College of Tropical Agriculture
and Human Resources
University of Hawai'i at Mānoa

Soil and Crop Management
October 2017
SCM-34

Soils and Agriculture on Tinian

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Introduction

The island of Tinian has a long history of agricultural production, dating back hundreds of years. Throughout history, Tinian has been considered the breadbasket of the Mariana Islands, with the capacity to produce a cornucopia of food including meats and a wide range of tropical fruits and fresh vegetables. The island's productive capacity can be attributed to favorable topography, tropical climate, and access to water. Additionally, its unique geological characteristics have produced a variety of soils with great potential for a diversity of agriculture.

This document aims to provide an overview of Tinian's soils and their potential in the context of its diverse and rich agricultural heritage. The document is organized to provide key background information on the geology and climate of Tinian, a description of soil diversity with accompanying maps, and a discussion of the agricultural potential of the soils. We hope this publication may serve as a guide to be used in planning for the island's future development so that agricultural capacity can be fully realized and sustained to serve present and future generations.

Physical Setting and Geology

Tinian (Latitude: 15.01°N, 145.62°E), one of the four inhabited islands of the Commonwealth of the Northern Marianas Islands, lies in the Western Pacific Ocean about 125 miles north-northeast of Guam and 3,900 miles west-southwest of Hawai'i. The island covers approximately 39 square miles, with Mt Kastiyu (614 ft) in the southeast marking the highest point on the island. Tinian has a warm tropical climate, with mean monthly highs of 87°F between May and July and only slightly cooler maxima of 84°F in the cooler months of January and February. Annual rainfall averages 82 inches, with a distinct wet season from July to October accounting for almost 60% of total annual precipitation (Fig 1). Between December and June, PAN exceeds precipitation, indicating the need for irrigation to maintain adequate moisture for crop production during the dry season.

The soils of Tinian are influenced by the unique geology of the island. Tinian is the fourth island from the

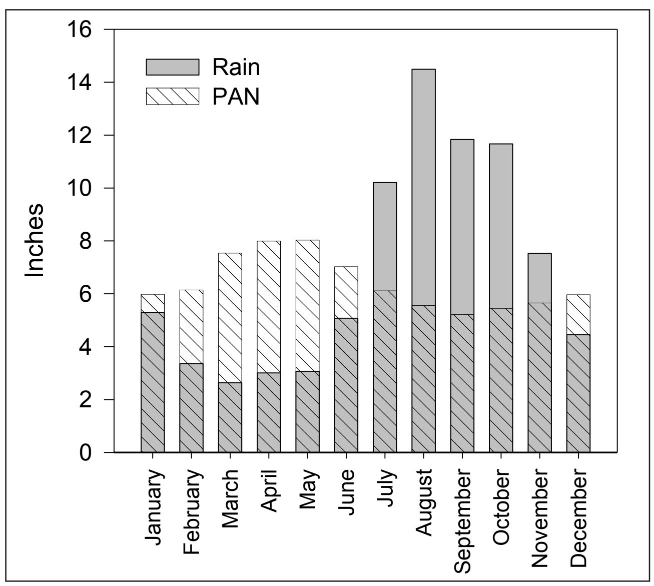

Figure 1. Mean monthly precipitation (1988–2012) at the Tinian Airport (National Climatic Data Center 2014) and pan evaporation (PAN) data adapted from Guam (Gingerich 2002).

south in the 17 islands that make up the Mariana Islands chain lying to the west of the Mariana submarine ridge. It is classified as a composite karst island composed of primarily coralline limestone rocks (95% of area) overlying volcanic tuffs and breccias with a few small outcrops of volcanic rocks. The volcanic outcrops are characterized by extensive weathering. Soils over limestone tend to be shallow, with weakly developed profiles and neutral to alkaline pH, whereas the soils formed on the volcanic parent material are older, with deeper profiles that are acidic throughout.

