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Facing food security risks: The rise and rise of the sweet potato in the Pacific Islands

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ABSTRACT

Pacific Island communities are highly exposed to a range of hazards including extreme weather events and outbreaks of pests and diseases. These hazards can cause severe losses to yields of traditional food crops and increase the risks of famine and food insecurity in Pacific Island communities. Historically, the cultivation of sweet potato enabled communities to adjust their farming systems and reduce food security risks before, during and after disasters. The food security features of sweet potato contributed to its adoption as a staple crop by communities at the "edge" of agro-ecological limits for their traditional crops. Sweet potato was also adopted as a supplementary crop, adding nutrition and stability to communities' food systems. In present times, sweet potato is being cultivated as part of food security and climate change adaptation projects in Pacific communities. This has been facilitated by regional mechanisms for sustainable use of plant genetic resources. But as climate change continues to intensify extreme events and cause sea levels to rise, the resilience of current sweet potato varieties is not guaranteed. Sweet potato, like other Pacific staple crops, is not 100% "disaster-proof". There is a need for multi-partner, proactive agro-ecological based research on sweet potato and other staple crops to reduce both short-term and long-term food security risks faced by Pacific Island communities.

1. Introduction

> *"Climate change will adversely affect food systems in the region, including the supply of food from agriculture and fisheries, the ability of countries to import food, systems for the distribution of food, and the ability of households to purchase and utilize food"* (Barnett, 2011).

Pacific Island communities are highly exposed to climate change impacts and other hazards, threatening food security. Pacific Islanders are experiencing prolonged droughts, intense flooding, severe tropical cyclones and storm surges (Sisifa et al., 2016). Although the Pacific has always experienced extreme weather events, these are becoming more severe and occurring more frequently as a result of climate change. Furthermore, Pacific communities are experiencing an increase in 'slow onset' impacts of climate change: global average sea level has risen by between 2.8 and 3.6 mm per year since 1993 and some Pacific Island Countries have experienced a rate of sea level rise that is four times the global average (Nurse et al., 2014). The average temperature and the number of hot days is also rising (Lough et al., 2016).

As agriculture is the main source of food, livelihood and income for many Pacific Island communities, the impacts of extreme weather events on this sector are highly critical. Severe droughts, intense floods, salt water inundation and intrusion and tropical cyclones reduce both crop yields and total production, increasing the risks of food insecurity in communities (Iese et al., 2016; McGregor et al., 2016a, 2016b). Most rural people in the Pacific rely directly on staple crops and farming for food. In Papua New Guinea, just over 80% of the population are rural villagers who grow most of their own food (Bourke and Harwood, 2009). In the Solomon Islands, between 80% and 84% of the rural population rely on crops and farming (Evans, 2006; Wairiu et al., 2012; Government of Solomon Islands, 2014). In Vanuatu, between 70% and

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80% of people in rural areas rely on crops and farming (Bourke, 1999; Allen, 2015), and in Tonga, between 50% and 60% of people in rural areas rely on crops and farming (FAO, 2008).

Pacific Island communities' leadership in resilient practices against disasters and climate change is well documented (Sudradjat, 1997; Allen and Bourke, 2001; Bourke, 2005b; Wairiu et al., 2012; Allen, 2015; Iese et al., 2015, 2016; McGregor et al., 2016a, 2016b; Taylor et al., 2016a, 2016b; Thomson et al., 2016). Communities have combined accumulated traditional knowledge and modern technologies to improve the resilience of their cropping systems by adopting a "no regrets" approach to decision making. "No-regrets" actions can be justified from an economical, environmental and social perspective whether or not climate change impacts and other natural hazards occur. Such actions increase the resilience of a system including its ability to deal with multiple hazards in an efficient, equitable and timely manner. In the context of agriculture and food security, one example of a no-regrets action is pursuing crop diversification through intercropping and crop rotation. Planting a high diversity of crops has no adverse impacts but increases the likelihood of at least one crop surviving if a hazard strikes. Another technique for reducing food insecurity is selecting and adopting crops that have resilient features, making them beneficial for increasing food security. Through these and other techniques, Pacific Island communities have managed to stabilise crop yields, reduce losses and damages and reduce the risk of food insecurity.

One of the success stories of selection and cultivation of resilient crops for food security was sweet potato being distributed, integrated and adopted in both traditional and modern agriculture systems in Pacific Island communities. Whilst its pre-historic and historic patterns of distribution and adoption have been widely researched (see Yen, 1974; Bourke, 1985; Allen, 2005; Ballard, 2005; Green, 2005; Leach, 2005; Roullier et al., 2013a, 2013b, 2013c), the recent increase in distribution and adoption of sweet potato across the Pacific is an under-investigated area of research.

This paper argues that sweet potato has been in the past, and continues to be, an important food security crop in many Pacific Island Countries. The importance of sweet potato to the Pacific is likely to continue to grow into the future, as sweet potato varieties have many resilient features that make its distribution and adoption more likely in the face of increasing slow and fast onset impacts of climate change. We demonstrate this argument by first discussing the food security features of the sweet potato. We then describe the history of the sweet potato in the Pacific, including the crucial role it played in reducing food insecurity in the past, facilitating population growth and enabling Pacific Islanders to cope with, and recover from, disasters. Next, we discuss the current role of sweet potato in the Pacific including its increased distribution and cultivation as part of various climate change adaptation and food security projects. Finally, we discuss the future potential of sweet potato in assisting Pacific communities to reduce food security risks and improve their resilience against regional and global environmental changes. Suggestions for research directions to support the important future role of sweet potato include targeted breeding programs, crop model development, multi-site evaluations and continued documentation of adoption processes at both the community and national levels.

2. Food security features of sweet potato

Globally, sweet potato is the seventh most consumed carbohydrate-rich food (Chueyen and Eun, 2013). About 105 million t of sweet potato was produced in 2016. China produced 71 million t in that year, making it the world's largest producer. Papua New Guinea produced around 700 thousand t in 2016 making it the only Pacific Island Country to be included in the list of the top 20 largest sweet potato producers globally (FAOSTAT, 2016). In the Sub-Saharan region, sweet potato provides the highest edible energy per hectare per day of all local food crops. It is a primary staple crop in Rwanda, Burundi, Malawi and parts of Uganda and is a secondary staple in eastern and southern Africa (Low et al., 2017).

In the Pacific Islands, sweet potato is the most important staple food crop in terms of total locally produced calories (McGregor et al., 2016a, 2016b). Its cultivation and use in the islands varies. Sweet potato is an important staple crop in Papua New Guinea and the Solomon Islands. Rural villagers in Papua New Guinea consume about 670 kg/person/year and sweet potato makes up almost two-thirds of the staple food crops both by weight (64%) and food energy (63%) (Bourke and Vlassak, 2004). Sweet potato represented about 65% of all food crop production in Solomon Islands in 2004 (Bourke et al., 2006). In Fiji, New Caledonia and Vanuatu, sweet potato is a supplementary food crop but with increasing importance in food, nutrition and livelihood security (Thaman, 1990; Bourke, 1999; Allen, 2005). Sweet potato is also an important cultural and food crop in New Zealand, Easter Island and Hawaii (Ladefoged et al., 2005; Leach, 2005; Wallin et al., 2005a, 2005b; Roullier et al., 2013a, 2013b, 2013c). For Polynesia and the low-lying islands and atolls of Micronesia, sweet potato is increasingly popular because of its climatic and ecological resilience (Iese et al., 2016; McGregor et al., 2016a, 2016b).

The many resilient features of sweet potato are what make it such an important food security crop across the world. Table 1 below outlines the features of the sweet potato and how these relate to the four pillars of food security, namely availability, accessibility, stability and utilization.

