Micronesica 30(2):389–415, 1997

Agricultural Crop Production on Guam during the 20th Century

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Abstract—Agriculture on Guam has changed dramatically during the period of American governance (1898 to 1941 and 1944 to present). The primary event affecting agriculture during this period was the transition to a cash based economy. Employment for monetary wages became widespread during the last years of World War II (WWII) and during the military build-up immediately afterwards. Prior to WWII, the economy of Guam was based on subsistence agriculture. In a historic sense, the crops on Guam can be divided into three categories: (1) those that have basically disappeared as commercial commodities because of complete replacement by imports, i.e. rice, arrowroot, sugarcane, field corn and tobacco; (2) those that were important before the introduction of the cash economy and have remained relatively important for cultural or economic reasons, i.e., coconut, taro, yam, sweet potato, banana, pineapple and papaya; and (3) those that have become important since the late 1950s, i.e. watermelon, cucumber, beans, eggplant, tomato and cantaloupe. Increased demand and erratic local supplies of fresh vegetables and fruits encourage the importation of many commodities. Sources of variation in local production of fruits and vegetables are: periodic typhoons and tropical storms; soil saturation during rainy season; physiological disorders due to high temperature, high relative humidity, water stress, imbalances of soil nutrients, and the occurrence of diseases and pests. The recent emergence of landscaping and ornamental markets as well as turf management business of golf courses has diversified the island's agriculture. Some issues on Guam's future agriculture addressed are development of environmentally sound and sustainable cropping systems, new crop development, mechanization, improvement of post harvest technology, development of profitable market system, and further expansion of the newly developed ornamental, landscape and turf industry.

Introduction

More than 90% of the food consumed on Guam is imported (Economic Research Center, Department of Commerce 1984) and current agricultural employment is 0.5% of total employment (Department of Labor 1995). This situation has not substantially changed in the last 25 years (Lee 1971). Despite a steady increase

in island population since World War II (WWII) (Figure 1), the numbers of commercial farms and growers have remained the same or decreased. The majority of fruits and vegetables consumed on the island are imported from the mainland United States, and foreign sources include Australia, Federated States of Micronesia, Korea, Japan, the Commonwealth of Northern Mariana Islands, New Zealand, Taiwan, Palau, Philippines, People's Republic of China, and Thailand (Department of Agriculture, Plant Protection & Quarantine 1996).

There are many environmental problems that limit local agricultural production. Guam is a tropical island that receives abundant heat and light the year-round and seasonal rainfall. The island environment is characterized by occurrences of unpredictable heavy rain and wind, and poor soils in most areas of the island. The periodic occurrences of typhoons constrain development of perennial crops. In addition, the introduction of new pests and diseases have created problems with crop production. Local producers frequently fail to provide a constant supply to the market due to abiotic and biotic constraints which results in a heavy reliance on imported produce.

Social, economic, and political factors also limit agriculture on the island. A historical review of agricultural production systems on Guam reveals that the change in the socio-economic structure on the island during and after WWII has greatly influenced production patterns. Prior to WWII, the economy of Guam was primarily based on subsistence agriculture. Shifts in the labor force from farming to a wage-based economy reduced local crop production and allowed for expanded imports of produce. Moreover, government policy on land use has greatly restricted farming activities. Lands in the central region of the island, which were primarily in agriculture, have been expropriated for development of military bases and as business districts.

This paper discusses the environmental and economic factors that have shaped the pattern of crop production on the island, focusing on historical events and the current status of agriculture on Guam.

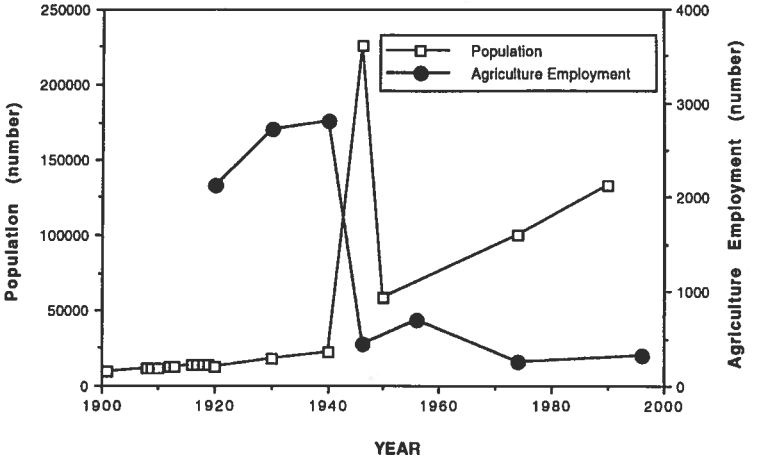

Figure 1. Population of Guam from 1901 to 1990 and the number of farmers and farm laborers from 1920 to 1996.

Environment and Agriculture

Geography

Guam is a tropical island of the Western Pacific, located at 144°55′ E longitude and 13°33′ N latitude. The island is 48 km long and 6 to 9 km wide with a total area of 549 km^2 or 135,680 acres (Young 1988). It is the largest and the southernmost island in the Mariana Islands chain, located about 6,100 km west southwest of Hawaii, 2,600 km east of the Philippines, and about 2,500 km south southeast of Japan.

The island topography divides Guam into three major geophysical regions. The northern part of the island is a flat limestone plateau with elevations between 30 and 174 m. In contrast, the southern part of the island consists of mountainous uplands of volcanic origin, with a highest elevation of 407 m. Surrounding hills are divided by numerous rivers and many steep slopes which are subject to erosion. Limestone is found along the south east coast and at areas around the highest point in the south. The central part of the island consists of both hilly limestone and plateaus. Development is the greatest in this area, where most government and business activities take place.

Soils

A total of 55 soil types are characterized on Guam (Young 1988). These soil types are grouped together into three classes; soils on bottom lands (4%), soils on volcanic uplands (35%) and soils on limestone uplands (61%). The soils in the first class are deep, level, poorly drained clay soils on bottoms of valleys and coastal plains. Floods are frequent during the rainy season. Soils on volcanic uplands are found in the southern parts of the island. There is a wide range of soil depths and drainage, and in general, steep slopes limit cultivation. The southern soils of volcanic origin have pH generally less than 5.5 (Demeterio et al. 1986a). The third class of soils overlying limestone in the northern and southeastern part of Guam are shallow and have a pH of 7.0 or higher.

Guam soils are low in phosphorus and can be limiting for crop production, especially in acid soils (Demeterio et al. 1986b). Liming to increase pH and to improve availability of soil nutrients and microbial activity is a recommended practice for acid soils. In calcareous soils from central and northern parts of the island, iron and other micro-nutrient deficiencies are common due to high soil pH. Water stress is common in shallow soils overlying the limestone during the dry season and transition periods between dry and wet seasons.

Many vegetable crops have been grown in the different soil regimes on Guam. Watermelon[1] which is the most important crop in economic terms and an acid-tolerant plant, is commonly grown in the deep soils of the southern part of the island, while many growers in the north cultivate yard-long bean and cucumber. These plants can be grown throughout the year in the field with well drained soils in the north. In general, inorganic chemical fertilizers are commonly used to supplement mineral nutrients of soils.

[1]Latin names of crops are given in Tables 3–5.

Daylength and Light Intensity

Guam has daylength ranging from 11 hours and 19 minutes in December to 12 hours and 56 minutes in June. Although the difference in seasonal daylength is small, some plants display photoperiodic responses in their development. As an example, *Euphorbia cyathophora* L., an introduced weed from the New World, flowers from December to February and winged beans flower and produce fruits from January through March. Some cultivars of potato e.g. 'Kennebec,' initiate formation of flowers and new tubers much earlier on Guam than when they are grown in temperate regions (Marutani 1986). Early tuberization can be attributed to physiological responses to short-day conditions of Guam. Conversely, supplemental lighting applied to kangkong, a leafy vegetable, increases its yield by promoting vegetative growth.

The highest monthly average of possible sunshine (57%) was recorded in March and April, and the lowest monthly average of possible sunshine (34%) was reported in August (NOAA, 1994). The average daily solar radiation at Barrigada (central Guam) from January 1 to March 31, 1986 was recorded as 18.2 $MJ \cdot day^{-1}$, ranging 10.0 to 25.2 $MJ \cdot day^{-1}$ (Marutani 1986). Effects of light intensity on plant phenology was studied on dendrobium orchids (McConnell 1988). Dendrobiums growing in 30% shade have been found to initiate flowering about one month earlier than those grown in full sun. Vegetable seedlings which are grown in shade and are not acclimatized before transplanting to the field are usually scorched by sunlight.

