through selective breeding and/or genetic engineering.[16,17,18]

Beyond plant life, food security is being increasingly threatened by on-going changes in the marine environment that provides much of the protein in islanders' diets. Warming seas are causing migrations of fish populations away from their traditional ocean habitats, in many cases moving poleward, following their preferred temperatures (or the preferred temperature of their food source). At the same time, and often in concert with warming, increasing acidity of the oceans is causing large-scale die-offs of the coral reefs that support islands' formerly bountiful fish populations.[19]

Fish populations in the Pacific are expected to continue to decline during the upcoming decades, exacerbating food insecurity among island residents.[20]

Multiple Drivers and Diverse Impacts

This regional food insecurity has multiple, interwoven drivers. "Food security issues in the Asia-Pacific Region are often caused by resource constraints, poverty and unfavourable terms of trade for food commodities. The basic causes of under-nutrition and household food insecurity include

14 Iese V, et al., 2021, Historical and future drought impacts in the Pacific islands and atolls. Climatic Change 166, 19 (2021). https://doi.org/10.1007/s10584-021-03112-1

15 ibid.

16 Tables of Salt-tolerant and Drought-tolerant species. Agroforestry in the climate of the Marshall Islands. http://oos.soest.hawaii.edu/pacific-rcc/Marshalls%20Agroforestry/site/salt-tolerant.php

17 Ashraf M, Wu L. 1994 Breeding for Salinity Tolerance in Plants, Critical Reviews in Plant Sciences, 13:1, 17-42, DOI: 10.1080/07352689409701906

18 Martignago D, Rico-Medina A, Blasco-Escámez D, Fontanet-Manzaneque JB, Caño-Delgado AI. 2018, Drought Resistance by Engineering Plant Tissue-Specific Responses. Front. Plant Sci. https://doi.org/10.3389/fpls.2019.01676

19 Van Dien K, Stone D, 2018, The Effects of Ocean Acidification on Coral Reefs. Climate Interpreter https://climateinterpreter.org/content/effects-ocean-acidification-coral-reefs

20 Borton J 2019 South Pacific islanders threatened by climate change and overfishing. *China Dialog, Ocean*. https://chinadialogueocean.net/9225-pacific-islanders-climate-change-overfishing/

low production and productivity from primary resources (aggravated by high year-to-year variability), scarcity of employment opportunities, and inadequate and uncertain incomes in both rural and urban areas. These causes are closely inter-related: low productivity from primary resources means insufficient food and income for subsistence use, and inadequate surplus of food to meet the needs of rapidly growing urban populations, both of which may contribute to chronic and deepening food insecurity."[21]

The results, however, are simple and disturbing – widespread under-nutrition. Across both the Federated States of Micronesia and Nauru, more than 50% of the population consumes less than the minimum level of dietary energy requirements.[22] Oceania states unenviably occupy three out of the top five positions globally of nations most vulnerable to food insecurity from ocean acidification (Table 2.1).

Vulnerability rank	Country	Ocean
1	Cook Islands	South Pacific Ocean
2	New Caledonia	Southwest Pacific Ocean
3	Turks and Caicos Islands	Caribbean
4	Comoros	Indian Ocean
5	Kiribati	Central Tropical Pacific Ocean

Table 2.1: Most vulnerable nations to food security threat from ocean acidification[23]

This vulnerability is of particular concern as seafood, particularly fish locally caught — subsistence fishery harvesting generally exceeds commercial harvesting of inshore resources by a factor of four or more — is

21 Gillett, 2000 The Sustainable Contribution of Fisheries to Food Security in the Oceania. Asia-Pacific Fishery Commission, Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific. https://www.fao.org/3/x6956e/x6956e09.htm

22 Food Security in Vulnerable Islands: A regional food security atlas of the Pacific. World Food Program; Pacific Community - https://docs.wfp.org/api/documents/WFP-0000071751/download/?_ga=2.41259298.1216997260.1631800070-177339789.1628520123

23 Hulesenbeck M 2012 Ocean-Based Food Security Threatened in a High CO2 World. *Oceana*. https://oceana.org/sites/default/files/reports/OceanBased_Food_Security_Threatened_in_a_High_CO2_World.pdf

a major source of protein across Oceania, with per capita consumption of fish on some islands as high as 250 kg per year, and eaten in over half of the meals.[24] "In most countries of the Pacific Islands area a large proportion of the subsistence fishery harvest comprises invertebrates and is gathered almost entirely by women. Fisheries development policies tend not to recognize or acknowledge the importance of subsistence fisheries in general, of inshore invertebrate harvests, or of the role of women in these fisheries. Most fishery development and management attention throughout the region continues to focus on the commercial components of the catch."[25] Given the poverty throughout the region, many lack the capacity to purchase alternative imported sources of protein, even when such are available.

Further, fisheries contribute to employment, estimated at almost 100,000 jobs, enabling many to purchase food. Additionally, "Licensing of foreign fishing vessels to fish in the waters of Pacific Island countries forms an important source of revenue for these countries. This revenue has implications for the purchasing of food as well as a range of programmes which could enhance the food security situation. The World Bank (1995) estimates that in 1993 total access fees for the Pacific Islands region were about US$ 56 million."[26]

A further troubling trend is the gradual transformation of subsistence fisheries to commercial or semi-commercial ones. As local fish populations decline, more distant, open-ocean fishing, necessarily done at larger (i.e., commercial) scale becomes increasingly dominant. This trend, in turn, tends to shift islanders' diets away from the traditional fish base, and towards a reliance on imported food, much of which "… is nutritionally inferior to a diet based on subsistence products, being low in complex carbohydrates and high in salt, sugar and fat. Many lifestyle-related diseases and nutritional disorders, including obesity, diabetes, vitamin A deficiency and, among children, low birth weights, slow growth rates, and anaemia, are directly attributed to a growing dependence on imported, low-quality foodstuffs that, because of their low cost, are progressively replacing local products. The development of commercial fisheries at the expense of

24 Gillett, 2000 Sustainable Contribution https://www.fao.org/3/x6956e/x6956e09.htm

25 ibid.

26 ibid.

subsistence fishing may therefore be detrimental to food security, at least at the household level."[27]

Thus, declining food security across Oceania contributes to islanders' ill health through diverse mechanisms. In 2019, the World Bank noted that, in large part due to this shift in diets, but exacerbated by poverty and other factors, "small Pacific island countries have one of highest rate of NCD [non-communicable disease] mortality in the world."[28]

Conclusions

Both water and food insecurity currently impact many residents of small island nations and are likely to increase in future years. Scientific and technological advances are addressing some of these challenges and may ameliorate certain problems, particularly in regard to decontamination and/or desalinization of water. While a myriad of factors contribute to these declines in food and water security, the environmental impacts of climate change are of paramount importance, and must be considered in all endeavors to alleviate these increasing challenges around Oceania.

27 ibid.

28 Chand SS, Singh B Non-Communicable Disease Mortality in Small Pacific Island Countries. https://devpolicy.org/2019-Pacific-Update/Day_1_Panel_3A_Shamal_Chand.pdf