ANALYSIS OF SUGAR CANE PRODUCTION IN RELATION TO CLIMATE, SOIL AND MANAGEMENT

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ABSTRACT

The yield of sugar cane is analyzed in relation to climate, soil and management. Detailed information is obtained from the Waialua Sugar Company Inc. on Oahu, where approximately 4200 ha of irrigated sugar cane are grown under fully mechanized conditions. The field records date back to 1930, but a selected group of data for the period 1960-1970 has been used for statistical interpretation. Management variables include month of harvest, crop cycle, age in months, nitrogen, potassium and phosphorus fertilization, amount of irrigation water applied and the number of days after the last round of irrigation until harvest. The climatic variables are rainfall during winter, rainfall during summer, rainfall one month before harvest; rainfall, maximum and minimum temperature and diurnal difference in temperature during the harvest month, average monthly evaporation and global radiation. The soils are mapped in detail and the yield data are grouped according to the major soil series on which sugar cane is grown in this plantation. Two soil series (Wahiawa and Lahaina) belong to the Order of the Oxisoils and cover almost 50% of the terrain, while another 40% is classified as Haplustolls (Ewa, Waialua, Kawaihapai, Pulehu, and Haleiwa). The remaining 10% of the area belongs to poorly drained Inceptisols and Vertisols (Pearl Harbor and Kaena).

The seasonal variation in climate with warm sunny summers and cool rainy winters is one of the determining factors in sugar production. Heavy rainstorms in winter show a negative effect on the production. Age of the crop is negatively correlated when the yield is expressed as Ton Sugar per Acre per Month. A significant drop in yield is observed in ratoon cropping. This decrease was more pronounced in the lowland soils. Sugar yield from the first plant crop is higher than the yield from the second plant crop. Since all other management practices and climatic factors are similar for both plant crops, this drop in yield must be considered as a genuine yield decline.

During the 1930's the lowland areas produced more sugar than the fields located on chemically infertile Oxisols in the uplands. Increasing amounts of fertilizers since that time reduced the effect of the limiting fertility factor. The heavy machinery introduced since 1935 created poor physical conditions in the alluvial soils - impeded drainage, compaction and stickiness.- The result is that during the last decade the Oxisols produced significantly more sugar than the alluvial soils in spite of less favorable climatic conditions at higher elevation. The limiting factor appears to have changed from fertility to physical conditions. An analysis of variance test clearly demonstrated the significant difference in yield between these two soil groups. From this study it becomes clear that all three systems-climate, soil and management-play an important role in the final yield figure. While it is not possible to estimate the yield satisfactorily with only one of these systems-the explained variation in yield varied from 18% to 34%- the combination of the three systems explained more than 70% of the yield variation. Almost 80% of the estimated yield data differed less than 5% from the actual yield.

Because this study was carried out over a relatively large area and actual plantation records were used instead of an experimental design, the unexplained variation is still considerable. However this study indicates that agricultural research designed to interpret actual field data should give equal importance to the three systems that control crop growth: Climate, soil and management.

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CHAPTER I

CROP PERFORMANCE IN RELATION TO ITS ENVIRONMENT

(A Literature Review)

The analysis of the yield of sugar cane as a function of climate, soil and management variables is the subject of this study. This chapter is devoted to a literature review, in which the major concepts of such a relationship are summarized. The basic philosophy behind this approach is clearly expressed by Northcote (1964): "Plant growth is a function of available water, available nutrients, atmospheric gases, temperature and light." In addition, a mechanical support to hold the plant upright is required. After reviewing the environment as related to plant growth, attention is focussed on one way of analyzing the yield, namely through soil survey interpretation. Finally some opinions are given to the yield-climate relationship.

An analysis of the yield of any given crop should be based on the principle that crop performance is the result of the interactions of the combination of soil properties and the combination of management practices in a certain climatic system (Kellogg, 1961). Maletic and Bartholomew (1966) state that the potential crop-producing ability of a given area is dependent primarily upon existing climatic and soil conditions. Kohnlein (1964) categorizes the factors that determine yield in four groups: climate, soil conditions, plant species characteristics, and management with emphasis on fertilizer practices. More literature could be cited to stress this point and the over-all conclusion is that the environment could be split up in three general systems:

Climatic system.

Soil system.

Management system.

Each system consists of a combination of factors. Which system dominates depends on the plant species and sometimes on the personal point of view. Clements (1952) states that the theoretical crop is determined by climate and the physiology of that particular crop: "Soils by themselves have no productive capacity: without energy, no crop can be produced on a soil, no matter how fertile it may be." However it is obvious that without soil as a supporting medium, no crop can be produced on a commercial scale no matter how much energy is available. Northcote (1964) states that: "Soil per se is not an indispensable ingredient for plant growth", but he goes on to say that "Soil is merely the most convenient medium available in nature for the retention, partial or complete, of some of the plant growth factors."

The major plant growth factors are: available water, available nutrients, available atmospheric gases, light, and a supporting medium. Each plant species requires a certain arrangement of growth factors for optimal production.

Vink (1963) points out that the oldest agricultural communities in Western Europe are definitely located in areas with loess deposits, which have a high natural fertility. Rice has been cultivated for thousands of years in the river delta's with young and often rich alluvial soils, because of its unique ability to grow under submerged conditions. The method of shifting cultivation, practiced by primitive tribes in the tropics, is another example where farmers traditionally search for the optimum combination of production factors. Highest actual and potential yield in the tropics can be obtained for some perennial crops like cacao and oil palm under conditions which resemble to some extent those of their natural environment (Best, 1962).

Due to increasing amounts of food required by an ever-increasing human population, food production per unit area had to be increased and new areas cultivated where the environmental factors were not optimal. This requirement forced men to change and improve the natural environment. More nutrients had to be added as fertilizers, more water as irrigation, higher yielding varieties through breeding programs, improving of the physical condition of the soil through cultivation, control of diseases and insects, etc.

In general it can be stated that management practices are aimed at providing an environment that produces the highest possible return at the lowest possible cost. Northcote (1964) concludes that "Theoretically all soils could be expected to give the same plant yields provided management practices are adjusted to suit the individual soil, other factors being equal." However, certain environmental factors are beyond the control of the grower. The production of sugar is, for example, related to the processes of photosynthesis, respiration and growth of cane (Silva, 1969). Sunlight, CO_2 and temperature have the greatest effect on these physiological processes; therefore the windward areas of Hawaii can never reach the maximum yields of the leeward areas where sunlight is high and where the shortage of rainfall can be supplemented by irrigation.

Chang (1970) states that in Hawaii the yield pattern of sugar cane is primarily determined by solar radiation. The same arguments are emphasized by Best (1962), who concludes that "In respect of the light factor the potential production of annual crops is often about one and a half times as high in the temperate zone as in the tropics" (where the daily radiation is only 60% of that in the temperate zone).

Much emphasis has been placed on the interpretation of soil survey data to better understand the variation in crop production. Aandahl (1958) states that the purpose of soil survey interpretation is "To provide people with the best possible information about every acre of soil in a form that is directly useful to them. Such interpretations are intended to furnish a better basis for making choices among alternatives in the use and management of soils." Although according to Odell (1958) soil scientists are interested in soils as such and are mainly concerned with their morphological, chemical, physical, and mineralogical properties, farmers are interested primarily in soil productivity and methods of increasing this productivity economically. Kellogg (1961) considers the purpose of soil interpretation as an attempt to predict the behavior of the soil as an entity. A kind of soil is based on a great number of characteristics existing together. Soil quality is considered as a result of interactions among soil characteristics and management practices.

In the past, much emphasis has been placed on soil fertility, a quality of the soil that enables it to provide the chemical compound in adequate amounts and in proper balance for the growth of plants when other factors are favorable. Krantz (1958) in discussing soil qualities important to management states that the natural fertility of the soil is rather unimportant, but it is highly desirable to know its response to management. Lupinovich (1968) found that the level of soil fertility was the main factor in determining plant productivity in the non-chernozem zone in Russia. In modern agriculture however the problem is rather the physical condition of the soil since all necessary plant nutrients can be added as fertilizers (Buringh, 1968). In this context Avery (1962) argues that the productive capacity of a soil under given climatic conditions is largely governed by its suitability as a rooting medium and by the ability of the horizons penetrated by roots to store water and nutrients in forms accessible to plants.

The question still remains whether it is possible to use soil survey data as a basis to establish the productive capacity of the soil, or whether the emphasis should be placed on individual soil properties. According to the Soil Survey Manual (1951) a detailed soil map should show all boundaries between mapping units that are significant to its potential use. Vink (1963) states that soil survey is the only basis for optimal land use. In contrast to this strong support for the use of soil survey data Butler (1964) considers the soil map "A very inadequate presentation of the pattern and kind of soil variation in a certain area, because of the restraint visible boundaries and the restriction to morphological criteria." Gibbons (1961) argues that those criteria which are needed to predict plant growth are often the hidden unmappable features whose correlations with mappable criteria are often unknown. His suggestion is to attempt to find visual key criteria which correlate with most of the criteria considered important for most foreseeable purposes together with other features of the environment, like climate, geology, topography and vegetation. These criteria should then be used in a mapping program.

Butler (1964) in reviewing several studies which attempt to correlate yield with soil type concludes that "the correlation between soil types and agricultural production is uncertain or absent." In contrast, he argues that many studies showed good correlations with certain soil properties. He cites Finck (1961) who found a high correlation between clay content and yield of cotton in the alluvial clay plains of the Sudan. However, in his concluding remarks, Finck states that the clay content may be a useful criterion for further surveys. Loveday (1964) obtained a yield prediction equation for irrigated Lucerne based on only two soil properties, and Wilde (1970) established a significant relationship between the average rate of growth of conifers and four soil characteristics. However, as stated before, soil characteristics interact among themselves as well as with management practices. Mulcahy (1967) considers interpretation of growth based on a few properties hazardous and Aandahl (1958) states this approach as follows: "To try to use a single characteristic or quality as a basis for prediction of plant growth is to invite error. The entire soil, i.e. the unique complex of characteristics, comprising each kind of soil must be considered as an entity of the landscape including its climatic setting. This is the environment for plants." This approach was used by Odell (1950) and Rust and Odell (1957), who conducted a study in Illinois to measure the productivity of certain soil types under various environmental conditions. They concluded that more yield variation was associated with the weather factors than with all others. However, five out of seven soil associations used in this study were correlated significantly with yield.

As stated earlier, climate plays a very important role in crop production. It is not the purpose of this review to discuss these relations in detail. Reference, though is made to Chang (1968) who in his concluding remarks points out that climatologists are no longer content with analyzing data designed only for weather forcasting. "They have begun to realize that the study of climatology should not be limited to the atmosphere but should include both vegetation and soil surfaces as well." Humbert (1968) states that temperature, light, and moisture are the principal climatic factors that control sugar cane growth. Chang (1970) in comparing the sugar cane production in Hawaii and Taiwan concludes that the higher sugar yield in Hawaii is primarily the result of the favorable climatic conditions rather than technological superiority. Similarly, he and Silva (1970) point out that the leeward plantations in Hawaii produce more sugar than the windward areas because of higher sunlight. However, should it not be stated that favorable climatic conditions only result in higher yields if other environmental factors are equal? To support this statement one may look at the data from Clements (1952). He has devoted his work to a study directed at determining factors "intimately associated with the welfare of sugar cane, influences of ecological facts on these factors and an evaluation of such a complex relative to the production of sugar cane." The factors he used to determine the sugar yield are physiological and climatic. However, testing his final prediction equation, he finds discrepancies between estimated and actual yield due to "difficulties in maintaining the moisture level- sheath moisture- properly". The conditions leading to this are, according to him, largely a matter of soil type. Chang (1970) considers the soil as an unimportant factor compared to solar radiation, but considers the impact that management practices have on the soil as a determining factor in yield.

From the above citations it can be stated that agricultural production is determined by climatic conditions, soil conditions and treatments applied by the grower (management practices). The ability of the grower to apply these treatments has not been discussed but certainly should not be overlooked. It may be part of the unexplained variation that is always present in a statistical analysis of actual field data. Although there is some controversy about the applicability of soil survey data, additional support to use this information is the fact that the farmer wants to know what he can expect from every acre of his land.

The only survey that takes every acre in consideration is a soil survey. If it is possible to express the soil mapping units in terms of productivity, providing that the other factors of the environment are explicitely described, that important requirement is fulfilled. An additional advantage is that the results of such study could be transferred to other areas with similar conditions.

These principles have guided the present study. Although in subsequent chapters the material and methods used to arrive at crop yield interpretations will be discussed in detail, an important requirement to arrive at such interpretations is the uniformity in recording data. Because of the complexity of variables involved in this kind of study, the data to be used should not only be reliable but also abundant. Fortunately, the sugar industry in Hawaii has this kind of data in a well organized form recorded over a long period of time.

CHAPTER II

THE SUGAR CANE ENVIRONMENT

This chapter may be compared with a section, called "MATERIALS" in a research, where a certain experimental design is involved. Since this study involves analysis and interpretation rather than collection of data, a detailed description of the area from which the data have been taken will be given. Yield can be expressed as a function of three sets of production factors: Climate, management and soil. This chapter is therefore divided in three sections: The present management practices of the company as they are carried out on the irrigated part of the plantation; a description of the prevailing climate, with emphasis on the rainfall distribution, temperature, evaporation and net radiation; and, a summary of the geography, geology, and soil conditions of the plantation.

I. THE WAIALUA SUGAR COMPANY AND ITS MANAGEMENT PRACTICES

The Waialua Sugar Company, Inc. (abbreviated as "WACO" in this study) is located in the northern part of Oahu, Hawaii (see Figure 1). In 1970 it covered 4954.7 ha (12,386 acres)[1] of which 4175.2 ha are irrigated. The total production of 96^o sugar in that year was 71,546 tons, which represents about 6% of the total sugar produced in the state of Hawaii.

1/ See Appendix III for conversion factors to c.g.s system.

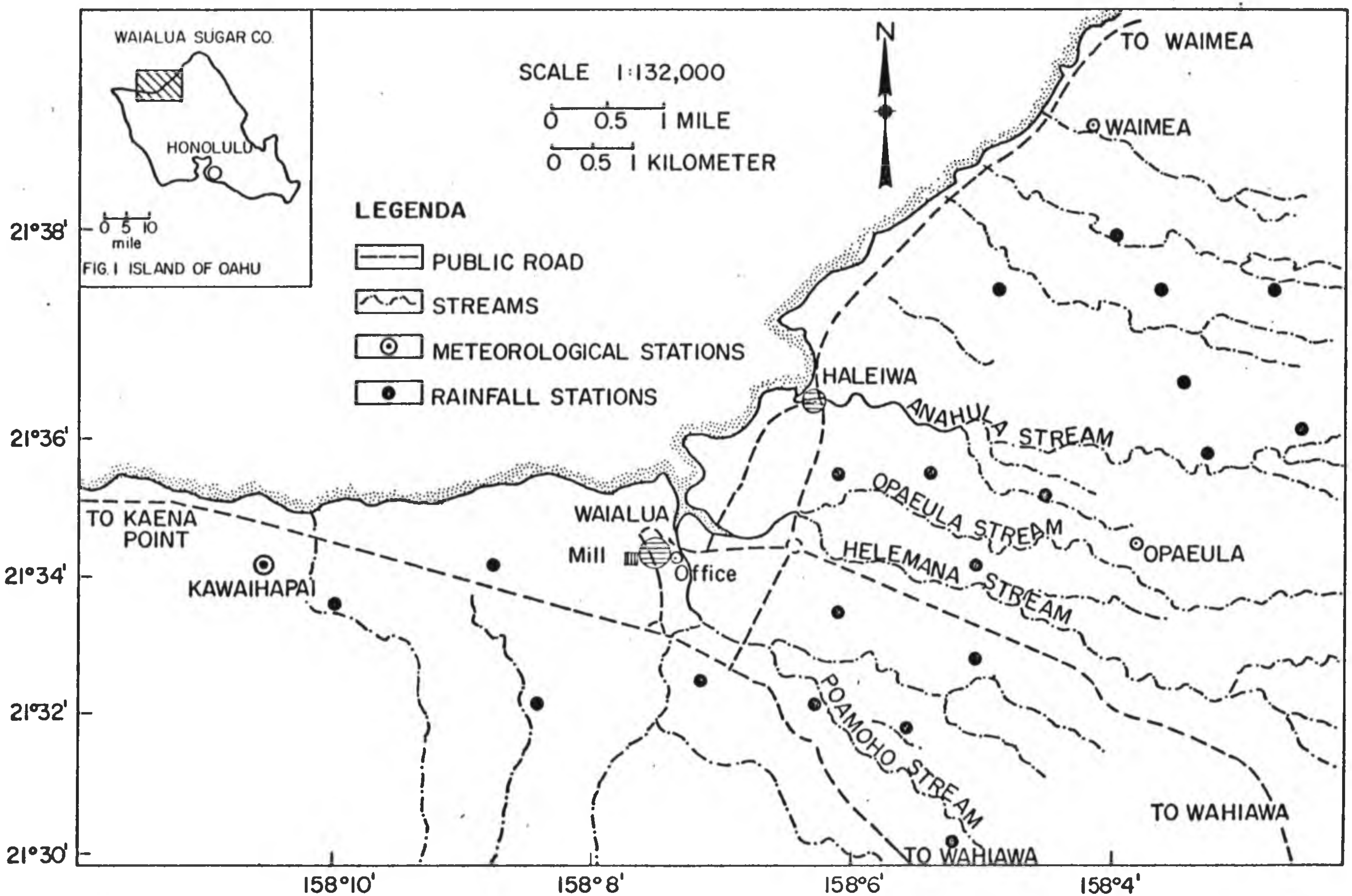

FIGURE 1. TOPOGRAPHIC MAP OF NORTHERN OAHU, SECTION WAIALUA

TABLE I

COMPARATIVE PRODUCTION FIGURES FOR SOME SUGAR COMPANIES IN HAWAII (SOURCE: HAWAIIAN SUGAR PLANTERS ASSOCIATION)

Plantation*	10 year average Ton 96° sugar	1969 TSA[a)]	1969 TSAM[b)]	10 year average TSAM	1969 TCA[c)]
Gay & Robinson (I)	17,156	13.94	0.606	0.606	90
Waialua (I)	70,342	13.66	0.579	0.591	103
Kekaha (I)	47,969	13.67	0.573	0.581	104
Olokele (I)	30,626	13.09	0.550	0.573	106
Oahu (I)	70,979	12.09	0.538	0.544	87
H.C. & S. (I)	177,657	12.66	0.530	0.551	101
Wailuku (I)	29,721	12.04	0.500	0.527	110
Ewa (I)	55,321	11.79	0.499	0.533	99
Maunakea (UI)	63,009	10.22	0.414	0.433	107
Pepeekeo (UI)	55,156	8.98	0.370	0.432	94

* (I) means irrigated; (UI) means unirrigated.
a) TSA: Ton sugar per acre
b) TSAM: Ton sugar per acre per month
c) TCA: Ton cane per acre

Table I summarizes the production statistics for some sugar companies in Hawaii.