Precipitation

Average annual rainfall from 1965–1994 was 256.7 cm (NOAA 1994). Average monthly rainfall ranges from 10.4 cm (March) to 38.1 cm (August). Dry months are February, March and April, and wet months are from August to October. Transitional periods are from November to January and from May to July. Several typhoons and tropical storms pass the island yearly, resulting in large amounts of precipitation within a short period of time and causing severe damage to crops, especially those grown in poorly drained clayey soils. During the rainy season, some agricultural lands become unusable because of poor drainage; on the other hand, irrigation is essential for optimal growth of crops during the dry season. In general, the best vegetable production is during the dry months when environmental conditions are favorable with workable soil, lower night air temperatures and lower air humidity. As an example, more tomatoes are produced during the dry season than the wet season (Lee 1980). Guam is subject to drought during ENSO (El Niño) events (Lander 1994).

Temperature and Humidity

Mean air temperature is about 26°C and it remains relatively constant throughout the year (NOAA 1994). There is a slight seasonal change in temperature with January and February being coolest. The average monthly maximum temperature is 30°C and the average monthly minimum temperature is 22°C. The

lowest recorded temperature occurred in March, 1965 at 12.2°C, and the highest temperature was recorded in September, 1957 at 35.0°C. Relative humidity usually ranges from 65–75% in the afternoon and above 85% at night. High temperature and high humidity limit development in some plants. On the other hand, some temperate crops can acclimatize to the tropical conditions, but exhibit early maturation and senescence. The most pronounced adverse effect of high temperature and humidity is poor flower development, failure of pollination and subsequently little or no fruit production of tomato. Some high yielding tomato cultivars recommended for the dry season produced few flowers and fruits with high incidence of flower and fruit drop when planted after April (Marutani, unpublished data). Reduced fruit production in tomatoes appears to be caused by high humidity and temperature from May to July. High temperature is a major stress causing some cultivars of lettuce to develop bitterness (Marutani et al. 1993). Similarly, some potato cultivars had bitter tubers perhaps because of high temperature (Marutani, unpublished data).

Winds

The trade winds blow easterly or northeasterly throughout most of the year. They are intermittent during the rainy season and become strongest and steady during the dry season (25–40 $km \cdot hr^{-1}$). Tropical depressions can become storms throughout the year. Damage to crops by these storms can be devastating. Several devastating typhoons, e.g. Karen (in 1962) and Pamela (in 1976) destroyed the island severely and defoliated many plants. The extreme occurred during 1992 when Guam was visited by five typhoons between late August and December. One of these was the powerful typhoon, Omar, that had peak gusts of 52.3 $m \cdot sec^{-1}$.

Planting windbreaks is recommended to reduce possible damage to crops by tropical storms. Ironwood or Australian pine tree, *Casuarina equisetifolia* Forst., is one of the common windbreaks on farms. Wild cane (*Saccharum* sp.) is also used as a windbreak, partitioning sections of cultivating areas.

Agricultural History

Spanish Rule—up to 1898

During the Spanish occupation, the island economy was based on subsistence agriculture. It was a product of pre-contact Chamorro culture as modified by 333 years of Spanish rule (Sanchez 1991). Most families maintained two residencies, one in a village and the other temporarily on a lancho (ranch) where a farmer spent weekdays (Thompson 1947) or they made a daily commute to the farm (Oakley 1944; Carano & Sanchez 1964). On the lancho, the primary crops were field corn and rice. Field corn was harvested primarily in July and August while rice, taro and yams were harvested from December to February (Thompson 1947). Breadfruit was harvested from May through August. Other staples were arrowroot, wild yams and a flour made from the seeds of the federico palm (*Cycas circinalis* L.) (Thompson 1947). Copra was the primary export product of the island (Safford 1905).

The island, however, was not self-sufficient in food production. Safford (1905) noted that the food shortages had occurred on many occasions due to typhoons and pest problems, particularly during the storage period between harvests. Stored grains were often destroyed by rats and weevils. Manual Sanz (ca. 1827) (Driver 1991) stated that "This grain (field corn) is scarce during the period between harvests because it is immediately attacked by grubs, motivating farmers to plant very little of it." Emergency supplies of food were imported from Manila during food shortages exacerbated by typhoons (Safford 1905).

US Naval Government, 1898–1941

Early American efforts in the area of agriculture development included the establishment of an experimental agricultural station and stock farm (Carano & Sanchez 1964), and the recommendation that the US Government send vegetable, grain, fruit and grazing grass seeds suitable for the tropics plus animals and tools to Guam (Sanchez 1991). Between 1900 and 1904, a sanitary slaughter house and a public farmers market were built in Agana (Carano & Sanchez 1964). The first plant and animal quarantine laws were promulgated on February 1, 1905, and on March 27, 1905, the Naval Government established an agricultural school with an affiliated Agricultural Experiment Station under H. L. W. Constenoble (Dyer 1905). Soon afterwards, the United States Congress appropriated the necessary funds and the USDA Agricultural Experiment Station was established in 1908 in Piti Village (Dorn 1909).

Despite the attempts of the Naval Government to encourage agriculture on Guam, the first ten years of US administration of Guam saw the beginnings of a pattern that was to characterize Guam's agricultural economy during most of the twentieth century. This was the abandonment of subsistence agricultural activities for wage paying jobs in the government sector. By 1911 almost one-fourth of the able-bodied men of the island were working for the government (Thompson 1947). Many lancho had been abandoned and land owners had begun to lease their coconut plantations to Japanese traders instead of farming themselves (Fullaway 1912).

The Naval Government encouraged agriculture but its efforts were sporadic. In 1913, the government began a project to encourage farmers to increase the planted areas on their farms. In 1917, the governor ordered all land owners to cultivate their farms to the fullest extent or to lease them to others. A compulsory labor law was passed in 1918 that required all unemployed males [farmers] aged 16 to 60 to cultivate at least one hectare. In spite of government support for agriculture, the trend towards a monetized economy with decreased subsistence farming continued through the pre-Japanese occupation period (Thompson 1947).

The US Bureau of the Census conducted the first Census of Agriculture on Guam in 1920, then again in 1930 and 1940. The 1920 Census found that 60.9% of male employment was engaged in agriculture (US Bureau of the Census 1921). There were 3,606 acres of field crops reported for Guam in 1919. The important

crops by acreage were field corn, sweet potatoes, taro, yams, tobacco, cassava, rice, arrowroot and sugarcane (Table 1). Coconut was the most important fruit crop, followed by banana, pineapple, coffee and breadfruit (Table 2). During the 1920's, there was a substantial growth of the rural population of 48.9% as compared to the growth of the urban population of Agana of 16.9% (US Bureau of the Census 1931). Guam still remained an agriculturally oriented society dependent upon US Government subsidies (Brown 1926) with a need to import great amounts of food (Anon. 1928). Vegetable production was not reported in the 1920 US Census, although several species of Cucurbitaceae had been documented by Safford (1905). Additionally, Fullaway (1912) reported that eggplants, beets, cucumbers, radishes and cabbages were grown. Taro leaves as a vegetable were also grown on family farms (Palomo 1992).

Table 1. Harvest area of field crops, root crops and vegetables grown on Guam in 1919, 1929, 1939, 1949 and 1959.[a]

Crop	Area harvested				
	1919	1929	1939	1949	1959
Field and root crop:	(acres)	(acres)	(acres)	(hectares)	(hectares)
Field corn	2,173	3,565	2176	279	30
Sweet potato	536	543	321	22	24
Taro	473	1,033	718	77	59
Yam	160	404	199	15	15
Tobacco	81	51	39	(1)[b]	—[c]
Cassava	80	165	181	4	24
Rice	58	197	517	—	3
Arrowroot	32	75	93	(1)	—
Sugarcane	13	53	86	2	—
Total	3,606	6,086	4,376	—	—
Vegetable crops:			(hectares)	(hectares)	(hectares)
Melons	—	—	5	15	15
Beans	—	—	2	10	28
Tomatoes	—	—	1	13	11
Cucumbers	—	—	(1)	5	35
Peppers	—	—	(1)	(1)	5
Eggplant	—	—	(1)	(1)	21
Radish	—	—	—	2	2
Chinese cabbage	—	—	—	(1)	10
Watermelons	—	—	—	—	27
Sweet corn	—	—	—	—	26
Pumpkins	—	—	—	—	12
Green onions	—	—	—	—	8
Lettuce	—	—	—	—	(1)
Mungbeans	—	—	—	—	(1)

[a]Data are based on US Bureau of the Census 1921, 1931, 1941, 1951, and 1961.
[b]The "—" means no data reported.
[c]The "(1)" means less than 1 hectare.