Soils of Tinian

In this publication we present maps and interpretations of the soils of Tinian using the U.S. Soil Taxonomy classification system and data from the Soil Survey (Young 1989). The U.S. Soil Taxonomy system classifies the soils of the world into twelve broad soil categories called soil orders (Appendix I). Soils are grouped based upon profile characteristics including a range of measurable soil physical and chemical properties (i.e., soil texture, bulk density, organic matter, soil pH, cation exchange capacity, etc.) and observable properties such as soil color, profile arrangement, and soil depth.[1]

The island of Tinian shows surprising soil diversity for its small size, comprising seven of the twelve soil orders (Fig. 2a), which the Soil Survey has grouped into three general landforms: upland soils, limestone plateau soils, and lowland soils (Fig. 2b). Mollisols, Inceptisols, and Oxisols are the dominant soil types on Tinian, covering approximately 97% of the island (Table 1). The dominant Mollisol, the Chinen series, is a shallow soil, with near-neutral pH, relatively high organic matter in the top 2 inches (organic carbon (OC)

[1]A detailed description of how soil-forming processes and factors interact to form the soils of Tinian can be found in the "Soil Survey of the Islands of Aguijan, Rota, Saipan, Tinian, Commonwealth of the Northern Mariana Islands" (Young 1989).