The WACO plantation increased in size from 2938 ha in 1930 to 4915 ha in 1969, while the production more than doubled (from 28,820 ton sugar in 1930 to 73,614 ton sugar in 1969). Unirrigated cultivation of sugar cane started in 1960 on land previously used for pineapple production. At present almost 800 ha in the higher elevations are now used for unirrigated sugar cane. In the following sections the most important management practices are discussed in detail. Table I of the Appendix summarizes the management practices for the period 1960-1969.

Since this study concentrates on irrigated sugar cane, only sporadic comments will be made about management practices in the unirrigated part of the plantation. The following information has been collected with the help of the staff of the field department of WACO.

1. Planting Material

The planting material is harvested from 125 ha, located in the unirrigated section of the plantation. No special treatment is given during its period of growth. The last application of fertilizers is given three months after planting. Before the seed pieces are cut the cane is thoroughly inspected for possible diseases. Since the cutting of seed pieces is done mechanically, special consideration is given to the length of the stalk. If the stalk is too short, the soft tops are discarded since they rot easily when planted. If the stalk is too long, considerable waste is incurred. In general the stalk is harvested after seven to nine months and cut in three to four seed pieces of an average length of 45 cm, each containing three buds. The seed pieces are loaded in containers and soaked for a few minutes in a 10% cold solution of P.M.A. (phenyl mercuric acetate). The remaining stubble will sprout again and three to four subsequent cuttings for seed pieces are made before the field is replanted. These later cuttings generally yield more planting material than the first cutting because of better tillering.

2. Seed Bed Preparation

The seed bed preparations vary considerably depending on the cropping system. There are three systems presently practiced in the plantation:

a. Plant Crop. The field is intensively plowed, including subsoiling operations, and fresh plant material is distributed.

b. Ratoon Planting. Only the compacted areas in the field are tilled, but fresh plant material is distributed throughout the field.

c. Mechanical Ratooning. Only the compacted areas are tilled, the furrows are reshaped and replanting is done only in those areas where a poor stand occurs after a few weeks.

The following operations are carried out in chronological order in case of a plant crop system:

Subsoiling.

The field is subsoiled to a depth of approximately 50 cm in two directions (parallel to the furrows and parallel to the flumes).

Plowing.

The soil is turned over with a "Townner" disc plow. Each plow has four discs with a diameter of 105 cm. Depending on the soil conditions the soil is turned over to a depth of around 40 cm.

Grading.

The field is leveled with bulldozers.

Subsoiling.

One more subsoiling operation is carried out, parallel to the flume.

Surveying.

Lines are laid out by surveyors in such a way that the planting machine will make furrows with an average slope of 1.5%.

If the field is to be ratoon planted, only the truck roads used for hauling the cane from the field are subsoiled. Thereafter the field is graded with bulldozers, subsoiled in one direction (parallel to the flumes) and surveyed.

In the case of mechanical ratooning compacted areas are loosened with a subsoiler machine parallel to the existing furrows. The field is leveled and the furrows are reshaped. Difficulties in soil preparation arise under wet conditions. The subsoiler merely cuts the soil like butter and the disc plows can not turn it over. In general the soils on higher elevation can be prepared more easily than the alluvial soils. It should be added that some areas cause problems because of stoniness and shallowness.

Of the total acreage harvested, approximately 60% is ratoon planted, 20% is plant crop and the remaining 20% is subject to mechanical ratooning. Ratoon planting, introduced in 1962, is preferred over mechanical ratooning and is carried out if the work load allows it.

3. Planting

The planting of seed pieces is completely mechanized. The planting machine, operated by three men, cuts two furrows, 1.75 m apart and 40 cm deep, places the seed pieces, applies fertilizer and covers the seed pieces with two to five cm of soil. The seed pieces should be placed edge to edge, but in practice there is some overlapping. On the average 2.5 ton material is required per acre. One machine can plant approximately nine acres per day. Uncovered seed is covered later by hand. At the lower end of the furrows soil material may accumulate due to silting.

4. Fertilization

Fertilizers are applied in several different ways: With the planting machine, with the irrigation water, by airplane or mechanically broadcasted. The amount of fertilizers is determined either by the variety requirement in the case of nitrogen, or by soil analysis in the case of potassium, phosphorus and silicon. Soil samples are taken immediately after harvest, only from the top soil (± 30 cm) and analyzed by the Hawaiian Sugar Planters Association (H.S.P.A). They make recommendations based on the amount of available nutrients. Since 1966 Si is also determined as well as trace elements like S and Mg and Zn. Based on experiments the following critical levels are established in lb/acre foot.

Level	S, Mg	Zn	Si
Deficient	30	10	80
Low	30-100	10-60	80-130
Adequate	100	60	130

Nitrogen

The general practice is to apply the required amount of N within nine months after planting. The amount applied varies for different varieties:

H 50-7209	-350 kg/ha
H 57-5174	-320 kg/ha
H 57-3775	-370 kg/ha

The first application of N is given with the planting machine either as di-ammonium-phosphate (21% N, 53% P_2O_5) if P is also required or as sulphate of ammonia (21% N, 24% S) if no P is required. This last practice was initiated in 1970. Prior to this, if no P was required the first N application was given with the second round of irrigation as aqua ammonia (20% N). All subsequent applications are carried out with the irrigation water every other month until the required amount is applied. In general 70 to 80 kg/ha is applied each time.

Potassium

Potassium is applied with the irrigation water as muriate of potash (KCl). The total amount varies considerably, depending on the soil analysis. Table II shows the relation between K available in the soil and the recommended amount of fertilizer. On the average 300-500 kg K_2O/ha is applied. The timing of application coincides with N and all K is given within nine months.

Phosphorus

This element is always applied with the planting machine. The total amount, depending on soil analysis (see

TABLE II

FERTILIZER RECOMMENDATIONS BASED ON SOIL ANALYSIS AS EMPLOYED IN WACO

Available K lbs K/acre ft (Soil analysis)	K_2O Kg/ha (recommended)	Available P lbs P/acre ft (Soil analysis)	P_2O_5 Kg/ha (recommended)
100	490	25	375
200	370	50	215
300	250	75	55
400	130	85	0
500	0	—	—

Table II), is applied at once and varies from less than 100 kg P_2O_5/ha to more than 200 kg P_2O_5/ha. Rock phosphate has been used in previous years in the upland section of the plantation, but not recently.

Silicon

In contrast to the other nutrients Si is broadcasted as $CaSiO_3$ (47% SiO_2, 34% Ca) prior to the plowing operation. It has been used since 1966, mainly on the higher elevations. Experiments have shown that furrow application did not improve the juice quality of the cane, but a definite increase in yield was observed when broadcasted.

Airplane application of fertilizers is mainly confined to the unirrigated part of the plantation, or when spot fertilization is required, mainly as urea.

5. Irrigation

The irrigated portion of the plantation covers almost 4200 ha (84.3% of the total area). Although recently experiments have been conducted with overhead irrigation, furrow irrigation is still the main practice. Some fields, where no measurable slope exists, have a "level-level ditch" system with furrows up to 300 m long, but more than 90% of the field is irrigated with the "Herring bone" system, developed by J.C. Rust in 1935 (Naquin, 1954). The lay-out of this system is pictured in Figure 2.

The two main sources of water for irrigation are mountain water (collected in four reservoirs), and ground water, pumped to the surface by 18 pumps scattered over the area. The salinity of the pump water varies with location and time of the year. Pump 1, pump 4, pump 18 and "MILL WELL" discharge water that contains about 60 g. salt per gallon in August compared to 30 g. in March. The other pumps have a considerable lower salt concentration. The amount of water used for irrigation purposes varies from year to year, but has increased steadily over the last 10 years (see Table III).

An additional source of irrigation water is supplied by the factory. The water used for cleaning the cane is separated from the soil and pumped into the field (hydro-separated water). Until 1963, irrigation water needs were computed by weekly soil moisture determinations. At present

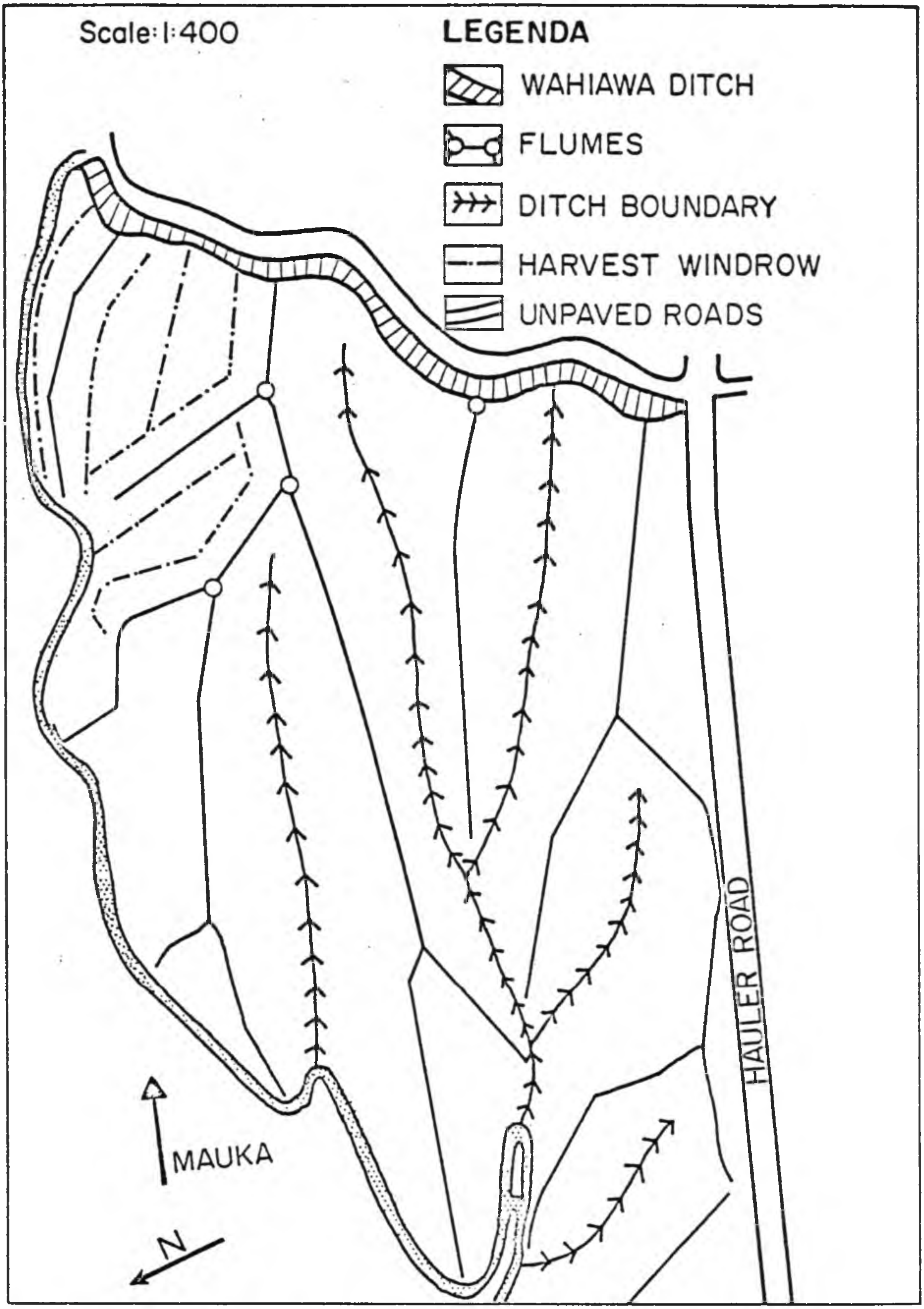

FIGURE 2. LAY-OUT OF IRRIGATION SYSTEM IN HELEMANO 7 (62)

TABLE III

THE AMOUNT OF WATER USED FOR IRRIGATION
IN MILLIONS OF GALLONS

Year	Total	Pumps	Reservoir	Factory
1960	27,070	13,223	13,847	639
1961	26,697	14,584	12,113	531
1962	27,404	15,515	10,889	961
1963	23,362	9,477	13,885	746
1964	31,079	15,185	15,894	1029
1965	21,646	10,883	10,763	802
1966	27,421	16,338	10,083	967
1967	32,618	17,259	15,359	934
1968	30,133	20,128	10,015	1043
1969	33,011	18,089	13,922	943
1970	40,130	23,681	16,449	1065

the easier and more effective pan evaporation method is used. The irrigation intervals are calculated by using weekly rainfall, pan evaporation data, and the soil moisture capacity, which has been determined for each field. The formula used is: Day Interval = F.M.C./weekly (evaporation-rainfall). While in the summer period the number of days between irrigation rounds can be as small as 10, during the winter months this interval can be as long as 20 days. The number of irrigation rounds varies from 20 to 40 per crop cycle. The first round of irrigation is applied within five days after planting, while the last round of irrigation generally is applied 50 to 80 days before harvest.

The amount of water applied is determined by the time it takes for the water to reach the lower end of the furrow. The furrows extend approximately 100 m from the flumes and should have a slope of 1.5%. The amount of water applied per irrigation round varies from six to ten acre inches. Although drainage facilities are installed in the low lying areas, they are inadequate and some fields are submerged during heavy rainfall periods in winter. At other places in this area the ground water table may rise to within 30 cm below the surface and the damaging effect shows up particularly in young cane.

Although the furrows follow the contour lines, damage and erosion may occur during heavy rainfall,(particularly in the center of the lines where water accumulates-see Figure 2) and with young cane.

6. Weed Control

Herbicide is applied immediately after the first irrigation round by aircraft. A mixture of Atrazine and Ametryne (50:50) is applied in the amount of 7 kg/ha. After about 65 days a "handgang" sprays 4 kg/ha of a contact herbicide mixture of Diuron and Delapon (50:50), or 2-4-d Amine, depending on the kind of weed. Normally a third application is not necessary, since by that time the field is closed-in. The most important weeds are Guinea grass and California grass.

7. Insect and Disease Control

Biological control has been sufficient to protect the cane from insect damage. No insecticides are used.

8. Varieties

Although WACO plants several varieties at any time during the last 10 years, one single variety occupied 70 to 90% of the total irrigated portion. As will be discussed later, this has been the general practice in the plantation since 1930. Variety H 50-7209 has variety H 44-3098 as female parentage and an unknown male parentage. It was under experimentation since 1950 and introduced on a large scale by WACO in 1961. At other plantations throughout Hawaii it has been planted since 1965. Initially this variety germinated rapidly with sturdy shoots, large internodes and produced a heavy tonnage of cane and sugar. The root system is not very extensive and during strong winds uprooting occurs. At the age of eight to nine months the cane lodges, after which a tremendous tillering takes place, compensating the loss due to lodging. Due to its poor holding quality, this variety is more accepted in leeward plantations. At present the internodes are much shorter, stalk diameter smaller and the sugar tonnage has decreased. The plantation, therefore, is experimenting with new varieties. In 1970 more than 800 ha have been planted with H 57-3775.

9. Harvest

Sugar cane is harvested from the beginning of March until late October with peaks during the summer months. The cane has been on the field for about 23 months. Table IV shows the frequency of harvests at certain months and at certain ages.

Rainfall is an important factor in the harvest operations. In general 30 to 40 acres can be harvested during a 24-hour period. The factory can handle up to 200 ton cane per hour. The cane is transported to the mill by truck, weighing 40 ton. Some trucks can carry as much as 60 ton material on specially constructed roads. The harvested material consists of 30 to 45% leaves, soil and rock. The harvest practices consist of the following operations:

a. Making fire breaks with push rakes.

b. Burning the cane preferably during noon when the best results are obtained. The main purpose of burning is to get rid of the trash and to improve the juice quality.

c. Pushing the cane on windrows. The push rakes consist of two sharp blades that cut or push the cane on windrows parallel to the flumes at a distance of 30 m. A ground crew follows the push rake to cut the remaining cane by hand and are followed by a "liliko rake" which pushes this cane in the windrow.

d. A bulldozer smooths a hauler road 10 m away from the windrow.

e. A crane transfers the cane in the trucks.

f. The cane is transported to the mill. Before unloading the trucks are weighed and the truck operator punches a card on which field, number of truck, gross weight and data are recorded.