Table 2. The number of fruit and tree crops grown on Guam in 1919, 1929, 1939, 1949 and 1959 and the amount of crops harvested in 1959.[a]

Crop	Number of Plants					Amount harvested
	1919	1929	1939	1949	1959	in 1959
	(number)					(pound)
Coconuts	404,581	1,021,884	885,424	241,816	—[b]	1,113,967
Bananas	155,142	250,521	535,240	142,222	153,687	660,964
Pineapples	42,637	157,528	134,263	35,603	77,816	48,950
Coffee	32,191	101,488	90,254	7,968	232	120
Breadfruit	15,970	36,493	36,615	12,405	—	315,406
Oranges	2,788	4,891	5,477	860	2,178	34,481
Lemons	1,992	8,496	11,270	1,330	3,431	53,776
Papayas	1,247	6,847	7,719	2,211	6,643	76,136
Cacao	490	1,820	1,026	—	—	—
Limes[c]	367	1,098	2,643	234	—	—
Mangoes	284	6,203	4,602	1,758	2,320	145,835
Avocado	69	7,407	10,220	1,870	2,798	41,931
Grapefruit	33	225	760	51	—	—
Kapok	—	6,380	9,629	418	—	—
Tangerines	—	—	3,951	1995	3,372	68,447
Betelnuts	—	—	—	—	—	37,583
Guavas	—	—	—	—	—	10,689
Soursops	—	—	—	—	—	15,656
Starfruits	—	—	—	—	—	7,776

[a]Data are based on US Bureau of the Census 1921, 1931, 1941, 1951, and 1961.
[b]The "—" means no data reported.
[c]The report was combined with lemons for 1959.

The 1930 Census reported 6,178 persons "engaged in gainful occupations" of which 5,217 were male. Of those males, 1,019 were active duty military stationed on the island. The agriculture sector employed 2,688 males or 64% of the male civilian work force. In 1929, Guam produced 6,086 acres of field crops. Field corn had again the largest acreage, followed by taro, sweet potatoes, and yams (Table 1). The number of coconut trees had increased to 1,021,884 reflecting the growth of the copra industry over the decade (Table 2). In 1929, copra exports reached a peak of almost six million pounds with a value of over $200,000. The agricultural economy flourished producing an era of relative prosperity for the island during the 1920's (Thompson 1947). Most fruit or tree crops increased by a factor of two to four over the period (Table 2) as the population expanded into the rural areas of the island and new homesteads were created. There were substantially larger increases in the number of mangos and avocados during this period (US Bureau of the Census 1931).

In 1933, the copra market collapsed and copra production on Guam fell to an all time low. The Naval Government tried to encourage kapok (*Ceiba pentandra* (L.) Gaertn) as an alternative to copra and it also initiated a program to encourage the production of rice. The effort with rice was a moderate success and rice

acreage increased from 197 in 1929 to 640 in 1937 (Thompson 1947). However, rice production decreased to 517 acres in 1939 (US Bureau of the Census 1941). The effort to produce kapok was a failure with production increasing only slightly from 14,856 pounds in 1929 to 18,283 pounds in 1939.

The farmers market was leased to a private enterprise in 1931 and produced average weekly sales of $400 in 1932 (Sanchez 1991). The work of the USDA Agricultural Experiment Station was discontinued in 1932 (Nafus & Schreiner 1991). By 1939, the Naval Government again felt the need to revitalize the Agana market by providing transportation by federal truck and by organizing a vegetable producers' cooperative.

The 1940 Census reported a greater increase in the population living outside of Agana than those living in the city. This is indicative of a continued growth of the rural population during the 1930s. There were 6,885 gainfully employed persons of which 5,313 were male with 640 on active duty. The agricultural sector accounted for 2,833 or 60.6% of the civilian male employment. The Census of Agriculture reported a total of 4,376 acres of field crops in 1939 (US Bureau of the Census 1941). Field corn was still the most important crop, followed by taro, rice, sweet potatoes, yams, cassava, arrowroot, sugarcane and tobacco (Table 1). Again, vegetable production apparently was not substantial enough to warrant enumeration. Oakley (1944) reported 150 acres of vegetable plantings in 1938. Thompson (1947) reported vegetable production to be about 350 acres in 1939. Of this, 50 acres were watermelon and 10 acres or less of cantaloupes, cucumbers, Spanish beans, string beans, pumpkins, eggplant and native eggplant, pepino, tomatoes and peppers listed in order of their importance.

During the period between 1898 and the Japanese invasion in 1941, the US Naval Government marginally succeeded in the joint goals of monetizing the economy and encouraging agricultural production (Rodgers 1995). Virtually all of the population were farmers in 1898. By 1940, the farming population including farm laborers had decreased to approximately 60.6%. Large amounts of foodstuffs were imported throughout the period. In 1934, rice imports were 2,335,773 pounds as compared to a local production of 416,000 pounds (Carano & Sanchez 1964). Food was the largest import expenditure averaging 39% in the pre-invasion period from 1916 to 1941.

World War II, 1941–1944

During the Second World War, much of the population moved from Agana and Sumay to family lancho lands or other farm lands away from the population centers. The population again turned to subsistence agriculture and fishing by necessity as there was little in the way of food imports or wage paying employment available under the Japanese occupation. Consequently small scale agriculture flourished during most of the Japanese period. By 1944, Japanese troop numbers had increased to approximately 18,500, and in 1944, the Japanese brought an agricultural production group known as the Kaikontai to the island. Forced agricultural labor began for all able-bodied women and children over the age of twelve.

Nevertheless, by the time of the American invasion in July 1944, food on the island had become scarce (Sanchez 1991).

American Return (Recapture), 1944–1945

The American forces landed on July 21, 1944. Destruction on the island was tremendous. Much of the Chamorro population was housed in temporary refugee camps and fed with the remains of the Japanese food stores. By August 10, the organized Japanese resistance was declared to be finished and the build-up of American military facilities began in earnest. Guam became the center of military activity in the western Pacific and the primary staging area for the planned invasion of the Japanese mainland. By October 1944, hundreds of jobs had become available within the vast military activities (Sanchez 1991). On August 31, 1945, there were 201,918 US troops on the island in addition to the local population of 21,838 (Carano & Sanchez 1964).

From late 1944 through 1945, many subsistence farmers who had never participated in the budding pre-war wage economy became wage earners for the first time (Sanchez 1991). By the end of 1945, 4,791 Guamanians were employed full time by the military or industry and another 1,382 were employed part time (Thompson 1947). Much farm land had been taken away for use as military bases either by the Japanese or by the US military, or had been ruined for agricultural use by the military activities.

US Naval Government, 1946–1950

Subsistence agriculture did not substantially recover after the war. In 1946, there were only 1,300 acres in cultivation with 435 farmers (Bowers 1951). Copra as an export industry was now dead due to a lack of labor, appropriation of coconut groves by the military and the destruction of trees during the war (Sanchez 1991). The Naval Government again tried to encourage agriculture as a major industry, however by 1948 it reported to the United Nations that a wage economy had been firmly established on the island and it was unlikely that the island would revert to its pre-war agricultural economy (Sanchez 1991).

The 1949 Census of Agriculture reported a drastic reduction in the area cultivated for the main field crops of Guam (US Bureau of the Census 1951) (Table 1). Masa harina, a ready made corn flour, imported from the United States had almost totally replaced locally grown field corn and imported rice was quickly becoming the dietary staple of the island. Small scale cultivation continued, primarily as a supplement to wage income, although for a few, subsistence farming remained a way of life. On these farms, the crops were traditional, i.e. breadfruit, bananas, taro and yams or fresh vegetables, i.e. eggplants, hot peppers, green beans, squashes, melons and tomatoes (Sanchez 1991).

The small farms and the remaining farmers on the island formed the nucleus for a slow development of a small-scale truck-farming industry that developed on the island over the next 40 years. This industry took advantage of the natural trade barriers of time and distance from the major post-war food supply sources on the

US west coast to specialize in the production of fresh vegetables and fruits for the local market. By 1949 the Census of Agriculture already reported the increase in fresh vegetable production on the island (Table 1).