Availability (AV) refers to the physical availability of food. The features that contribute to the availability of sweet potato include its ability to grow on both rich and poor sandy soils, its ability to grow non-seasonally in tropical regions, its good storage properties, its high yield per hectare, its demonstrated drought and salt tolerance, and its resistance to some pests and diseases. These features ensure that sweet potato plants produce a yield that is available when communities need food.

Accessibility (AC) refers to factors that enable households to access food. This is not necessarily guaranteed by sufficient supply at the national level. Accessibility generally refers to economic factors such as household income, expenditure and food prices. In the Pacific context, the fact that sweet potato can grow non-seasonally and is available all year, is able to tolerate some pests and diseases and can be farmed close to the house enables communities to access the sweet potato for food when needed. Furthermore, the involvement of women, children and men in cultivating sweet potato increases the accessibility of the crop. Households can also sell sweet potato to obtain income to purchase other food to diversify their diet.

Utilization refers to the ability of the body to utilize the nutrients in food. This includes the nutrition and health benefits of consuming sweet potato. It is well documented that consuming orange sweet potato reduces vitamin A deficiency in women and children in Uganda and other Sub-Saharan African countries (Haskell et al., 2017; Low et al., 2017). Orange sweet potato roots are rich in bioavailable beta-carotene, vitamin C, K, E and several B vitamins (Lebot, 2010, 2017; Low et al., 2017). Some varieties in tropical countries such as PNG, Vanuatu and Melanesia have low sugar content as well as low glycemic index (Lebot, 2017).

Stability refers to the sustainability of the other three food security pillars. Having an adequate supply of food and being able to access and utilize that food can be interrupted on a periodic basis as a result of extreme weather events, political instability or other factors (FAO, 2008). Sweet potato with its resilience and its ability to grow quickly ensures people have access to food before, during and after disaster events. As further explained later in this paper, the overlapping roles of many sweet potato varieties help to fill the "gap" in traditional food production systems in Pacific Island Countries, making sweet potato a very important crop for food security stability.

Table 1
Features of sweet potato that enhance its role in food security in the Pacific Islands: NOTE: these are general features but not specific to a variety. Not all varieties of sweet potato have these features however, the accumulated and overlapping features of sweet potato varieties make it useful for food security.

	Sweet potato features	Food security pillars	Key References
1	Can be produced on soil with moderate or low fertility	AV, ST, AC	(Yen, 1974, 1982; Bourke, 1985; Bouwkamp, 1985; Allen, 2005; McGregor et al., 2016a, 2016b)
2	Tolerant to mild droughts	AV, ST	(Allen and Bourke, 2001; Bourke, 2005a; Wallin et al., 2005a, 2005b; FAO, 2010; McGregor et al., 2016a, 2016b)
3	High tolerance to pests and diseases	AV, ST	(Bourke, 1985, 2005b; Bouwkamp, 1985)
4	Can be planted and harvested all year round (non-seasonal growth)	AV, ST	(Yen, 1974; Ballard, 2005; Bourke, 2005b)
5	Easily propagated and easy to obtain planting materials	AV, AC	(Bourke, 1982, 2005a; Bouwkamp, 1985)
6	Limited association with rituals in PNG (can be planted and harvested by women, children)	AV, UT/NT/SC	(Leach, 2005; Wiessner, 2005)
7	Can grow in high altitudes (up to 2800 m) and has a high temperature range tolerance	AV, AC, ST	(Bourke, 1982, 2005a; Lebot, 2010)
8	Produces higher yield than taro	AV	(Bourke, 1982, 2005a; Wallin et al., 2005a, 2005b)
9	High tolerance for rainfall range	AV, ST	(Bourke, 2005a; McGregor et al., 2016a, 2016b)
10	Can survive mild frost	AV, ST	(Bourke, 1982, 2005a; Allen and Bourke, 2001)
11	Resilient against cyclone impacts	AV, ST	(Wairiu, Lal and Iese, 2012)
12	Can produce acceptable yield with intensified land use due to population growth	AV, AC	(Bourke, 2005a; Allen, 2015)
13	Short and flexible growing season (can be harvested three times a year)	AV	(Yen, 1974; Ballard, 2005; Bourke, 2005b)
14	Whole plant is edible for humans and livestock	UT/NT/SC	(Bourke, 2005a; FAO, 2010; Johnson and Pace, 2010; Chueyen and Eun, 2013; Iese et al., 2015; Motsa et al., 2015)
15	Highly nutritious (orange-fleshed types contain high amount of pro-vitamin A)	UT/NT/SC	(Bouwkamp, 1985; FAO, 2010; Chueyen and Eun, 2013; Iese et al., 2016; McGregor et al., 2016a, 2016b; de Brauw et al., 2017; Lebot, 2017)
16	Can be harvested progressively (can harvest a few storage roots and leave the rest to continue bulking)	UT/NT/SC, AC	(Bourke, 2005a; Allen, 2015)
17	Can be stored for a long period	AV, AC	(Bourke, 1982, 2005a; Green, 2005; Leach, 2005)
18	Easily processed into value-added products	UT/NT/SC	(Nelson and Elevitch, 2011; McGregor et al., 2016a, 2016b)
19	Can be consumed raw by humans	UT/NT/SC	(Tromp and Dudgeon, 2012)
20	Can be rotated and intercropped with many other crops and trees	AV, AC, ST	(Thaman, 1990; Bourke, 2005a; Allen, 2015; Iese et al., 2015; Taylor et al., 2016a, 2016b)

AV = availability; AC = accessibility; ST = Stability; UT = utilization (including NT (nutrition) and SC (socio-cultural uses)).

3. Sweet potato, food security and disaster risk reduction in the past in Pacific Islands

3.1. Agents of historical distribution

The origin and distribution of sweet potato in Pacific Island Countries has been widely researched and well documented (see O'Brien, 1972; Yen, 1974, 1982; Villareal, 1982; Ballard, 2005; Coil and Kirch, 2005a, 2005b; Green, 2005; Ladefoged et al., 2005; Leach, 2005; Wallin et al., 2005a, 2005b; Montenegro et al., 2008; Wenda, 2012; Roullier et al., 2013a, 2013b, 2013c). Although a minority of researchers contend that sweet potato was distributed throughout the Pacific by birds and ocean currents (Montenegro et al., 2008), all convincing evidence points to the deliberate distribution and adoption of sweet potato. Sweet potato originated in Central America and made its way to the Pacific Islands through the early Polynesians (kumara line) and the early European explorers (Camote and Batatas lines). Maps detailing the distribution routes of sweet potato are presented by Yen (1974, 1982), Allen (2005), Green (2005) and Roullier et al. (2013a, 2013b, 2013c). Apart from the early Polynesian and European explorers, other actors involved in the distribution of sweet potato included missionaries, whalers and traders, exchange teachers, returned students, plantation laborers and soldiers during the Second World War. Colonial agricultural intensification programs also played a role in the distribution of sweet potato.

3.2. Historical role of sweet potato in reducing food insecurity (pre-1970)

The food security that sweet potato helped to provide was centrally important to the cultural evolution and population expansion of many Pacific Island Countries. Sweet potato became dominant in the food systems of the highlands of Papua New Guinea because of its ability to grow up to 2,800 m altitude, produce high storage root yields and tolerate mild droughts and frosts (Bourke, 2005a). The ready availability of sweet potato caused an expansion of the population and an increase in the geographical spread of settlements, enabling people to settle in areas of higher altitude. The role of sweet potato in both enabling the formation of settlements in these areas and connecting people in these settlements is recognised and celebrated in rituals in Papua New Guinea (Wiessner, 2005). Sweet potato also features in Maori mythology because of its central role in enhancing food security through its ability to be stored and preserved for winter (Leach, 2005). In Rapa Nui (Easter Island) sweet potato replaced taro and yam and became the main staple food because of its tolerance to drought (Wallin et al., 2005a, 2005b; Tromp and Dudgeon, 2012). The food surplus created through sweet potato cultivation supported Rapa Nui's population expansion and enabled the construction of the "*moai*" monuments. Hawaiians favored sweet potato because of its ability to grow in arid environments and rotate well with traditional staples (Coil and Kirch, 2005a, 2005b; Ladefoged et al., 2005). In Kahikinui - a leeward and young volcanic soil area in Maui, Hawaii - sweet potato was the only crop that would grow. Sweet potato facilitated a high population increase, leading some to call Kahikinui an "Ipomoean landscape". Because of its significance, strong rituals surround the planting, growing and harvesting of sweet potato in Kahikinui.