These mechanized harvest operations result in efficient use of labor, but sugar recovery is reduced. The push rakes are supposed to cut the cane at ground level, but under wet soil conditions the whole stubble (and with it a considerable amount of soil) is removed. Under rainy conditions the burning process is not complete. The success of burning also depends on the variety. Stoniness of the surface soil also hampers the harvest operations.

In 1953 the railroad as a means of transporting the cane to the mill was abondoned and an additional 45 miles of cane hauling roads was constructed.

10. Yield Determination

The harvest supervisor estimates the amount of trash in the field for each truck load, which may be as high as 50%. After processing the cane in the factory, the net weight,

TABLE IV

FREQUENCY OF HARVEST
AT DIFFERENT AGES AND IN DIFFERENT MONTHS
FOR THE PERIOD 1960-1969, EXPRESSED AS A PERCENTAGE
OF THE TOTAL NUMBER OF HARVESTS

Month	Frequency	Age in months	Frequency
March	6.3%	21-22	2.4%
April	7.5%	22-23	19.1%
May	16.0%	23-24	51.5%
June	14.7%	24-25	24.0%
July	13.4%	25-26	3.0%
August	16.0%		
September	13.2%		
October	11.4%		
November	1.5%		

the pol weight in cane and the tons 96DA sugar are calculated with the so called "inferential method" developed by the H.S.P.A. This information, together with the punched card for each incoming truck (see above) provides the information needed to determine the yield figure for each field. A record is then filled out on which management practices, some climatological data and yield data are written. The data used in this study have been taken from these records.

II. CLIMATE

This section describes the variation in climate in the area of WACO. The climatic behavior in Hawaii will not be discussed and reference is made to Chang (1963), and Blumenstock and Price (1967). In subsequent sections rainfall, evaporation, radiation, and temperature in WACO will be discussed. The data were collected from observation stations in the area for the period 1960-1969. There are 30 locations where rainfall is measured and four locations where also temperature, evaporation and radiation measurements are taken. While three stations: Office (847), Opaeula (861), and Waimea (892) have complete records, radiation in Kawaihapai (841) was only measured until December 1964, after which date it has been out of order until November 1969. Therefore the data pertaining to this period and location have been excluded in most statistical computations. Figure 1 shows their location. The complete set of climatic data used in this study is compiled in the Appendix, Table V.

1. Rainfall

The median rainfall varies from 671 mm in Office to 1135 mm in Waimea. Variation in a given year however is much greater. The lowest annual rainfall during 1960-1969 was measured in Kawaihapai (600 mm), in 1961, while the wettest year was 1965, when 1720 mm of rain was recorded in

Waimea. Because of the wide variation, the median rainfall was chosen as a better estimate than the average rainfall. The same fluctuations can be observed in the monthly rainfall. Figure 3 shows this variation. In general it can be said that October through March are the wettest months, while April through September are drier. In the lower elevations (Kawaihapai: 16 m and Office: 0 m) the highest rainfall is observed during January and March, but in the higher elevations (Opaeula: 210 m and Waimea: 108 m) heavy rainfall occurs during November and December. The driest months are June and August, which is quite pronounced in the lower elevations. Table V summarizes the median monthly rainfall for the four stations. That the amount of rainfall in any given period is a function of elevation is discussed by many climatologists (Leopold, 1949; Chang, 1961) and may also be observed for this plantation, although large deviations do occur. It should be noted that the plantation is located for the most part on the leeward side of the Koolau mountains. The northernmost part of the plantation receives more rain than other locations at the same altitude, while the annual rainfall on the Wahiawa plateau is lower in spite of its relative higher elevation. Riehl (1949) reports in a study of some aspects of Hawaiian rainfall that in contrast to the total precipitation, rainfall on days with less than 2.5 mm per day, has little seasonal variation. He reports that in WACO 91% of the

TABLE V

MEDIAN RAINFALL, EVAPORATION, RADIATION AND TEMPERATURE FOR METEOROLOGICAL STATIONS: (1) KAWAIHAPAI, (2) OFFICE, (3) OPAEULA AND (4) WAIMEA. OBSERVATION PERIOD:1960-1969 (SOURCE: WACO RECORDS)

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
	MEDIAN MONTHLY RAINFALL IN MM.											
1	102	83	105	52	33	12	20	12	18	40	70	75
2	103	91	103	43	28	8	35	12	33	52	88	75
3	118	100	120	68	55	30	60	35	45	81	138	123
4	90	90	148	95	55	55	87	80	55	85	165	120
	MEDIAN MONTHLY EVAPORATION IN MM.											
1	102	100	116	130	155	180	195	178	160	113	115	89
2	95	100	132	142	170	195	203	210	179	145	105	92
3	95	99	128	123	165	168	183	193	158	138	117	87
4	117	127	138	143	153	177	190	194	179	135	115	94
	MEDIAN MONTHLY RADIATION IN GR.CAL. PER DAY											
1	349	315	383	403	469	510	516	496	476	408	302	296
2	341	350	406	436	502	515	518	520	495	435	365	327
3	335	327	383	409	461	496	490	505	464	410	343	325
4	330	330	394	402	490	488	502	492	475	427	334	337
	MEDIAN MONTHLY MAXIMUM TEMPERATURE IN DEGREE FAHRENHEIT											
1	78.0	78.5	79.4	80.4	83.9	85.2	85.4	85.7	86.9	85.2	81.7	79.6
2	78.1	78.2	78.7	80.3	82.7	85.6	85.1	86.0	86.1	84.2	80.9	79.7
3	77.0	75.6	77.8	77.7	79.0	81.5	81.5	82.6	82.2	81.6	79.3	78.2
4	74.8	75.6	76.5	77.7	80.3	80.9	81.2	82.1	82.2	82.0	78.7	76.5
	MEDIAN MONTHLY MINIMUM TEMPERATURE IN DEGREE FAHRENHEIT											
1	63.5	62.6	63.2	64.5	66.1	67.0	68.0	68.9	68.1	66.9	66.5	64.0
2	60.9	59.7	60.9	62.1	63.9	65.3	66.7	66.4	65.6	64.7	64.4	61.7
3	64.3	63.2	64.2	65.5	66.9	68.7	69.4	69.9	70.0	68.5	68.1	65.0
4	62.9	65.8	66.6	67.9	66.9	64.4	71.6	71.2	71.4	70.0	68.9	65.7
	MEDIAN MONTHLY MEAN TEMPERATURE IN DEGREES FAHRENHEIT											
1	70.8	70.8	71.1	72.4	74.0	76.5	76.7	77.6	77.4	76.9	73.8	71.8
2	69.3	69.3	69.5	71.2	73.5	75.4	75.8	76.1	75.7	74.8	72.6	70.8
3	71.1	69.4	70.9	72.2	72.7	74.8	75.3	76.0	76.8	74.6	73.7	70.8
4	71.1	71.0	71.4	72.9	73.9	75.3	76.3	77.5	77.2	75.9	74.1	71.1
	MEDIAN MONTHLY DIURNAL DIFFERENCE IN TEMPERATURE (FAHR.)											
1	14.8	13.8	14.7	15.9	17.9	17.7	17.8	18.2	20.8	16.5	14.0	13.3
2	17.4	18.0	17.7	18.2	18.8	19.5	18.9	19.9	20.6	19.4	16.2	17.1
3	13.0	12.4	12.9	12.2	12.5	12.1	11.7	11.9	12.3	12.5	10.5	11.6
4	10.6	11.0	10.5	11.4	8.7	10.4	9.7	10.5	10.4	10.3	9.7	10.9

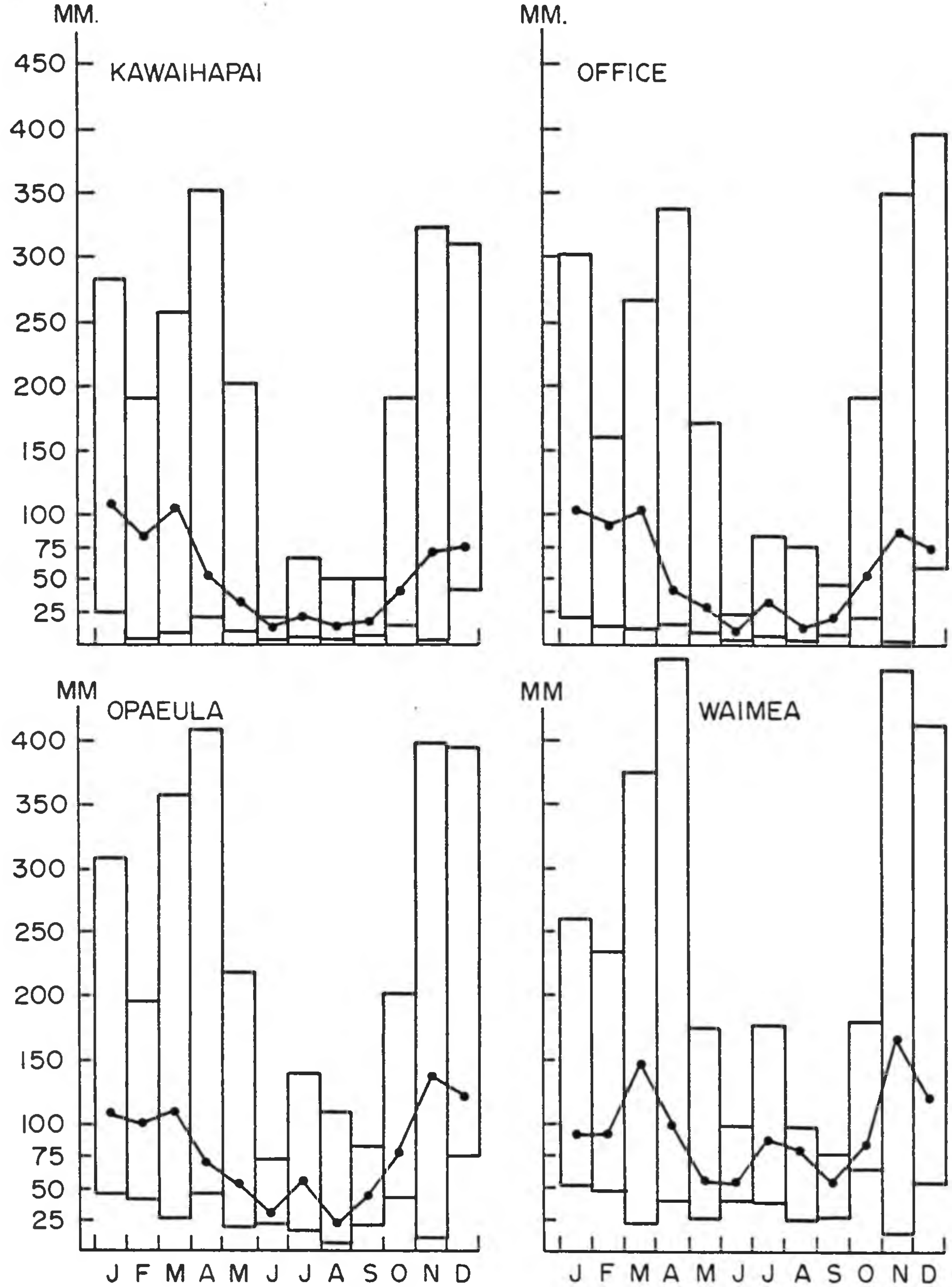

FIGURE 3. MONTHLY FLUCTUATION IN RAINFALL AND MONTHLY MEDIAN RAINFALL FOR FOUR OBSERVATION STATIONS (1960-1969)

total precipitation occurs in the form of rainstorms (when more than half of the stations in the same region receive rain at the same day). The average rainstorm expectancy is lowest in June and highest in March. The rainfall distribution is, therefore, a function of altitude as well as location. By calculating third degree polynomial coefficients, monthly rainfall distribution maps were constructed. Figure 4 shows the trend surface of the annual rainfall in WACO. More than 90% of the monthly variation in rainfall can be explained by location except for January (r^2=0.78). This reflects the greater variability in rainfall during this month, when trade winds occur only 40% of the time and cyclonic weather prevails (Chang, 1963).

2. Evaporation

Evaporation measurements are taken daily from U.S. evaporation pans located at four different meteorological stations in the plantation.

The annual evaporation varies much less than the annual rainfall (see Table VI). During December, January and February the evaporation is around 100 mm monthly, while during June, July and August evaporation doubles. The lowest annual evaporation was recorded in Kawaihapai in 1960 (1186 mm) while the highest evaporation was during 1966 in Office (2140 mm). As will be discussed later,

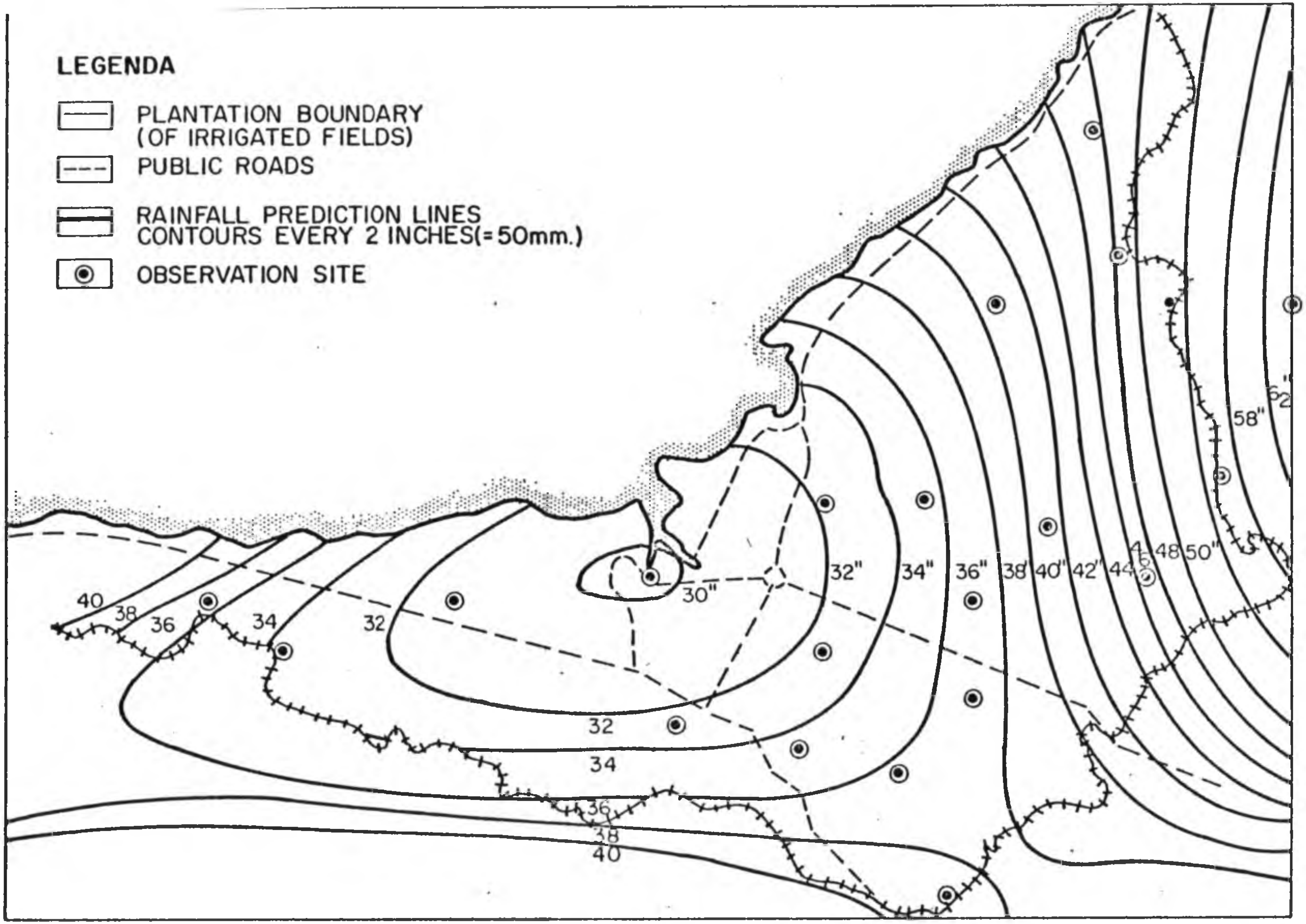

FIGURE 4. TREND SURFACE OF ANNUAL RAINFALL IN WACO

evaporation in this location is more strongly correlated with radiation than with rainfall.

3. Radiation

The global radiation is measured at four different locations. Until 1968 photochemical tubes were used. The photochemical measurement of sunlight depends upon the decomposition of a solution of oxalic acid, sensitized with uranium sulphate, when it is exposed to sunlight. The close correlation between the photochemical tube and the pyrheliometer, the low capital investment, and the simplicity of the techniques were the main reasons that this method was used widely in Hawaii for solar radiation measurements (Brodie, 1964). The "Wig-Wag", which is presently installed at all locations in WACO and is considered superior to all other field radiation instruments (Brodie, 1965) is based on the principle of the expansion of the gaseous phase of a volatile liquid as a result of the conversion of radiant energy to sensible heat. Weekly readings were taken and the monthly totals are summarized in the Appendix, Table V.