Interior Governance, 1950–1959

After the implementation of the Organic Act on August 1, 1950, which transferred responsibility for the governance of Guam from the Navy to the Department of Interior, the USDA investigated Guam's agricultural development in September 1956 (USDA 1958). The USDA report estimated 700 full time farmers on island and in addition 3,400 families who produced some of their own food. There was a considerable amount of mechanical equipment available, but agriculture was "very much underdeveloped." Fertilizer use was new and not widely practiced. The use of insecticides and pesticides was also new and somewhat more common than fertilizer use. The most common cultivation practice was to clear an area and plant a single crop without the use of fertilizers, insecticides or pesticides, and then permit the area to revert to jungle.

Marketing knowledge was reported as severely lacking. Marketing was done in a primitive manner with the farmers feeling that they should be paid extremely high prices. Few farmers had any knowledge of their production costs. Although a fairly wide variety of produce was offered, quantities were small. There was little or no packaging and a wide variation in maturity of the products offered. The large potential market to the armed services was being only partially and sporadically met (USDA 1958).

Agricultural credit was not viewed as a constraint, because of the existence of a number of government programs. Agricultural statistics were said to be practically non-existent. Research assistance was needed, with "agronomy and soils" and "agricultural economics and marketing" being the two most important areas. Extension personnel needed training. Better development of water resources was needed along with a soil and water conservation program. The local diet was said to be sorely deficient in fresh vegetables and fruits. A plant and animal quarantine program was suggested (USDA 1958).

Two thirds of the value of Guam's farm output came from animal husbandry. Egg production was the most important component with a value of $1,301,385. There was no dairy activity. Meat production, primarily small hogs for roasting, was valued at $982,740. There was some slaughter of cattle (440 head) and carabao (86 head) for meat. Most slaughter was done for home consumption, but some was done under inspection and marketed at the Agana farmers' market or through local stores. Feed costs, the small scale of production activities and the lack of a packing house were seen to be the primary constraints to the animal husbandry industry. Education on sanitation and a livestock improvement program were suggested (USDA 1958).

Many of the traditional field crops that had direct substitutes available from the United States such as arrowroot, sugarcane and tobacco had completely disappeared from the 1959 Agricultural Census report (Table 1). Production of field corn dropped dramatically in 1959. The traditional crops such as bananas, taro, sweet

potatoes, yams, cassava and breadfruit remained significant, but at lower levels of production. For those crops, there were no direct substitutes available from the mainland US markets. Vegetable production had again increased and the number of vegetable types had increased in 1959 (US Bureau of the Census 1961). These changes indicated that the switch from a subsistence agricultural economy to a market oriented agricultural economy was substantially complete at the end of the 1950's.

The Period of 1960–1996

In 1962, two events influenced the island's economy significantly. First, President Kennedy lifted the travel restriction to and from Guam. During the same year, Supertyphoon Karen stuck Guam. The island was virtually defoliated and 90% of the island's buildings were destroyed (Sanchez 1991). The recovery efforts included launching a program to broaden the economic base of the island away from its dependency on the US military and reconstruction of the island after the typhoon. The emphasis was to be placed on agriculture, tourism and possibly light manufacturing. In 1963, a tourism commission was formed. A new air terminal was opened in 1967 along with the inauguration of direct air service between Guam and Japan. From these beginnings, tourism grew to become the dominant industry of the island.

In 1965, the US Congress mandated that the states and territories establish their own meat inspection programs or fall under the jurisdiction of the federal meat inspection program. The government of Guam did not meet this mandate. Guam did not obtain a federal inspector and the local farmers were unable to continue to slaughter meat for sale to the island consumers. All sales of meat since 1965 have been of live animals for home consumption. This initiated a long-term decline in the beef industry on Guam. Pork production was not impacted as strongly as the beef industry, because the pork producers had long specialized in the production of young pigs for roasting at special events (V. Artero, personal communication).

In 1966, the Guam Department of Agriculture began to report annual agricultural production statistics for the island. The University of Guam was formed from the Territorial College in 1968 and it was awarded Land-Grant status in 1972. Local agricultural research and extension functions were transferred from the Guam Department of Agriculture to the University of Guam in 1973. In 1974, the College of Agriculture and Life Sciences was established within the University with three components: the Agricultural Experiment Station, the Guam Cooperative Extension Service, and Resident Instruction.

Karolle (1978) conducted a survey from January, 1973 to March, 1974 and reported that out of a population of 100,000 there were 256 active farmers, 37% of them full-time producers. The average farm size was 6.6 acres (2.7 ha) and the average tilled or vegetable cropping area was 3.6 acres (1.5 ha) with the median of 1–2 acres (0.4–0.8 ha). The total estimated area for vegetable, tree crop and pasture cultivation was about 1700 acres (688 ha). A detailed map of farm locations was also provided by Karolle (1978). The majority of farms were located on lime-

stone plateaus in the northern and central regions of the island. In the South, there were two separate areas of farming; (1) south-western coastal plains and coastal river valleys, and (2) the south-eastern volcanic plateau surface. In 1980, Karolle reported 226 viable farms between 1974–1979.

In 1983, the Guam Department of Commerce reported the detailed statistics of import and local production. Guam produced locally 38% of fresh fruits and vegetables (Economic Research Center, Department of Commerce 1984). They were products where freshness was of importance to the consumer and transportation over long distances was difficult, expensive and time-consuming. Guam's agricultural community specialized in products with a natural competitive advantage, not staple products that could be imported cheaply. This general statement has been true for the island's agriculture since the early 1960's and remains so today.

Khamoui (1984) reviewed market potentials for Guam produce. Guam did experience market gluts of a few commodities, but these were occasional experiences and relatively small in size. The gluts could best be alleviated by improving and expanding storage and cooling facilities on island. Production levels of several local crops could be expanded at the expense of imported produce. If farmers were willing to accept prices slightly lower than import prices, then import substitution would readily occur. Khamoui was not optimistic about the prospects of developing export markets for Guam produce with the possible exception of avocados.

Khamoui (1985) also reviewed agricultural production constraints on Guam. He classified these into physical and institutional constraints. Under physical constraints, he listed the underdevelopment of infrastructure, i.e., roads and irrigation systems, and support structures, i.e., storage and cooling facilities. Under institutional constraints, he listed six major constraints: (1) inefficient and ineffective marketing, (2) unavailability of labor, (3) the land tenure policy, (4) inadequate capital, (5) an absence of effective agricultural policy and planning, and (6) the effects of current local and federal programs and policies.

The population of Guam in 1990 was 133,152 (US Bureau of Census 1991). About one third of the island is presently being used for military bases and other US government facilities. Once prime agricultural land, the central part of the island is now used by the Federal government for their facilities. Additionally, with the development of golf courses and an increase of residential and commercial buildings, agricultural land used for crop production has rapidly become even more scarce. In April, 1996, the number of farmers registered at the Guam Department of Agriculture was recorded as 324 and there were 66 people leasing either local and federal government lands with the total of 665 acres for farming (R. Barber, personal communication).

In recent years, along with landscaping businesses and plant nurseries, golf courses have become an important part of agricultural activities on the island. In 1996, there were eight commercial plant propagators/whole sellers of potted plants and landscape plant materials on Guam (R. McCarthy, personal communication) and there were nine golf courses with an estimated green area of 2000 acres (545 hectares) (G. Wiecko, personal communication). Additionally, many hobbyists sell

ornamentals on roadside stands, at flea markets, or in backyards. The plant rental business has also emerged as a fledgling industry.

Classification of Agricultural Crops on Guam

Based on available agricultural statistics, crops grown on the island can be categorized into three groups (Table 3). In the first group are crops that have basically disappeared because of replacement by imports, including rice, arrowroot, sugarcane and tobacco. Second, there are the crops of importance to the indigenous culture and economy, which are still produced even after the introduction of a cash economy. Examples are taro, yams, sweetpotatoes, and the tropical fruits such as coconut, banana, pineapple and papaya. Table 4 lists some locally important crops that have been harvested from the wild and many of these can be included in the second category. Disappearance of commercial copra industry has contributed the significant reduction in coconut production. Crops in the third category include those that have become important since the late 1950s. Examples of vegetables in this group are watermelon, cucumber, yard-long bean, eggplant, cantaloupe and tomato. Changes in production of these three groups of crops from 1898 to present is shown in Figure 2.