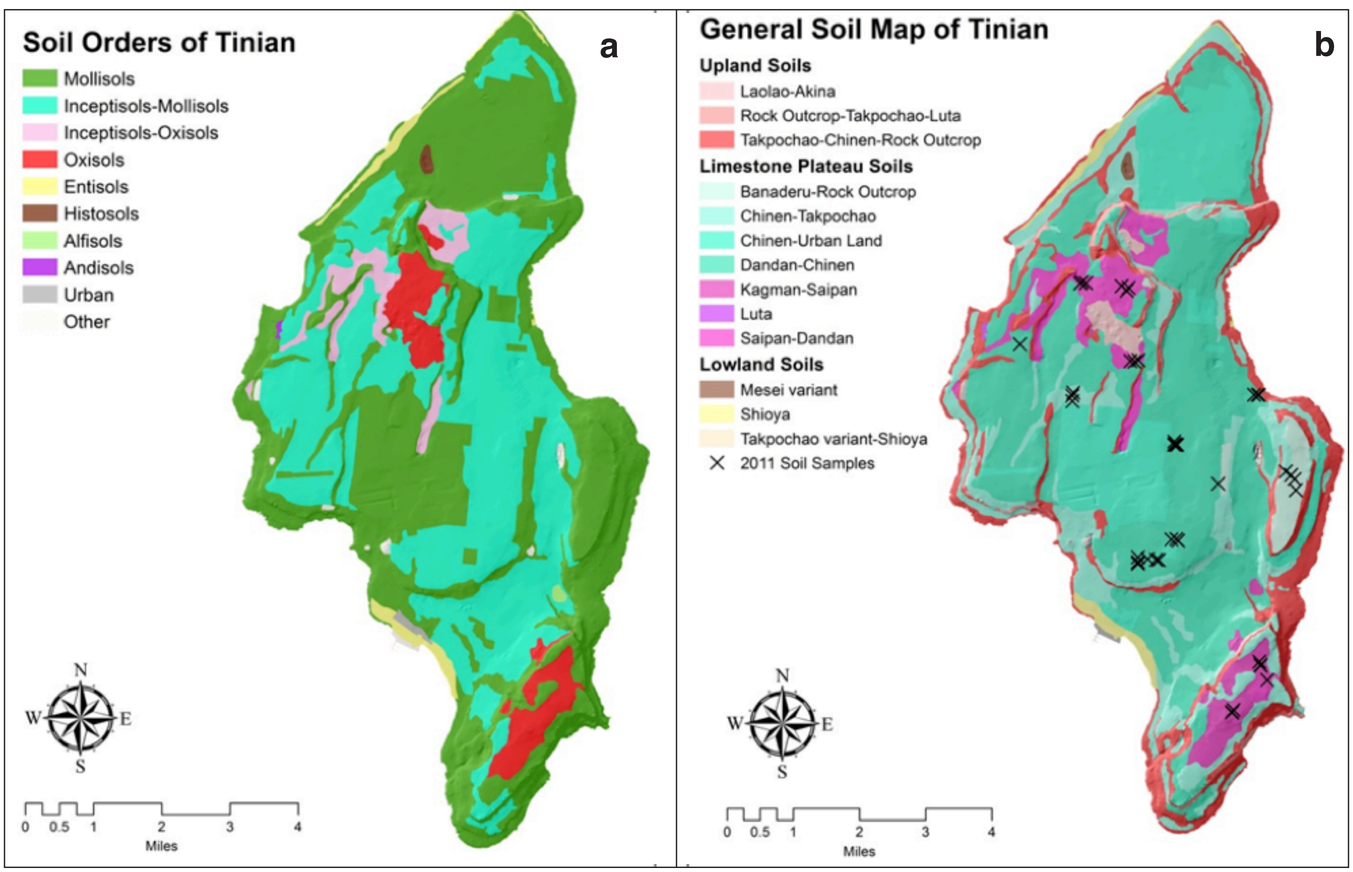

Figure 2. Distribution of the seven soil orders on the island of Tinian (a). Names and locations of individual map units in relation to the three land forms (b). X symbols represent sites where soil samples were collected for nutrient analysis.

= 7.62%), and very high calcium (Ca) and magnesium (Mg) throughout the profile as a result of the limestone parent material. The dominant Inceptisol, the Dandan series, which often occurs in association with the Chinen series on the landscape, is a moderately deep soil with a slightly acidic surface horizon (pH = 6.3), lower organic matter content (OC = 4.7%), and very high Ca and Mg throughout the profile. Together, the Chinen and Dandan soils cover approximately 74% of the landscape on Tinian. The Oxisols are comprised of the Kagman and Saipan soils, which formed over limestone, and the Laolao soil, which formed from volcanic parent rock. The Kagman and Saipan are deep soils with near-neutral pH, lower amounts of organic matter (OC = 3.1–3.5%), and moderate to high Ca and Mg, whereas the Laolao soil is acid with moderate organic matter and Ca and Mg. The Histosols, Alfisols, and Andisols are limited to very small areas in the north, west, and southeastern portions of the island, respectively (refer to the Soil Survey for more information on these minor soils of Tinian).

Soil Fertility

Soil fertility refers to a soil's capacity to retain and supply essential plant nutrients for crop growth. Soil pH, clay content and mineralogy, and organic matter content all play key roles in determining nutrient retention and supply.

Because most of the soils on Tinian formed from limestone, they have neutral to alkaline pH and are well

Table 1. Predominant soil orders, major individual soil series, and their approximate acreages on Tinian.

Soil Orders	Soil Series	General Description	Area (acres)
Mollisols			**16,535**
	Chinen	Shallow, well-drained soils over limestone bedrock found on uplifted limestone plateaus. These soils are slightly alkaline and contain high organic matter and Ca and Mg.	9,174
	Takpochao-Rock Outcrop	Very shallow, well-drained soils on limestone plateaus, side-slopes, and escarpments. These soils are slightly alkaline and contain high Ca and Mg.	2,788
	Banaderu	Shallow, well-drained soils on uplifted limestone plateaus. These soils are slightly alkaline and contain high Ca and Mg.	470
Inceptisols			**5,168**
	Dandan	Moderately deep, well-drained soils on uplifted limestone plateaus. These soils are slightly acidic and contain high Ca and Mg.	5,168
Oxisols			**1,306**
	Kagman	Deep to very deep, well-drained soils on uplifted limestone plateaus. These soils are neutral and contain moderate organic matter and Ca and Mg.	600
	Saipan	Deep to very deep, well-drained soils on uplifted limestone plateaus. These soils are neutral and contain moderate organic matter and Ca and Mg.	416
	Laolao	Moderately deep, well-drained soils on volcanic uplands. These soils are acidic to slightly acidic with moderate organic matter and high Ca and Mg.	290
Entisols			**392**
	Shioya	Deep to very deep, excessively drained, sandy soils on coastal strands and water-deposited coral sand. They are alkaline soils with low organic matter and high Ca.	374