The annual global radiation varies slightly among the several locations. Kawaihapai recorded the lowest radiation during the 14 years it was in operation, mainly because of its location on the north slope of the Waianae range. The monthly fluctuation however varies to a much

TABLE VI

MEDIAN ANNUAL RAINFALL, EVAPORATION, AND RADIATION FOR KAWAIHAPAI, OFFICE, OPAEULA, AND WAIMEA (SOURCE: WACO RECORDS)

Station	Elevation m (1m=3.3 ft)	Rainfall mm (25mm=1 inch)	Evaporation mm	Radiation gr.cal. (Weekly aver.)
Kawaihapai	16	827	1715	3382
Office	0	737	1769	3894
Opaeula	210	1175	1641	3765
Waimea	108	1310	1799	3769

greater extent (see Figure 5). During the winter months the radiation totals around 10.000 gr cal/cm^2 per month or expressed on a daily basis 333 Langleys*, while summer values exceed 600 Langleys.

4. Temperature

Maximum and minimum temperature readings are taken daily from the same locations. The monthly averages for the last 10 years are summarized in Table V of the Appendix. In addition the mean monthly temperature and the monthly difference between maximum and minimum temperature is calculated.

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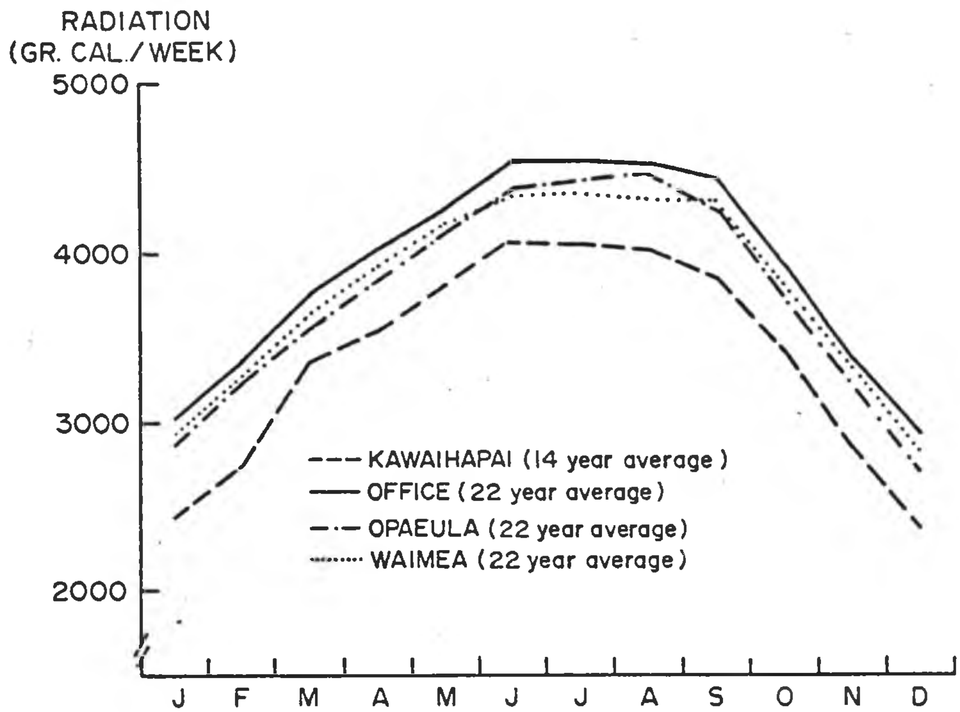
* Langley is a unit of energy equivalent to one gram calorie/cm^2



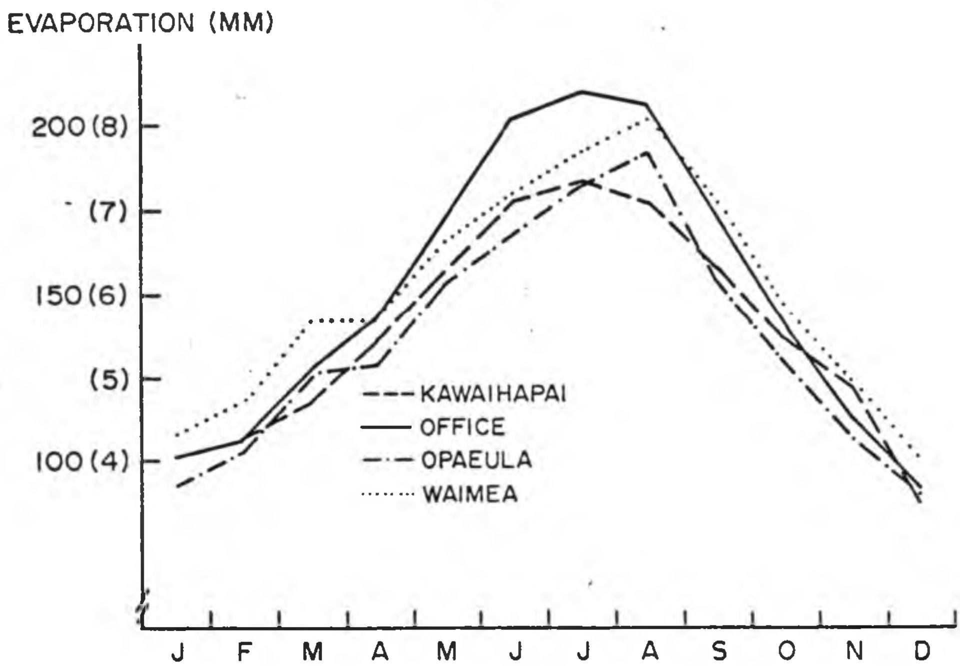


FIGURE 5. MONTHLY FLUCTUATION OF RADIATION AND EVAPORATION AT FOUR METEOROLOGICAL STATIONS

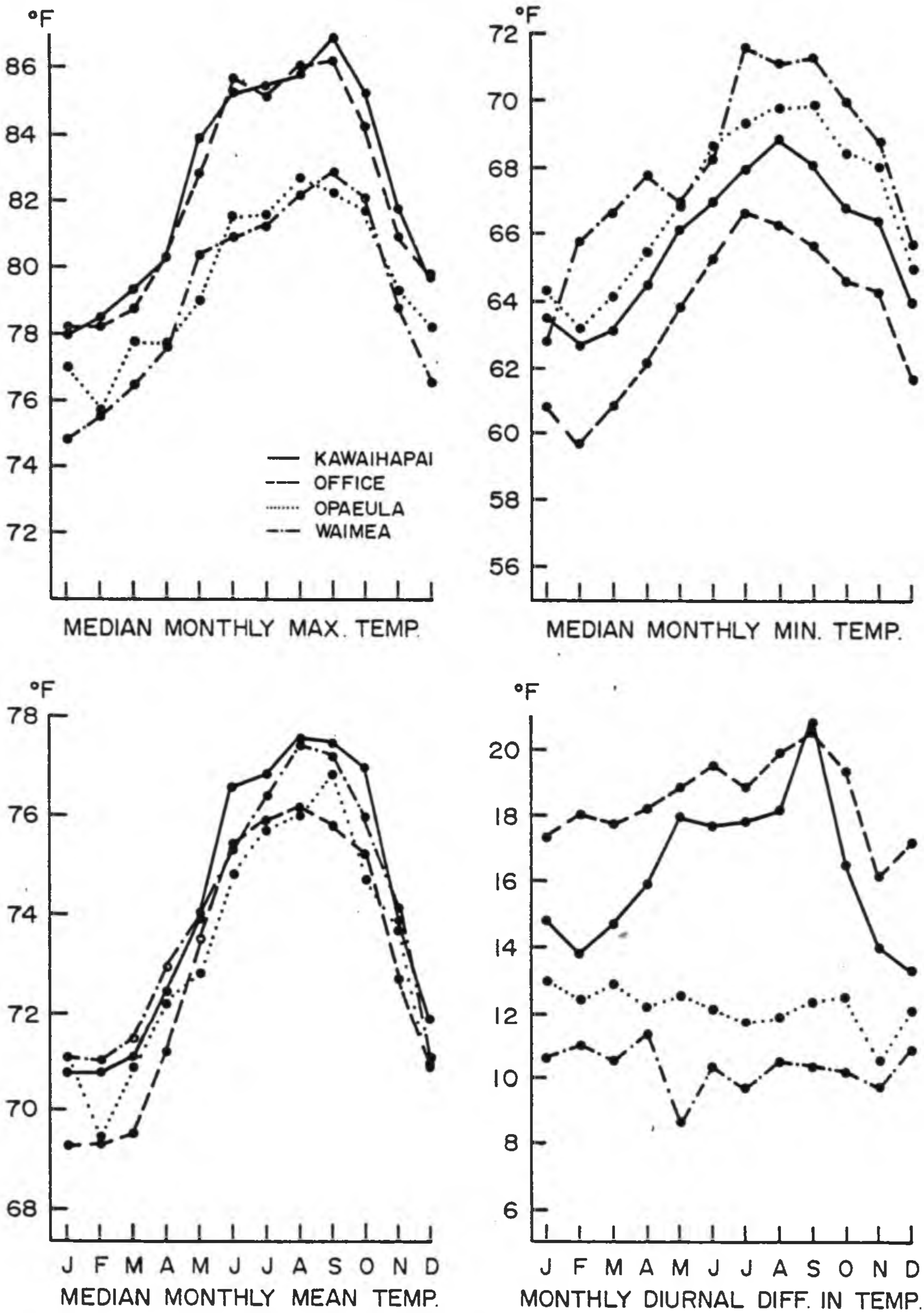


FIGURE 6. FLUCTUATION OF MONTHLY TEMPERATURE AT FOUR METEOROLOGICAL STATIONS.

The difference in temperature between summer and winter is more pronounced in the lower altitudes. February appears to be the coldest month. During the ten-year period the lowest temperature was 55.2°F (Kawaihapai, February 1962), while the highest temperature was recorded in the same year and same location (90.8°F in August). The average monthly temperature in the two higher located areas never dropped below 60°F and reached 87°F only during the summer of 1968. Figure 6 shows the monthly fluctuations at the four stations. It is apparent that the daily fluctuation is greatest during summer and at the low lying locations (Kawaihapai and Office).

III. GEOLOGY, GEOMORPHOLOGY, AND SOILS IN THE WAIALUA SUGAR COMPANY INC.

This section briefly describes the main geologic and geomorphologic features in the area under investigation and will discuss the soils in more detail. Reference is made to the extensive geological studies by Stearns (1935).

1. Geology

The island of Oahu is formed by two volcanic ranges: Waianae and Koolau. Both volcanic series are dated back to late Tertiary or early Pleistocene, but the Koolau series are definitely younger. The main portion of the plantation is located on residuum of the Koolau series (see Figure 7). Stearns (1935) describes it as "aphanitic, porphyritic, dense, very vesicular and effusive basalts." Except where they form cliffs, the surface of these rocks is deeply weathered. The basalt is more than 1000 m in thickness and near the margin of the range the slope is five to ten degrees. Since this basalt is uniformly permeable it supplies most of the artesian wells. The remainder of the area is alluvial in origin. The following geological units are delineated on the geologic map, prepared by the U.S. Geologic Survey (1938):

PA-Consolidated non Calcareous Deposits. They are described as older alluvium, consisting of mottled red-brown deeply weathered, poorly assorted and nearly impermeable conglomerates, usually forming conspicuous terraces along streams. Near Waialua this alluvium grades into partly consolidated sands and silts that are emerged delta deposits. The total thickness of these sediments extends about 70 m (200 ft) above sea level, while borings show that these sediments occur 400 m (1200 ft) below sea level.

RA-Unconsolidated non Calcareous Deposits. These deposits consist of younger alluvium, a black to brown fluviatile deposit. Near the coast the deposit is described as a black sticky mud. The thickness of this sediment does not exceed 6 m (20 ft).

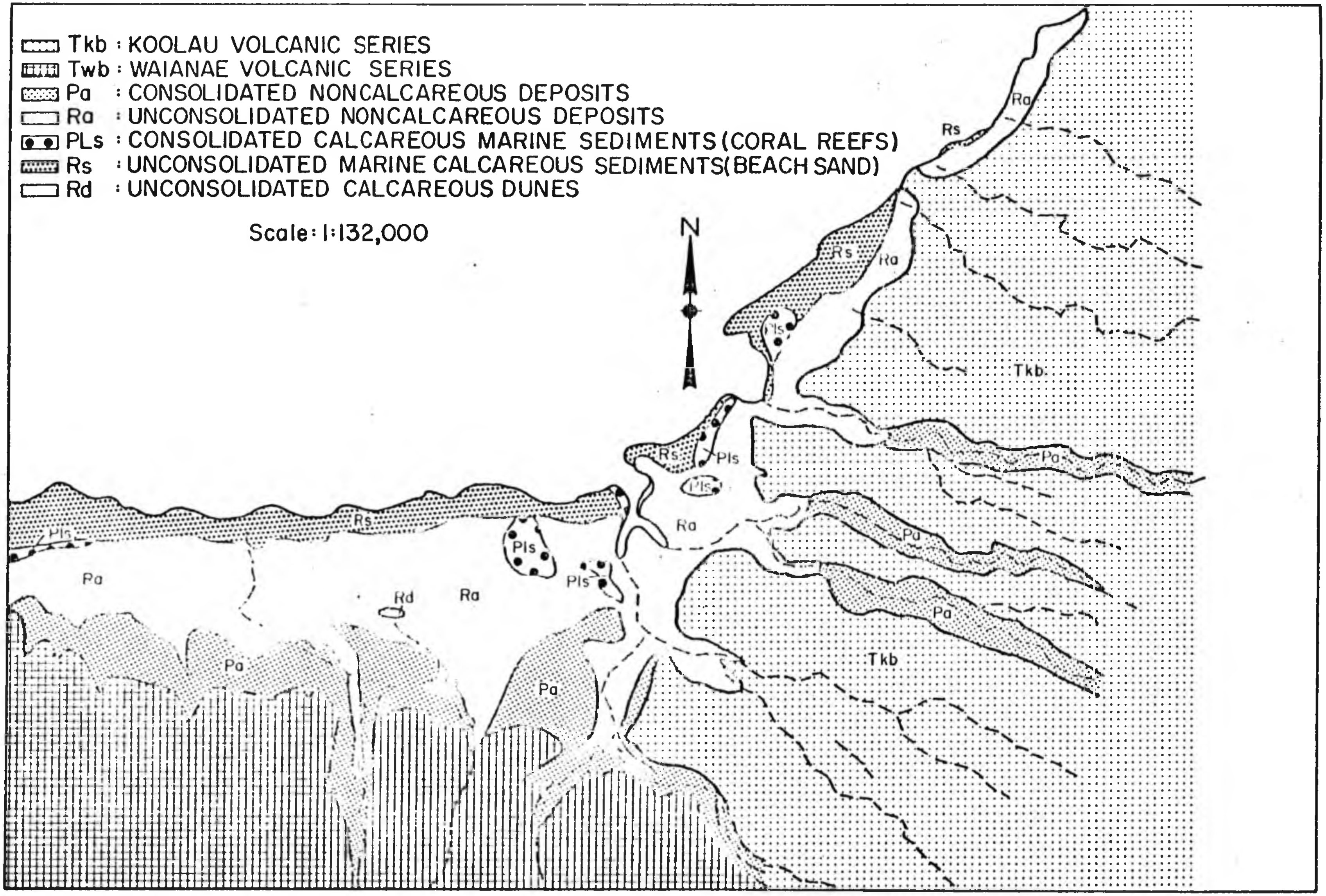


FIGURE 7. GEOLOGIC MAP OF NORTHERN OAHU, SECTION WAIALUA.

PLs-Consolidated Calcareous Marine Sediments or coral reefs. At several locations (see Figure 7) outcrops of coral limestone are observed. Only in the area around Waialua are these outcrops within the boundary of the plantation.

Rs-Unconsolidated Calcareous Marine Deposits or beach sand. This geological unit is of little importance because it does not occur in the plantation area.

2. Geomorphology

The area can be divided in several landscape units:

a. Gently sloping upland.

b. Nearly level to level coastal plain.

c. Steep gulches.

d. River valleys.

e. Beach sand.