During the 1991–1994 survey, about 40 species of 26 families were found cultivated and sold at stores, flea markets and roadside stands on Guam (Table 5).

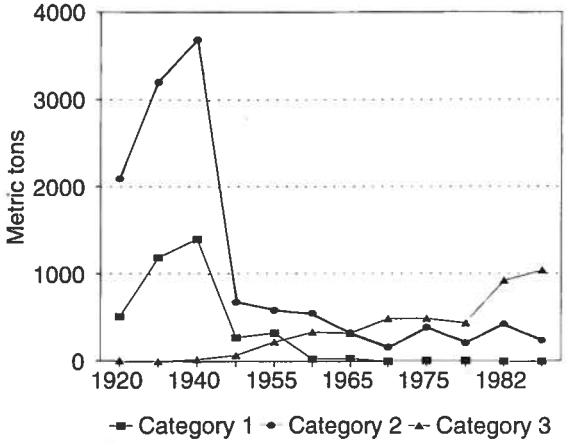

Figure 2. Agricultural production on Guam from 1920 to 1987. Agricultural production is divided into three categories: Category 1—subsistence crops that have disappeared from production with the transition to a cash economy, e.g., rice and sugarcane. Category 2—traditional crops that have remained in production under the cash economy, e.g., taro and coconut. Category 3—crops that are primarily grown for commercial marketing, e.g., watermelon and cucumber.

Table 3. Three categories of crops grown commercially on Guam since 1898 to present

Category 1: Crops which have disappeared from commercial production after 1950's because of complete replacement by imports
- Rice (*Oryza sativa*)
- Arrowroot (*Tacca leontopetaloides*)
- Sugarcane (*Saccharum officinarum*)
- Tobacco (*Nicotiana tabacum*)
- Field corn (*Zea mays*) (cultivated up to early 1970's)

Category 2: Crops which are very important to the island indigenous culture and economy before and after introduction of off-farm wage economy in 1950's to present
- Taro (*Colocasia esculenta* and *Xanthosoma* sp.)
- Yams (*Dioscorea* spp.)
- Sweetpotato (*Ipomoea batatas*)
- Sweet Corn (*Zea mays*)
- Cassava (*Manihot esculenta*)
- Coconut (*Cocos nucifera*)
- Banana (*Musa* spp.)
- Pineapple (*Ananas comosus*)
- Papaya (*Carica papaya*)
- Breadfruit (*Artocarpus altilis* and *A. mariannensis*)

Category 3: Crops which have become important since the late 1950s.
- Watermelon (*Citrullus lanatus*)
- Cucumber (*Cucumis sativus*)
- Cantaloupe, Honeydew, & Pepino (*Cucumis melo*)
- Eggplant (*Solanum melongena*)
- Tomato (*Lycopersicon esculentum*)
- Yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*)
- Pole bean (*Phaseolus vulgaris*)
- Peppers, sweet and hot (*Capsicum* spp.)
- Bittermelon (*Momordica charantia*)
- Leafy vegetables which include:
  - Chinese cabbages, pak-choi, & head cabbages etc. (*Brassica* spp.)
  - Green bunching onion (*Allium fistulosum*)

Table 4. Crops that have been harvested from the wild and the backyard garden on Guam.

- Anonas (*Annona* spp.)
- Bamboo (*Bambusa vulgaris*)
- Betel nut (*Areca catechu*)
- Breadfruit (*Artocarpus mariannensis*)
- Coconut (*Cocos nucifera*)
- Cycad (*Cycas circinalis*)
- Guava (*Psidium guajava*)
- Donne or wild hot pepper (*Capcicum frutescens?*)
- Mango (*Mangifera* spp.)
- Pandanus (*Pandanus* spp.)
- Piut or sour cherry (*Ximenia americana*)
- Turmeric (*Curcuma domestica*)
- Yams, spiny (*Dioscorea esculenta* var, *spinosa*)
- Yams, wild (*D. esculenta* var. *fasciculata*)
- Yams, white (*D. rotundata*)

Table 5. Crops planted, field collected and sold at various markets in Guam during 1990–1994.

Scientific name	Common name
Vegetables & Root crops:	
Amaranthaceae:	
Amaranth sp.	Amaranth
Araceae:	
Colocasia esculenta (L.) Schott	Red taro, suni
Cyrtosperma chamissonis (Schott) Merril (=*C. edule* Schott)	Giant swamp taro
Xanthosoma sagittifolium (L.) Schott	Coco yam (white tuber taro). sunin Honolulu
Brassicaceae:	
Brassica rapa L.	Pak-choi, petsai, napa
B. oleracea L. var. *capitata* L.	Head cabbage
B. pekinensis (Lour.) Rupr.	Chinese cabbage, napa
Raphanus sativus L.	Radish, daikon
Convolvulaceae:	
Ipomoea batatas (L.) Lam.	Sweet potato, kamuti
I. aquatica Forsskal.	Kang kong, water spinach
Cucurbitaceae:	
Benincasa hispida (Thunb.) Cogn.	Wax gourd, kondot
Citrullus lanatus (Thunb.) Matsum. and Nakai	Watermelon, chandiya
Cucumis melo L.	Pepino melons
C. melo L. var. *inodorus* Naud	Honeydew, melon-fino
C. melo L. var. *reticulantus* Naud	Cantaloupe, melon bastos
C. sativus L.	Cucumber, kamba
Cucurbita maxima Duchesne var. *maxima*	Kabocha pumpkin
C. moschata (Duchesne) Duchesne ex. Poiret	Squash, pumpkin, butternut squash
C. pepo L.	Zucchini squash
Lagenaria siceraria (Molina) Standley	Bottle gourd, kalabasa
Luffa acutangula (L. Roxb.	Luffa
Momordica charantia L.	Bittermelon, atmagosu
Sechium edule (Jacq.) Sw.	Chayote
Dioscoreaceae:	
Dioscorea alata L.	Winged yam, dagun agaga
D. esculenta var, *spinosa* (Roxb.) Prain & Burkill	Spiny yam, gadu
D. esculenta var. *fasciculata* (Roxb.) Prain & Burkill	Wild yam, nika
D. rotundata Poir.	White yam, dagun apaka
Euphorbiaceae:	
Manihot esculenta Crantz	Cassava, mendioka, tapioka
Fabaceae:	
Phaseolus vulgaris L.	Pole bean, bush bean
Tetragonolobus purpureus Moench (=*Psophocarpus tetragonolobus* (L.) DC.	Winged bean
Vigna radiata L.	Mungbean for bean sprout
Vigna unguiculata subsp. *sesquipedalis* (L.) Verdc.	Yard-long bean
Pachyrhizus erosus (L. Urb.	Yam bean, jicama, hicama

Table 5. *(continued)*

Scientific name	Common name
Liliaceae:	
Allium fistulosum L.	Green bunching onion
A. tuberosum Rottboell ex Sprengle	Chinese chives, nira
Malvaceae:	
Abelmoschus esculentus (L.) Moench (=*Hibiscus esculentus* L.)	Okra
Poaceae:	
Zea mays L.	Sweet corn
Bambusa vulgaris Schrad. ex Wendl.	Bamboo for bamboo shoot
Solanaceae:	
Capsicum annuum L.	Bell or sweet pepper, hot pepper
C. frutescens L.	Hot pepper, tabasco pepper, doni
Lycopersicon esculentum Mill.	Tomato
L. esculentum var *cerasiforme* (Dunal) A. Gray	Cherry tomato
Solanum melongena L.	Eggplants
Tiliaceae:	
Corchorus olitorius L.	Jew's marrow, tossa jute, "Moroheiya"
Zingeberaceae:	
Curcuma domestica Valeton (=*C. longa* L.)	Turmeric (yellow ginger)
Zingiber officinale Roscoe	Chinese ginger (white ginger)
Fruits & Nuts:	
Anacardiaceae:	
Mangifera indica L.	Mango
M. odorata Griff.	Saipan mango
Annonaceae:	
Annona squamosa L.	Sweetsop, atis
A. muricata L.	Soursop, laguana
A. reticulata L.	Custard apple, anonas
Arecaceae:	
Areca catechu L.	Betelnut, pugua, ugum
Cocos nucifera L.	Coconut, niyog
Bromiliaceae:	
Ananas comosus (L.) Merr.	Pineapple, pina
Caricaceae:	
Carica papaya L.	Papaya
Lauraceae:	
Persea americana Mill.	Avocado
Moraceae:	
Artocarpus atilis (Park.) Fosb.	Breadfruit, lemai
A. mariannensis Trec.	Seeded breadfruit, dokdok
A. heterophyllus Lam.	Jackfruit, langka, nangka
Musaceae:	
Musa spp.	Banana (cooking and dessert types)
Myrtaceae:	
Psidium guajava L.	Guava, abas
Oxalidaceae:	
Averrhoa carambola L.	Starfruit, carambola

Table 5.*(continued)*

Scientific name	Common name
Rutaceae:	
Citrus aurantifolia (Christm.) Swingle	Local limes, kusai limes, Mexican lime, keylime
C. mitis Blanco (Neal, 1965) or *Citrofortunella mitis* (Bailey and Bailey, 1976)	Calamondin, kalamansi
C. sinensis (L.) Osbeck	Orange
C. aurantium L.	Sour orange
C. reticulata Blanco	Tangerine
Sapotaceae:	
Manilkara zapota (L.) P. v. Roy	Chiku, chico, zapote

References: Artero et al. (1993); Bailey and Bailey (1976); Fosberg et al. (1979 and 1987); Neal (1964); Stone (1971).