3.3. Historical role of sweet potato in disaster recovery

Sweet potato has also played an important recovery role following disasters in the Pacific Islands. Two missionaries introduced sweet potato to the Cook Islands from Tahiti in 1832 as a recovery crop after a cyclone hit in 1831. Unfortunately, the Rarotongans did not want to cultivate the crop for their own use, but they were motivated to plant sweet potato when the missionaries demonstrated its value as a trading commodity with whalers and traders. When another cyclone hit in 1846, the sweet potato that was initially planted for trading helped to relieve food shortages, demonstrating its use-value (Green, 2005). Sweet potato has also played an important role in reducing famine following droughts in Papua New Guinea. For example, the adoption of sweet potato and increased rice imports reduced drought related famines in the Trobriand Islands in the early 1900s (Allen, 2005). Sweet potato also reduced the impacts of droughts in Goodenough Island, Papua New Guinea where it was planted in time to harvest during the “season of scarcity” and fill the “gap” created by the vulnerability of seasonal staple crops (Allen, 2015). Sweet potato was also quickly adopted around Papua New Guinea and the Solomon Islands as a staple food crop after taro production was severely affected by taro leaf blight and other pests and diseases in the 1940s to 1950s (Allen, 2005; Bourke, 2005b; Evans, 2006; Wairiu et al., 2012; Iese et al., 2015). In the 1970s, sweet potato was increasingly used as a strategy in processes of agriculture intensification, leading to increased production for food security and income generation purposes in Pacific Island Countries. The favorable agro-ecological features of sweet potato ensured that communities were able to access and utilize nutritious food before, during and after hazards. Unfortunately, the historical modes and agents of distribution of sweet potato were more informal than today, increasing the incidence of pests and diseases.

3.4. The role of sweet potato in the traditional food system in Pacific Island Countries

The traditional food system in Pacific Island Countries is designed such that traditional staple crops and trees provide an all-year-round supply of food (Thaman, 1990; FAO, 2008, 2010; Allen, 2015). For example, breadfruit and wild nuts provide food when yam and taro are in transition between the planting and harvesting seasons. Unfortunately, this traditional food system is very vulnerable to climatic and environmental changes (Barnett, 2011). The high dependence on rainfall for planting of some traditional crops means communities are unable to plant them when the rainfall shifts or is reduced for a prolonged period. In addition, normal fruiting seasons for some important food security trees are during the cyclone or “bad weather” season in the Pacific Islands, increasing the risk of fruits being damaged and wasted (Wairiu et al., 2012; Allen, 2015; Sisifa et al., 2016). These factors can create a “gap” in the traditional Pacific food supply systems when availability or accessibility is reduced. Uncontrolled pests and diseases impact on traditional staples widening this food security “gap”. Addressing this gap is paramount to achieving food security. Sweet potato has been instrumental in reducing this food supply gap in the food systems of many Pacific Island Countries.

4. Sweet potato, food security and disaster risk reduction in the present

4.1. International, regional and national mechanisms promoting distribution

The role of sweet potato as a critical risk reduction and food security crop continues in Pacific Island Countries in the present. The features of sweet potato that drove its distribution and adoption in the past are still facilitating its distribution and cultivation in the present day. However, the means of distribution has changed slightly: international, regional and national mechanisms have been put in place over recent decades to facilitate the safe documentation, collection, distribution and evaluation of plant genetic resources including sweet potato in the Pacific. This has been critical in reducing the risks of pests and diseases spreading through uncontrolled and informal methods of sweet potato distribution.

More than two decades ago (in 1996) Pacific agricultural ministers called for the development of a regional strategy for the safe collection and distribution of plant genetic resources (APAARI, 2011). This call was in response to the loss of plant biodiversity from a severe outbreak of taro leaf blight in Samoa in 1993. A strategy was developed and put in place with support from development partners (donors), regional organizations, national governments, farmers and non-government partners. From the late 1980s to the early 2000s the European Union funded a series of projects focused on understanding the benefits of tissue culture and collecting accessions of sweet potato, yam, taro and cassava from Pacific Island Countries. These were conserved at facilities at the University of the South Pacific, Alafua Campus in Samoa. The crop varieties at Alafua Campus were used for breeding and multiplication and were then distributed to Pacific Island Countries for field evaluation. Funds from the Australian Agency for International Development (AusAID) established the Regional Germplasm Centre – which later changed to the Centre for Pacific Crops and Trees (CePaCT), hosted by the Pacific Community (SPC) in Fiji.

The Pacific Community is the leading regional agency in implementing plant genetic resources strategies and is crucial in coordinating and providing technical and capacity support for countries in the region. The establishment of national focal points on plant genetic resources has also been crucial to the success of this strategy. In addition, the FAO International Treaty for Plant Genetic Resources for Food and Agriculture (ITPGRFA), which was adopted in 2001 and put in force in 2004, has been important for facilitating the conservation and sustainable use of plant genetic resources and facilitating access by member countries to the genetic materials of the 64 crops in the multilateral system for research, breeding and training for food and agriculture.

Through these mechanisms, the Pacific Islands have received many resilient and useful sweet potato varieties from regions such as the USA, South America, Asia, Europe, Africa and the Caribbean. Key sweet potato research areas in the Pacific such as Papua New Guinea, Solomon Islands, Vanuatu, Samoa, Tonga, and Cook Islands have contributed the most to the sweet potato collection at CePaCT. The countries that have contributed to the CePaCT collection in Fiji are shown in Fig. 1.

The establishment of national mechanisms with strong links to regional and international processes and facilities has been a factor contributing to the ability of Pacific Island Countries to increase sweet potato production and cement sweet potato's continuing food security role in Pacific Island Countries. It has also been critical in assisting the Pacific region to adapt to climate change and other challenges. Increasing concern due to climate change led to the establishment of the "climate ready collection" funded by the Australian Aid Program. For sweet potato, the “climate ready collection” focuses on varieties with properties that are tolerant to the observed and projected impacts of climate change in the Pacific (especially salt tolerance, drought tolerance and tolerance against water logging) (Tuia et al., 2012; Sisifa et al., 2016).

Between 2000 and 2014 there was a total of 166 varieties of sweet potato distributed to Pacific Island Countries (Fig. 2). Most of the sweet potato varieties originated from Papua New Guinea (50 varieties), Solomon Islands (28 varieties), USA (20 varieties) and Peru (13 varieties). These were varieties produced through breeding programs, evaluated and considered as resilient in their countries of origin. These varieties still need to be evaluated in the government research stations of Pacific Island Countries before distributing to farmers. There were 1332 different plants of sweet potato distributed from CePaCT to Pacific Island Countries over this time period (Fig. 2). About 25.7% of plants distributed were drought tolerant varieties, 9% were salt tolerant varieties, 0.8% were varieties tolerant to water logging and 1.1% were distributed because of flesh color (nutrition). About 63% were distributed based on other features such as short and flexible growing season, resistance to pests and diseases, good eating, high dry matter and low sugar content, marketability and so forth.

