Agroforestry in the Climate of the Marshall Islands (*Green Dashboard*): An Interactive Website.[1]

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Abstract

An interactive website, *Agroforestry in the Climate of the Marshall Islands* (*or Green Dashboard*), was developed in response to requests from Marshall Island public agencies and stakeholders. The purpose of this website is to provide easily accessible decision-making tools for government officials, public agencies, and citizens striving to mitigate the impacts of climate change and sea level rise that are affecting their coasts, agroforestry systems, and resources. The agroforestry information for the website is based on literature reviews, surveys, and interviews of Marshall Islanders regarding their understanding of their traditional agriculture and environment. The surveys were conducted in 2015-2016 on Majuro and Arno atolls. The website information is presented in both English and Marshallese. The website includes climate information in simple language, using terminology consistent with that used by meteorologists advising the Marshall Islands, and drawing from monthly data presented in scientific detail on the University of Hawaiʻi's *Blue Dashboard* for the Marshall Islands. The relationship and interfaces of the two dashboards, and the protocols for developing and maintaining the website, are also presented.

Keywords: climate change, sea level rise, Marshall Islands, dashboard

Introduction

With respect to global climate change and sea level rise, in the last three decades, the Marshall Islands have experienced at least five El Niño driven droughts and annual saltwater flooding of coastal lands during abnormally high tides or storms, and since 1993, a sea level rise of approximately 0.3 inches per year (Australian Bureau

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of Meteorology [ABM] and Commonwealth Scientific Industrial Research Organization [CSIRO], 2014). Higher rates of beach erosion and flooding during high tides, and storm surges superimposed on heightened sea levels have eroded, destabilized, and modified coastal topographies, and salinized soils and groundwater. As most of the islands are small, low-lying and have poor ground water resources, these events have seriously impacted their physical geography and in particular, their agricultural sustainability. A recent scenario by the U.S. Global Change Research Program (Reidmiller et al., 2018) suggests a sea level rise of 1 foot by 2050, 4 feet by 2100, and El Niño-Southern Oscillation (ENSO) impacts 2 times stronger in the next century than the present. Such studies call into question how long low-lying atoll environments will be habitable under such conditions and address a wide range of mitigation and adaptation measures to consider.

Following the 2013 drought in the Marshall Islands, government officials, agroforestry extension agents and stakeholders sought information about whether the drought and other extreme events should be interpreted as the result of climate change or natural variation, and how to plan for and respond to them. Agroforestry practitioners and their extension agents sought information about suitable species and cultivars to plant after the drought ended in order to respond to anticipated future severe drought conditions (Haws, 2018). Stakeholders also wanted seasonal outlooks about sea level as affected by daily tides, ENSO, probabilities of storms and other disturbances, and information on appropriate species in order to guide the timing and location of restoration of coastal vegetation. At least one government erosion control planting of coastal trees and shrubs was washed away by a "king" tide before the plants were well-established, indicating a need to plan around tidal and ENSO-related variations in sea level.

In response to this and related concerns, the authors and associates developed an interactive website called *Agroforestry in the Climate of the Marshall Islands,* or *Green Dashboard* (Friday,, 2017).[2] This website provides agroforestry extension agents and community leaders with information about seasonal and long-term changes in climate, and the steps that Marshall Islanders can take to mitigate the short and long-term impacts of global climate change and sea level rise on their agriculture/agroforestry systems. The project primarily focused on climate conditions within a planning horizon of 40 years, which corresponds to the productive lifespan of newly planted coconut and other perennial trees that are the framework of traditional agroforestry in the Marshalls. Various tree species in the Marshalls begin to provide nutritious leaves and fruit beginning within as few as 2-5 years; 40 years represents the

[2] The *Green Dashboard* is a companion to the *Marshall Islands Climate Outlook (Blue Dashboard)* which provides information about oceanic and atmospheric conditions. Recent and forecast conditions are updated monthly for temperature, rainfall, storms, sea level and waves, ocean conditions, and ENSO (El Niño, La Niña) indices. It is an ongoing collaboration between the Asia-Pacific Data Research Center (APDRC) and the NOAA Climate Information System (PaCIS). Information on the website and its development is discussed in the latter half of this paper. The website is accessible at: http://oos.soest.hawaii.edu/pacific-rcc/Marshalls%20Agroforestry/site/index.php.

opportunity for the present generation to provide for their children and grandchildren. This focus is similar to that of an engineer who specifies the design timeframe of a building or road that has a long but not unlimited useful life. Beyond this timeframe, there are many uncertainties based on future decisions and actions affecting greenhouse gas emissions, and uncertainties in scientific models of the responses of the world's ecosystems; it is not possible or necessary to resolve those uncertainties to make agroforestry recommendations for the next few decades. Even if people begin to emigrate within that timeframe, they are better positioned for success if they have been well-nourished.

This paper presents information on the *Green Dashboard* and its interactive agricultural calendar. It is presented in this journal because of its social, existential, and interdisciplinary relevance to all Pacific islands.

The methods used for this paper included a literature review, three survey questionnaires, and interviews of Marshall Islanders on topics about their knowledge of traditional knowledge (e.g., agricultural practices, cultivated food plants, and the seasonality of Marshallese weather and climate).[3] The survey questions were translated into Marshallese by the language and culture faculty at the College of the Marshall Islands and other Marshall Islanders. The questions and interviews were administered in Marshallese by Marshall Islanders affiliated with the project. The questionnaires were given to 39 people, of which 65% + were residents of Arno, an atoll in the eastern island chain, and the rest, residents of Majuro, the capitol and atoll in the eastern island chain, who migrated there from the other atolls of the country. The respondents' answers to the questions were filled out by the interviewer. The interviews began on Arno Atoll on April 27, 2015 and ended in mid-December 2015 on Majuro Atoll. Fourteen of the 39 respondents were asked to fill out a form which listed salt and drought tolerant plants by their scientific and Marshallese names. The number of respondents for each survey form and questionnaire may be considered adequate if each respondent is considered a case study, or if the sample is deemed a sufficient basis for a more in-depth analysis involving a larger sample size. We feel that the numbers of respondents are more than enough to give us a good idea of Marshallese understanding of the topics listed above.

This paper also summarizes the climate and meteorological sources based upon which the authors developed public education graphics and tables for the website. While such graphics are necessarily simplifications and incomplete models, it is important to document their foundations and acknowledge the gaps therein.

A Brief Geographic Sketch of the Marshall Islands

Physical Geography

The Republic of the Marshall Islands (RMI) consists of 29 low-lying atolls and 5 upraised limestone islands located in the Central Pacific Ocean between 4.5° N and

[3] A more extensive discussion of these questionnaires and their results are presented in Manner et al. (2017) and Haws (2018).

15° N latitude and 160° E and 170° E (Figure 1). The atolls are arranged in two NW to SE trending chains: *Ratak* on the east and *Ralik* towards the west. The total dry land area of the country measures only 69.84 mi^2 (110 km^2) (Bryan, Jr., 1971), with 98% of the area distributed over 1200 islets averaging 0.057 mi^2 (0.15 km^2) per islet. As an example of this fragmentation, Majuro Atoll, which consists of 64 islets, has a total dry land area of 3.54 mi^2 (9.17 km^2) for an average of 0.05 mi^2 (0.13 km^2) per islet (Bryan, Jr., 1971). The total land area of the upraised islands measures only 1.66 mi^2 (4.30 km^2), with Mejit - the largest island - measuring 0.72 mi^2 (1.86 km^2) in area. As a consequence of their small size, ground water lenses and other agricultural resources are limited in quality and quantity. Because these islets average only 2 m in elevation, they are subject to saltwater storm wave flooding during high tides. By contrast, the lagoon area measures 4,037 mi^2 (6,511 km^2) and the Republic's EEZ (Exclusive Economic Zone) occupies an oceanic area of 750,000 mi^2 (1.2 million km^2) (Crawford, 1993).

Population and its Distribution

According to the 2011 census, the population of the Marshall Islands numbered 53,158 people in 2011, of which 27,797 resided on Majuro; 11,408 on Kwajalein; and 13,953 on the other atolls (Republic of the Marshall Islands [RMI] & Secretariat for the Pacific Community [SPC], 2012). Both Majuro and Kwajalein have experienced positive net migration from the other atolls as Majuro is the center of government and trade while Kwajalein offers employment as a US missile testing site. The Marshallese workforce for Kwajalein lives on Ebeye Islet which has a population of 9,614 people and a population density of 80117/mi^2 (31,013 km^2) (Republic of Marshall Islands, 2012). Majuro's population density is less at 7413/mi^2 (2,860/km^2). The current rate of population growth for the Republic is low, at 0.4% per year; the result of large out-migration to the United States and its territories. This has been made possible by the Compact of Free Association, an agreement made between the Marshall Islands and the United States at the end of the United Nations Trust Territory agreement created at the end of World War II.