Table 6. Top ten crops by production (weight in kg) over ten year intervals from 1965 to 1993 on Guam.[a]

Rank	1965–74		1975–84		1985–93	
	Crop	Production	Crop	Production	Crop	Production
		(kg)		(kg)		(kg)
1	Bananas	143,274	Watermelon	641,635	Watermelon	1068,685
2	Watermelon	104,788	Cucumber	196,570	Cucumber	285,519
3	Tomato	86,519	Brassicas	119,765	Bananas	204,943
4	Cucumber	79,530	Bananas	116,815	Melon	190,951
5	Melon	62,215	Melon	112,049	Pineapple	133,997
6	Eggplant	59,776	Beans	99,832	Beans	131,413
7	Beans	53,471	Eggplant	70,295	Squash	69,634
8	Brassicas	38,438	Squash	62,177	Tomato	69,079
9	Yam	31,984	Sweet potato	56,011	Eggplant	64,660
10	Taro & Tips	29,587	Bittermelon	56,011	Bittermelon	62,894

[a]Beans include bush, yardlong and winged beans; brassicas include Chinese and head cabbages; and peppers include hot and sweet types. Weights are the average of annual production for the time period. Source: estimated production from the University of Guam and Guam Department of Agricultural farm survey.

A variety of vegetable and fruit commodities are now being cultivated and consumed by a diverse ethnic group of people on the island. Within a species, cultivar preference by consumers has shifted to the "oriental" types of vegetables. As an example, long eggplants are more commonly grown instead of large round US types and slender Japanese-type cucumbers are more popular than large slicing cucumbers. There are no records of crop exports; however, finding a market in Japan has given one grower a possibility of exporting processed leaves of 'Moroheiya' or Jews marrow.

The top ten important commercial crops from 1965 to 1993 are listed in Table 6. During the last decade, watermelon has been the most important crop on the is-

land. Other important crops include cucumber, beans, melons, eggplant, bananas, and pineapple. Lee (1971) noted that when Americans came to Guam, they did not try to adapt their tastes to fit the local produce. Instead they imported their familiar vegetables and fruits. American culture has been adopted by the local community and the shift of food preferences and changes in crop production started to occur after WWII. In later years, immigrants from the South-East Asian countries, especially the Philippines, Korea and Taiwan have been influencing the production of "oriental vegetables."

Current Crop Production System and Marketing

No commercial seed companies exist on the island. Growers purchase seed and other plant materials mainly from companies in the US, Taiwan and Japan. Small quantities of vegetable seeds are sold at garden shops, hardware stores and supermarkets. Sometimes growers collect their own seeds and propagate their own plants. Exchange of seeds and other planting materials occurs among growers. The Guam Department of Agriculture sells seedlings of some vegetables and fruits, and offers a service to produce seedlings for growers if they provide their own seeds. The Guam Cooperative Extension at the College of Agriculture and Life Sciences, University of Guam often distributes seeds of new commercial cultivars or breeding lines for growers to try out under local conditions.

Commercial fertilizers are available and commonly used to increase soil fertility. Organic matter such as chicken manure is also utilized, but it is not readily available in large quantities since the decline of the poultry industry in Guam. Drip irrigation is the most common method of applying supplemental water. In the northern part of Guam, municipal water is used exclusively to irrigate crops while in the south both municipal water and surface water from rivers are used. Use of drip irrigation has allowed some farmers to adopt the practice of fertigation. Occasionally black plastic mulch is used to control weeds. Mechanization in cultivation commonly includes the use of tractors and sprayers, although the equipment is usually much smaller than that used on the farms in the continental United States. Commonly, backpack-type sprayers are used to apply pesticides, although the use of power sprayers is increasing. Pesticides can be purchased at hardware shops, garden stores and other chemical distributors. Pesticide users are required to follow the USDA and the Environmental Protection Agency (EPA) regulations governing the use of pesticides. The Guam Cooperative Extension offers training workshops to provide information on pesticide safety and usage and to provide certification for purchase and use of restricted chemicals.

A few commercial growers have regular employees, while many farmers have assistance from extended family members. Lack of farm labor is a constraint to efficient production. Harvested crops are delivered to stores, hotels or government agencies. Only a few individuals act as wholesalers buying produce from growers and selling to third parties, and this system is not well established.

In order to overcome production constraints, new cultivation methods such as hydroculture and bag culture have been employed. Greenhouse hydroponics was first attempted in the 1960's to grow tomatoes (Brown et al. 1991), but has not been successful. High capital costs for buildings and equipment require high produce value for economic returns. Problems associated with hydroponics systems are the lack of information on cultivar selection, high and variable water pH, shortage of knowledgeable and experienced operators, need for a typhoon resistant structure, and a poorly developed marketing system. Currently, a simple hydroculture system without a roof structure is the only commercially operational system on island.

Agricultural Pests

More than 200 arthropods were recognized as pests of economically important plants on Guam in the late 1980's (Nafus 1990). The number of accidental introductions of insect pests to Guam was reported as 15 during 1945–1954, 13 during 1955–1969, 21 during 1970–1979 and 25 during 1980–1991 (Schreiner 1991). Although the origin of some pests are unknown, three major sources were Hawaii, neighboring Micronesian islands, and Southeast Asian countries. It was assumed that prior to 1975, Asia and other Micronesian islands were the main sources of new pests, while the number of pests originated from Hawaii has increased since 1975 (Schreiner & Nafus 1986, Schreiner 1991). One of the most recently introduced pests was silverleaf whitefly (*Bemisia argentifolii* Bellow and Perring) which was found in farmlands in 1993. A survey in 1995 revealed that this pest had a wide range of host plants, and was especially damaging to eggplants, tomatoes and many cucurbits (Marutani et al. unpublished data).

Over 200 plant pathogens of vegetable and fruit crops have been identified (Russo et al. 1985, Wall 1987, 1988, & 1991). The number of new diseases has increased as rapid transportation systems have developed, and with the increasing introduction of plant materials to the island. Introduction occurs not only from importation of new planting materials, but also from imported produce. Wall & Santos (1988) reported a bacterial blight of cassava, an epidemic triggered by recent introduction of *Xanthamonas camperestris* pv. *manihotis*. Another epidemic caused by *Pseudomonas pseudoalcaligenes* subsp. *citrulli,* nearly devastated watermelon production in the main growing area of Guam during 1987–1991 (Wall 1991). New diseases are also endangering ornamental plants such as plumeria (*Plumeria* spp.). Recently, plumeria rust and dieback have been identified, and are now widespread (G. Wall unpublished data).