supplied with Ca and Mg. The primary soils on Tinian (Chinen, Dandan, Saipan, and Kagman) tend to have moderately high cation-exchange capacity (retention) and moderate nutrient-supply capacity due to relatively high clay contents and elevated soil organic matter in the surface layers. Water retention and availability tends to be moderate in the deeper soils and limited in the shallow soils (see below). Given the presence of high calcium carbonate from the limestone parent material and the accumulation of iron oxide colloids weathered from volcanic alluvium, P solubility can be low and limit availability to the plant due to P-fixation reactions. Phosphorus solubility, and thus its availability for plant uptake, is controlled by precipitation reactions with calcium at pH above 7.0 and by fixation reactions on the surfaces of iron oxide clays. Both the precipitation and fixation reactions reduce P availability to growing plants. Furthermore, as soil pH increases above 7.0, the solubility and availability of essential micronutrients (boron, copper, iron, manganese, and zinc) decreases rapidly, which may result in micronutrient deficiencies.

Surface soil samples (0–15 cm) collected in 2011 from the major land types on Tinian provide a snapshot of soil-fertility parameters for some important soils (see Figure 2b for location of sample sites). In general, the soils have relatively high organic matter contents and pH values that mostly fall within the desirable range for agricultural soils (Table 2). As expected, Ca and Mg concentrations are high. For P and K, nutrient levels at each of the sampling points showed a wide range of concentrations from deficient, in 55% and 79% of samples for P and K respectively, to very high, in 6% for both P and K. The sites showing very high P and K levels were situated on land known to have been under intensive cultivation, reflecting the residual value of historical fertilization. In areas where P and K are low, the use of high-quality compost, organic soil amendments, and/or blended fertilizers can be used to increase nutrient availability and improve soil fertility. We recommend regular soil testing as the most effective way to assess and monitor soil nutrient status.

Soil Depth

Soil depth fundamentally affects plant growth and agricultural productivity. Deep soils offer plant roots a large volume of soil to acquire essential nutrients and water. On the other hand, shallow soils can limit plant growth and productivity by restricting root growth and limiting soil water and nutrient storage and availability. Plants growing in shallow soils are especially vulnerable during dry periods when soil water reserves are quickly depleted to levels that restrict plant growth. These limitations are mitigated where access to irrigation infrastructure exists. In addition to increasing drought susceptibility, shallow soils can make cultivation difficult, limiting certain cropping systems, especially annual row crops that rely on tillage.

More than half of Tinian's land area (51%) is covered with shallow soils that limit crop production (Figure 3a). Approximately 38% of the land exhibits mixed depth,

Table 2. Mean soil organic matter, pH, and macronutrient levels in 33 surface soil samples (0–6 in) collected from main soil types on Tinian.

Soil	N	TOC	TN	pH	P	K	Ca	Mg
		------------%------------			---------------------mg kg^{-1} -----------------------			
Kagman	6	5.81±1.06	0.61±0.09	6.18±0.67	6.23±3.58	166±126	3732±1935	714±117
Dandan-Chinen	18	6.41±1.37	0.67±0.13	7.24±0.41	41.2±26.5	317±224	6131±1673	527±71
Saipan-Laolao	6	4.45±0.54	0.48±0.10	6.14±0.32	28.6±21.6	102±65	3699±852	697±185
Chinen	4	6.69±0.33	0.68±0.03	7.33±0.31	14.0±2.00	89.2±4.1	6621±413	787±205
Banaderu	4	4.02±0.33	0.46±0.04	6.63±0.35	6.10±4.25	381±319	3302±813	526±25
Sufficiency Range†		*NA*	*NA*	*6.0 – 7.0*	*20-70*	*250 - 600*	*2,500 - 3,500*	*300-600*

†Adapted from Uchida et al. (2006)

where exposed limestone is interspersed with pockets of soil varying in depth (Figure 3b). Where the ridges occur, shallow depth limits water storage and poses a serious obstacle for any kind of mechanized tillage operations. Soils without any depth limitations cover about 10% of the land and are found on plateau areas of the southeastern and north central highlands of the island.

Land Use

Farmland

Tinian has a long agricultural heritage. During the Japanese period (1914–1944), approximately 98% of the island was cultivated with sugarcane, earning the island the nickname of "Sugar Island" from American troops who conquered the island in 1944 (Figure 4a & 4b). In addition to sugar, the Japanese grew a wide range of food crops including vegetables and pineapples in these fertile soils.