Sugar cane is mainly cultivated on the first two landscape units with some fields located in the mouth of some river valleys. The gulches intersect the gently sloping uplands at many locations (see Figure 8). They are sometimes more than 100 m (300 ft) deep and at some locations are almost 1000 m (3000 ft) wide. Most of these major gulches extend far beyond the plantation boundary towards the mountains, but minor drainage patterns originate within the observed area. In contrast to the gentle slopes of the Koolau side, the Waianae side has steeper slopes but a much wider coastal plain. Due to changes in sea

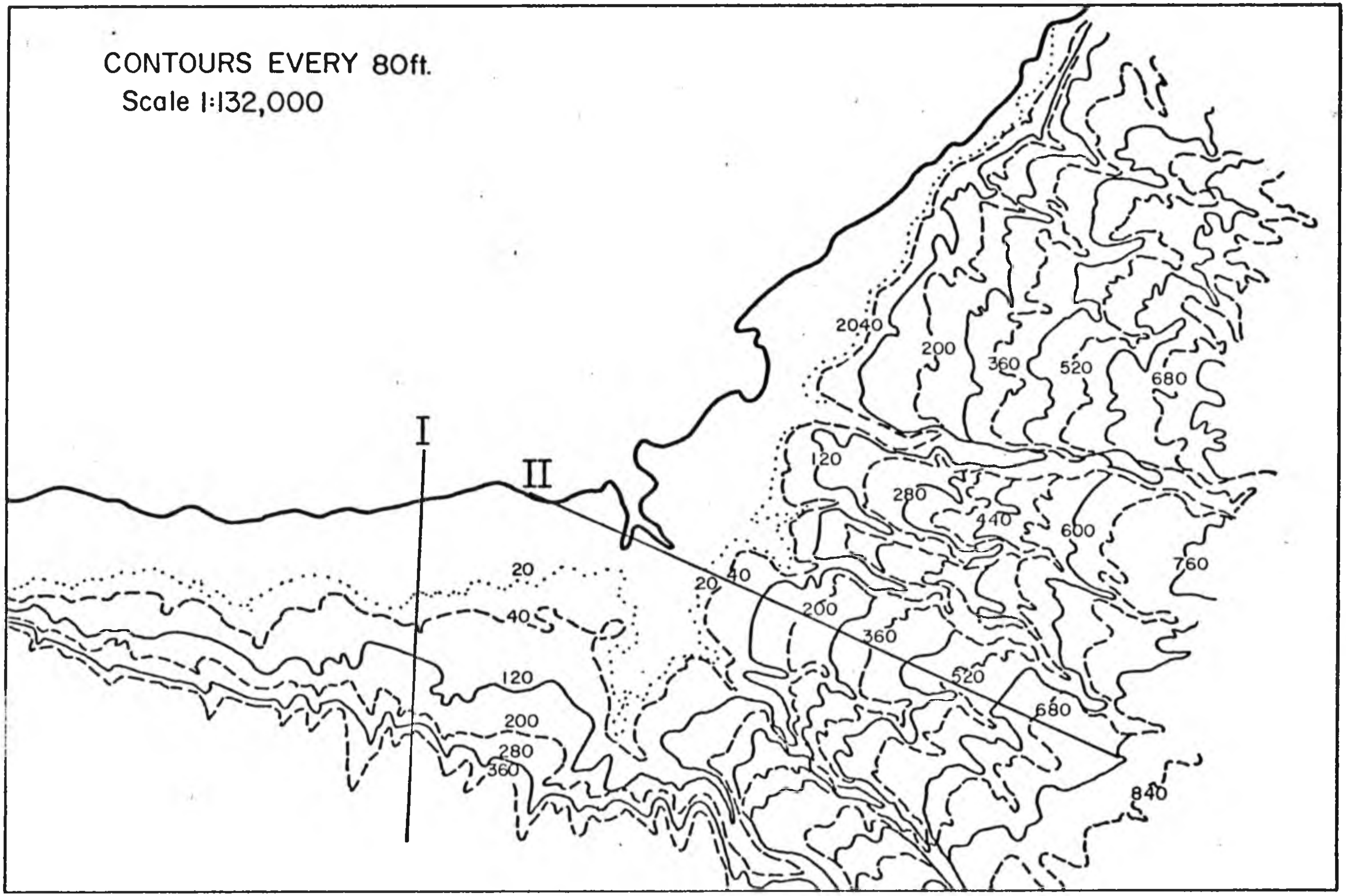


FIGURE 8. ELEVATION CONTOUR MAP OF NORTHERN OAHU, SECTION WAIALUA.

level several terraces are observed on Oahu and described in detail (Stearns, 1934; Ruhe et al., 1965). The latter writer concludes, based on morphometric analytical data, that two shorelines above present sea level - "Waimanalo" and "Kaena" - are distinct on Oahu, while a third level - "Hanauma" - may be present. The Waimanalo level is around 8.5 m above present sea level, while Kaena level shows up at 30 m (90 ft) above sea level. A topographic profile taken near Haleiwa shows knickpoints at 13 m (40 ft) and 33 m (100 ft). These shorelines all developed during the Pleistocene, after Oahu was submerged more than 400 m (1200 ft).

3. Soils

The Soil Conservation Service (S.C.S.) made a detailed soil survey of all the islands and soil boundaries are delineated on various aerial photographs. A map (Appendix II) is compiled from these photographs and shows the phases of the soil series occurring in WACO. Table VII lists the most important soil series with their present classification according to U.S. Comprehensive System of Classification (1970 supplement), and in parentheses the old classification (Cline, 1955). For the purpose of this study, some soil series that are very similar in nature were combined (Ewa-Waipahu; Pulehu-Kawaihapai; Pearl Harbor-Kaena). A simplified map showing only the soil series is drawn on

TABLE VII

SOIL SERIES, OCCURRING IN IRRIGATED PART OF WACO,
THEIR CLASSIFICATION, TOTAL ACREAGE AND ACREAGE IN WACO

Soil Series	Classification (U.S.D.A. 1970)	Classification (Cline, 1955)	Size in hectares Total Hawaii	WACO (%)
Wahiawa	Tropeptic Eutrustox	(Low Humic Lat.)	8565 ha	1722 (39)
Lahaina	Typic Torrox	(Low Humic Lat.)	6479	1055 (24)
Waialua	Typic Haplustoll	(Low Humic Lat.)	2569	471 (11)
Ewa	Aridic Haplustoll	(Low Humic Lat.)	2627	344 (8)
Pulehu	Cumulic Haplustoll	(Alluvial)	999	190 (4)
Haleiwa	Typic Haplustoll	(Alluvial)	962	174 (4)
Kawaihapai	Cumulic Haplustoll	(Alluvial)	2580	90 (2)
Leilehua	Humoxic Tropohumult	(Humic Ferr. Lat.)	1915	86 (2)
Pearl Harbor	Typic Tropaquept	(Gray Hydromorphic)	790	74 (2)
Waipahu	Torrertic Haplustoll	(Low Humic Lat.)	943	122 (3)
Kaena	Typic Pelludert	(Gray Hydromorphic)	1683	56 (1)

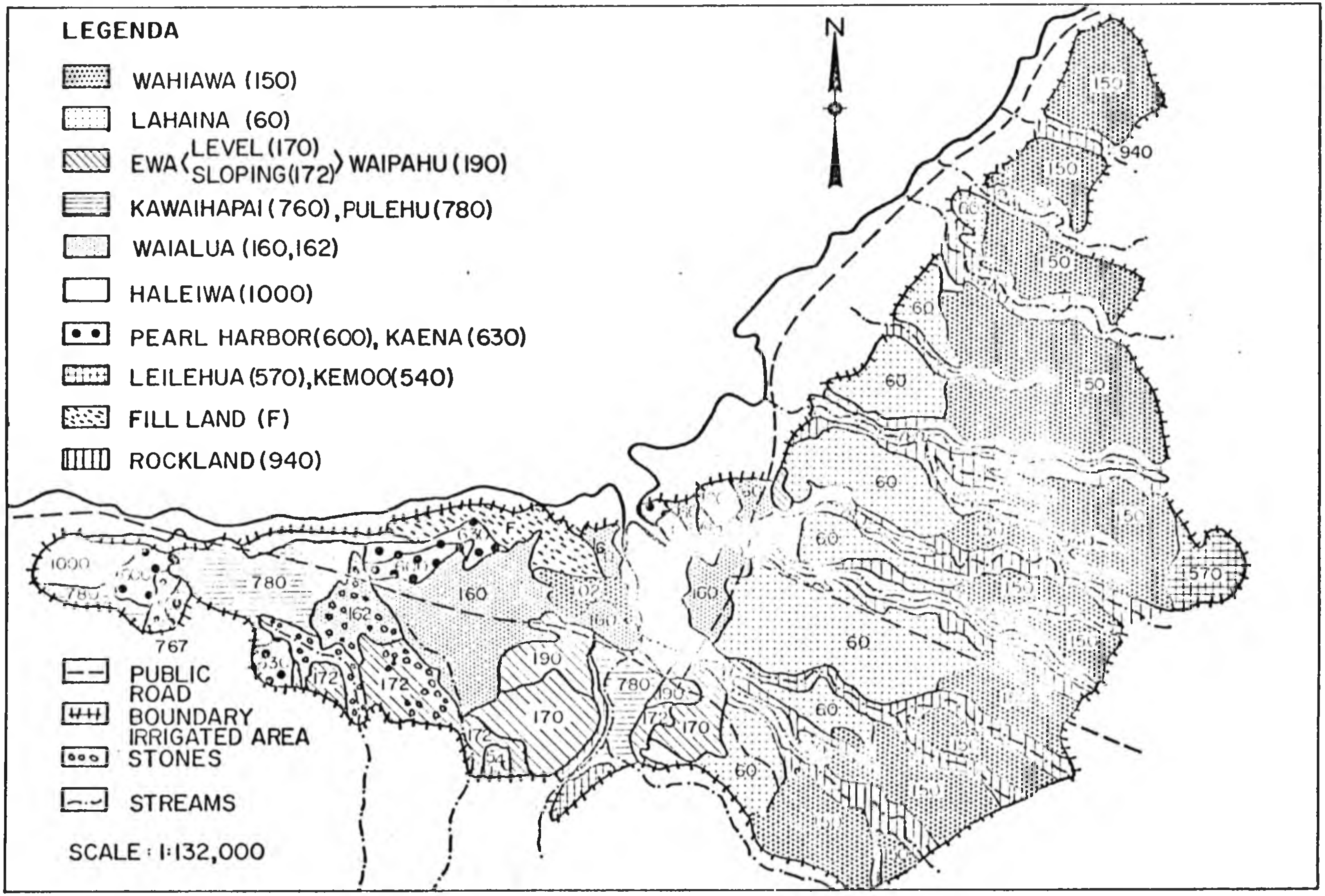


FIG. 9 SIMPLIFIED SOIL MAP OF IRRIGATED LAND OF "WAIALUA SUGAR CO. INC."

scale 1:132,000 (Figure 9). Soil profile descriptions have been made by S.C.S. (unpublished) and several pits have been dug and described by this writer. In order to compare the most important morphological characteristics as well as some genetic factors, Table VIII is compiled from the available information. Leilehua soil series is included in this table although this soil is present in only two fields. It is, however, an important series in the unirrigated plantation. On the basis of parent material and physiography the series may be divided into four groups:

Wahiawa and Lahaina: Developed on residuum and alluvium from basaltic rock; located on sloping upland.

Waialua, Ewa and Pulehu: Developed on alluvium from weathered basaltic rock; located in alluvial fans and river valleys.

Haleiwa and Pearl Harbor: Alluvium and colluvium from mixed origin and located in coastal plains.

Leilehua: Developed on residuum from basaltic rock in gently to strong sloping upland.

The texture of the top soil varies from silty clay loam, silty clay to clay, while the structure grade varies from weak to strong. An important feature that is observed in almost all the profiles is the abrupt, wavy boundary between the Ap2 horizon and the B horizon. This apparently influences the root distribution: Very few roots appear below 50 cm (20 inches). The consistency in the top soil is

TABLE VIII
GENETIC AND MORPHOLOGICAL CHARACTERISTICS FOR SOME SOIL SERIES IN "WACO"

SOIL SERIES NAME	LEILEHUA	WAHIAWA	LAHAINA	WAIALUA	EWA (WAIPAHU)	PULEHU (KAWAIHAPAI)	HALEIWA	PEARL HARBOUR (KAENA)
SIZE HA.	1915 (86 LOC)	4555 (1722 LOC)	6479 (1055 LOC)	2569 (471 LOC)	3570 (466 LOC)	3579 (240 LOC)	962 (174 LOC)	2473 (129 LOC)
SUB GROUP	HUMOXIC	TROPEPTIC	TYPIC	TYPIC	ARIDIC (TORRERTIC)	CUMULIC	TYPIC	TYPIC
GR. GROUP	TROPOHUMULT	EUTRUSTOX	TORROX	HAPLUSTOLL	HAPLUSTOLL TIC	HAPLUSTOLL	HAPLUSTOLL	TROPAQUEPT (PELLUDERT)
(1938 CL)	HUM. FER. LAT.	LOW HUM. LAT.	LOW HUM. LAT.	LOW HUM. LAT.	LOW HUM. LAT.	ALLUVIAL	ALLUVIAL	GRAY HYDROMOR.
CLAY MIN.	OXIDIC	KAOLINITIC	KAOLINITIC	KAOLINITIC	KAOLINITIC	MIXED	MIXED	MONTMORILL.
				GENETIC FACTORS				
RAINFALL								
ANNUAL MM	1250	1035	865	840	850	860	800	800
MAY-SEPT.	300	200	160	140	145	160	135	140
M.<100MM.	5	7	7.5	8	8	8	8.5	8.5
M.< 50MM.	1	3	5	5	5	2	1.5	2
M.< 25MM.	0	0.5	0.8	1.7	2	2	1.5	2
TEMP.FAHR RANGE	68.9-76.0	70.0-77.7	69.8-76.8	69.8-76.8	69.8-76.8	69.9-77.6	69.8 76.8	69.9-77.6
PARENT MATERIAL	RESIDUUM FROM BASALTIC ROCK	RESIDUUM AND ALLUVIUM FROM BASALTIC ROCK	RESIDUUM AND ALLUVIUM FROM BASALTIC ROCK	ALLUVIUM FROM WEATHERED BASALTIC ROCK	ALLUVIUM FROM WEATHERED BASALTIC ROCK	ALLUVIUM FROM WEATHERED BASALTIC ROCK	ALLUVIUM FROM WEATHERED BASALTIC ROCK	ALLUVIUM AND COLLUVIUM FROM MIXED ORIGIN.
ELEVATION	315 M.	255 M.	225 M.	15 M.	21 M.	45 M.	36 M.	25 M.
PHYSIOGRAPHIC SETTING	GENTLY TO STRONG SLOPING UPLANDS	LONG,SMOOTH GENTLY SLOPING UPLANDS	NEARLY LEVEL TO MOD. STEEP INTERM.UPLAND	GENTLY TO MOD. SLOPING ALLUVIAL FANS	NEARLY LEVEL TO MOD. STEEP ALL. FANS AND TERRACES	NEARLY LEVEL TO GENTLY SLOPING FANS AND RIVER VALLEYS	ALLUVIAL FANS AND FLOOD PLAINS	COASTAL PLAINS (STEEP SLOPING ALL. FANS)
SLOPE	2-12%	1-6%	2-15%					
DRAINAGE	WELL	WELL	WELL	WELL	WELL	WELL	WELL	VERY POORLY
PERMEAB.	MOD. RAPID	MOD. RAPID	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	VERY SLOW
				PROFILE DESCRIPTION				
LOCATION	DOLE CO.	KAWAILOA 12	KEMOO 2A	RANCH 3	KEMOO 1	GAY 3	VALLEY I	EWA PLANTATION
AP1 HOR.								
THICKNESS	15-30CM.(6-12)	5-15CM.(2-6)	15-22CM.(6-9)	12-30CM.(5-15)	27-32CM.(11-13)	12-20CM.(5-8)	10-23CM.(4-9)	20-35CM.(8-12)
COLOR M.D	5YR3/3 5YR4/3 DRK REDD.BROWN	25YR2/2 - 2/4 VERY DUSKY RED	25YR2/4 - 3/4 DRK.REDD.BROWN	5YR3/3 5YR3/2 DRK.REDD.BROWN	25YR2/4 - 2/3 DRK.REDD.BROWN	10YR2/2 - 3/3 DARK BROWN	10YR3/2 - 3/3 V.D.GRAY BROWN	10YR3/1 - 4/1 VERY DARK GRAY
MOTTLES	NONE	NONE	NONE	NONE	NONE	NONE	NONE	MANY FINE PROM.
TEXTURE	SILTY CLAY	SILTY CLAY V.F	SILTY CLAY	SILTY CLAY	SILTY CL. LOAM	CLAY LOAM	SILTY CLAY	CLAY
STRUCTURE	MODERATE FINE,MED.,COAR GRANULAR	MOD. TO STRONG V.F.,FINE,MED. GRANULAR	WEAK TO MOD. F.,MED.,COARSE GRAN.(SUBANG.)	MODERATE MED.,COARSE SUBANGULAR BL.	WEAK TO MOD. FINE,VERY FINE GRANULAR	WEAK FINE,MEDIUM GRANULAR	MODERATE FINE,MEDIUM GRANULAR	STRONG FINE,MEDIUM GRAN.,SUBANG.
CONSISTENCY	VERY HARD,FIRM STICKY,V.PLAS.	V.HARD, V.FIRM STICKY,PLASTIC	HARD, FIRM STICKY,PLASTIC	VERY HARD,FIRM V.ST.,V.PL.	SL.HARD,FRIABL SL.ST.,PLASTIC	HARD,FRIABLE STICKY,PLASTIC	HARD,FIRM STICKY,PLASTIC	VERY HARD,FIRM V.ST., V.PL.
PORES	MANY FINE	MANY MED.,V.F.	MANY F.-V.F.	COMMON F-V.F.	MANY FINE-V.F.	COMMON F.-V.F.	MANY FINE-V.F.	COMMON F.-V.F.
ROOTS	PLENTIFUL	MANY (3-5MM.)	MANY (2-3MM.)	MANY FINE	MANY FINE-V.F.	MANY FINE-V.F.	MANY FINE-V.F.	MANY FINE-V.F.
EFF.H2O2	-	VIOLENT	STRONG	STRONG	STRONG	SLIGHT	MODERATE	MODERATE
BOUNDARY	ABRUPT,SMOOTH	GRAD.,WAVY	CLEAR IRREG.	CLEAR WAVY	DIFFUSE,WAVY	GRADUAL,SMOOTH	GRADUAL,SMOOTH	CLEAR,WAVY
AP2 HOR.								
THICKNESS		12-20CM.(5-8)	15-22CM.(6-9)		3-6CM.(7-15)	22-35CM.(9-14)	15-22CM.(6-9)	
COLOR M.D		25YR2/2 10R3/4 VERY DUSKY RED	2.5YR3/4 ID. DRK.REDD.BROWN		25YR3/3 -3/4 DRK.REDD.BROWN	10YR2/2 -3/3 VERY DARK BR.	10YR3/2 -3/3 V.D. GRAY BR.	
TEXTURE		SILTY CLAY	SILTY CLAY		SILTY CL. LOAM	CLAY LOAM	SILTY CLAY	
STRUCTURE		MOD.TO STRONG COARSE SUBANG. BL.	WEAK TO MOD. COARSE PRISM.,SUBANG.		WEAK TO MOD. FINE,MEDIUM GRAN.,SUBANG.	WEAK FINE,MEDIUM SUBANGULAR BL.	MODERATE FINE SUBANGULAR BL.	
CONSISTENCY		VERY HARD,FIRM STICKY,PLASTIC	HARD,FIRM STICKY,PLASTIC		HARD,FIRM STICKY,PLASTIC	HARD,FRIABLE STICKY,PLASTIC	HARD,FIRM STICKY,PLASTIC	
PORES		COMMON F.-V.F.	FEW MED.-FINE		COMMON V. FINE	COMMON F.-V.F.	COMMON F.FEW M	
ROOTS		COMMON	COMMON 2-3MM.		COMMON	MANY V.FINE	ABUND. V.FINE	
EFF.H2O2		VIOLENT	VIOLENT		STRONG	SLIGHT	SLIGHT	
BOUNDARY		ABRUPT,WAVY	ABRUPT,WAVY		ABRUPT,WAVY	ABRUPT,WAVY	CLEAR,WAVY	
SUBSOIL GENERAL CHARACTERISTICS OF SUBSOIL	COLOR REMAINS DARK REDD.BR. STRUCTURE WEAK SUBANGULAR. CLAY SKINS AT 50-100 CM. ARE VERY PROMINENT	COLOR BECOMES DARK REDD.BR. STR. IS STRONG SUBANGULAR AT 100CM. SOME PATCHY CLAY FILMS SLICKENSIDES	COLOR REMAINS DUSKY RED TO RED. STRUCTURE BECOMES STRONG VERY FINE SUBANG.AND COMPACT..SAPROLYTE 150 CM.	COLOR REMAINS DARK REDD.BR. STRUCTURE BECOMES WEAKER,CONSISTENCY IS V.ST..V.PL..HIGHLY WEATHERED PEBBLES	COLOR CHANGES TO RED. SOIL APPEARS MASSIF, BUT BREAKS IN SUBANG. SAND IN LOWER HORIZONS.THIN COATINGS BELOW	COLOR BECOMES BROWN TO GR.BR STRUCTURELESS AND SANDY BELOW 50CM. CONSISTENCY CHANGES TO V.FR..SL.ST..SL.PL.	COLOR CHANGES TO DRK.YEL.BR. STRUCTURE BECOMES WEAK.STRATIFIED SAND.GRAVEL AT 100CM. SOME PATCHY RED CLAY FILMS.	COLOR BECOMES V.DRK.GRAY BR. SOME MUCK IN LOWER HOR. MOTTLES THROUGHOUT CONSISTENCY REMAINS V.ST..V.PL. SHELL 50CM
ROOT DEVE	VERY FEW ROOTS BELOW 53 CM.	COMMON TO FEW ROOTS BELOW PLOW LAYER.	SOME COARSE ROOTS AT 60 CM.	FEW FINE ROOTS BELOW 75CM.	FEW ROOTS OBS. BELOW PLOWLAYER	NO ROOTS BELOW 75CM.	NO COARSE ROOTS BELOW 25CM.	MANY FINE ROOTS UP TO 50CM.
DEPTH TO SAPROLYTE	100-> 150CM.	150-> 300CM.	90-> 150CM.	> 150CM.	> 150CM.	> 150 CM.	STRAT. SAND AT 100CM.	MUCK AND PEAT AT 50-100CM.