Almost all Pacific Island Countries received drought tolerant sweet

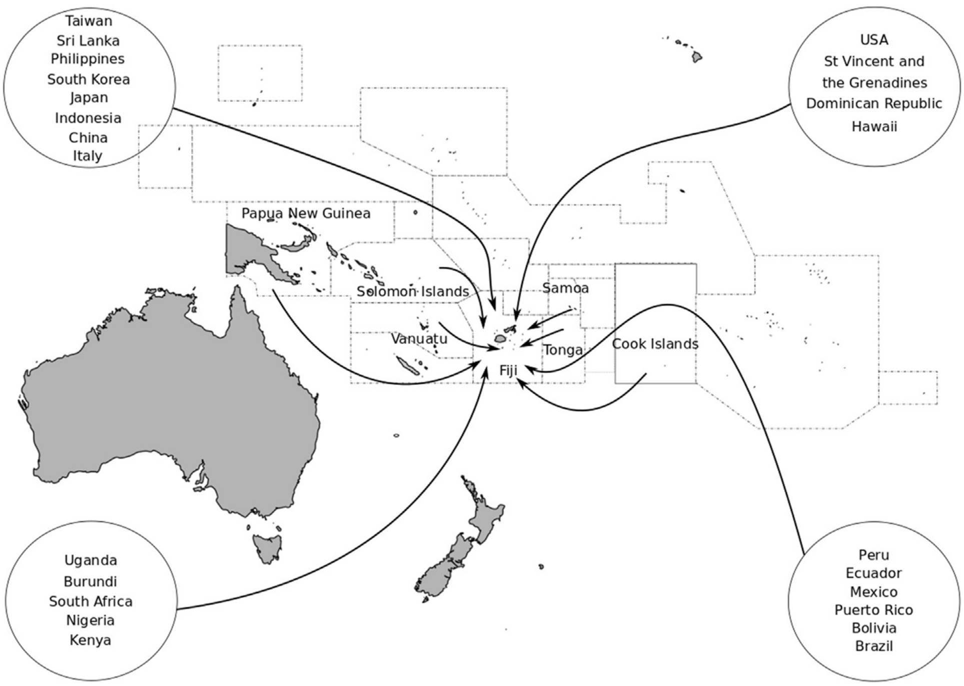

Fig. 1. Map of Pacific showing the countries where 166 varieties of sweet potato distributed by CePaCT between 2000 and 2014 originated. Drawn from data provided by the Pacific Community. NOTE: This map only shows the sources of varieties that are conserved at CePaCT germplasm centre in Fiji. It does not show many sweet potato varieties from Pacific Island Countries (PNG, Fiji) that are currently stored in other regional germplasm and research centres in the world.

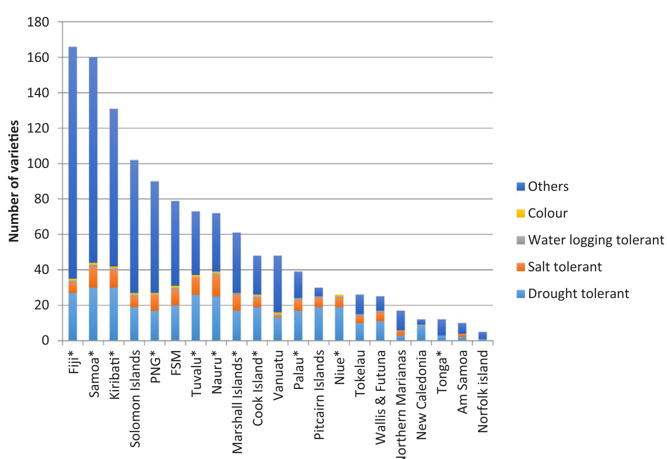

Fig. 2. Number of sweet potato varieties with resilient and other characteristics distributed by CePaCT to Pacific Island Countries between 2000 and 2014. NOTE: resilient characteristics are not the result of evaluations in countries but rather the characteristics recorded by country of origin. *Contracting party for the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) as of 5/08/2017.

potato varieties. This is because Fiji and Western and Northern Pacific countries suffered severe droughts during recent El Niño Southern Oscillation (ENSO) events. Salt tolerant sweet potato plants were also widely distributed to alleviate the impacts of sea-level rise and storm surges on food systems in countries with atoll islands, low-lying islands and coastal communities.

The distribution of varieties from CePaCT to the national level is mainly through the respective agricultural ministries of governments. Food security non-government organizations also assist in distribution and trialing of plant genetic resources. Agriculture ministries usually conduct trials for the new varieties at their research stations before distributing them to farmers. They use demonstration farms at both agriculture research stations and in the field to showcase the good features of new varieties. Farmers themselves are also very influential in distributing varieties between demonstration plots and farm field sites. Unfortunately, there is limited documentation on the performance of new varieties of sweet potato from field trials, evaluations and adoption by farmers.

5. Evaluating the adoption of sweet potato in Pacific Island Countries: Project case studies

> *"Acceptability depended on the willingness of the gardener to fit a new crop into his various plots and of the cook to fit a new food into the menu. The gardener needed to know how to propagate the plant, what spacing it required, its moisture needs and when it is ready for harvest. The cook had to know which parts were edible, and when, how to process them, and for how long."* (Leach, 2005)

There is a lack of studies evaluating the adoption of resilient sweet potato varieties in Pacific Island Countries. Nevertheless, several case studies from regional projects highlight sweet potato's success in enhancing food security, livelihood and tolerance against sudden and slow onset impacts of climate change and other natural hazards. The Development of Sustainable Agriculture in the Pacific Project (DSAP), funded by the European Union in mid-2000, identified distribution and adoption of sweet potato in Pacific Island Countries as a key strategy for enhancing sustainable agriculture. In the Republic of the Marshall Islands (RMI), sweet potato was promoted because of its ability to develop a full canopy quickly, thereby reducing the potential for moisture loss on the sandy atoll soils of Majuro, the capital of the RMI. The evident benefits of sweet potato demonstrated through this project have led to its widespread adoption. Sweet potato has now become a staple crop (together with breadfruit) for communities in Majuro (Edmond, 2009). In Kiribati, the same project facilitated a competition to plant crops including sweet potato to improve the health of rural communities on Marakei Island in Kiribati. The outcome of this competition speaks for itself, with sweet potato now a popular crop in Marakei (Bakineti et al., 2009). In Nauru, DSAP focused on planting sweet potato alongside taro and other vegetables to increase local vegetable production for food and income security. The project was successful in increasing local food production, and is helping to buffer against the high cost of imports (Kun, 2009). For all of these projects, sweet potato varieties were transferred from the "climate ready" collection within CePaCT and transplanted and distributed to farmers for on-field evaluation and adoption.

Another major regional project focusing on food security was the Pacific Adaptation to Climate Change (PACC) Program, which covered 14 Pacific Island Countries. Four countries (Fiji, PNG, Solomon Islands and Palau) adopted a "no-regrets" approach to adaptation for agriculture and food security. As previously mentioned, the "no regrets" approach to decision-making focuses on adaptation activities that are likely to result in beneficial outcomes regardless of whether or not (or to what extent) climate change impacts and other natural hazards occur. Such approaches focus on expanding choices, spreading risk and building overall resilience to present climate variability and future climate risks.

The approach focused on supporting the distribution and adoption of sweet potato varieties from the CePaCT climate-ready collection, especially varieties resilient to drought, saltwater inundation and water logging. Several orange-fleshed varieties that are tolerant to water-logging and salt-water inundation were released in Fiji and Palau. The targeted varieties in Solomon Islands and Papua New Guinea were mainly yellow-orange fleshed drought tolerant varieties (SPREP, 2014).

Other project activities that have increased the cultivation of sweet potato for food security risk reduction in Pacific Countries include the Adaptation Fund project Enhancing Resilience of Communities in Solomon Islands to the Adverse Effects of Climate Change in Agriculture and Food Security; the University of the South Pacific and European Union Global Climate Change Alliance (USP-EU-GCCA) food security project in Vanuatu; the International Fund for Agriculture Development (IFAD) Tonga Rural Development Project (TRIP) implemented by Mainstreaming of Rural Development Innovation Tonga Trust (MORDI TT); and the Live and Learn Environmental Education food security programs in Kiribati, Vanuatu, Solomon Islands and Tonga. Alongside the formal mechanisms above, farmer-to-farmer exchange is an important method of distribution, and crucial for adoption of new sweet potato varieties in Pacific Island Countries. Farmers have also been crucial in supporting field trials to evaluate sweet potato varieties as part of the formal projects and mechanisms mentioned above.