Soil-survey activities carried out by the Soil Conservation Service (United States Department of Agriculture) on Tinian in 1989 developed soil-capability rankings. According to the ranking system, approximately 6% of the land on Tinian (1,515 acres) is classified as Prime Farmland if irrigated. The area shaded with cross hatches in Figure 3a shows the distribution of Prime Farmland on Tinian. These soils are all deep soils. Historically these were important vegetable farm lands, depicted by the dots in Figure 5. They remain well suited for vegetable production and other forms of intensive agriculture if irrigated.

The approximately 9,800 acres classified as mixed-depth soils in Figure 3a were productive sugarcane soils during the Japanese period but do not meet Prime Farmland classification in the NRCS capability-ranking system, primarily because of variable depth across the landscape. They are, nevertheless, fertile soils capable

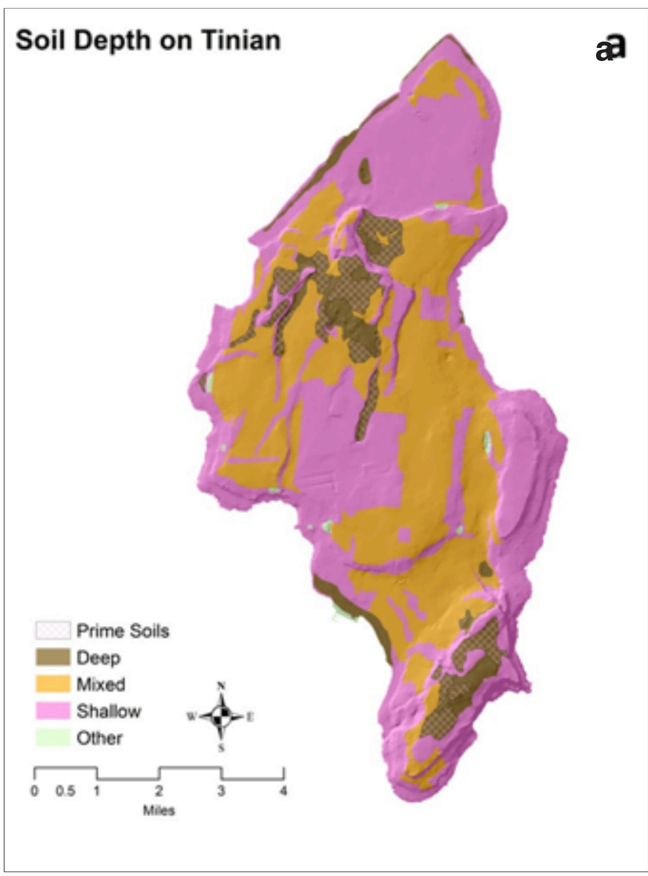

Figure 3. Map depicting the distribution of soil depth on Tinian (a) and a photograph showing the limestone bedrock topography with interspersed pockets of soil (b).