generally sticky and plastic when wet, but Waialua and Pearl Harbor soils are very sticky and very plastic when wet, while Ewa is only slightly sticky. This is in general agreement with comments made by plantation people, namely that the soils on higher elevations are more easily worked. Although the drainage and permeability as quoted in Table VIII do not vary very much (except for the Pearl Harbor series) it appears that drainage problems occur also on the Waialua and Haleiwa series.

The soils are in general very deep, but the Haleiwa series show stratified layers of sand at 100 cm (40 inches) and Pearl Harbor soils show peat and muck at depth between 50 cm and 100 cm (20 to 40 inches). The chemical properties as far as they are available are listed in Table IX. They are calculated as an average taken from soil analyses data made by H.S.P.A. The distribution of the above mentioned chemical properties will be discussed later (see Figures 24, 25 and 26 in Chapter IV). Although no direct information is available on other chemical properties, Cline (1955) states that the Low Humic Latosols are practically uniform in all mineral constituents throughout the profile.

The cation exchange capacity ranges from 25 meq. per 100 g in the top soil to 13 meq. per 100 g at 100 cm (Swindale and Uehara, 1966). There is a abrupt drop in C.E.C. between the Ap horizon and the B horizon. The base saturation increases in Wahiawa with depth from 40% to 58%,

TABLE IX

SOME CHEMICAL AND PHYSICAL PROPERTIES OF THE SOILS LOCATED IN WACO (SOURCE: WACO FIELD RECORDS)

Soil Series	K*	P*	Si*	pH	S.M.C. (inches)
Wahiawa	298	66	107	5.5	3.2
Lahaina	394	58	210	6.6	2.9
Waialua	531	149	665	7.0	3.3
Ewa	313	73	310+	6.7	3.2
Haleiwa	398	258	444+	7.0	3.4
Pulehu	1019	315	N.D.	7.0	3.2
Pearl Harbor	383	284	N.D.	6.9	3.0
Leilehua	301	61	82	5.2	3.4

* Expressed as lb per acre foot.

\+ Only few data available

N.D. No determination made.

while it is rather uniform in the Lahaina soil series (± 50%). Table X shows the total analysis of the Wahiawa and the Lahaina soil series. Although the samples were not taken from the area discussed here, they are presented for later discussion. Very little information is available on the physical properties of the soils under question. Although the apparent texture is described as a silty clay (except Pearl Harbor) they may contain as much as 80% particles smaller than 2 microns. The clay fraction is described as kaolinitic, but it is considered mixed kaolinitic and montmorillonitic in soils belonging to Haleiwa, Pulehu and Pearl Harbor. The soil moisture capacity has been determined and is listed in Table IX. Other characteristics like shallowness, stoniness, drainability, and slope are very important for mechanized cultivation of sugar cane.

More discussion about the soils and their behavior will be presented later (Chapter IV).

TABLE X

TOTAL ANALYSIS FOR WAHIAWA AND LAHAINA SOIL SERIES EXPRESSED AS A PERCENTAGE (SOURCE: WAHIAWA SERIES FROM TAMURA, 1953; LAHAINA SERIES FROM SHERMAN, 1959)

WAHIAWA					
Depth cm	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	TiO_2 %	H_2O* %
0-25	33	28	17	3	16
25-50	34	29	19	3	12
50-105	32	28	20	3	20
105	31	27	25	5	12

LAHAINA					
Depth cm	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	TiO_2 %	H_2O* %
0-8	31	24	23	5	14
8-37	32	24	24	6	12
37-80	33	25	23	6	12
80-105	33	26	23	5	12

* H_2O represents "Loss on ignition"

CHAPTER III

METHODS

This Chapter is divided into two sections. Because the analysis of plant growth can be approached in many different ways, a review of the literature, dealing with these approaches is given in the first section.

The second section of this Chapter describes the methods used in this research to arrive at a yield analysis of sugar cane.

1. METHODS FOR CROP ANALYSIS

Two main approaches to understand the great variability in crop yields are generally followed. One method involves small-plot techniques in which crop production is examined under well defined and completely controlled conditions. The other approach uses actual field data and seeks to interpret the yield variation in terms of existing ecological conditions of soil, climate and applied management practices. Both techniques are subject to limitations but offer distinct advantages as well. In the case of small-plot techniques, the results are often more precise than when farm records are used but this technique is more expensive (Odell, 1958). The accuracy is shown statistically in a low "between-trial error", but as Sandison (1959) points out: "This is not necessarily a matter of congratulations, but it suggests that the trial centres may not have been sufficiently representative." Barley (1964) indicates that it is more important to sample a wide range of the environment than to attain high accuracy in individual trials. Kellogg (1962) states that yield prediction methods can follow two ways: Induction from knowledge of the interactions among soil characteristics, the needs of the crop, and the management practices or empirical observation of the yield of the crop produced on the soil under specified management. In actual practice he concludes both approaches should be combined and used to check each other.

a. Small-Plot Approach Involving an Experimental Design

Butler (1964) makes a distinction between two types of designs: Agronomic trials and edaphic trials. In the case of agronomic trials a site is selected that is as uniform as possible with respect to soil conditions and climate and a series of plots are established with selected differences of kind and level of treatments. Edaphic trials - the term was first used by Loveday (1964) - involves a standard management practice on plots laid out on different kinds of soil. A major shortcoming of this technique is, according to Loveday, that only a restricted range of soils can be included in order to avoid other intervening variables. Climatic variations easily can confound soil variation. The ideal process would be to conduct edaphic studies in glass houses to control the climatic factors. However, this approach seems realistic only where this type of agricultural farming is generally used by farmers. As an example Van Liere (1948) related yield of grapes grown in glass houses in Holland to 5 different soil types. Carmean (1961) conducted a study which could be considered edaphic. He related site index of black oak, which characteristic varied widely within soil types of South-Eastern Ohio, with a number of soil and topographic characteristics by selecting 96 0.2 acre plots to cover a wide variety of soils. His results show that characteristics other than those mapped show high correlation. His conclusion is that existing soil description of soil types should be modified to suit forest site quality predictions. From these studies it can be concluded that small-plot techniques in experiments where the kind of soil is tested can be conducted successfully in areas where climate is homogeneous or with perennial crops. Agronomic trials give very valuable information about the impact of management on yield, but do not help to predict the yield over a large area with variable soil and climatic conditions.

b. Farm Records as a Base for Yield Prediction

The Soil Survey Manual (1951) considers farm experience potentially the most important source of data on soil productivity if these data are accurately recorded over a long period of years to account for climatic variation. This method was used by Odell and Smith (1940) in a study of crop yield records by soil type and again by Odell (1959), but this time he measured yield variation under various environmental conditions, including some selected management practices. In a concluding paper, Odell (1958) states that at least 50 observations per kind of soil are necessary to make satisfactory crop yield estimates. De Smet (1962) followed a similar approach in a soil productivity study carried out in Holland. Although the limited accuracy and the great variability in yield are major drawbacks in this method, it can be applied directly. Vink (1963) states this part of agricultural research very strongly: "We should not be satisfied with just giving theoretical lessons in pedology and perhaps some excursions in our soil survey areas, but we should also develop a system which really makes our subject matter available for daily practice in agriculture."

c. Other Methods of Yield Prediction

Two highly contrasting methods will be discussed because they are widely used in Hawaii. The method of soil evaluation developed by Storie is applied in a revised form by the Land Study Bureau of the University of Hawaii for making land classifications. The method of tissue analysis as a basis for crop logging and crop control developed by Clements is used in a large group of sugar plantations in Hawaii.

c1. Soil Evaluation with "Storie-Index"

Storie (1964) describes the Storie-Index for rating soils as a numerical expression of the degree to which a particular soil presents conditions favorable for plant growth and crop production under good environmental conditions. The index is based on soil conditions only and is "independent of other physical or economic factors which might determine the desirability of growing certain plants in a given location." Although he realizes that the soil is only one of the many factors that determine the value of a given area, it is a factor that does not readily change. The method is based on multiplying the ratings for four factors, expressed as a percentage of the most ideal conditions:

1. The character of the soil profile
2. Soil texture
3. Slope of the land
4. Other modifying characters such as drainage, salinity, soil acidity, etc.

In Hawaii a fifth factor is added: Average annual rainfall (Nelson, 1963). In case the land is irrigated this factor is valued at 100%. Besides texture is described as "apparent texture." This system does not take into account other climatic parameters, such as radiation and temperature and it assumes a certain management level. As discussed many times, these two systems together with the soil system determine the productivity of a given site. Another problem with the Storie-index is the degree of subjectivity involved. The ratings for the different properties are determined according to the favorableness of that factor for plant growth, but it remains obscure how this percentage was calculated. Buringh (1964) concludes that this method can only be used successfully by the inventor in a small limited area where soil conditions, agriculture, economic and social conditions are very well known.

c2. Tissue Analysis as a Basis for Crop Logging, Crop Control and Yield Prediction

This system, originally developed for pineapple by Nightingale in the 1940's was developed by Clements for sugar cane in 1943. The Crop Log is defined as the record of the progress a crop makes from its start until harvest (Clements, 1952). Tissue sampling is done every 35 days. In addition soil pH, and soil moisture tension is determined, but "soil analysis as a guide to the plant's nutrient requirements is regarded as archaic." (Clements, 1968)

WACO used the Crop Log, but abandoned it because the recommendations based on tissue analysis did not differ substantially from the recommendations based on soil analysis. However, it should be realized that the fertilizer schedule and timing may have been based in part on the experience with Crop Log.

Although the most important role of the Crop Log is to properly guide the cane growth until harvest, it was also used by Clements to establish a prediction equation. Using the technique of multiple regression for his data collected during a two-year period, he was able to explain 29% of the yield variation with climatic variables only (relative humidity, wind velocity, maximum and minimum temperature and light). Addition of plant physiology factors realigned the weather factors and increased the R^2 value to 0.79. His final prediction equation included the following factors in order of importance: Sheath moisture, age, minimum temperature, maximum temperature and light. The difficulties in predicting crop yield based on climatic and physiological characteristics is discussed earlier (see Chapter I).

2. PROCEDURES FOLLOWED IN THIS STUDY

In this study the method of using farm records has been followed. This was the most logical approach since accurate data are generally available in the sugar industry. For the sake of uniformity in management practices and yield determination, and because of easy accessibility, the Waialua Sugar Company Inc. was selected to test the approach of using a combination of growth factors to analyze and eventually estimate sugar production. The large amount of data available and access to a digital computer (IBM 360) were the main reasons for punching all available information on IBM cards. The procedures followed can be divided in three Steps:

a. Collection and Organization of Data. Management practices and yield data for 97 fields varying in size from less than 10 ha to more than 80 ha have been recorded since 1930. These fields were numbered (see Figure 10) and Table XI lists the kind of data collected for each field.

Rainfall information was obtained from 28 stations and the monthly figures since 1960 were punched. Evaporation, radiation, and temperature data (maximum and minimum) were available for four meteorological stations scattered over the plantation (see Figure 10).

A detailed soil map was made available by the Soil Conservation Service. By transferring the soil map over the field location map, the acreage of each soil mapping unit within one field was calculated by using a grid. Additional soil information (PH, K, P, soil moisture capacity) was punched together with the percentages of the acreage for the two major mapping units.

b. Selection and Reorganization of Variables

In order to make reliable interpretations, a complete set of homogeneous information is required. Since only partial data were available during 1930-1940, irregularities occurred during 1940-1960 (e.g. second world war, labor

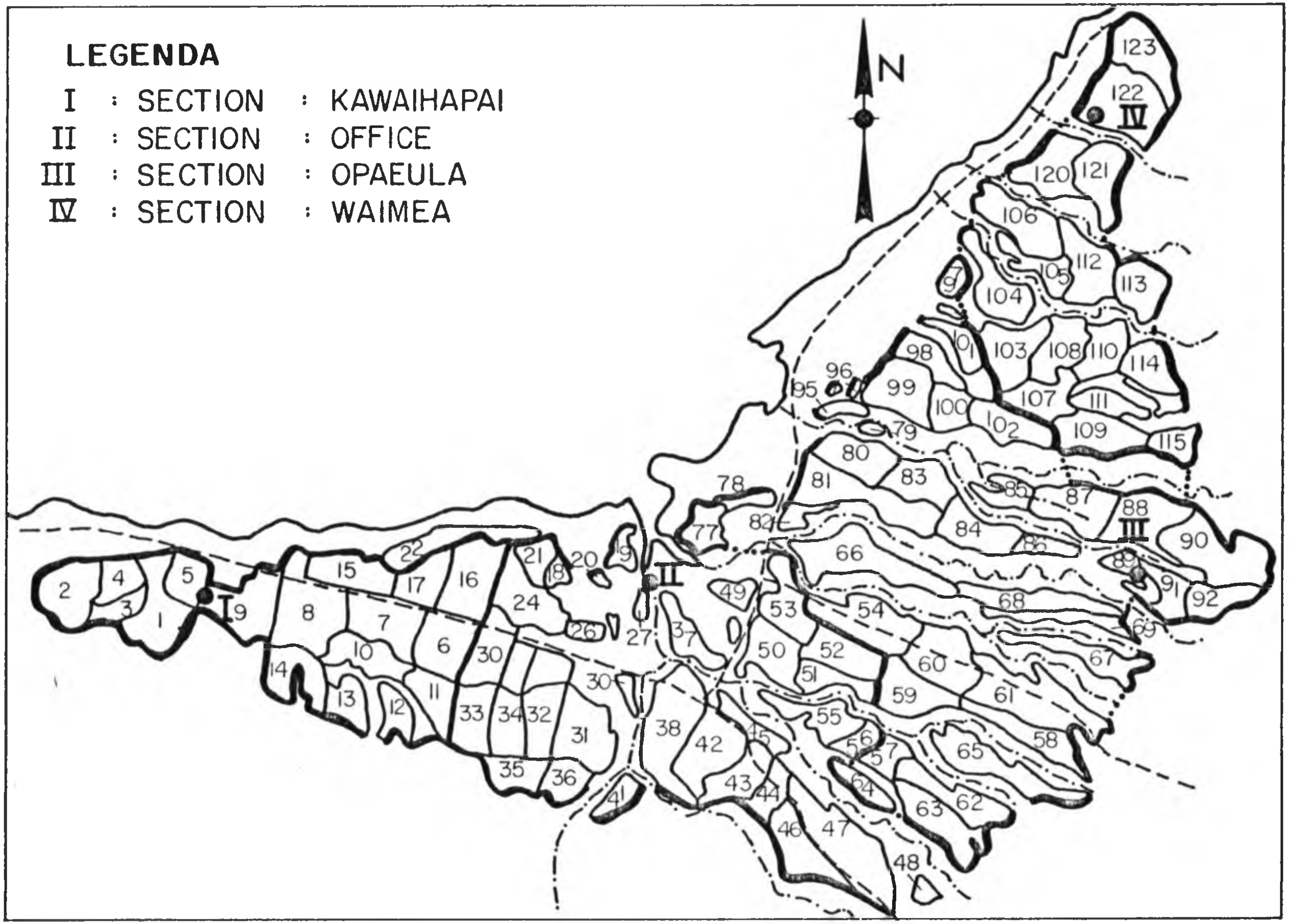


FIGURE 10. LOCATION OF FIELDS IN WACO

TABLE XI

VARIABLES FOR WHICH DATA HAVE BEEN PUNCHED ON IBM CARDS

Card I: Management + Yield per Field Since 1930			
a.	Field number	b.	Acreage harvested in acres
c.	Month, year planted	d.	Month, year harvested
e.	Variety used	f.	Age in months
g.	Crop cycle (coded)	h.	Irrigation rounds
i.	Average acre inch	j.	N applied (lb/acre)
k.	K_2O applied (lb/acre)	l.	P_2O_5 applied (lb/acre)
m.	Ripening days	n.	total rainfall (inches)
o.	Rain after ripening (inches)		
p.	Ton cane per acre	q.	Ton sugar per acre

Card II: Climatological Information for 4 Stations			
a.	Monthly rainfall (inches)	b.	Monthly evaporation (inches)
c.	Monthly radiation kg cal/cm^2	d.	Monthly min. temp. (^oF)
		e.	Monthly max. temp. (^oF)

Card III: Soil Information per Field			
a.	Acreage major soil series	b.	Percentage of total acreage of field
c.	Acreage second soil series		
d.	Percentage of total acreage of field	e.	pH
		f.	K (lb/acre foot)
g.	P (lb/acre foot)	h.	Soil moisture capacity (inches)

strikes) the reorganized set of data with which statistical computations have been carried out includes only data from the 1960's. During this period several varieties were cultivated but the major variety occupying the land during this period was H 50-7209. Therefore most interpretations deal with this variety.