During disaster recovery operations, distribution of sweet potato planting materials to affected farmers is an increasingly prioritized action by the national and regional food security clusters. Sweet potato is the main choice because of its short and flexible growing season, high nutrition value, and its ability to grow in a wide variety of environments (see Table 1). In post-disaster situations, sweet potato can provide food, income (from surplus supply) and feed for livestock. For example, more than 49,100 sweet potato cuttings were distributed with vegetable seeds to affected farmers in Fiji Islands after the severe Tropical Cyclone Winston struck in 2016 (Food Security and Livelihood Cluster, 2017). After Tropical Cyclone Ian hit Tonga in 2014, about 20,000 sweet potato planting materials were distributed to affected farmers. These 20,000 sweet potato planting materials were used to plant and produce more planting materials for farmers to use in their recovery. A private sector partner Nishi Trading Ltd donated a tractor to prepare the land for women to cultivate sweet potato for food security recovery at Ha'apai Island. After 3 months, 12 t of yield was harvested and 80,000 new sweet potato planting materials were available for distribution. These sweet potato planting materials (vine cuttings) were sourced from the Ministry of Agriculture and farms that were located away from the routes of the tropical cyclones. The poor condition of sweet potato planting materials during prolonged droughts is a key challenge for this post-disaster strategy. Some suggestions to improve sweet potato planting materials before, during and after prolonged droughts are discussed in the later part of this paper.

In several Pacific Island Countries such as Fiji, Papua New Guinea and the Solomon Islands, sweet potato production has increased significantly over the past three to four decades (see Fig. 3). This is likely due to distribution of high yield, virus free and disease free planting materials to these countries. These countries received a high number of varieties categorized as 'others', as shown in Fig. 2. On the other hand, production in Tonga and Niue decreased in the 1980s as farmers were reluctant to plant sweet potato due to the impacts of weevil pest and scab disease. Sweet potato production started to recover after a sweet potato breeding program produced resistant varieties in Tonga. Production in the Cook Islands has significantly declined, most likely due to the high migration rate to New Zealand. Whilst there are numerous factors that may have contributed to the increased production of sweet potato over recent decades in Fiji, Papua New Guinea and the Solomon Islands (e.g. increased demand driven by population increase), the ability of countries to be able to meet this demand by increasing production of sweet potato is likely at least partly due to the ability of countries to access disease free planting materials, facilitated by the strategies, mechanisms and policies described above. It may also be the result of sweet potato replacing other staple crops such as taro, as the resilient characteristics and health benefits of sweet potato become more valuable in an increasingly unstable climate.

6. The role of sweet potato in addressing climate change challenges

The central importance of sweet potato as a food security and disaster risk reduction crop in the past and present is clear. However, the question remains: will the currently available varieties of sweet potato continue to be useful for the future? Sweet potato, despite its resilient features, can be vulnerable to pests, diseases and impacts of climate change. Moreover, whilst specific varieties are tolerant to specific impacts (e.g. water logging), it is unclear how different sweet potato varieties will cope with projected increases in the intensity and frequency of multiple hazards. Sweet potato production declined around the late-1980s and mid-1990s in some Pacific Island Countries (see for example Niue, Tonga and the Cook Islands in Fig. 3 above). This was probably due to the incidence of pests and diseases (Jackson, 2003). Sweet potato varieties distributed around this time were not stable and therefore performed poorly after three to four years. This was also observed in Uganda mainly due to the accumulated impacts of virus disease from continuous planting of sweet potato from asexually propagated virus infected plant materials (Adikini et al., 2015). To respond, farmers switched to new and improved varieties, facilitated by a constant supply from national, regional or internationally funded projects. Whilst this addressed the issue temporarily, the continuous re-supplying of varieties is expensive, time consuming and requires continuous breeding, selection and production of new, virus-free seeds for distribution.

There are a limited number of studies that have explored the impacts of extreme events and climate change on sweet potato production in Pacific Island Countries (see Bourke, 1982, 2005a; FAO, 2008; Wairiu et al., 2012; McGregor et al., 2016a, 2016b). These studies suggest that climate change is indeed impacting production; Extreme droughts have reduced the yield of sweet potato and increased the incidence of weevil (*Cylas formicarius*) infestation. Excess water logging and soil moisture encourages above-ground growth but reduces growth of the storage root. Sweet potato has also been impacted by severe frosts as experienced in the highlands of Papua New Guinea, and has been affected by salinity, although the extent of these impacts is not clear. More detailed information on impacts of climate change and extreme events on sweet potato are provided by Allen and Bourke (2001), Bourke (2005a), Iese et al. (2015) and McGregor et al. (2016a, 2016b).

6.1. *Future perspectives for sweet potato resilience in Pacific Island Countries*

Sweet potato shows promise to be an important crop to reduce food insecurity in the Pacific Islands in the future. However, there are strategic interventions needed in Pacific Island Countries to build the resilience of food systems and continue to ensure sweet potato remains a key crop for the future. Sweet potato research for development must be