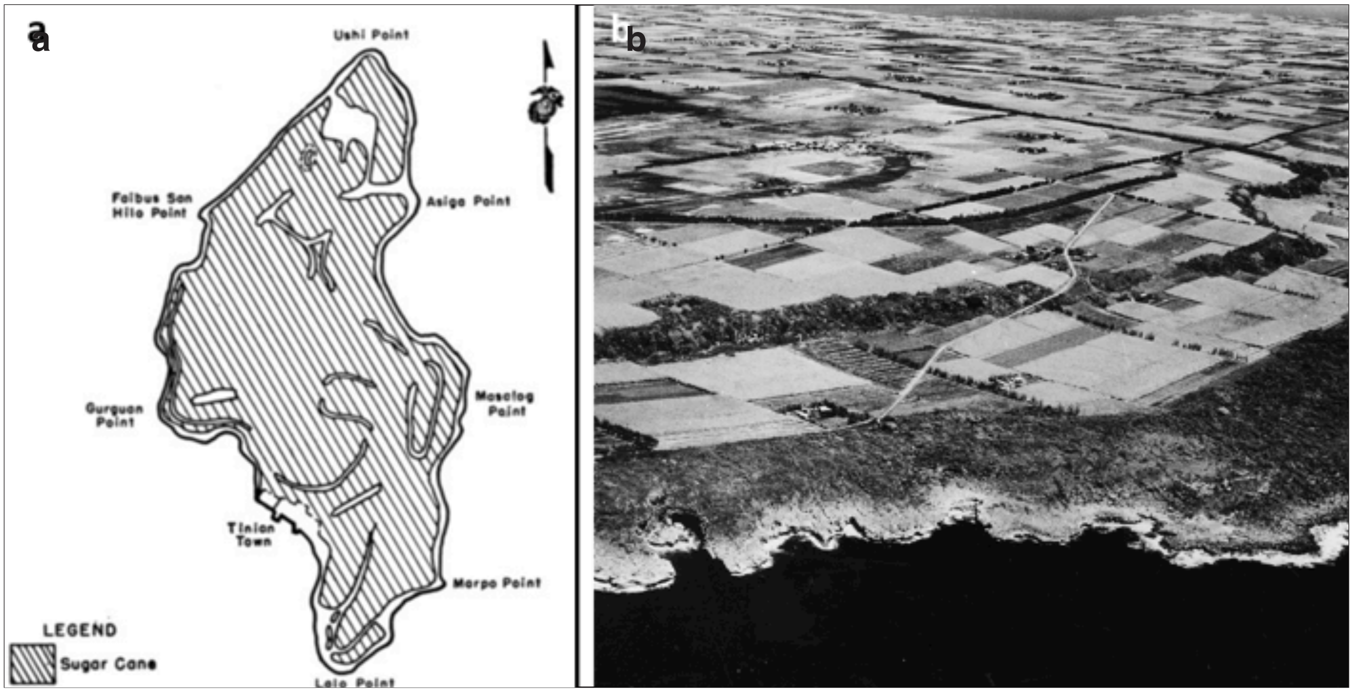

Figure 4. A map developed during the Japanese era depicting the extent of sugarcane cultivation on Tinian (a) and an aerial photograph of cane fields on Tinian (b).

of supporting a range of small-scale irrigated cropping systems. The Soil Survey regards these lands as moderately suited to agriculture. Their historical record as productive agricultural lands is testament to the important role they have played in Tinian agriculture. With appropriate matching of cropping systems and management strategies to the landscape, these soils continue to offer great agricultural potential and should be preserved and promoted for agriculture.

Cattle Production

Tinian has a long history of cattle and livestock production. Cattle were first brought to Tinian by the Spanish in the 16th century (Coomans 2000). After the Spanish-Chamorro War, which began in 1668, at a time when there were no Chamorro residents on the island, cattle were allowed to proliferate, providing an important source of protein for the incoming and outgoing Spanish galleons that voyaged across the great expanses of the Pacific Ocean. The feral cattle herds on Tinian, described by Admiral Anson and his crew (circa 1742) as being entirely milky-white in color, with only their ears being black, roamed this fertile land for a few hundred years and numbered in the tens of thousands (Barrat 1988). As the administration of the island of Tinian was transferred from the Spanish to the Germans, the herds were preserved and encouraged to grow. During the German period, livestock production expanded and gained economic importance as purchase for consumption and slaughter fees became commonplace. It was not until the Japanese administration that the beef herds were greatly reduced as the island was put into sugarcane production.

After World War II, local residents returned to the island to resume crop and livestock production. During the 1960s much of the island was leased to Ken Jones, who developed a large-scale beef and milking cattle operation, with over 7,000 beef cattle and 1,000 milking cows in their inventory (Figure 6a). Today, cattle ranching continues to be an important part of life for many residents on Tinian (Figure 6b). Tinian's cattle ranches are all family owned and operated, providing local residents with fresh beef for household consumption and traditional offerings for cultural events such as weddings, funerals, and fiestas. There is a growing movement to expand cattle production on Tinian.