Exceptional management practices were also excluded from interpretations such as harvesting or planting during December, January or February, growing season exceeding 25 months or less than 21 months, rounds of irrigation more than 40 and acreages harvested less than 10 acres. Also a number of fields that occupied many contrasting mapping units and those that were located on so called fill land (man made soils from the hydro-separator) were excluded. The rearranged final set of data used for most of the statistical interpretations is listed in Appendix I, Table I. In addition, a number of climatic data belonging to this new set of data was calculated by using the data from the four meteorological stations. These data are: Total rainfall, summer rainfall, winter rainfall, rainfall during month of harvest, rainfall one month before harvest, total evaporation, summer evaporation, winter evaporation, total radiation, summer radiation, winter radiation, and average daily radiation, maximum temperature at harvest, minimum temperature at harvest. In addition, the data were converted to the metric system (see Appendix I, Table II). The field data were rearranged for some calculations according to crop cycle. Since the number of variables are limited by the number of columns of a card, rearrangements were sometimes made by specially designed programs.

c. Statistical Methods

Scott (1969) in discussing the kind of statistical methods, which can be used for interpreting ecological problems, arranged variables according to their nature (qualitative, mixture of qualitative and quantitative, continuous quantitative) their distribution (normally distributed, randomly selected) and their relation to other variables (independent of each other, correlated with each other). In this study the dependent variable is continuous quantitative (T.S.A.M.) but some independent variables are qualitative - crop cycle, mapping unit, month of harvest, month of planting. To understand the relation between independent variables and yield, single linear and quadratic regression techniques were used first with all sets of data, then with grouped sets of data. A special program that calculates all the necessary statistics for linear and quadratic regression lines and plots the observations as well as the regression lines was written.

Analysis of Variance techniques were used to test the significance of the qualitative type of independent variables. Stepwise multiple regression, considered by Scott (1966) as a method that has all the advantages of multiple regression, but in addition is designed to deal with interacting factors, has been used to obtain more statistical evidence of the significance of the factors that influence yield. Simultaneously these techniques calculate regression coefficients, which can be used to generate a prediction equation. The predicted values can then be compared with the actual values and a plot of predicted against observed yields can be constructed. The program used is a canned program available at the Computer Center under the code name: BMD 02 R.

Another statistical device used is the calculation of polynomial coefficients, as described in Krumbein and Graybill (1965). By using the coordinates for each observation point in the field and the value obtained at that point (rainfall, yield) polynomial coefficients are calculated. These coefficients can then be inserted in another program that will plot contour lines according to specified intervals. The program can also be modified for any desired scale. Schroth (1970) used it successfully to make trend surfaces of certain soil characteristics in Western Samoa. This technique has been used here to map trend surfaces of annual and monthly rainfall and yield distribution.

CHAPTER IV

RESULTS AND DISCUSSION

In order to clarify the possible relationships between sugar yield and variables of the environmental system, this Chapter will be divided into several sections. This is justified as long as it is kept in mind that the sugar production is a function of the total system and not dependent on single variables.

Because actual plantation records are used it is not possible to relate the whole range of values for a certain variable. The two main restrictions are the location that sets climatological boundaries and the fact that any commercial industry-in this case a sugar company-tries to use the optimal combination of input-management practices-to obtain the maximum output-sugar-that is economically feasible.

First the history of the sugar production in WACO will be discussed since 1930. Although no statistical interpretations have been carried out with all these data (see Chapter III), some interesting observations can be derived from the average yield.

The second section deals with the soil-management complex in relation to yield, as it occurs in this area, while the third section discusses the climate-management relations to yield.

Since one of the goals is to relate soil mapping units to sugar yield, the impact of certain kinds of soil in relation to the other variables will be emphasized.

Finally a section is devoted to possible ways to estimate sugar yield based on earlier observations.

1. HISTORY OF SUGAR PRODUCTION ON WACO SINCE 1930

The total sugar production increased from less than 35,000 ton sugar in the early 1930's to approximately 44,000 ton in the early 1940's (see Figure 11). After World War II sugar production raised in less than five years to 60,000 ton sugar per year, after which it remained more or less constant until 1958, when a labor strike hit the plantation. The effect of this strike was still felt in 1960. During the last decade sugar production increased again to 65,000 ton with a peak in 1966 when more than 80,000 ton sugar was produced. Several factors have contributed to this increase in sugar production since 1930:

1. Acreage

Until 1945 the total acreage harvested each year did not substantially vary from the average 1200 ha. However, during 1945-1955 around 400 ha more could be harvested per year due to improved and mechanized harvest techniques. Although occasionally more than 2000 ha per year have been harvested during the last decade, on the average 1900 ha have been

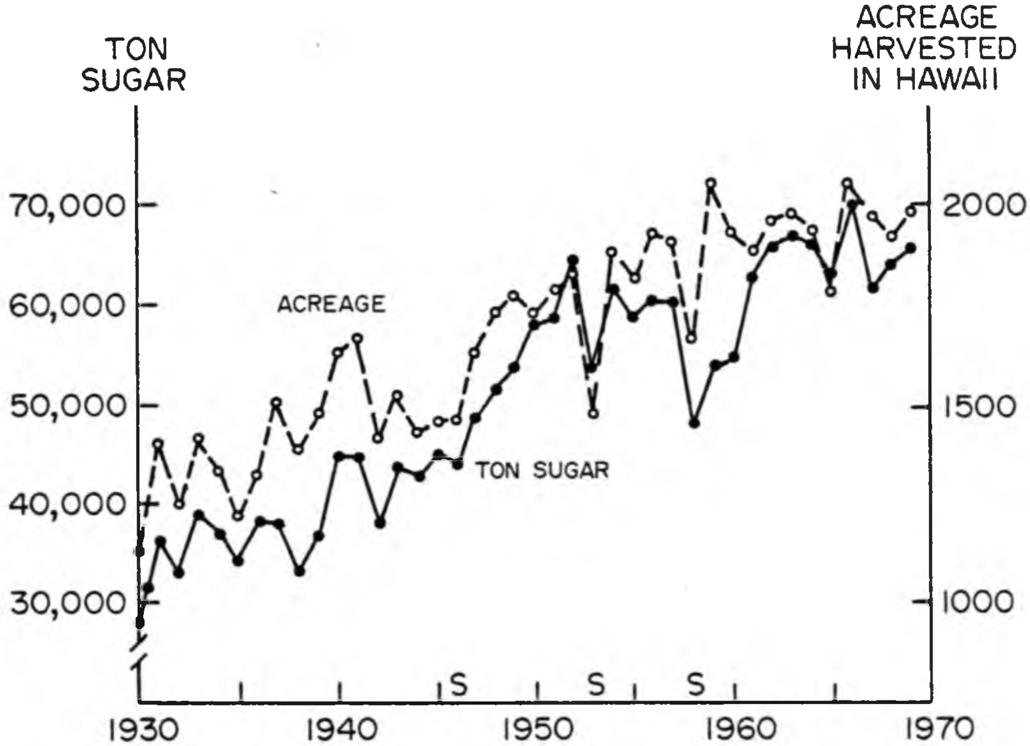


FIGURE 11. YEARLY VARIATION IN TOTAL SUGAR PRODUCTION AND TOTAL ACREAGE HARVESTED IN WACO

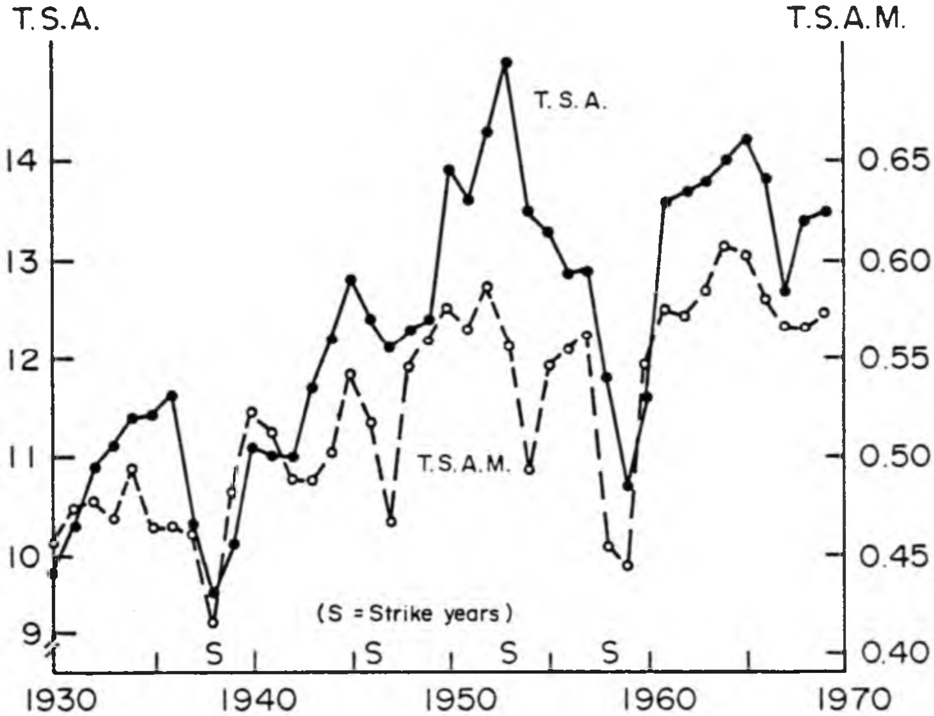


FIGURE 12. YEARLY VARIATION IN TON SUGAR PER ACRE AND TON SUGAR PER ACRE PER MONTH

harvested every year. To eliminate this size factor, a more useful statistic to be considered is ton sugar per unit land (see Figure 12). Periods of significant yield increase are 1930-1935; 1942-1953; 1960-1965. Decrease in yield is observed during 1937-1939; 1954-1959; 1965-1967.

2. Age of Crop

As will be discussed later, the age of the sugar cane plant plays an important role on the yield of sugar. The longer the cane is on the field, the higher will be the sugar yield up to a certain age. Although during most of the years the age varies around 24 months, peaks of over 27 months occur during strike years often followed by years with a relative short crop (see Figure 12). To eliminate the age factor, a more realistic figure can be derived: Ton sugar per unit area per unit time. The most commonly used index is Ton Sugar per Acre Month (T.S.A.M.). Throughout this discussion yield is expressed as TSAM unless otherwise stated. By expressing the yield on a monthly basis we see that the peaks in yield expressed as Ton Sugar per Acre become depressions when TSAM is considered (see Figure 12).

Although a statistical analysis shows that 71% of the variation in TSAM can be explained with year of harvest (The linear regression equation: TSAM= 0.3516 + 0.0036 x year of harvest is highly significant), this variable cannot be considered as a growth factor. In addition, major peaks and depressions can be observed during these 40 years. While four depressions can be explained by labor strikes, this does not explain yield increases during 1939-1940; 1947-1951; 1961-1964.

3. Varieties

The importance of new varieties is clearly pictured in Figure 13. Four major varieties occupied the plantation since 1930.

Variety H 109 was the main variety during the early 1930's. The yield occasionally reached more than 0.50 TSAM. Around 1940 a new variety was introduced: H 32-8560. It reached its peak in 1945 (0.54 TSAM) after which year its yield dropped mainly because of a labor strike in 1946. Variety H 37-1933 occupied the plantation for more than 70% during 7 years, reaching average yearly yields of 0.57 to 0.58 TSAM. It was again a labor strike in 1958 that marked the change for a new variety. H 50-7209 turned out to be in experiments a very promising variety and it gave excellent yields during 1964-1965 (0.625 TSAM for 1964). After 1965 it apparently lost its potential. The average yield for the four varieties is as follows:

H 109	0.479 TSAM	(based on 296 data)
H 32-8560	0.536 TSAM	(based on 263 data)
H 37-1933	0.565 TSAM	(based on 298 data)
H 50-7209	0.600 TSAM	(based on 334 data)

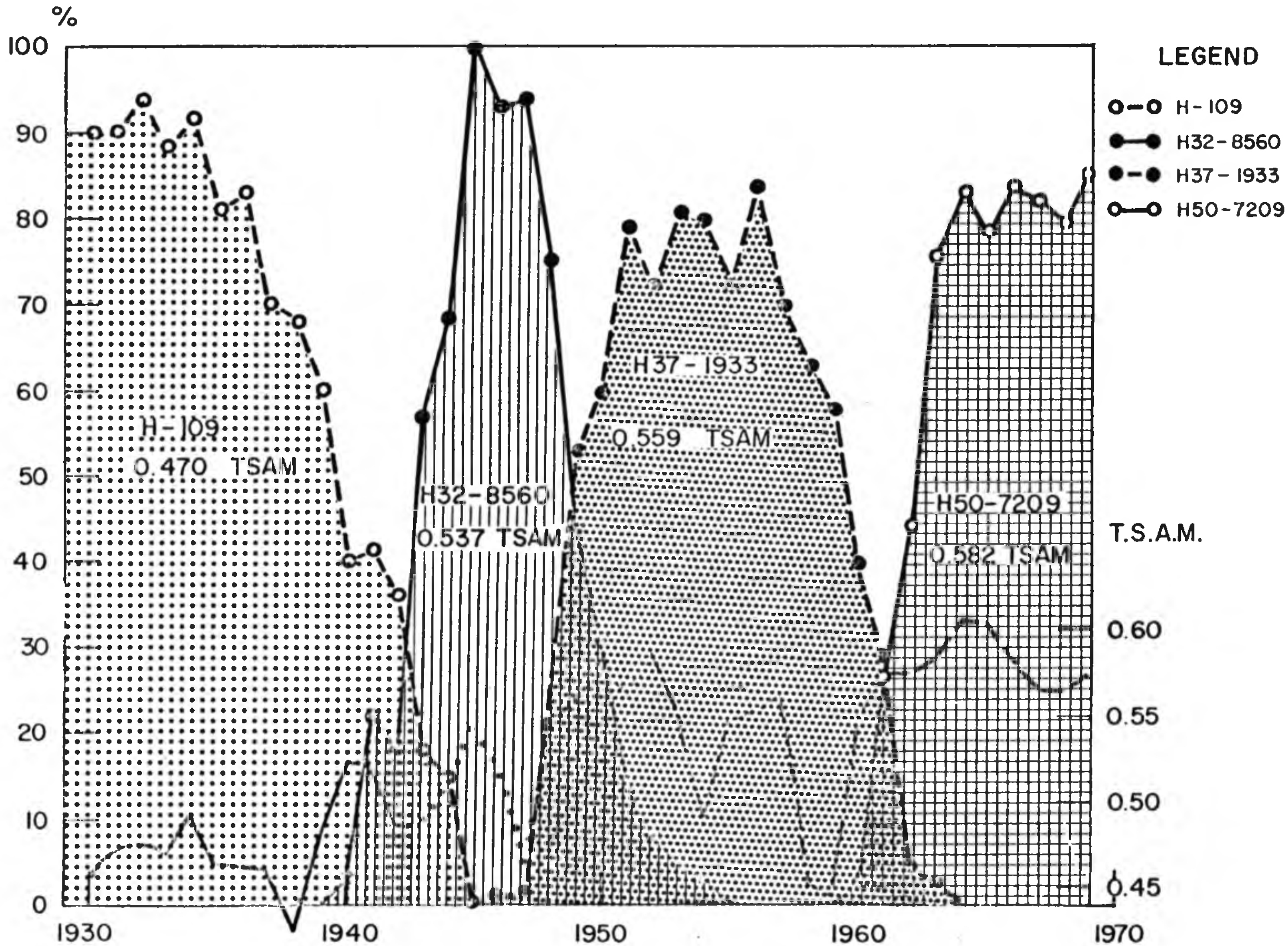


FIGURE 13. HARVESTED ACREAGE OF FOUR VARIETIES EXPRESSED AS A PERCENTAGE OF TOTAL ACREAGE HARVESTED FOR EACH YEAR SINCE 1930

TABLE XII

FERTILIZER APPLICATION AND YIELD IN TSAM DURING FOUR DECADES*
(FIGURES FOR HAWAIIAN SUGAR INDUSTRY FROM HUMBERT, 1960)

Decade	Nitrogen WACO kg/ha	Nitrogen (Hawaii) ton	P_2O_5 WACO kg/ha	P_2O_5 (Hawaii) ton	K_2O WACO kg/ha	K_2O (Hawaii) ton	TSAM WACO
1930-1940	242	(13,990)	141	(8,409)	108	(10,826)	0.457
1940-1950	195	(11,466)	99	(4,394)	118	(9,341)	0.526
1950-1960	280	(15,978)	148	(7,277)	276	(15,479)	0.572
1960-1970	305		118		304		0.582

* War period and labor strike years are excluded.