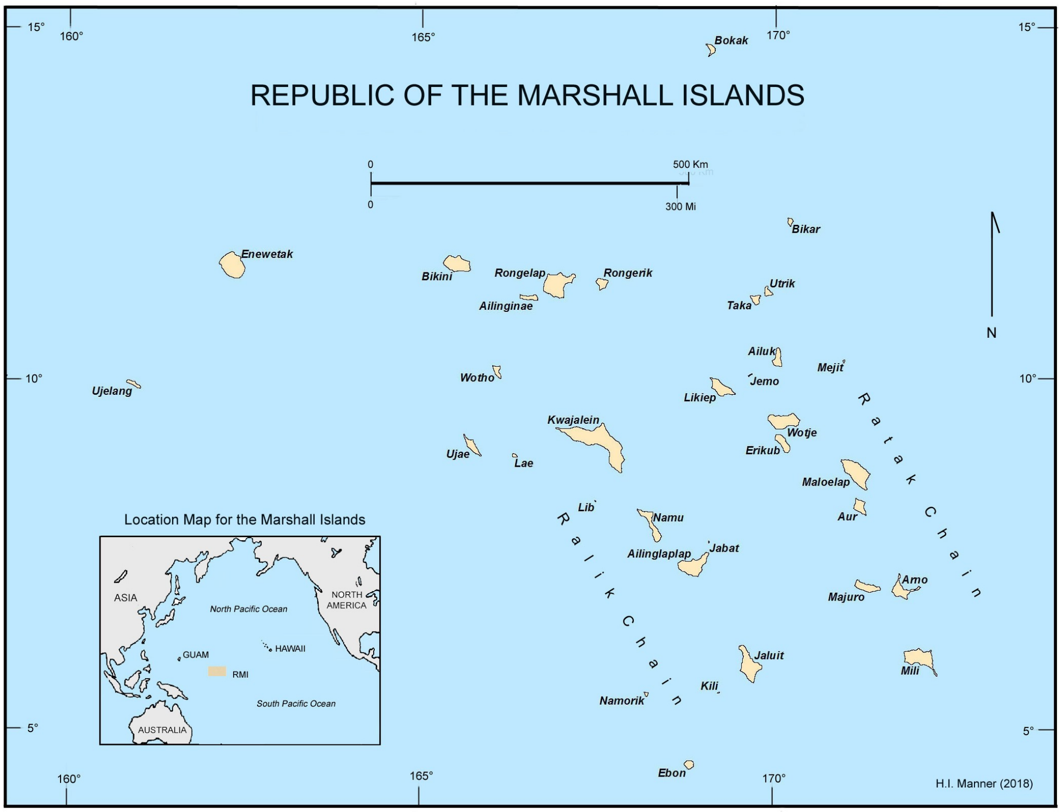

Figure 1. Location map of the Marshall Islands (Cartography by H.I. Manner 2018).

Weather and Climate

By virtue of its latitudinal position in the Central Pacific Ocean and its location relative to the Intertropical Convergence Zone (ITCZ) and the NE trade winds, the climate of the Marshall Islands ranges from a *Köppen Aw* (tropical winter dry climate) and/or *BSh* (hot, semi-arid climate) in the northern atolls such as Taongi and Bikar to *Af* (tropical rainforest climate) in the central and southern atolls of Majuro and Jaluit. Thus, a noted feature of the Marshall Islands is a gradient of increasing rainfall as one progresses from the northern to southern atolls (Thomas et al., 1989; Stoddart & Walsh, 1992). As an example, the annual rainfall, in the absence of records for Taongi Atoll, "…is likely to be in the range of 30-40 in (750-1,000 mm), comparable to that recorded for wake island (sic) located some 300 m (500 km) to the north" (Thomas et al., 1989:10). In contrast, that of Majuro and Jaluit are in excess of 100 in (2,540 mm) per annum (Mueller-Dombois & Fosberg, 1998). The distribution of precipitation is not even, particularly in the more northern atolls where lower amounts are recorded for the months of January to March and the higher totals are recorded for July to September. The lower precipitation totals are directly related to the cooler, more stable air of the NE trades of the Hawaiian High (a subtropical high-pressure cell) that dominates during this period. The greater precipitation of summer and late summer is directly linked to the variable winds and unstable air of the Intertropical Convergence Zone, which migrates northward during the northern hemisphere summer. In terms of temperature, all locations are warm with average annual temperatures in the low 80°F range (27-28°C). At Majuro, the annual temperature average is 81.4°F (27.4°C), with little variation between the warmest and coldest months (0.6°F) (~0.3°C), while at Wake the average annual temperature is 81.2°F (27.3°C), but with a higher monthly variation (4.9°F) (2.7°C). The Marshallese refer to the cooler dry period as *Aņōneaņ* and the warmer moister period as *Rak*.

Drought, as a part of an El Niño event is a serious factor relative to the environmental and economic well-being of the Marshall Islands. In the past three decades, the Marshall Islands experienced droughts in 1982-83 (Reti, 2008); 1992, 1997-98 (Anthony, 2012); and 2013, 2015-16 (Leenders et al., 2017). Drought is not restricted to just the drier northern atolls. In the 1997-98 drought, Majuro received only 8% of its normal rainfall between January and April 1998 (Anthony, 2012).

Climate Change and Sea Level Rise Impacts

Various studies on the future of agriculture and fisheries in the Pacific Islands suggest that climate change and sea-level rise are expected to exacerbate the problems of food access and security (Asian Development Bank [ADB], 2011, 2013; Food and Agriculture Organization [FAO], 2008; Sharma, 2006; Bell & Taylor, 2015; Bell et al., 2016). Rapid population growth, urbanization, the shortage of arable land for agriculture, limited income earning opportunities, financial constraints, and the availability of cheap low quality food imports constitute some of the contributing factors. The ADB (2011) and the ABM & CSIRO (2014) climate change scenarios for the Marshall Islands have posited an increase in severe droughts and a host of weather and sea level changes that are predicted to have a negative impact on the quality of the islands' vegetation, soil, and water resources. The latter group states that for the Marshall Islands, the natural cycle of La Niña and El Niño events (storms, rain and drought, sea level) will be more noticeable than climate change during those next 40 years. Specifically:

1. Rainfall has been on a downward trend in the Marshalls, but most models predict it will increase in the future. Within just the next 40 years, any changes as a result of climate change will not be very noticeable compared to the natural variability of rainfall in the Marshalls, especially as a result of the ENSO cycle.
2. Average, minimum, and maximum air temperatures will all probably increase by about 1.5-2.2 degrees Centigrade (2.7-4.0 degrees Fahrenheit), with most of the increase in the latter decades under the least favorable emissions scenarios. This will affect evapotranspiration and stress on crops, but because the models predict increases in rainfall, the net effect on freshwater stress in the Marshall Islands from changes in temperature and rainfall alone over the next 40 years is negligible (Karnauskas et al., 2016).
3. Changes in the frequency of droughts and storms in the next 40 years in the Marshalls will also probably be a result of ENSO instead of climate change.

4. Worldwide sea levels are now rising at least 0.3 inches/year and will probably rise at least 13 inches within 40 years. In addition, sea levels may temporarily rise by 12 inches during a La Nina and drop by 5 inches during an El Nino event in the Marshalls. Sea level rise is also added to the effect of each king tide and storm surge, making inundation events more frequent.

After the project began, Storlazzi et al. (2018), working on Roi Namur Island, Kwajalein Atoll, in the western (Ralik) island chain, found that wave dynamics over less-shallow reef flats amplify the effects of sea level rise, leading to more severe flooding. He predicted this could result in the islands becoming uninhabitable by mid-century because of frequent damage to infrastructure and the inability of their freshwater aquifers to recover between *overwash* events. While their findings have had a demoralizing effect upon project partners, it has also been criticized. Kopp (2018), for example, is critical of Storlazzi et al.'s conclusions because the scenarios of sea level rise flooding they used were "intended as tools for risk management, not as forecasts of what would be likely under different emissions scenarios." McSweeney (2018) notes that there are atolls with contaminated ground water resources but are populated because they have alternate sources of fresh water.

Elsewhere, analysis of remotely sensed data of Tuvalu atolls by Kench et al. (2018) which showed a net increase in land area in eight of nine atolls over the past four decades despite sea level rise, indicate that atolls are not static landforms, but are "geologically dynamic features that will adjust to changing sea level and climatic conditions." In an interview with *CarbonBrief* (McSweeney (2018), Kench said that Roi Namur had been substantially modified by construction and was therefore "representative of a very limited number of atoll islands". Furthermore, in contrast to Storlazzi's study of one island, Kench's analysis of all of Tuvalu's atolls offer "a nuanced set of options to be explored to support adaptation in atoll states" rather than the "narratives of environmentally determined exodus," and "persistent messages" which "have normalised island loss and undermined robust and sustainable adaptive planning in small island nations" (Kench et al., 2018).

While climate change caused migration is a much-discussed strategy amongst international organizations and the news media [4] (see for example, Yamamoto and Esteban, 2017; Barnett and O'Neill, 2012), few Marshallese consider it to be a viable alternative at this time. A survey of 199 households on Majuro, Maloelap, and Mejit Island in the Marshall Islands and 79 households Hawai'i, Oregon, and Washington by van der Geest et al. (2019, 2020) showed that education, health care, work, and family connections (visits) were the main drivers for migration; climate change and sea level rise were "not yet common reasons for which people migrate but rather something that might spur migration in the future." (van der Geest et al., 2020:119). Respondents living in the RMI ranked the lack of job opportunities (1), drought (2), the lack of fresh water (3) and sea-level rise (4) as major problems, and one half of these respondents

[4] Between 2000 and 2011, climate change coverage appeared in 249 out of 626 issues of *The Marshall Islands Journal* (Rudiak-Gould, 2013: 43).

perceived a "general negative trend in ecosystem services (the provision of local food and access to freshwater, fuelwood, and safety)." (van der Geest et al., 2019:7). In an earlier study about how Marshall Islanders receive climate change information, Rudiak-Gould (2013: 43) wrote that for residents of Majuro, environmental changes (changes in climate, changes in the ocean, "climate change," and "global warming" ranked fifth of 13 concerns. More important concerns were social, economic, and cultural, for example, population growth and overcrowding, and changing lifestyles and mores, to name a few. According to Rudiak-Gould, the Marshallese reject climate change caused exodus as such migration would mean a loss of the homeland and Marshallese culture.