With its flat to gently sloping landscapes and fertile

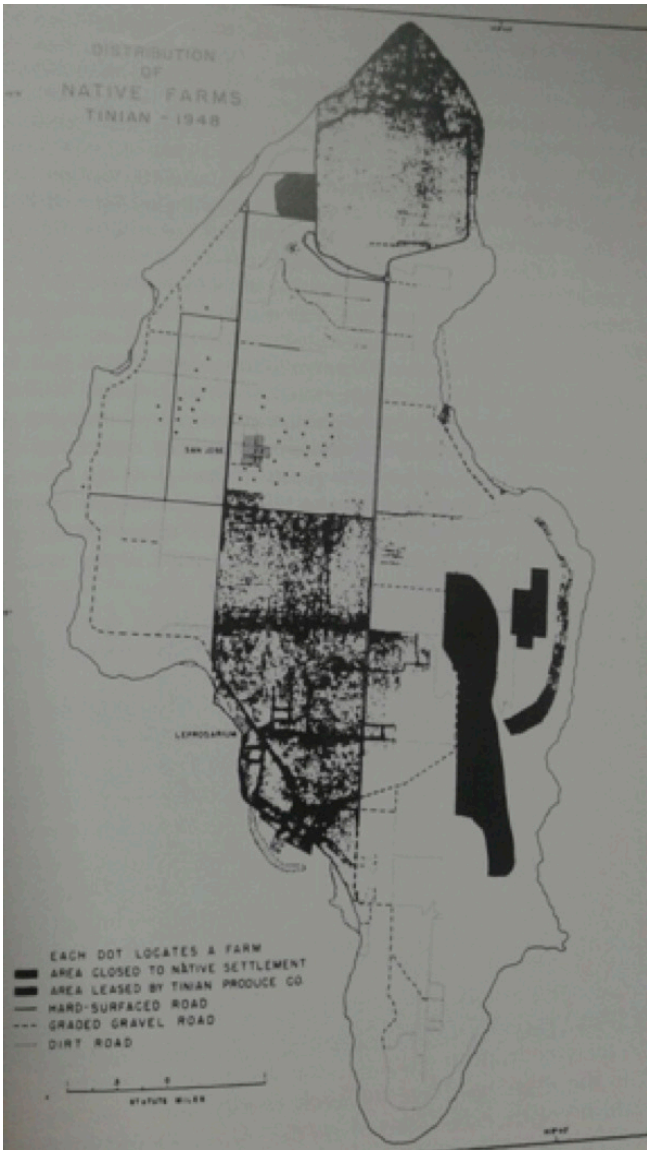

Figure 5. Location of vegetable farms (dots) on Tinian ca 1948.