Many plant species have become weeds on Guam. Some plants were brought in as ornamentals (McConnell & Muniappan 1991) or accidentally introduced. Information on weeds and weed control practices in farming lands is limited. Major weeds identified at a mango plantation in Talofofo were *Ipomoea congesta* R. Br., *Cyperus rotundus* L., *Eleusine indica* (L.) Gaertn., and *Wedelia trilobata* (L.) Hitche (E. Manalastas, personal communication). The viny habit of *I. congenta* has become troublesome, as this plant climbs mango trees. *W. trilobata* was origi-

nally planted as a ground cover around trees, however its aggressive growth has made this plant a weed. Twelve weeds were important in a herbicide experiment conducted in Barrigada, the central region of Guam in 1988 (Marutani, unpublished data). They were *Dactyloctenium aegyptium* (L.) Willd, *Boerhavia erecta* L., *Portulaca oleracea* L., *I. congesta, Commelina benghalensis* L., *Euphorbia cyathophora* Murray, *Euphorbia hirta* L., *Momordica charantia* L., *Cleome viscosa* L., *Amaranthus spinosus* L., *Corchorus aestuans* L., and *Physalis angulata* L. All of these plants were introduced into the island long ago, and some now have local common names. In taro fields, weeds recognized as causing problems were *Cyperus rotundus, Portulaca oleraceus, Echinochloa colonum* (L.) Link, *Cenchrus echinatus* L., *Sorghum halepense* (L.) Pers., *Mimosa pudica* L., *Mikania micrantha* HBK., *Eleuzine indica,* and *Paspalum conjugatum* Berg. (Manner 1991). A parasitic weed, dodder (*Cuscuta campestris* Yuncker), occasionally infests vegetable farms and some landscape plants (J. McConnell, personal communication).

Some weeds serve as alternative hosts of pests and diseases. As an example, bittermelon, was originally introduced as a vegetable crop, became naturalized, and now is distributed throughout the island (Stone 1971). This wild bittermelon can be a host to major virus diseases of cucurbits, i.e. Watermelon Mosaic Virus I (syn. Papaya Ringspot Virus-W) and Zucchini Yellow Mosaic Virus, which damage many important cucurbits. Additionally, bittermelon serves as a host for melonfly (*Dacus cucurbitae* Coquillett), which is one of the major insect pests of cucurbits.

Guam's Agriculture in the 21th Century

Changes in economic and social structure and land tenure over the past 100 years have greatly influenced agricultural activities on Guam. Agriculture remains a small but vital component of the island's culture, community and economy. In 1995, the sustainable agriculture extension program was initiated by Guam Cooperative Extension to survey needs for improvement and development of the island's future agriculture (Barber 1995). The survey results indicated that for the agriculture industry to develop into a major component of Guam's economy and for the development of sustainable and environmentally sound agricultural systems, private and public sector entities must focus efforts on securing land and water resources and capitalize on appropriate technological developments. The important issues and opportunities facing the agricultural sector include: (1) need for lands dedicated for agricultural production and processing, (2) need for water to support production and processing of agricultural products, (3) need for labor to support crop production and agribusiness, (4) need for improvement of crop production and management systems to conserve and enhance the island's natural resources, (5) need for development of sound agricultural marketing systems, (6) need for diversification and expansion of agricultural commodities that capitalize on specific market niches-both locally and for export, (7) need for continuous development and transfer of information supported by both local agribusiness and government.

Current land prices limit the dedication of private lands to long term agricultural production. The return of lands to the Government of Guam from the US Federal Government could provide some much needed acreage for agricultural activities. The Chamorro Land Trust Commission is tasked with managing Government of Guam lands for housing and agriculture for Chamorros. Current agricultural production lands as well as lands for future agriculture production need to be protected from the pressure of urbanization and other developments.

Presently, water availability is one of the main limiting factors in agricultural production. Most farms rely on municipal water for irrigation and other water needs. The current water distribution system is inadequate even for the small sized farms. Infrastructure upgrades are required in order to support agriculture expansion. Many farmers have adopted a drip irrigation system which has the potential to save up to 40% of the water used in comparison to a sprinkler irrigation system. A drip irrigation system also added an advantage of operating at relatively low water pressures. An efficient use of currently available water would result in more production from the limited natural resources and to ensure a safe environment for the island. Education on proper water management would assist in advancing the adoption of technologies that increase the water use efficiency.

The shortage of agricultural labor is a serious impediment to promoting a vital agricultural industry. The word "agriculture" often implies "pulling weeds under the hot sun", "a low paying job", "hard work", "a second job" and "something to do after retirement." This misconception results in there being very few young people who are willing to engage in agricultural production. Some effective government policies to secure agricultural laborers should be considered to overcome this problem.

Improvement of the marketing system would lesson he burden of searching for buyers, resulting in farmers being able to focus their efforts upon crop production and field management. Undoubtedly, mechanization of cultivation has to be implemented to overcome labor shortages. New cultivation methods should be investigated for their potential. Crops grown in high-input operations must have high returns to maintain profit. Selection of crops and cultivars for a specific cultivation system will be an important factor in determining their success and further development of the system.

Productivity of existing cultivated farmlands can be improved by selection of cultivars which are adapted to Guam's climate, resistant to pests, and have good post-harvest properties. Crop rotation, multiple cropping, use of green manure crops, alley cropping and hedgerow plantings are examples of management practices which help to fully utilize a limited farmland while maintaining an environmentally sound ecosystem. Planting of windbreaks, and establishing proper orientation and planting patterns of crops can reduce damage from storms.

Soil management is another factor to be considered in improving the productivity of fields. The type of fertilizers and fertilizer application methods should be suitable for specific crops, soil classification and a type of irrigation system used.

Compost or organic matter from animal and plant waste materials as well as proper soil amendments, e.g., liming, should be applied to increase soil productivity without contaminating the surrounding environment.

For proper pest management, chemical and organic pesticides (e.g., *Bacillus thuringiensis* and botanicals) should be used judiciously to maximize efficacy and minimize negative environmental impact. Various types of protective cultivation methods can be adopted to reduce the pest populations. The current quarantine system should be reevaluated and improved to minimize the entry of new pests. Personnel at the quarantine station should be well-trained and knowledgeable. A proper quarantine facility should be built for the island.

One of the major obstacles to expanding the agriculture industry is the lack of an adequate marketing structure (Barber et al. 1996). Local middlepersons are required to channel product flow and communication between local producers and buyers. The establishment of grades and standards for local products would facilitate marketing. With the establishment of proper postharvest handling practices and development of a vibrant marketing system, production of commodities would increase for local consumers and possibly for export. A system for processing produce for export needs to be investigated since the use of dried or frozen fruits and vegetables reduces quarantine problems in shipping to neighboring countries (Barber & Cruz 1996).

Diversification of agricultural commodities and expansion of crops that capitalize on specific market niches both locally and for export would promote the island's agriculture. It is certain that the ornamentals, landscaping and turf industries on the island will expand as long as tourism is a major industry and as an increasing population requires new housing developments. Demand for indoor and outdoor landscaping plants and for establishment and maintenance of the leisure industry such as golf courses will drive the development of new types of agribusiness on the island.

Statistics on Guam agriculture should be readily available to the community. Information on current local production of agricultural produce and imports of commodities would provide guidance to the agricultural community. A marketing study is urgently needed to identify locally important agricultural commodities which have high economic values and crops that have high potential as export. These statistics will provide direction to the development of new crops for local consumption and for export. If appropriate marketing niches are found, then locally important herbs, spices and medicinal plants may be grown for export because of their uniqueness.

Undoubtedly, education in agricultural sciences will take a major role in guiding the adoption of modern technologies in crop production and promoting environmentally sound and profitable agriculture. Local research results should provide the basic information to support agriculture education and production. Healthy agroecosystems will provide the island community not only with nutritious food but also with recognition of esthetic values of plants and the maintenance of indigenous culture and history.

Acknowledgments

We are grateful following colleagues who have reviewed our manuscript and have provided valuable information and references; Victor Artero, Bob Barber, Joseph Mafnas, Edwin Manalastas, Robert McCarthy, James McConnell, Peter Motavalli, Donald Nafus, Lynn Raulerson, Robert Schlub, Ilse Schreiner, Greg Wiecko, and Lee Yudin. This publication is supported by Guam Agricultural Experiment Station, USDA Hatch Project No. 0155783 (GUA 00081).

References

Anon., 1928. Conditions noted by an interested sojourner. Guam Recorder (August): 102.

Artero, V. T., F. Cruz & V. Santos. 1993. Chamorro and scientific names of fruits and vegetables. Agriculture and Natural Resources, Guam Cooperative Extension Publication, 10 pp.

Bailey, L. H. & E. Z. Bailey. 1976. Hortus Third. A Concise Dictionary of Plants Cultivated in the United States and Canada. Revised and expanded by the Staff of the Liberty Hyde Bailey Hortorium. MacMillan Publishing Co., Inc. New York.

Barber, R. 1995. Sustainable agriculture: survey results. Territory of Guam, Cooperative Extension Service. 35 pp.