Climatic Components Used in Defining the Dashboard Levels and the Climate Outlooks and Advisories

The atmospheric and oceanographic components that form the underlying basis of the *Green Dashboard* (in particular the Home and El Niño/La Niña Pattern pages) are rainfall, winds, storms, sea levels, tides, storm surges, and trains of large wind waves. These components are significant in defining productivity of agroforests and weigh greatly in coastal vegetation and stability. Underlying data are summarized with authority and precision by the *Blue Dashboard* (Potemra & Marra (2016); this project (*Green Dashboard*) interpreted them for the agroforestry management community. These components were selected for dashboard gauge of Below, Normal, and Above conditions of rainfall, wind speed, and sea level of the *Blue Dashboard*, then copied onto the Home page of the *Green Dashboard* (to be described in detail below). Table 1 presents the actual figures and data sources which were presented as color gradients in the calendars for "El Niño" and other years. These variables are discussed below.

Rainfall. As part of a related project, Sutton et al. (2015) developed a rainfall atlas for the Marshall Islands, based on 30 years of satellite data (Luchetti et al., 2016). Unlike the traditionally defined seasons of *Añōneañ* and *Rak,* Sutton's data describes annual wet and dry seasons based on rainfall alone, for an *average* year, a *neutral* year, and for strong and weak El Niño and La Niña phases for Kwajelein and Majuro as shown in Table 1. Figures 2 and 3 show these wet and dry seasons in absolute terms for Kwajalein and Majuro, respectively, so that the ENSO effects can be easily compared with seasonal variation in rainfall. Referring to these figures, the most notable effect of the ENSO cycle is the extreme drought at the beginning of Year 1[5] of a strong El Niño cycle, which fortunately, can be predicted several months ahead of time, typically in April-July of Year 0 (National Oceanic and Atmospheric Administration [NOAA], 2016b). There is also a strong drought at the beginning of Year 0 of a strong La Niña year, but this is recognized in hindsight rather than predicted, and may largely be due

[5] Note that the scientific literature includes multiple systems of nomenclature for the phases of each ENSO cycle. The website adapted and displays a commonly used graphic showing the effects of the "onset," "peak" and "after-effects" phases (Lander, 2016), correlating them to the "Year 0" and "Year 1" nomenclature used by Sutton et al. (2015).

to the cyclical tendency for a La Niña year to follow an El Niño year. Thus, Year 0 of a La Niña is often Year 1 of an El Niño year.[6] The means of the Majuro and Kwajelein data for the 30-year average and for moderate-to-strong El Niño phases, respectively, were averaged in order to provide simple indexes of "average" and "El Niño" rainfall for the Marshall Islands and the agricultural calendars of the *Green Dashboard*.

Winds. In an ENSO-neutral year, the Marshall Islands experience normal easterly winds. During a La Niña year, the easterlies tend to be stronger. In an El Niño year, the easterlies are weaker and there may be westerly winds (Fletcher & Sussman, 2014). Potemra (personal communication, 2017) provided average monthly data from 2008-2015 (Table 1) for an "average" year as well as for a strong El Niño year (2015-16) that formed the basis for wind colorations and/or shadings of the website calendars. During 2015, average wind speeds were lower during the March to August period, but the year as a whole was variable because of storms.

Storms. Tropical cyclones form within the Marshall Islands almost exclusively during El Niño cycles, with a risk of storms in March-June of Year 0, a peak in July of Year 0, continuing through January of Year 1 (NOAA, 2016c). The risk may be higher for a short period around March of Year 0 and during the following November-January period (Lander, 1994). Storms affect agroforests directly, through wind damage, salt spray, and heavy rain; as well as wave action and inundation that may wash out plantings and deposit salty water on inland soils. Based on their analysis of 139 years of records Spennemann and Marschner (1994) found that typhoons were 2.69 times more likely in El Niño years than in non-El Niño years.

Sea Level. The success of coastal stabilization and maintenance of coastal forests (mangroves and strand forest) depends greatly on the interactions of sea level heights with storm surges, tides, and ENSO variation. Sea level is of great interest to forestry practitioners because out-plantings of strand forest or mangrove forest must be positioned and timed to maximize seedling survival. Depending on the species, seedlings should be planted at the appropriate position above or below the high tide mark so that they will become firmly rooted before they are washed away by unusually high-water levels. Sea levels in the Marshall Islands can be about twelve inches above neutral during La Niña events and five inches below neutral during El Niño events (NOAA, 2016a; 2016b). Mangrove species generally grow between mid-tide and high tide mark. If mangroves are planted at mid-tide mark during an El Niño year, they may be planted too deep to receive sufficient oxygen during a following La Niña. Planting of strand species during the lowered sea levels of an El Niño must take into consideration that seedlings must be planted high enough on the beach berm in order to survive the El Niño-associated storms and the stresses of high tides in a later, La Niña year. These sea level impacts are described in the El Niño calendar (Figure 5) using data from NOAA (2015a; 2015b; 2016b).

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[6] Readers of the atlas should note that rainfall averages are presented as total rainfall during a three-month period (for example, May-June-July or MJJ) averaged with the same three-month period in different years; these periods overlap, because a similar average is also presented for June-July-August or JJA. For purposes of brevity, this paper may refer to "June" meaning the time period centered on June (MJJ).

Tides. "King tide" known in the Marshall Islands as *ialap lep ko* refers to an especially high tide which occurs quarterly. Tide charts are published by NOAA (2016a) each October for the following year for the Marshalls. As the dates of king tides vary and are more clearly presented in tidal charts, they are not presented in Table 1 nor any of our figures. The tidal charts may show windows of opportunity to plant coastal seedlings a week after a king tide has passed, in order to maximize root development while high tides are a few inches lower for several weeks before the next king tide. In the press and popular usage, "king tide" is also imprecisely used to refer to larger inundation events from storms or unusually large wave trains resulting from distant northern storms.

Storm Surge. Storms and the surges and swells that accompany them persist through more than one tidal cycle and are superimposed on the high tides within that cycle. As a rule of thumb, thirteen-foot (approximately 4 m) surf leads to inundation on atolls (i.e., overtops the beach berm) and is predicted in the short term on "hazardous surf advisories" (Lander, personal communications, 2014-2015). As discussed above, tropical storms are associated with El Niño in the Marshalls, and may either include direct hits on an atoll or swells from nearby storms.

Wave Trains. The Marshall Islands also experience inundation events from trains of large wind waves generated by storms that are too distant for their winds to affect the islands directly. While waves from small sources dissipate as they spread, waves traveling in straight parallel lines from large storms lose little energy as they travel long distances. As with storm surges, these events last through more than one tidal cycle and are superimposed on the high tides within the cycle. Wave trains from storms in the northeast-to-northwest are often severe and are not seasonally predictable. Wave trains from southern storms typically occur in June or the rest of the summer. They are moderate, infrequent events (Lander, personal communications, 2014-2015). The increased possibility of large wave train events in summer is included in the calendars. Inundations in the Marshalls may be predicted up to several days in advance (travel time for the waves) and the effects of predicted inundations superimposed on daily tides are forecasted and posted by Guiles et al. (2016). These forecasts are experimental and do not include the effects of tsunamis or local tropical storms.

Large-scale Ocean Circulation Patterns. These differences between one part of the year to another (ranging 5 cm above and below the mean) are small and are not considered to have much impact on coastal and agroforestry systems. Discussion of these patterns is shown in the *Marshall Islands Climate Outlook* webpage (Potemra & Marra, 2016).

Temperature. As the annual temperature ranges for Majuro and Kwajelein are small, ranging between 28° C in September-October and 27.5° C in February-March, temperature was not selected as a variable for inclusion in the seasonal calendars.

Agricultural Calendars for Normal and El Niño Years - Seasonal Calendars Relating ENSO Predictions to Agroforestry

Traditional Agricultural Calendar. As a unifying concept for agroforestry and in response to requests from stakeholders for a calendar or "planting almanac" in the Marshalls, we developed a traditional agricultural calendar (Table 2) based on a review of the literature and our survey results. The calendar provides partial confirmation of the weather and climate data in Table 1. The information in Table 2 is based on the availability of food crops for the Marshall Islands reported by Spennemann (1992) and for Majuro by Aikne and Kusto (2016). This in turn was used as the basis for Figure 4a and 4b, which is a graphic representation of the availability of food crops and its relationship to the seasonal distribution of rainfall and other climate variables during *Añōneañ* and *Rak* for the Marshall Islands. We generated a single normal calendar for the whole of the Marshall Islands because precipitation and agricultural data (i.e., crop availability) were not available for all parts of the Marshall Islands. The rainfall data used in Figures 4a and 4b is an average of the 30-year mean rainfall for Kwajalein and Majuro, as shown in Table 1. Analysis of the rainfall data with the Marshallese wet and dry seasons shows that *Añōneañ* and *Rak* do not translate simply as "dry" and "wet" seasons. Even given differences between locations and sources, the beginning of *Añōneañ* - September and October according to Merlin et al. (1994), and November according to Williamson and Stone (2001), includes some of the wettest months for both Majuro and Kwajalein, and also according to the data of Sutton et al. (2015). The onset of *Añōneañ* may be defined by the onset of the northeastern trade winds (Abo et al., 1976; Knight, 1982), which clearly takes place in November according to wind data compiled by Potemra (personal communication, 2017). *Rak* begins sometime during the April-July period when rainfall is gradually increasing, and winds are gradually decreasing the representation of the harvest or availability times of various crops in the calendar is a weighted average of the source information in Table 1. A fuller discussion of the traditional agricultural knowledge and calendar of the Marshall Islands will be published in another paper.