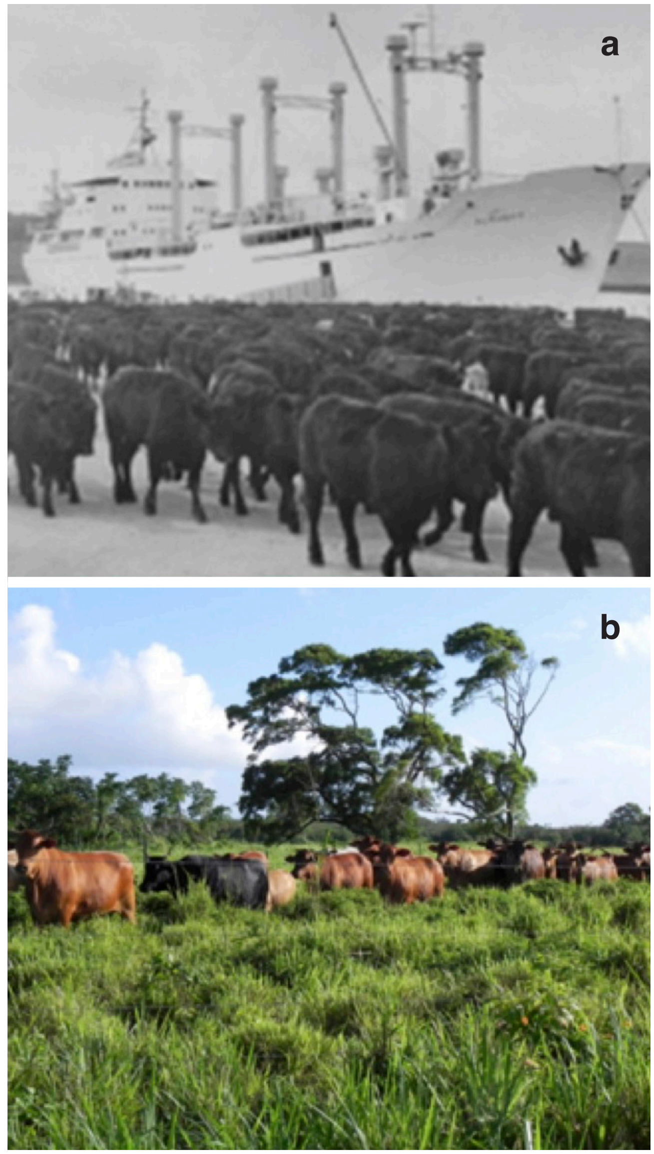

Figure 6. Cattle at the dock during the height of cattle production on Tinian (a). A healthy herd of cattle in a verdant, productive pasture on Tinian today (b).

soils with good infiltration rates, which minimize erosion potential, Tinian offers ample opportunities for raising grass-fed beef cattle. According to the soil survey (NRCS 1989), more than 14,000 acres, equivalent to approximately 55% of the land area, are well suited to grazing cattle (Figure 7). These lands support vigorous growth of high-quality forages throughout much of the year. An additional 7,100 acres are moderately suited to grazing, with some limitations associated with shallow soils where reduced water-holding capacity decreases grass productivity during the dry season. These lands are currently being returned to cattle production, and there is growing interest in expanding.

Acknowledgements
The authors wish to thank Sam Palacios for his help in arranging access to farmlands on Tinian, for sharing his extensive knowledge of the landscape, and for his assistance in collecting soil samples. We also thank Don

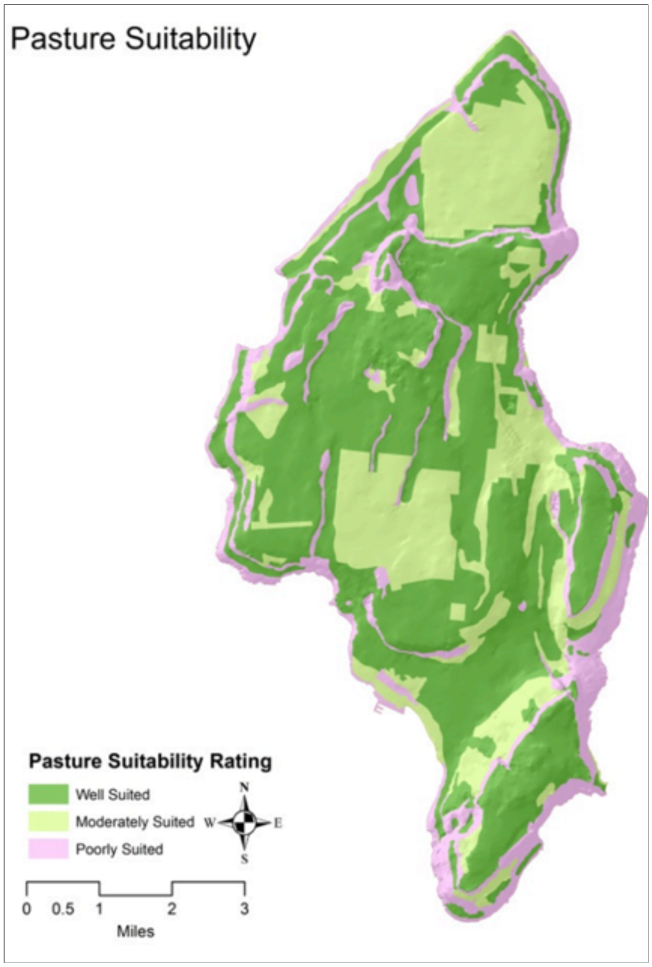

Figure 7. Pasture suitability map for Tinian based upon suitability classifications developed by the Natural Resources Conservation Service (NRCS, 1989)

Farrel for his guidance and assistance with identifying the appropriate historical records. We are especially thankful for Dr. Robert Gavenda's thoughtful review of the manuscript and his invaluable insights and suggestions. Financial support from USDA-NIFA project 2009-51200-19601 enabled the soil sampling and sample analysis.

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