Barber, R., A. Williams, F. Cruz & M. Pangelinan. 1996. Problems and issues in Guam's agricultural markets: an overview. *In* Proceedings of the Guam Economic Conference sponsored by the Small Business Development Center. (in press).

Barber, R & F. Cruz. 1996. Exports and value-added processing, research and extension's role in the Micronesian Region. *In* Proceedings of a workshop: Enhancing the role of value added agriculture in tropical island economics. pp. 55–59.

Bowers, N. M. 1951. The Marianas, Volcano, and Bonin Islands. *In* Otis, W. Freeman (ed), Geography of the Pacific, pp. 205–236. New York, Wiley.

Brown, P. 1926. Small hope for Guam to become self-supporting. Guam Recorder (December): 241.

Brown, J. W., D. Salia & J. Blanchard. 1991. Growing greenhouse tomatoes on Guam: history, prospects and risks. Agricultural Experiment Station Technical Report #88. College of Agriculture and Life Sciences, University of Guam. 20 pp.

Carano, P. & P. C. Sanchez. 1964. A Complete History of Guam, Charles E. Tuttle, Rutland VT.

Demeterio, J. L., D. D. Ventura & F. J. Young. 1986a. Some chemical and physical properties of the agricultural soils of Guam. Technical Report. Guam Agricultural Station Publication #56. 16 pp.

Demeterio, J. L., F. J. Young & M. B. Yamanaka. 1986b. Guam Soil Test summary, 1975–1984. Technical Report. Guam Agricultural Station publication #58. 18 pp.

Department of Agriculture, Plant Protection & Quarantine. 1996. Fiscal Year 1995 Annual Report. Compiled by R. Campbell. Mangilao, Guam.

Department of Labor. 1995. Current Employment Report (June 1995) Territory of Guam, Bureau of Labor Statistics, Tamuning, Guam.

Dorn, 1909. Governor's Report: Annual Report US Naval Station, Island of Guam 1909.

Driver, M. 1991. (Translater) Description of the Mariana Islands, Manual Sanz, 1982. MARC Educational Series No. 10. 54 pp.

Dyer, 1905. Governor's Report: Annual Report US Naval Station, Island of Guam 1905.

Economic Research Center, Department of Commerce. 1984. Guam Trade 1983: With the United States and Foreign Countries. Government of Guam. 3 pp.

Fosberg, F. R., M. H. Sachet & R. Oliver. 1987. A geographical checklist of the Micronesian monocotyledons. Micronesica 20: 19–129.

Fosberg, F. R., M. H. Sachet & R. Oliver. 1979. A geographical checklist of the Micronesian dicotyledons. Micronesica 15: 41–295.

Fullaway, D. B. 1912. Annual Report of the Guam Agricultural Experiment Station for 1911. Washington 1912.

Karolle, B. G. 1978. Changing agricultural patterns of Guam. Technical Report No. 2. Agricultural Experiment Station, College of Agriculture and Life Sciences, University of Guam. 33 pp.

Karolle, B. G. 1980. Changing agricultural patterns of Guam (part 2). Technical Report No. 8. Agricultural Experiment Station, College of Agriculture and Life Sciences, University of Guam. 28 pp.

Khamoui, T. 1984. (Compiler). Guam Agricultural and Related Statistics. Guam Agricultural Experiment Station Publication, College of Agriculture and Life Sciences, University of Guam. 102 pp.

Khamoui, T. 1985. Agricultural Production Constraints on Guam. Guam Agricultural Experiment Station Publication, College of Agriculture and Life Sciences, University of Guam. 54 pp.

Lander, M. A. 1994. Meteorological Factors Associated with Drought on Guam. University of Guam Water & Energy Research Institute, Technical Report 75.

Lee, C. T. 1980. Performance studies on AVRDC selections and commercial cultivars of tomatoes in Guam. Technical Report. Guam Agricultural Experiment Station Publication #9. 20 pp.

Lee, D. 1971. Problems in tropical agriculture. Yearbook. Micronesian Area Research Center, University of Guam, 33: 47–64.

Manner, H. 1991. Report of the rapid rural, assessment of taro production systems in Guam. *In* A. Vargo & L. Ferentinos (eds) Project report of a rapid rural appraisal of taro production systems in Micronesia, Hawaii and American Samoa. pp. 39–49. Pacific Agriculture Development Office. 168 pp.

Marutani, M. 1986. Evaluation of potato (*Solanum* spp.) cultivars in Guam during 1985–1986 dry season. CIP Region VII Working Paper #86–11: 122–128.

Marutani, M., F. Cruz, V. Santos & G. Wall. 1993. 1989–1992 Vegetable Cultivar Trials on Guam. College of Agriculture and Life Sciences Publication. 14 pp.

McConnell, J. 1988. Environmental factors affecting flowering in some vanda and dendrobium hybrids in the Tropics. Guam Agricultural Experiment Station Annual Report. University of Guam. pp. 47–48.

McConnell, J. & R. Muniappan. 1991. Introduced ornamental plants that have become weeds on Guam. Micronesica Suppl. 3: 47–49.

Nafus, D. 1990. Report of an entomological survey of the Federated States of Micronesia and Republic of Palau. South Pacific Commission.

Nafus, D. & I. Schreiner. 1991 Biological control activities in the Mariana Islands from 1911 to 1988. Micronesia 22: 65–106.

Neal, M. C. 1965. In Gardens of Hawaii. Bernice P. Bishop Museum Special Publication 50, Bishop Museum Press. 924 pp.

NOAA (National Oceanic Atmospheric Administration). 1994. Local Climatological Data, Guam, Pacific. NOAA National Climatic Data Center, Asheville, NC.

Oakley, R. G. 1944. Agriculture in Guam. Foreign Agriculture 8(10): 215–223.

Palomo, J. R. 1992. Recollections of Olden Days. MARC Educational Series No. 13. 181 pp.

Rodgers, R. F. 1995. Destiny's Landfall: A History of Guam. University of Hawaii Press. Honolulu. 380 pp.

Russo, V. G., Beaver, F. Cruz and H. Rubin. 1985. Plant Pathogens and Associated hosts on Guam. Technical Report. Guam Agricultural Experiment Station Publication No. 46. 33 pp.

Safford, W. E. 1905. The Useful Plants of the Island of Guam. Contribution from the United States National Herbarium Volume IX. Smithsonian Institution. Bulletin of the United States National Museum, Washington Government Printing Office. 416 pp.

Sanchez, P. C. 1991. Guahan Guam. The History of our Island. Sanchez Publishing House, Agana, Guam. 451 pp.

Schreiner, I. & D. Nafus. 1986. Accidental introductions of insect pests to Guam, 1945–1985. Proceedings of the Hawaiian Entomological Society 27: 45–52.

Schreiner, I. H. 1991. Sources of new insects established on Guam in the post World War II period. Micronesica Suppl. 3: 5–13.

Stone, B. C. 1971. The flora of Guam. Micronesica. 6: 1–659.

Thompson, L. 1947. Guam and Its People. Greenwood Press, Westport Conn. 367 pp.

US Bureau of the Census. 1921. United States Census of Agriculture: 1920. Washington, D.C.

US Bureau of the Census. 1931. United States Census of Agriculture: 1930. Washington, D.C.

US Bureau of the Census. 1941. United States Census of Agriculture: 1940. Washington, D.C.

US Bureau of the Census. 1951. United States Census of Agriculture: 1950. Washington, D.C.

US Bureau of the Census. 1961. United States Census of Agriculture: 1959. Washington, D.C.

US Bureau of the Census. 1991. United States Census of Agriculture: 1990. Washington, D.C.

United States Department of Agriculture (USDA). 1958. The Agricultural Needs of Guam, Mariana Islands. Agricultural Research Service, ARS-24-3, 1958. 63 pp.

Wall, G. C. 1987. Determination of plant disease on Guam. Guam Agricultural Experiment Station, 1987 Annual Report p. 49.

Wall, G. C. 1988. Determination of plant disease on Guam. Guam Agricultural Experiment Station, 1988 Annual Report pp. 18–20.

Wall, G. C. 1991. Plant diseases of recent introduction to Guam. Micronesica Suppl. 3: 41–45.

Wall, G. C. & V. M. Santos. 1988. Bacterial blight of mendicka. Guam Cooperative Extension publication #88-1. 4 pp.

Young, F. 1988. Soil Survey of Territory of Guam. United States Department of Agriculture, Soil Conservation Service. 166 pp.

Received 20 May 1996, revised 10 April 1997.