Table 1. Climate source information for calendars

Rainfall (mm/3 months centered on:)		*Jan*	*Feb*	*March*	*April*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
Kwajalein (30 Year average)		326	271	312	395	451	507	541	594	630	656	606	471
Kwajalein, Moderate-Strong La Niña:	Year 0	287	154	172	225	307	426	498	564	605	636	558	410
	Year +1	316	285	253	324	388	492	509	564	630	656	618	466
Kwajalein, Moderate-Strong El Niño:	Year 0	385	341	437	514	519	558	660	778	781	735	636	518
	Year +1	329	173	175	249	347	471	503	546	592	636	581	428
Majuro (30 Year average)		537	482	530	609	682	701	719	721	725	764	750	672
Majuro, Moderate-Strong La Niña:	Year 0				390	505	673	769	800	790	833	705	591
	Year +1	494	492	466	505	566	680	712	735	740	787	795	753
Majuro, Moderate-Strong El Niño:	Year 0	558	501	599	737	771	764	769	800	783	772	720	685
	Year +1	505	362	313	414	566	757	820	793	747	795	750	618
Average of Kwajelein & Majuro 30-year average (to provide a simple index of annual rainfall for the Marshall Islands)		432	377	421	502	567	604	630	658	678	710	678	572
Average of Kwajelein & Majuro Moderate-strong El Nino: (to provide a simple index of El Nino affected rainfall)	Year 0	472	421	518	626	645	661	715	789	782	754	678	602
	Year 1	417	268	244	332	457	614	661	670	669	715	666	523
Other data-based information:													
Strong El Nino sea levels relative to mean: (inches)	Year 0	0*	0*	0*	0*	0*	0*	-3	-3	-4	-4	-5	-5
	Year 1	-4	-4	-3	-1	-1	0	0*	0*	0*	0*	0*	0*
Average wind speed and direction (knots)		15.7 NE	15.3 NE	14.8 NE	14.2 NE	13.7 NE	12.1 NE	9.5 NE	5.5 E	6.3 E	6.5 E	10.9 NE	13.2 NE
Average wind speed – strong El Nino (knots)	Year 0 (2015)	*15.7*	*15.3*	13.7	11.5E	11.9	12	5	5.2	8.8	5.5	10.5	14.2
	Year 1 (2016)	15	15	*14.8*	*14.2*	*13.7*	*12.1*	*9.5*	*5.5*	*6.3*	*6.5*	*10.9*	*13.2*
El Nino - Tropical storm probability.	Year 0	Virtually no risk	Virtually no risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Risk	Higher Risk	Higher Risk
	Year 1	Higher Risk	Little risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk
Neutral/La Nina – Tropical storm probability		Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	Virtually no risk	No risk
Wave train probability (any phase)		Possible	Possible	Possible	Possible	Possible	More likely	More likely	More likely	Possible	Possible	Possible	Possible

* For these months at the beginning and end of a two-year "strong El Nino", the cycle would be transitioning from and into another cycle. Therefore, the "average" value of 0 is shown in these cells and used for purposes of illustration in Figure 5.

Italicized values. For these months at the beginning and end of the "strong El Nino" cycle in 2015-2016, the cycle was transitioning from and into another cycle. Therefore, values from the corresponding "average" month (prior table row) are shown in these cells and used for purposes of illustration in Figure 5.

Information sources: Rainfall data from Sutton et al. (2015); El Nino sea levels from NOAA (2016b); Average wind speed and direction, and average wind speed and direction-strong El Nino from J. T. Potemra (personal communication, 2017); Tropical storm probability from NOAA (2016b; Wave train probability from M.A. Lander (personal communication, 2016).

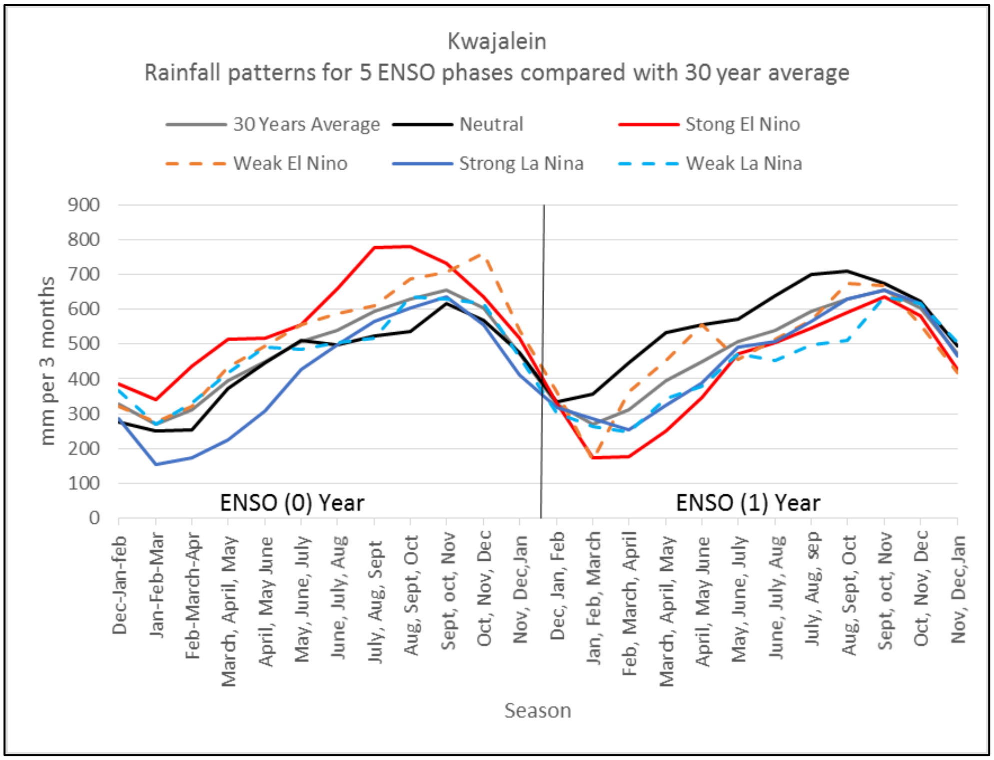


Figure 2. Comparison of rainfall patterns of Kwajalein Atoll for the 5 ENSO phases. Graph by Rufus, L. based on data from Sutton et al. (2015)

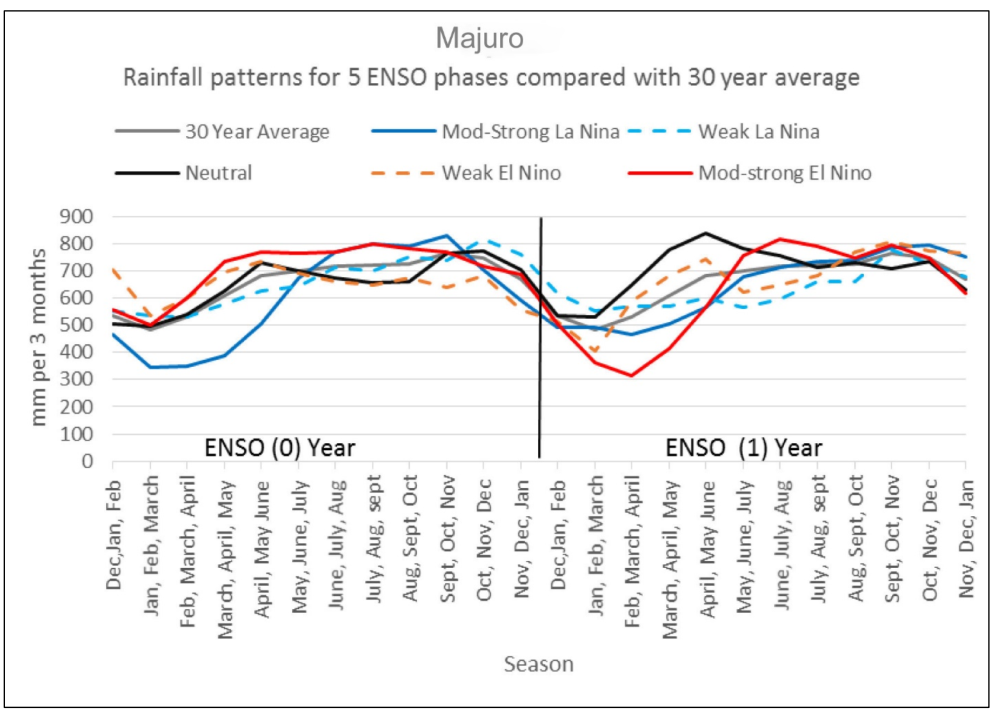


Figure 3. Comparison of rainfall patterns of Majuro Atoll for the 5 ENSO phases. Graph by Rufus, L. based on data from Sutton et al. (2015).