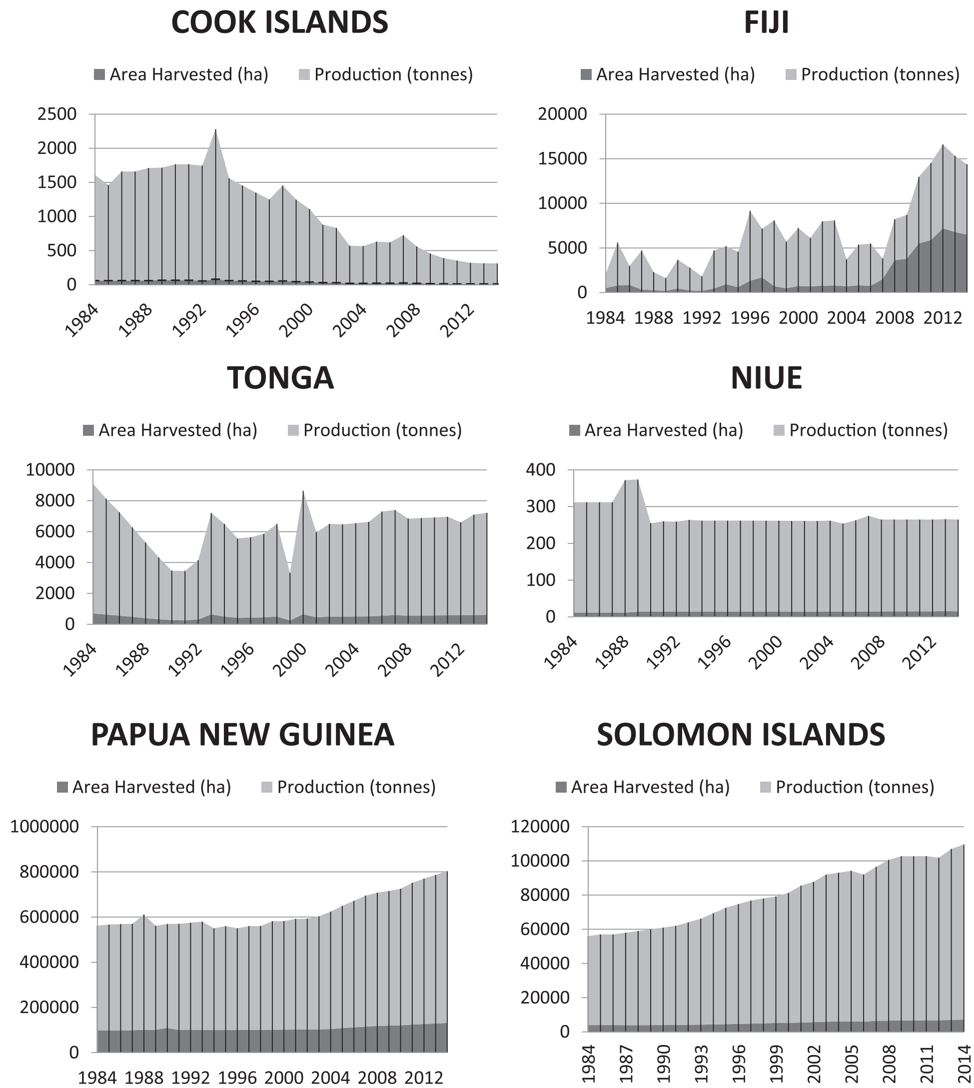

Fig. 3. Estimated and recorded 30 year (1984–2014) sweet potato production in 6 Pacific Island Countries. Adapted from FAOSTAT. NOTE: Sweet potato production estimates from FAOSTAT for PNG seem to be significantly underestimated. The estimated production in 2000 was 2.9 million t (Bourke,pers. comm 2017).

re-energized as a key regional priority. A vast body of knowledge about sweet potato was accumulated during the sweet potato research-active era of the 1970s and 1980s. The resilient and suitable varieties Pacific Island Countries are using for food security and adaptation now were probably researched, bred and evaluated more than 20 years ago. Pacific strategies should have the foresight to establish future climate change scenario based approaches. There is high confidence that the sea level is continuing to rise, extreme events will continue to increase in intensity and frequency, salt water inundation and intrusion will continue to affect limited arable lands and pests and diseases will increase (Lough et al., 2016; Taylor et al., 2016a, 2016b). Population growth will also continue, adding significant demand for food and placing pressure on land and other resources.

Support is needed to strengthen and expand national, regional and international mechanisms for management, conservation and utilization of plant genetic resources. More proactive and well-designed field evaluation mechanisms need to be implemented in order to select vigorous, stable, resilient and nutritious sweet potato varieties for specific communities. More research is also needed into the diversification and added value of sweet potato products to encourage the private sector. Collaborations between the private sector, farmers and non- government organizations in research and extension services should be a key strategic direction for the Pacific Islands.

There are few active research programs on sweet potato in the Pacific. The most active programs are in PNG and Vanuatu. These include a research program to estimate genotypic variability of agronomic traits for selection in sweet potato polycross, which is being carried out by the National Agriculture and Research Institute (NARI) in PNG (Wera et al., 2014) and an ongoing research program on developing methods to study sugar content and nutrition in sweet potato in Vanuatu (Lebot et al., 2016; Lebot, 2017).

By contrast, there have been many sweet potato focused research activities in Africa that could benefit the Pacific Islands and other Small Island States. A very good example of this is the Biofortification Program, which involved breeding staple crops, including sweet potato, to increase micronutrient content. The orange sweet potato produced from this program has proven successful in reducing Vitamin A deficiency in Uganda and Kenya (Andersson et al., 2017; Andrade et al., 2017; Low et al., 2017). The Accelerated Breeding Scheme (ABS) that successfully shortened the breeding time to produce a new variety from 7–8 years to 4–5 years could benefit the Pacific Island Countries. This breeding program produced orange-fleshed sweet potato and fifteen drought tolerant varieties in Mozambique between 2010 and 2015 (Low et al., 2017). The Pacific Island Region should instigate a regional or multi-regional (Africa, Caribbean, Pacific) accelerated breeding scheme to produce salt tolerant, drought tolerant and more pest and disease resistant sweet potato varieties. There is also a need for Pacific Islands to develop a proper model for distribution of new varieties and have a good adoption research approach to evaluate the impacts of sweet potato distributed from CePaCT and other national centres on household food security. A good example of such a project was conducted in Africa by de Brauw et al. (2017) and Low et al. (2017).

Furthermore, as droughts have significant impacts on planting material supplies in Pacific Island Countries, there is a need to trial safe seed production approaches and Triple S technology that was successfully adopted in sub-Saharan Africa (SASHA, 2009, 2015). The Triple S technology involves storing of sweet potato in sand during drought months and then sprouting them after drought to produce clean planting materials for farmers to plant. About 82% of roots stored in sand successfully sprouted after four months of storage. This method is a simple and cost-effective way of conserving and multiplying clean sweet potato planting materials (SASHA, 2015). This would enable a more effective response and recovery after prolonged droughts. Pacific Island Countries could also benefit from trainings on how to access and use the Sweet Potato Knowledge Portal to exchange information, technology and advice between Pacific Island Countries, Africa and other sweet potato producing regions. These could be complemented by efforts to document, collect and characterize existing PNG landraces that could be useful for future breeding programs. This is important as PNG is also considered as a secondary centre of genetic diversity for sweet potato. These landraces plus other Pacific traditional varieties should be conserved in regional and global germplasm centres.

Research for physiological and genetic pathways for drought, frost, waterlogging and salinity tolerance should be revisited in the Pacific. Evaluations and testing are needed to develop an understanding of the real level of tolerance of sweet potato varieties stored in CePaCT's climate ready collection. This can be achieved through active field evaluations of different varieties to document tolerance against water stress or drought, salinity and combinations of environmental variables. New research should also include the impacts of increasing carbon dioxide, temperature and synergistic interactions between stress variables on sweet potato growth, development, carotenoid accumulation, behavior and yield. One key research strategy for building this knowledge is through the development, validation and application of sweet potato crop models that can simulate the yield stability of different varieties in relation to soils, microclimates and farm management techniques. Another key research strategy is the documentation and sharing of proven adaptive practices employed by farmers, field researchers, agriculture officers and research organizations. Consultation and engagement with farmers, universities, research institutes, donors and non-government organizations in participatory research will help to ensure that research in this area meets the needs of all stakeholders.

7. Conclusion

The distribution and adoption of sweet potato in the Pacific Islands demonstrates the culture of resilience of Pacific communities. Pacific Islanders have chosen to cultivate sweet potato in the past and present because it plays a critical role in the traditional food system and fills food supply gaps created by agro-ecological stressors such as pests and diseases, variable rainfall, and extreme events. In the future, global climate change will continue to exacerbate food insecurity, increasing demand for resilient nutritious food sources such as sweet potato. Pacific Island communities were innovative more than 100 years ago in adopting new varieties and cropping systems to improve food security against global and local environmental, social, economic and climatic stressors. There is a need for Pacific Island Countries to once again demonstrate this culture of resilience by developing future-focused strategies to mobilize and utilize resources, knowledge, skills and strong partnerships for food security resilience.

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None.