This single generalized agroforestry calendar (Figures 4a and 4b) may be used to represent overall average conditions or ENSO neutral and even La Niña phases. The rationale for this statement is that while the neutral and La Niña phases certainly differ from the average, as shown in the rainfall graphs (Figures 2 and 3) and the rainfall data in Table 1 (Sutton et al., 2015), the differences between these phases are not as striking as those for the medium-strong El Niño phase. Therefore, separate calendars or recommendations for "Neutral" versus "La Niña" conditions are not warranted at this time. For June of Year 0 through May of Year 1 of a neutral or La Niña phase, rainfall does stay within -16% to 26% of the 30-year average for each three-month period, with a few exceptions. The greatest deviation occurs where March-May of Year 1 of the neutral phase generally has 22-28% (Majuro) or 32-43% (Kwajalein) more rain than the 30-year average. Additional rain does not pose as much of a problem as insufficient rain in well-drained atoll soils. The greatest negative deviation (-17-21%) occurs around March-April of year 1 of a La Niña cycle. Until and unless there is more certainty and predictability in the differences between these phases, agroforestry recommendations and practices for average, neutral and La Niña conditions should continue to focus on diversification, resiliency, and "no-regrets" practices for sustainability and risk avoidance. This is considered a fundamental general strategy of diversified traditional agroforestry systems worldwide (Malézieux et al., 2009).

By contrast, a medium-strong El Niño event has a distinct and predictable drought, as well as an increased probability of storms. These conditions make a separate agroforestry calendar and recommendations (Figures 5a and 5b) valuable for El Niño. This calendar runs for about two years and encompasses all 18 months when the storm and rainfall patterns are characteristic of El Niño (i.e., onset, peak, and post-peak after-effects); plus, additional months during which crops mature to harvest following the El Niño drought. These two calendars (Figures 4a, 4b and 5a, 5b) do not attempt to provide quantitative harvest information or timing specific to a given atoll; instead, they illustrate the difference between the El Niño pattern and the agricultural norm. The representation of diminished harvests is based on actual conditions; e.g., in April 2016, the U.S. provided 4-7 months of food aid to moderately to severely affected Marshallese atolls where breadfruit, coconut, and other trees were no longer producing crops (Heine, 2016; United States Embassy Marshall Islands, 2016). This calendar (Figure 5a) is shown with a gap that prevents it from circling on itself, since after 24 months it does not usually return to another El Niño cycle, but typically transitions to the generalized conditions (average, neutral, or La Niña) represented by Figures 4a and 4b.

The *Green Dashboard*

The *Agroforestry in the Climate of the Marshall Islands* website (i.e., the *Green Dashboard* by Friday et al., 2017) was developed in order to provide agroforestry and related practitioners in the Marshall Islands with information on suitable plant species to mitigate the effects of ENSO induced drought, seasonal outlooks about sea level in relation to tides, storms and other disturbances, and information on appropriate plant species for the protection or restoration of coastal vegetation. The *Green Dashboard* achieves the following (Haws, 2018):

1. It draws directly from online, constantly updated, spatially referenced information about environmental variables provided by NOAA's National Climatic Data Center in the *Blue Dashboard* (Potemra & Marra, 2016).

Table 2. Marshallese Agricultural Calendar

		Eprōḷ	Māe	Juun	Juḷae	Ọkwōj	Jeptōṃba	Oktoba	Nobōṃba	Tijōṃba	Jānwōde	Pāpwōde	Ṃaaj
Traditional Marshallese Seasons General (Marshalls-wide) Source: Merlin et al (1994); Abo et al (1976)		Rak (Summer, Wet)					Anonean (Winter, Dry)						
		Wōtōn Ma (Breadfruit Season)					Pal (Ṃakṃōk Season)						
							Wōtōn Bob (Pandanus Season) (Also called Wōtōn Iertob)						
Traditional Marshallese Seasons Namu Atoll (between Kwajelein and Majuro) Source: Williamson and Stone (2001)		Anonean (Winter, Dry)		Rak (Summer, Wet)					Anonean (Winter, Dry)				
		Pal (Ṃakṃōk Season)		Wōtōn Ma (Breadfruit Season)					Pal (Ṃakṃōk Season)				
		Wōtōn Bob (Pandanus Season) (Also called Wōtōn Iertob)							Wōtōn Bob (Pandanus Season) (Also called Wōtōn Iertob)				
Seasonality of Marshallese Food Plants After Spennemann, (1992) • = In full production + = Harvestable	Artocarpus altilis		+	•	•	•	+					•	•
	A. mariannensis		+	•	•	+							
	Pandanus tectorius							+	•	•	•	+	
	Tacca leontopetaloides						+	•	•	•	•	•	+
Availability of Majuro and Arno Plant Foods After Aikne & Kusto (2016)	Alocasia maccrorhiza	•					•	•	•	•	•	•	•
	Colocasia esculenta	+	•	•	•	•	+						
	Cyrtosperma merkusii	•	+			+	•	•	•	•	•	•	•
	Cocos nucifera	•	•	•	•	•	•	•	•	•	•	•	•
[green] = In full production	Musa spp.	•	•	•	•	•	•	•	•	•	•	•	•
[yellow] = Harvestable	Crinum bakeri	•	•	•	•	•	•	•	•	•	•	•	•
	Ixora casei	•	•	•	•	•	•	•	•	•	•	•	•
	Ipomoea batatas												
	Citrus sp.												
Rainfall (mm)	Kwajalein (30 Year)	395	451	507	541	594	630	656	606	471	326	271	312
Rainfall (mm)	Majuro (30 Year)	609	682	701	719	721	725	764	750	672	537	482	530

Rainfall data from Sutton et al., (2015).

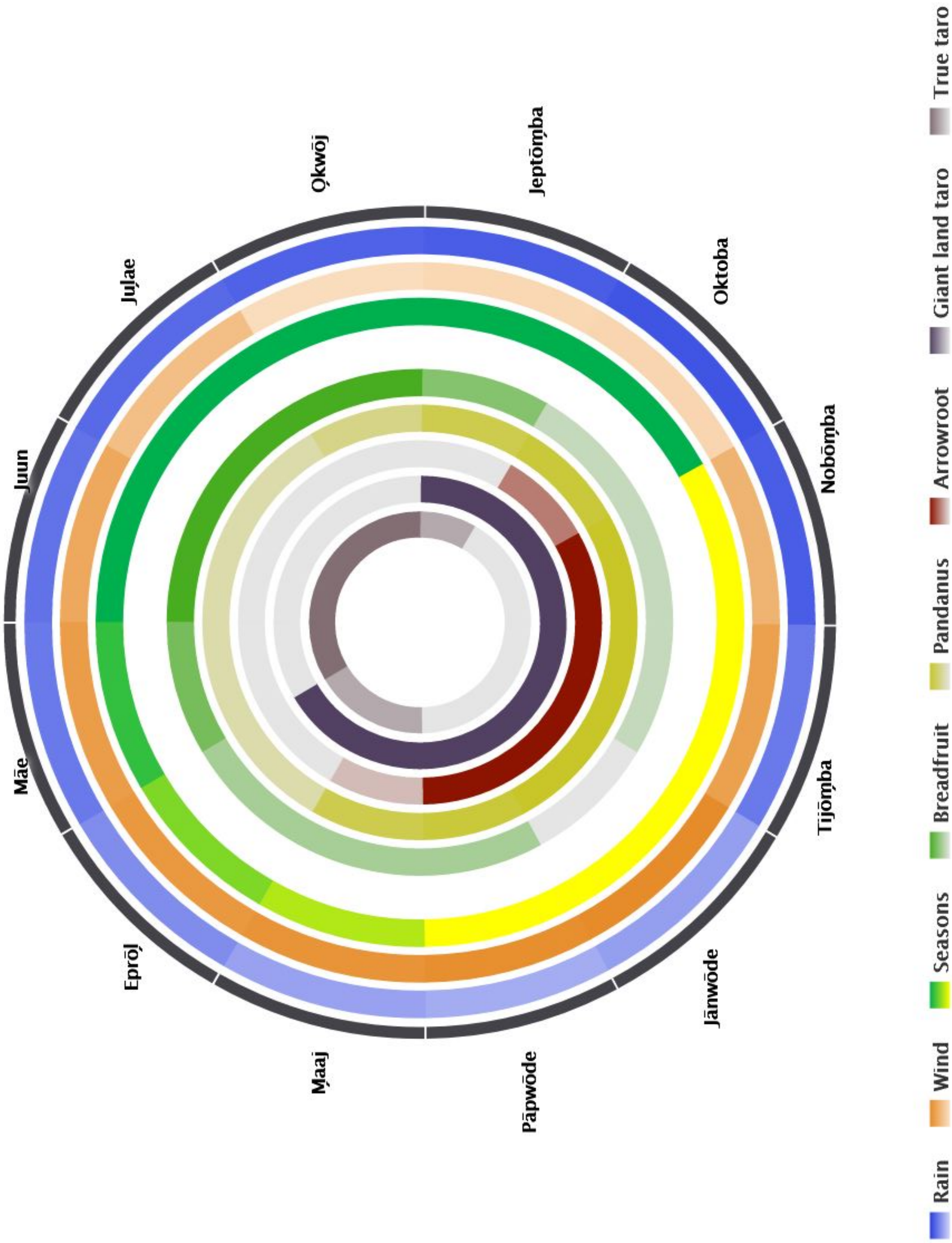
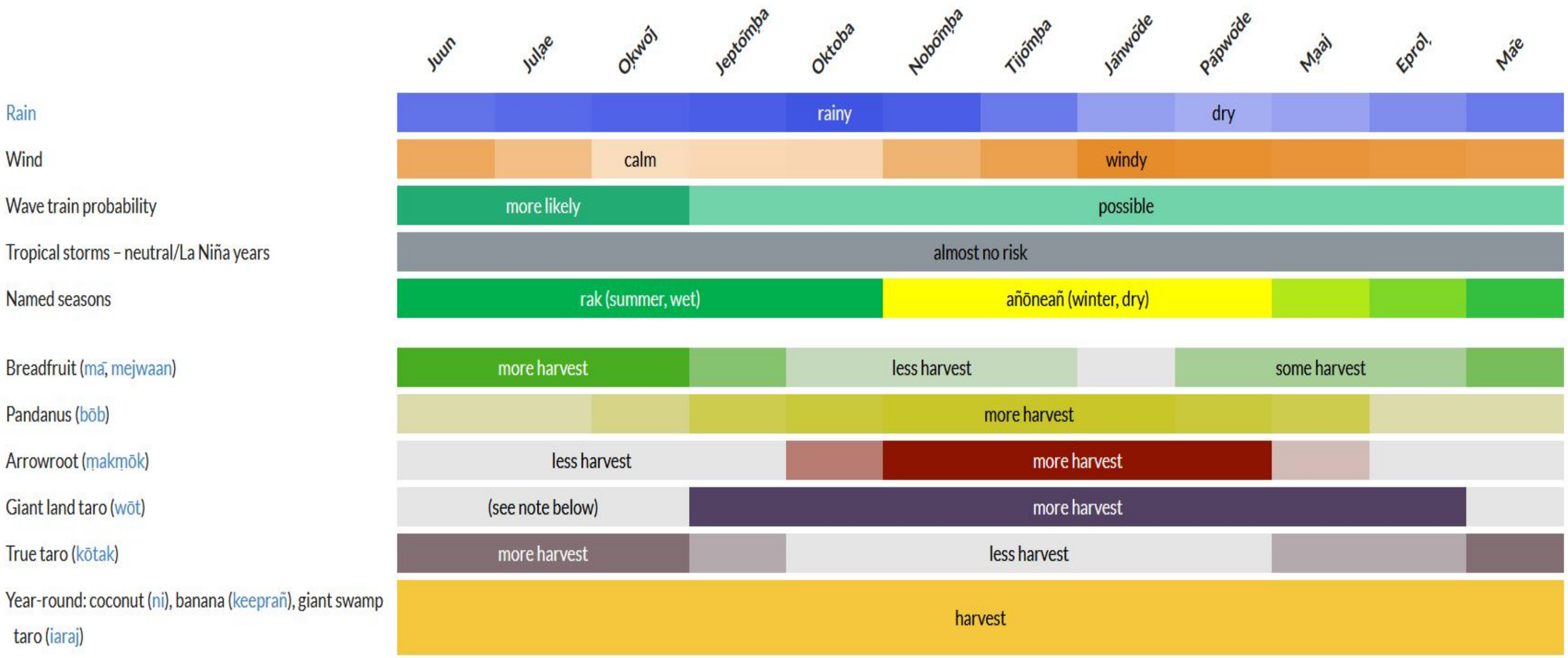


Figure 4a. The traditional Marshallese agricultural calendar.
Computer graphics by Michael Best as conceptualized by Kathleen Friday.



Note: Giant land taro (wōt) and some other crops could be harvested year round; this calendar shows them with harvest seasons during Añōneañ because people prefer to harvest breadfruit and taro during Rak.

Other planting or harvesting calendars can be created for different crops and different atolls. Examples include:

- Seasonality of Marshallese Food Plants by Spenneman
- Availability of Fruits and Vegetables in Majuro by Aikne and Kusto

Figure 4b. The traditional Marshallese agricultural calendar
Computer graphics by Michael Best as conceptualized by Kathleen Friday.

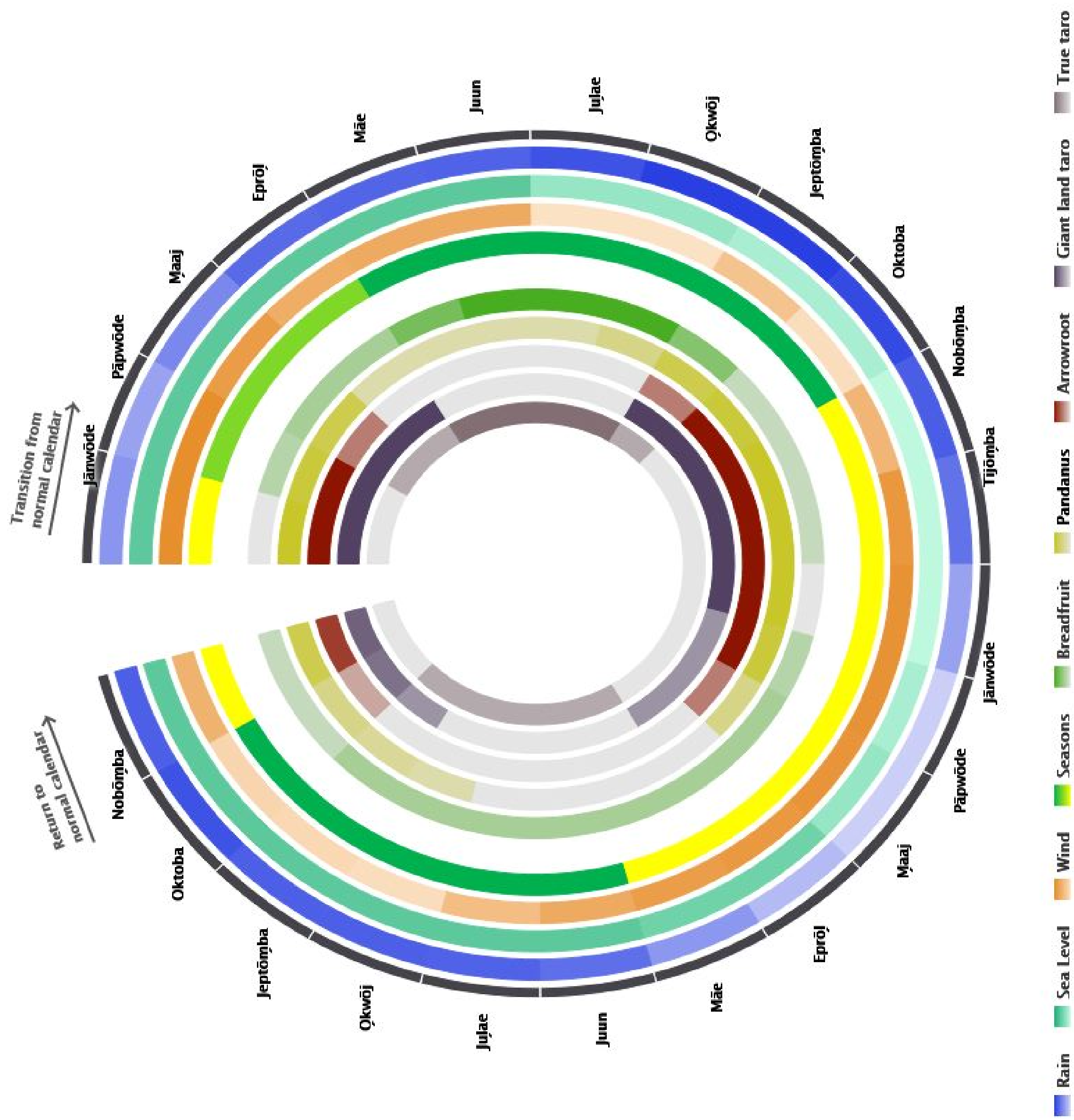
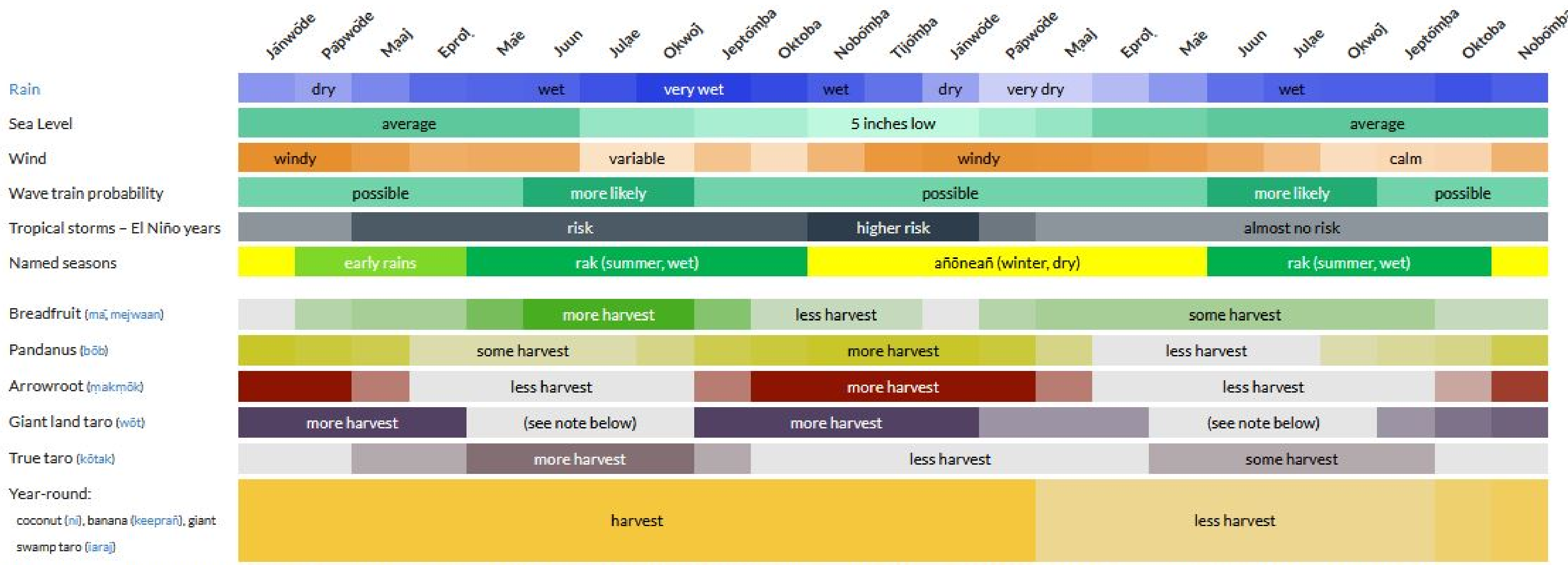