References

Adikini, S., et al., 2015. Sweet potato cultivar degeneration rate under high and low sweet potato virus disease pressure zones in Uganda. Can. J. Plant Pathol. 37 (1), 136–147. https://doi.org/10.1080/07060661.2015.1004111.
Allen, M.G., 2005. The evidence for sweet potato in Island Melanesia. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 99–108.
Allen, M.G., 2015. Framing Food Security in the Pacific Islands: Empirical Evidence from an Island in the Western Pacific, Regional Environmental Change. 15. Springer Berlin Heidelberg, Berlin, Heidelberg, Germany, pp. 1341–1353.
Allen, B.J., Bourke, R.M., 2001. The 1997 Drought and Frost in PNG: Overview and Policy Implications', Food Security for Papua New Guinea. In: Proceedings of the Papua New Guinea Food and Nutrition 2000 Conference, (Papua New Guinea University of Technology, Lae), pp. 155–163.
Andersson, M., et al., 2017. Progress update: crop development of biofortified staple food crops under Harvest Plus. Afr. J. Food Agric. Nutr. Dev. 17 (2), 11905–11935. https://doi.org/10.18697/ajfand.78.HarvestPlus05.
Andrade, M.I., et al., 2017. Release of orange-fleshed sweetpotato (Ipomoea batatas [l.] Lam.) cultivars in Mozambique through an accelerated breeding scheme. J. Agric. Sci. 155 (6), 919–929. https://doi.org/10.1017/S002185961600099X.
APAARI, 2011. Strengthening of Plant Genetic Resources for Food and Agriculture: Conservation and Utilization in the Pacific. A Status Report. Asia-Pacific Association of Agriculture ResearchInstitutions (APAARI), Bangkok, Thailand.
Bakineti, T., Timon, B., Maio, T., 2009. Kiribati: investing in our future. In: Case Studies Lessons from the Field the DSAP Experience. Noumea, New Caledonia: Secretariat of the Pacific Community, pp. 42–51. ⟨10.1097/MLR.0b013e3182239331⟩.
Ballard, C., 2005. Still good to think with: the sweet potato in Oceania. In: Ballard, C. et al. (eds) The Sweet Potato In Oceania: A Reappraisal. Sydney and Pittsburgh, pp. 1–14.
Barnett, J., 2011. Dangerous climate change in the Pacific Islands: food production and food security. Reg. Environ. Change 11 (Suppl. 1), 229–237. https://doi.org/10.1007/s10113-010-0160-2.
Bourke, R.M., 1982. Sweet potato in Papua New Guinea. In: Villareal, R.L., Griggs, T.D. (Eds.), Sweet Potato: Proceedings of the First International Symposium. Asian Vegetable Research and Development Centre, Taiwan, pp. 45–58.
Bourke, R.M., 1985. Sweet potato (Ipomoea batatas) production and research in Papua New Guinea. Papua New Guin. J. Agric. For. Fish. 33 (3–4), 89–108.
Bourke, R.M., 1999. Vanuatu Agriculture System Survey - April - May. Canberra, Australia.
Bourke, R.M., 2005a. Sweet potato in Papua New Guinea: the plant and people. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 15–24.
Bourke, R.M., 2005b. The continuing Ipomoean Revolution in Papua New Guinea. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 171–179.
Bourke, R.M.et al., 2006. Main Findings - Solomon Islands Smallholder Agriculture Study, Volume 1. Canberra, Australia.
Bourke, R.M., Vlassa, V., 2004. Estimates of Food Crop Production in Papua New Guinea. Land Management Group, The Australian National University, Canberra, Australia.
Bouwkamp, J., 1985. Introduction. In: Bouwkamp, J. (Ed.), Sweet Potato Products: A Natural Resource for the Tropics. CRC Press, Florida, USA, pp. 9.
de Brauw, A., Gilligan, D.O., Low, J., 2017. Introducing organge sweet potato: tracing the evolution of evidence on its effectivness. Afr. J. Food Agric. Nutr. Dev. 17 (2), 12106–12115. https://doi.org/10.18697/ajfand.78.HarvestPlus15.
Chueyen, H.V., Eun, J.-B., 2013. Nutritional quality of foods: sweet potato. In: Preedy, V.R., Hunter, L., Patel, V.B. (Eds.), Diet Quality: An Evidence-based Approach. Springer Science + Business Media, New York, pp. 243–256. https://doi.org/10.1007/978-1-4614-7339-8.
Coil, J., Kirch, P.V., 2005a. An Ipomoean landscape: archaeology and the sweet potato in Kahikinui, Maui, Hawaii Islands. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 71–84.
Coil, J., Kirch, P.V., 2005b. An Ipomoean landscape: archeology and the sweet potato in Kahikinui, Maui, Hawaiian Islands. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 71–84.
Edmond, B., 2009. Republic of Marshall Islands: sweet potatoes a potential crop for Majuro Atoll. In: Case Studies Lessons from the Field the DSAP Experience. Secretariat of the Pacific Community, Noumea, New Caledonia, pp. 52–55.
Evans, B.R., 2006. Solomon Islands Smallholder Agriculture Study: Literature Review: A