Figure 5a. The Marshallese agricultural calendar for the El Niño cycle.
Computer graphics by Michael Best as conceptualized by Kathleen Friday.



Note: Giant land taro (wōt) and some other crops could be harvested year round; this calendar shows them with harvest seasons during Añōneañ because during Rak, people prefer to harvest breadfruit and true taro.

Figure 5b. The Marshallese agricultural calendar for the El Niño cycle.
Computer graphics by Michael Best as conceptualized by Kathleen Friday.

2. It provides information for a given location and timeframe, concerning recommended agroforestry species, cultivars, and management practices.
3. It provides information for shoreline protection efforts.
4. It supplies a framework for referring users to additional relevant information concerning nutrition and culture.
5. It has a user interface and secondary products suited to Marshallese users.

Table 3 summarizes the structure and organization of the *Green Dashboard*, along with its components and links to other websites and related information. The website consists of six interlinked website pages (Home, El Niño/La Niña Pattern, Calendars, Recommendations, Coastal Forest, and Salt and Drought Tolerant Species). Most of the information is presented in both English and Marshallese. Readers may want to access the *Green Dashboard* while reading the ensuing discussion: http://oos.soest.hawaii.edu/pacific-rcc/Marshalls%20Agroforestry/site/

The Home Page

The Home page of the Green website consists of dashboard styled dial gauges that indicate the atmospheric and oceanographic conditions of the Marshall Islands, namely current quarterly rainfall, wind speed and sea levels presented earlier in Table 1, and the current advisory and outlook for an El Niño, Normal, or La Niña year. These variables are indicated on the gauges as Below, Normal, and Above as defined earlier in Table 1 by Sutton et al. (2015). The indicator levels are updated monthly through a direct link with the Marshall Islands Climate Outlook website.

The El Niño/La Niña Pattern Page

Using the trade winds as its basis, this page defines and graphically illustrates the two-year cycle of the El Niño Southern Oscillation. The 24-month graph (Figure 6) depicts the onset, peak and after- effects of the cycle; it illustrates the distribution of tropical cyclones, rainfall, sea level, drought, and harvests with symbols. The page also presents information of the El Nino alert system and its stages, the La Nina pattern, the ENSO rainfall pattern for Kwajalein and Majuro and (Figures 2 and 3), and links to the distribution of rainfall and drought in the Marshall Islands during the major phases of the El Niño Southern Oscillation and other relevant information.

The Calendars Page

This page presents the two agroforestry calendars described previously; the traditional, normal, generalized calendar (Figure 4) and the El Niño agroforestry calendar (Figure 5) by drop-down links. As the climatic rationale for the two calendars has been discussed previously, the discussion here serves to point out that the horizontal bar graph includes two additional descriptions, probability of large wind wave train events and tropical storm occurrences. Additionally, the horizontal graphs include a brief easily readable textual description of each listed climate or food plant item. Links to the Marshallese traditional food plants, the food availability lists by Spennemann (1992) and Aikne and Kusto (2016), and other relevant topics are presented.

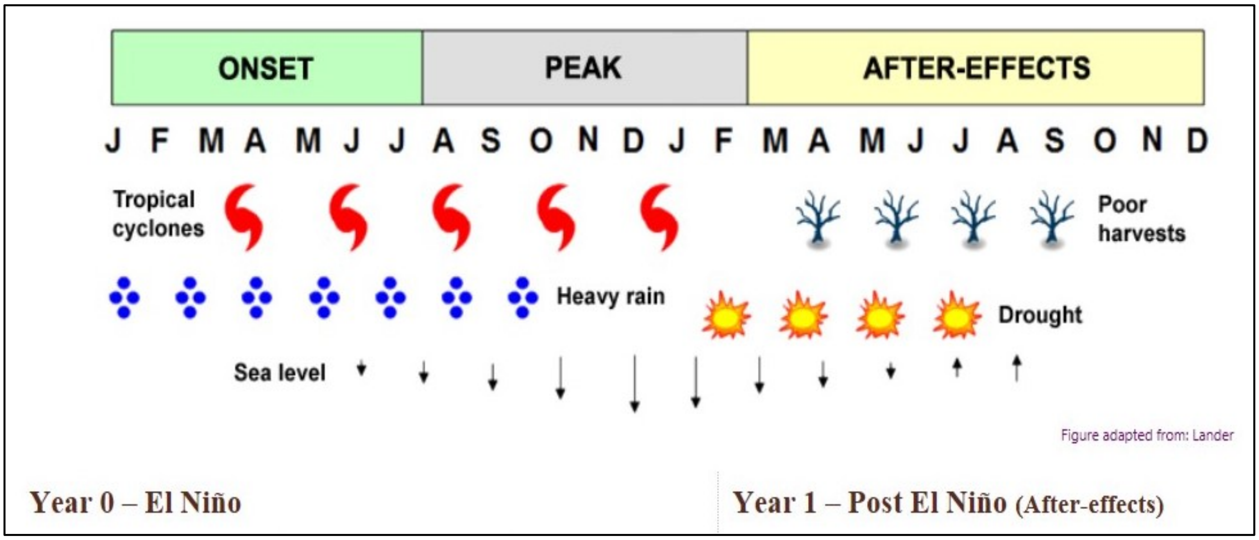


Figure 6. The 24-month graph of the ENSO cycle for the Marshall Islands showing symbolically the distribution pattern of tropical cyclones, rainfall, sea level, drought, and harvests. This graph by Lander (2016) is found on the El Niño/La Niña pattern page of the *Green Dashboard*.

The Recommendations Page

It is evident that sea level rise and El Niño induced droughts have and will continue to have serious negative impacts on the physical and human environments of the Marshall Islands. The observations and respondents' answers regarding Marshallese traditional knowledge, and their perceptions of the drought and salt tolerant cultivars suggest a range of recommendations. These are aimed at promoting and therefore strengthening the knowledge and practice of traditional agroforestry. Also needed are simple, common sense, hard and soft recommendations and relatively inexpensive approaches and efforts to mitigate the erosive effects of storm surges and higher tides which will become more severe with global climate change and El Niño. Many of these recommendations are found throughout the *Green Dashboard* and on the Recommendations Page. Examples of other comparable recommendations are presented in Bell and Taylor (2015), Reti (2008), ADB (2011, 2013), and in the publications of PIRCA. A full list of these recommendations that consider the social, economic, and physical environments of the Marshall Islands are presented by Manner et al. (2017). They advocate conservation and maintenance of the coastal forests; development of educational programs that foster the importance of coastal vegetation as a protective, stabilizing component of atoll life; identification of crop species that are less susceptible to drought and salinity; the use of *Alocasia* *macrorrhiza* (*wot*) as a food source; and the increased number of water catchment systems, along with increased frequency of catchment repair.

The Coastal Forest Page

For the flora and vegetation of the Marshall Islands, as well as the factors that determine their distribution, documentation has been plentiful (e.g., Fosberg, 1949, 1960; Mueller-Dombois & Fosberg, 1998; Bechte, 1884; Koidzumi, 1915; Devaney, 1987; Taylor, 1950; Wiens, 1962; Vander Velde, 2003; and Thaman, 2008). Fosberg (1949) has ascribed this pattern of atoll vegetation to a gradient of salinity which decreases as one moves from the coastal stand to the more mesic interior atoll forests on large islets. On smaller islets or cays, this zonation is limited to the first two salt-tolerant plant communities. While the mixed broadleaf forest is the most common vegetation in undisturbed places, there are also mono-dominant forest and single species communities.