Brief National Assessment of the Agriculture Sector. AusAID, Canberra, Australia (Available at ⟨http://www.ausaid.gov.au/publications/pdf/solomon_study_vol5.pdf⟩).
FAO, 2010. Pacific Food Security Toolkit: Builing resilience to climate change; root crop and fishery production. Rome, Italy. Available at: ⟨http://www.fao.org/docrep/013/am014e/am014e04.pdf⟩.
FAO, 2008. Climate Change and Food Security in Pacific Island Countries. Available at ⟨http://www.fao.org/climatechange/17003-02529d2a5afee62cce0e70d2d38e1e273.pdf%5Cnhttp://www.gbrmpa.gov.au/__data/assets/pdf_file/0016/4444/chpt-3-Steinberg-2007.pdf⟩.
FAOSTAT, 2016. ⟨www.fao.org/faostat/en/#home⟩. Accessed 23rd August 2017.
Food Security and Livelihood Cluster, 2017. Seed and planting material distribution for Severe Tropical Winston recovery. Suva, Fiji.
Government of Solomon Islands, 2014. Solomon Islands: PACC Country Brief - Pacific Adaptation to Climate Change. Available at ⟨http://www.sprep.org/PACC-Countries/pacc-solomon-islands⟩.
Green, R.C., 2005c. Sweet potato transfers in Polynesian prehistory. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 43–62.
Haskell, M., et al., 2017. Effect of regular consumption of provitamin A biofortified staple crops on Vitamin A status in populations in low-income countries. Afr. J. Food Agric. Nutr. Dev. 17 (2), 11865–11878. https://doi.org/10.18697/ajfand.78.HarvestPlus02.
Iese, V., et al., 2015. Farming adaptations to the impacts of climate change and extreme events in Pacific Island Countries. In: Ganpat, W.G., Isaac, W.-A.P. (Eds.), Impacts of Climate Change on Food Security in Small Island Developing States. IGI Global, United States of America, pp. 166–194. https://doi.org/10.4018/978-1-4666-6501-9.ch006.
Iese, V., et al., 2016. Food Security: Best Practices for the Pacific. Pacific Centre for Environment and Sustainable Development (PaCE-SD) and The University of the South Pacific (USP), Suva, Fiji. https://doi.org/10.1080/10357718.2012.658620.
Jackson, G.V.H., 2003. Sweet potato improvement in the Pacific: have we got the right strategy? In: Proceedings of PAPGREN Meeting: Focus on Sweet Potato. Nadi, Fiji, p. 6.
Johnson, M., Pace, R.D., 2010. Sweet potato leaves: properties and synergistic interactions that promote health and prevent disease. Nutr. Rev. 68 (10), 604–615.
Kun, P., 2009. Nauru: using simple technologies to promote vegetable growing. In: Case Studies Lessons from the Field the DSAP Experience. Secretariat of the Pacific Community, Noumea, New Caledonia, pp. 56–59.
Ladefoged, T.N., Graves, M.W., Coil, J.H., 2005. The introduction of sweet potato in Polynesia: early remains in Hawai'i. J. Polyn. Soc. 114 (4), 359–373.
Leach, H., 2005d. Ufi Kumara, the sweet potato as yam. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 63–70.
Lebot, V., 2010. Sweet potato. In: Bradshaw, J. (Ed.), Root and Tuber Crops: Handbook of Plant Breeding. Springer, New York, pp. 97–125. https://doi.org/10.1007/978-0-387-92765-7.
Lebot, V., 2017. Rapid quantitative determination of maltose and total sugars in sweet potato (Ipomoea batatas L. [Lam.]) varieties using HPTLC. J. Food Sci. Technol. 54, 718–726. https://doi.org/10.1007/s13197-017-2510-2.
Lebot, V., Michalet, S., Legendre, L., 2016. Identification and quantification of phenolic compounds responsible for the antioxidant activity of sweet potatoes with different flesh colours using high performance thin layer chromatography (HPTLC). J. Food Compos. Anal. 49, 94–101. https://doi.org/10.1016/j.jfca.2016.04.009.
Lough, J., et al., 2016. Observed and projected changes in surface climate of tropical Pacific Islands. In: Taylor, M., McGregor, A., Dawson, B. (Eds.), Vulnerability of Pacific Island Agriculture and Forestry to Climate Change. Pacific Community (SPC), Noumea, New Caledonia, pp. 47–102.
Low, J., et al., 2017. Sweet potato development and delivery in sub-Saharan Africa. Afr. J. Food Agric. Nutr. Dev. 17 (2), 11955–11972. https://doi.org/10.18697/ajfand.78.HarvestPlus07.
McGregor, A., et al., 2016a. Vulnerability of staple food crops to climate change. In: Taylor, M., McGregor, A., Dawson, B. (Eds.), Vulnerability of Pacific Island Agriculture and Forestry to Climate Change. Pacific Community (SPC), Noumea, New Caledonia, pp. 161–238.
McGregor, A., Fink, A., Dawson, B., 2016b. Implications of climate change for contributions by agriculture and forestry to Pacific Island economies and communities. In: Taylor, M., McGregor, A., Dawson, B. (Eds.), Vulnerability of Pacific Island Agriculture and Forestry to Climate Change. Pacific Community (SPC), Noumea, New Caledonia, pp. 447–482.
Montenegro, A., Avis, C., Weaver, A., 2008. Modeling the prehistoric arrival of the sweet potato in Polynesia. J. Archaeol. Sci. 35 (2), 355–367. https://doi.org/10.1016/j.jas.2007.04.004.
Motsa, N.M., Modi, A.T., Mabhaudhi, T., 2015. Sweet potato (Ipomoea batatas L.) as a drought tolerant and food security crop. S. Afr. J. Sci. 111 (11/12), 1–8.
Nelson, B.S.C., Elevitch, C., 2011. Farm and forestry production and marketing profile for sweetpotato (Ipomoea batatas). In: Elevitch, C.R. (ed.) Speciality Crops for Pacific Island Agroforestry: Permanent Agriculture Resources (PAR). Holualoa, Hawaii. Available at: ⟨http://agroforestry.net/scps⟩.
Nurse, L.A., et al., 2014. Small islands. In: Barros, V.R. (Ed.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, pp. 1613–1654.
O'Brien, P.J., 1972. The sweet potato: its origin and dispersal. Am. Anthropol. 74 (3), 342–365(Available at ⟨http://www.jstor.org/stable/671520⟩).
Roullier, C., Duputié, A., et al., 2013a. Disentangling the Origins of Cultivated Sweet Potato (Ipomoea batatas (L.) Lam.). PLoS One 8 (5).
Roullier, C., Benoit, L., McKey, Doyle B., Lebot, Vincent, et al., 2013b. Historical collections reveal patterns of diffusion of sweet potato in Oceania obscured by modern plant movements and recombination. Proc. Natl. Acad. Sci. USA 110 (6), 2205–2210.
Roullier, C., et al., 2013c. On the origin of sweet potato (Ipomoea batatas (L.) Lam.) genetic diversity in New Guinea, a secondary centre of diversity. Heredity 110 (6), 594–604(Available at ⟨http://www.ncbi.nlm.nih.gov/pubmed/23531982⟩).
SASHA, 2009. Sweet Potato Seed Systems: Training Manual for Farmers.
SASHA, 2015. From seed security to food security : validating 'Triple S' seed conservation technology in new contexts.
Sisifa, A., et al., 2016. Pacific communities, agriculture and climate change. In: Taylor, M., McGregor, A., Dawson, B. (Eds.), Vulnerability of Pacific Island Agriculture and Forestry to Climate Change. Pacific Community (SPC), Noumea, New Caledonia, pp. 5–46.
SPREP, 2014. Improving resilience of food systems. Available at: ⟨http://www.sprep.org/pacc/experiences⟩.
Sudradjat, A., 1997. Australia's Response to the 1997 PNG Drought the First Drought Assessment : Australia's Contribution to the, pp. 218–221.
Taylor, M., et al., 2016a. Adapting Pacific agriculture and forestry to climate change: management measures and investments. In: Taylor, M., McGregor, A., Dawson, B. (Eds.), Vulnerability of Pacific Island Agriculture and Forestry to Climate Change. Pacific Community (SPC), Noumea, New Caledonia, pp. 483–518.
Taylor, M., et al., 2016b. Agriculture and climate change: an overview. In: Taylor, M., McGregor, A., Dawson, B. (Eds.), Vulnerability of Pacific Island Agriculture and Forestry to Climate Change. Pacific Community (SPC), Noumea, New Caledonia, pp. 103–160.
Thaman, R.R., 1990. The evolution of the Fiji food system. In: Jansen, A.A.J., Parkinson, S., Robertson, A.F.S. (Eds.), Food and Nutrition in Fiji: A Historical Review. Volume One: Food Production, Composition and Intake. Department of Nutrition and Dietetics, Fiji School of Medicine and the Institute of Pacific Studies, The University of the South Pacific, Suva, Fiji, pp. 23–107.
Thomson, L., Thaman, R., Fink, A., 2016. Native forests, plantation forests and trees outside forests: their vulnerability and roles im mitigation and building resilience to climate change. In: Taylor, M., McGregor, A., Dawson, B. (Eds.), Vulnerability of Pacific Island Agriculture and Forestry to Climate Change. Pacific Community (SPC), Noumea, New Caledonia, pp. 383–446.
Tromp, M., Dudgeon, J.V., 2012. Dietary microfossils from Rapa Nui dental calculus: Does regional variability provide evidence for subsistence practices? In: Proceedings of the 8th International Conference on Easter Island and the Pacific. Santa Rosa, Califonia.
Tuia, V.S. et al., 2012. Role of the Centre for Pacific Crops and Trees in the sustainable conservation and the safe movement of plant material. Suva, Fiji.
Villareal, R.L., 1982. Sweet potato in the tropics - progress and problems. In: Villareal, R.L., Griggs, T.D. (Eds.), Sweet Potato: Proceedings of the First International Symposium. Asian Vegetable Research and Development Centre, Taiwan, pp. 3–15.
Wairiu, M., Lal, M., Iese, V., 2012. Climate change implications for crop production in Pacific Islands Region. In: Prof Aladjadjiyan, A. (Ed.), Food Production - Approaches, Challenges and Tasks. InTech, London, United Kingdom, pp. 67–86. https://doi.org/10.5772/1870.
Wallin, P., Stevenson, C., Ladefoged, T., 2005a. Sweet potato production on Rapa Nui. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 85–88.
Wallin, P., Stevenson, C., Ladefoged, T., 2005b. Sweet production on Rapa Nui. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 85–88.
Wenda, K., 2012. Sweet Potato: A Source of Life and Livelihood for the Papuan People. Oxfam Papua Program, Republic of Indonesia.
Wera, B., et al., 2014. Genotypic variability estimates of agronomic traits for selection in a sweetpotato (Ipomoea batatas) polycross population in Papua New Guinea. J. Plant Breed. Genet. 2 (3), 131–136.
Wiessner, P., 2005e. Social, symbolic, and ritual roles of the sweet potato in Enga, from its introduction until first contact. In: Ballard, C. (Ed.), The Sweet Potato in Oceania: A Reappraisal. University of Pittsburgh and University of Sydney, Sydney and Pittsburgh, pp. 121–130.
Yen, D.E., 1974. The Sweet Potato and Oceania: An Essay in Ethnobotany. Bishop Museum Press, Honolulu, Hawaii.
Yen, D.E., 1982. Sweet potato as a supplemental staple food. In: Villareal, R.L., Griggs, T.D. (Eds.), Sweet Potato: Proceedings of the First International Symposium. Asian Vegetable Research and Development Centre, Taiwan, pp. 17–30.