The Coastal Forest page of the *Green Website* consists of two sections: 1. Strand Vegetation; and 2. Mangroves. Each section is described by means of a colored profile diagram showing the location of representative species (with their Marshallese names) along the shore and shallow waters. The profile diagrams are based on the personal observations and work experience of Sared (2016), who planted mangroves in the atolls of Chuuk, and contain information and directions for protecting, conserving, and rehabilitating mangroves and coastal forests in the face of rising sea levels, storm surges, and king tides. For example, the notation for *(Rhizophora mucronata)* reads:

> *Eoeak* or *Būļaboļ (Rhizophora)* is called a *fringe* species because it can grow on the seaward edge of a mangrove forest. Plant large propagules at mean sea level, about halfway between the high tide and low tide points, where it will be inundated by any day's high tide. If it is an El Niño year, the sea levels might be unusually low, so plant them where it is shallow, because when normal weather returns, the water will be deeper.

Similarly, for planting strand species, the recommendation reads:

> Plan ahead. Soon after a king tide is a good time, to allow a few months for seedlings to take root before the next king tide. Check the tide charts.

Salt and Drought Tolerant Species Page

One objective of the *Green Dashboard* project was to revise and update the species information and practice standards for the Marshall Islands in the Pacific Islands Area Vegetative Guide (PIAVG) so that it would better reflect the ecology of these islands. For example, many species that were not native to the Marshall Islands or were better adapted to the environmental conditions of the high Pacific Islands were removed; while many coastal strand and mangrove species that were missing from the database (e.g., *Pemphis acidula, Hibiscus tiliaceus, Bruguiera gymnorrhiza, Rhizophora* *mucronata, Lumnitzera littorea and Sonneratia alba*) were added. The species identified for listing in the PIAVG database were mainly based on field observations (of species distribution), the experiences and opinions of Marshallese experts and lay people, and the literature.

This web page presents a list of 47 salt-tolerant species and a list of 70 drought-tolerant species. Each species is listed by its common names (English and Marshallese) and scientific names. Wind tolerance and plant type are listed for the salt-tolerant species. For drought-tolerant species, the maximum and minimum rainfall limits, drought-tolerance, and plant type are indicated.

Table 3. Simplified Structure and Contents of the Agroforestry in the Climate of the Marshall Islands (Green) Website.
http://oos.soest.hawaii.edu/pacific-rcc/Marshalls%20Agroforestry/site/

Home	El Nino/La Nina Pattern	Calendars	Recommendations	Coastal Forest	Salt and Drought Tolerant Species
Dashboard-Gauges of current conditions of rainfall, wind speed and sea level for the beginning and ending of the quarter, updated monthly	The El Nino Southern Oscillation (ENSO) Diagram showing the onset, peak, and after-effects of tropical cyclones, rainfall, drought, poor harvests, and sea level	Marshallese traditional Agroforestry calendar-normal years (12 months)	El Nino Recommendations for Agroforestry: 1. Protection of coastal vegetation 2. Preparation for storms. 3. Caring of crops during wet weather during El Nino. 4. Planning ahead for drought during La NIna.	Care for Coastal Forests 1. Work with people 2. Work with nature 3. Strand vegetation Species & zones When to plant Protection Case studies 4. Mangroves Definition Whether to plant Species & zones When to plant Technical advice Case studies	Tables of Salt-tolerant and Drought-tolerant Species. 1. Salt-tolerant species table (Lists 5 mangrove, 11 strand and 31 other species) 2.Drought-tolerant species table (Lists 70 tree, shrub, herbs, and vines)
El Nino/La Nina Watch-Gauges of the current advisory and outlook, updated monthly	Year 0 – El Nino and Year 1- Post El Nino (after-effects)	Marshallese agroforestry calendar for El Nino years (23 months)			
Traditional Agroforestry Calendar	La Nina (Note)		Long-term: The lifetime of a tree or Person (See listing of recommendations presented on the Home Page).		
Recommendations, Long term: The lifetime of a tree or person Plant resilient trees and crops that can tolerate drought and salty conditions. Enjoy traditional foods that keep you healthy with vitamins and fiber. Care for coastal forest that holds the shoreline and protects crops from salt spray. Learn about the effects of climate change in the Marshalls.	Rainfall pattern for 5 ENSO phases compared with 30-year averages for: Majuro and Kwajalein Two panel maps of rainfall and drought across the Marshall Islands for the 5 ENSO phases: Moderate – Strong El Niño Weak El Niño Neutral Weak La Niña Moderate – Strong La Niña				
Links to related materials and websites					
Marshall Islands Climate Outlook Pacific ENSO Applications Center (PEAC) bulletin Inundation information for Majuro and Kwajelein What is the El Niño/La Niña pattern? Learn about the Marshallese traditional agroforestry calendar.	ENSO alert system El Niño recommendations for agroforestry in the Marshalls More about El Niño and its impacts in the Marshalls Information about ENSO and why the climate in the Pacific is different from year to year.	Seasonality of Marshallese Food Plants Availability of Fruits and Vegetables in Majuro Pandanus (bōb) The northern atolls have a strong dry season and are more affected by the El Niño drought.	Advice on rainfall predictions Additional relevant readings: Climate Change in the Marshall Islands and Climate Variability, Extremes and Change in the Western Tropical Pacific. Information on Edible hibiscus Readiness for El Nino Project	Strand vegetation Mangroves Coastal Change in the Pacific Islands (8MB). 2015 Out planting on Woja Causeway, Ailinglaplap Atoll "Coastal Change Toolkit"	Coral Atoll Agroforestry Plant Screener in the USDA NRCS website

There is also a direct link to the USDA Natural Resources Conservation Service (NRCS) Coral Atoll Agroforestry Plant Screener (NRCS, 2017). The screener is a simple plant sorting tool designed to select non-invasive plant species that are best adapted to the ecosystems of the islands. It should be noted that the information of the salt and/or drought tolerances of these species are rarely definitive as experimental data on the tolerances of these species to salt or drought is generally unavailable.

Organization and Maintenance of the *Green Dashboard* Website

The *Green Dashboard* is hosted by the Asia-Pacific Data Research Center at the University of Hawaiʻi in Manoa (UH). It has been duplicated on the College of the Marshall Islands (CMI) website where its ongoing corrections and maintenance are funded through a grant from the USDA Forest Service. It is envisioned that the website will be hosted solely by the CMI in the near future as more Marshall Islanders gain the skills required to maintain and update the site, whereas the UH *Green Dashboard* will not be further edited. It is also noteworthy that the *Green Dashboard* is one of the few management and planning tools to have been translated into Marshallese at this point in time. Meetings are intended to be regularly held to evaluate and update the content, inform Marshall Islanders of the website and how to use it, address problems and issues of content and availability, and sound out Marshall Islanders and others of future directions and needs to be addressed. For example, at the April 13, 2019 meeting on the *Green Dashboard*, it was recommended that recent findings by Reidmiller et al. (2018) be incorporated. These are based on the Fourth National Climate Assessment of relevance to the Marshall Islands. Also to be considered is the addition of information on La Niña and Normal events to the Recommendations tab, repair of broken links, addition of new links and recommendations, a smartphone application, and publicity through social media.

Concluding Remarks

The *Agroforestry in the Climate of the Marshall Islands*, or *Green Dashboard* was developed to meet the requests from agricultural stakeholders and other relevant agencies in the Marshall Islands for information about suitable food species to plant after a drought and the effects of long-term global climate change and sea level rise. It is linked directly to the *Climate Dashboard* (or *Blue Dashboard)* developed by Potemra and Marra (2016), which provides current information on the Marshall Islands climate.

The *Green Dashboard* is presented in 6 pages with drop-down menus and links to other information and websites. The information for this project was based on a literature search, observations in the field, and interviews with 39 Marshall Islanders regarding their traditional ecological knowledge. For the interviews a series of questionnaires were developed, with the questions translated into Marshallese and administered by Marshallese speakers. The *Green Dashboard* provides Marshall Islanders with up-to-date ocean, climate, and agro-ecological information that they can use to mitigate the impacts of sea level rise and droughts associated with ENSO in their native language. As such, it could serve as a model for the development of similar dashboards for the other Pacific Islands which also have to deal with the threat and impacts of global climate change and sea level rise.

It should be noted that the recognition of ENSO patterns and the associated ability to predict stormy seasons and drought is relatively new to western science. As our data collection was limited to a short field research time frame and interviews on Majuro and Arno, we were not able to determine if this information ever existed in Marshallese traditional knowledge. If so, explanation of this pattern and its applicability to atoll agroforestry is new, valuable, and practical information for the Marshall Islands.

The intended audience for the *Green Dashboard* is agroforestry extension agents and community leaders, who we believe would be able to understand the information and convey recommendations to agroforestry practitioners. The content of the website includes indigenous knowledge of older generations, data from Western science, and practical experience of managers from outside the Marshalls. In practice it appears that those perusing the website in depth have included education programs in the Marshalls working with the younger generation, and non-Marshallese professionals seeking an overview before beginning in-depth work in the Marshalls.

Finally, as many Marshallese have little desire to migrate in response to the negative impacts of climate change on their islands (Rudiak-Gould, 2013), we feel that the *Green Dashboard* is a very timely and appropriate agroforestry tool for the Marshall Islands. It offers much needed information, strategies and adaptations to community leaders and the citizenry in an innovative way that we believe will promote the availability of the atoll's resources to support human life, hopefully at least for the next 40 years.

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