4. <u>Fertilization</u>

The fertilizer practices have been changed considerably over the past 40 years. The greatest variation can be observed with total amount of K_2O applied. Table XII gives the average amounts of fertilizers applied during the four decades and the average yields. In parentheses the average amount of fertilizer purchased for all Hawaiian sugar plantations is mentioned.

Another interesting aspect that can be derived from these historical graphs is that more fertilizer is applied during the final years a certain variety is cultivated. Table XIII summarizes this phenomenon:

TABLE XIII

AVERAGE FERTILIZER APPLICATIONS FOR TWO VARIETIES DURING THE PERIOD IT OCCUPIES MORE THAN 70% OF THE PLANTATION AREA

	Variety H 37-1933					Variety H 50-7209			
Year of Harvest	N kg/ha	P_2O_5 kg/ha	K_2O	Yield (TSAM)	Year of Harvest	N kg/ha	P_2O_5 kg/ha	K_2O	Yield (TSAM)
1950	230	103	183	0.573	1962	344	156	263	0.623
1951	248	141	181	0.563	1963	328	148	294	0.597
1952	276	170	253	0.586	1964	330	71	292	0.625
1953	328	148	317	0.553	1965	352	70	392	0.613
1954*	352	162	391	0.492	1966	356	88	388	0.600
1955	322	184	412	0.543	1967	338	120	399	0.585
1956	404	211	398	0.551	1968	332	151	381	0.576
1957	454	188	528	0.560	1969	356	160	369	0.569

* Yield affected by labor strike in 1953.

Although K_2O and N applications more than doubled during the 1950's it apparently did not affect the yield in a positive manner.

The same trend can be observed with variety H 50-7209. The low amounts of phosphorus during 1964-1966 do not seem to affect the yield. At this stage of the discussion it should be realized that most probably other factors override the effect of fertilization. A more detailed treatment of this aspect will be given later.

Other management practices that have changed during the last 40 years are the increased mechanization of almost all management practices (The impact on the soil conditions will be discussed later) and ratooning practices. As can be seen from Table XIV, only a small percentage is ratooned more than two times in the last decade (variety H 50-7209) while four ratoons were more normal during the 1930's. The effect of ratooning will be discussed in a separate section because of its important effect on the yield.

2. SOILS AND ITS MANAGEMENT AS A FACTOR IN SUGAR PRODUCTION

The function of the soil in plant growth is complex because of the many interactions among its properties and with management inputs. Except under specially designed circumstances -edaphic trials- it is hazardous to relate plant growth to single soil characteristics. Since management influences the soil properties (chemical as well as

TABLE XIV

FREQUENCY OF RATOONING FOR FOUR VARIETIES EXPRESSED AS A PERCENTAGE

Crop Cycle	H 109*	H 32-8560	H 37-1933	H-50-7209*
Plant crop	16%	33%	24%	41%
1st ratoon	19%	30%	23%	34%
2nd ratoon	22%	26%	24%	19%
3rd ratoon	21%	10%	16%	5%
4th ratoon	22%	1%	13%	1%

* Not complete, since variety H 109 was cultivated before 1930 and variety H 50-7209 is still cultivated.

physical) it is not possible to discuss soil behavior without considering management practices. This discussion, therefore, will merely assess the potential of the soil under various conditions of management. One way to analyze the soil potential is to study those properties that are not easily influenced by management. In this respect physical and mineralogical soil properties might be studied instead of the chemical characteristics. However neither accurate nor sufficient data are available for statistical interpretation.

Another way to arrive at certain conclusions with respect to the soil potential is an indirect approach. Assuming that the management is designed to optimize production and that the practices are homogeneous over the total area, those areas that still give lower yield may be considered to have a lower potential under the present system of management. This indirect approach will be followed in the course of this section.

The function of the soil in relation to plant growth can be divided into three groups:

a. Supply of nutrients to the plant.

b. Supply of water to the plant.

c. Supply of a supporting medium to the plant.

Therefore, growth and development of the above-ground portion of the crop depends largely on the development of its root system (Humbert, 1968).

The most important and most frequently discussed essential nutrients are nitrogen, phosphorus and potassium. In recent years, the beneficial effect of silicon has been demonstrated in upland fields and should be added to this list. Although trace elements play an important role, no data are available on this aspect of nutrition in the area under study.

The distribution of P, K and Si in WACO is shown in Figures 14, 15, and 16. These data represent averages of soil samples taken from the top 25 cm, immediately after harvest. It is, therefore, not appropriate to use these data to describe the chemical properties of the soils. It is justified, however, to compare these distribution patterns in relation to yield distribution because the method of soil

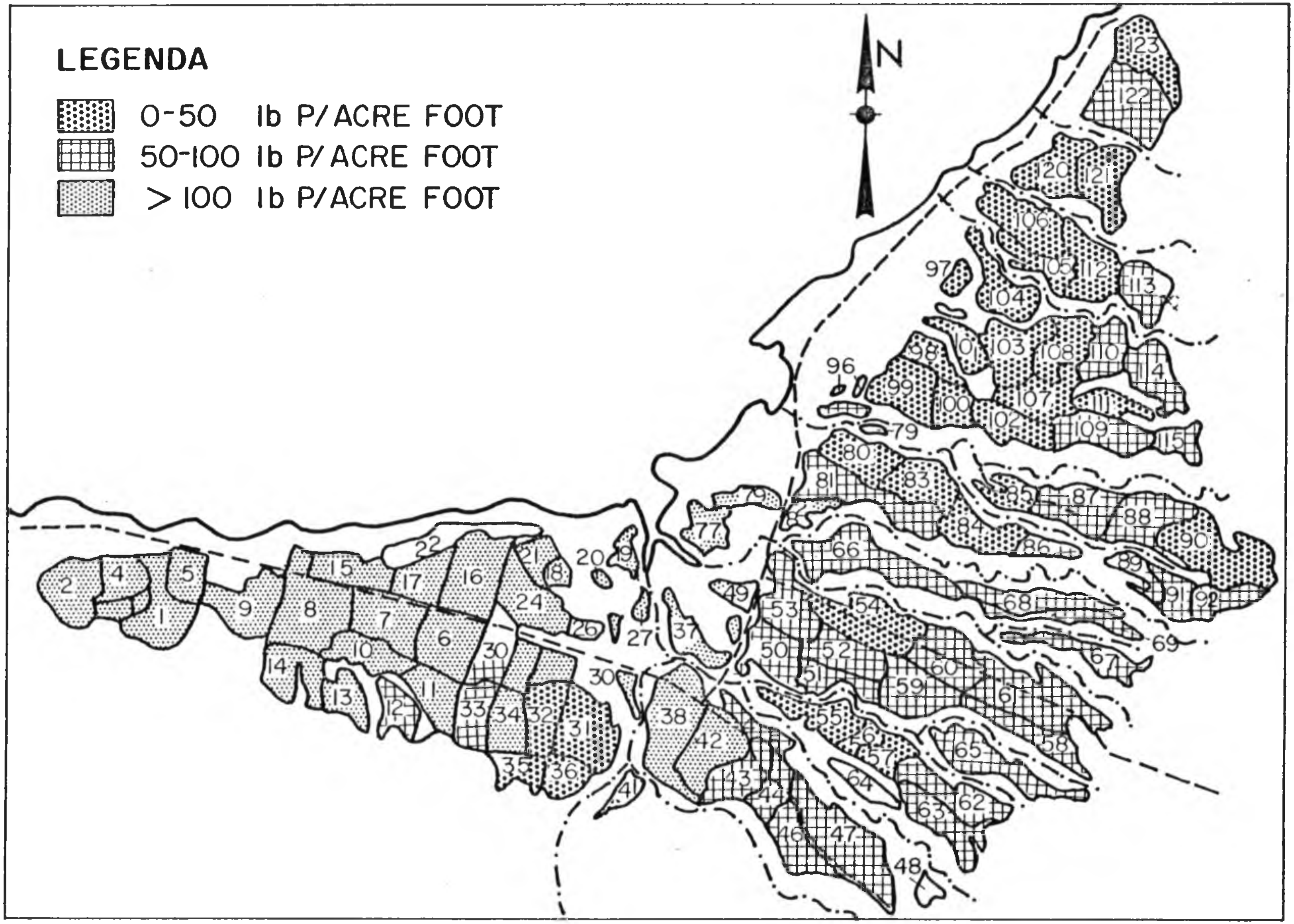
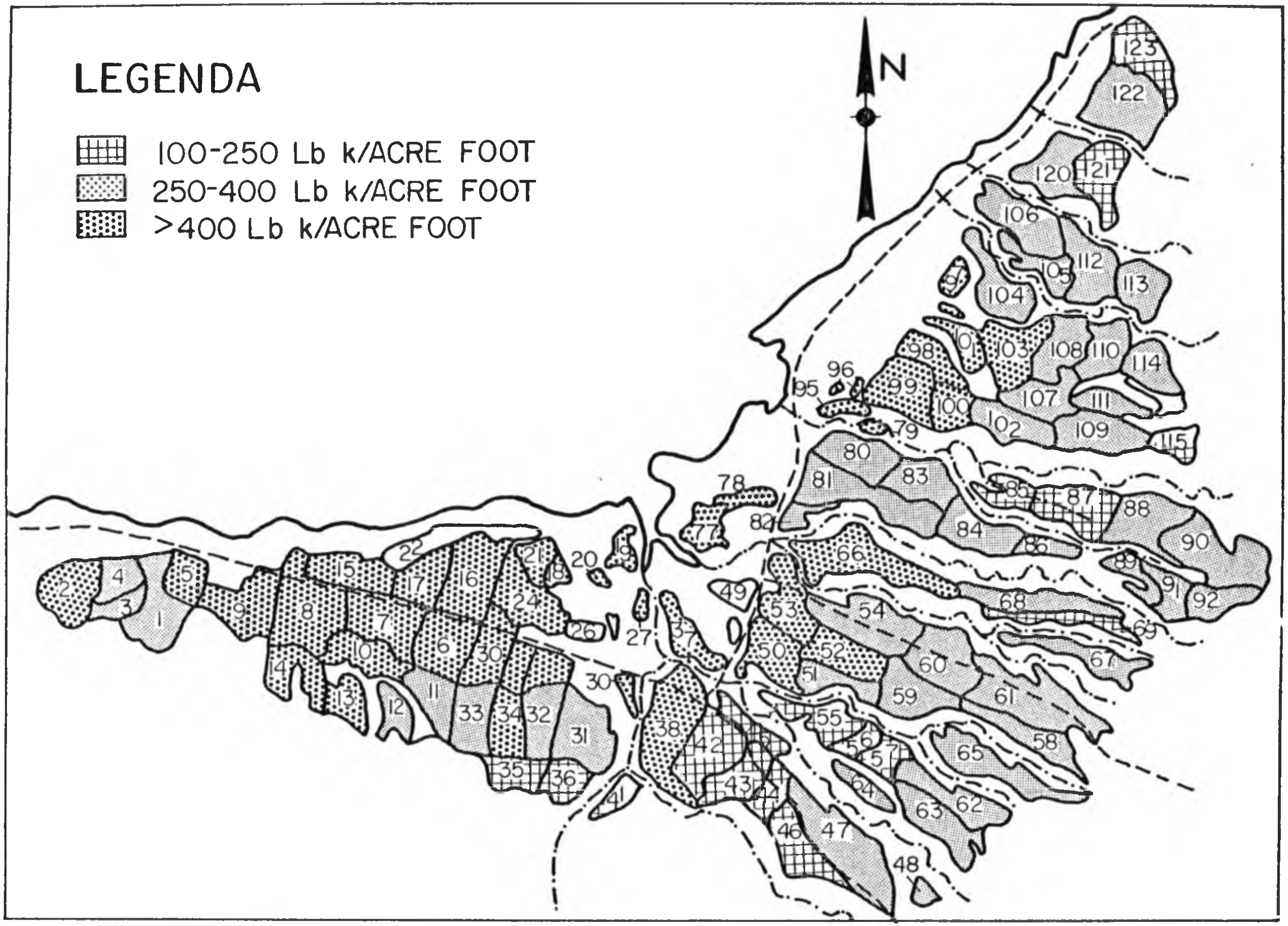


FIGURE 14. DISTRIBUTION OF AVAILABLE PHOSPHORUS IN THE TOP SOIL


LEGENDA
100-250 Lb k/ACRE FOOT
250-400 Lb k/ACRE FOOT
>400 Lb k/ACRE FOOT
N

F GURE 15. [illegible]

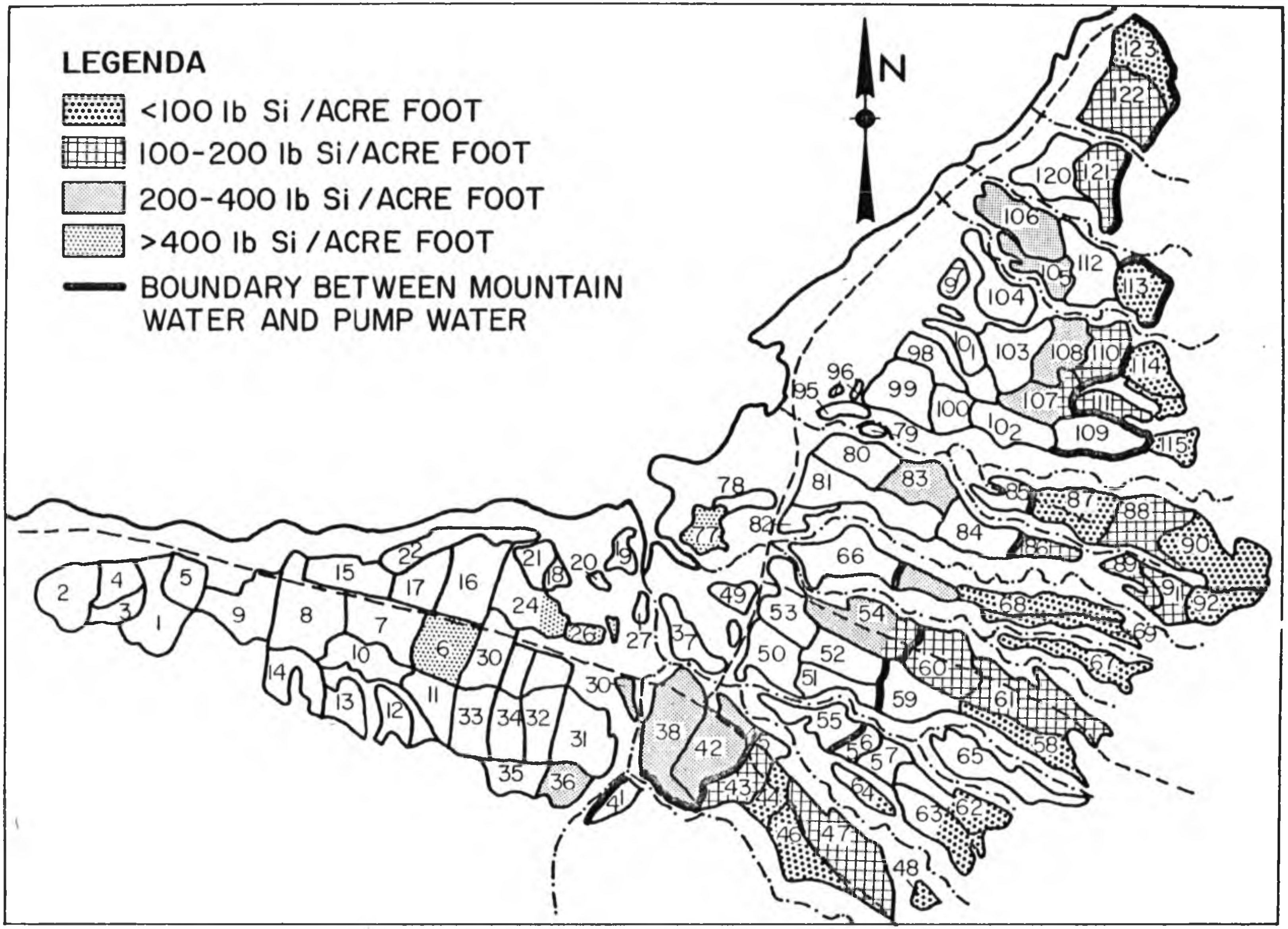


FIGURE 16. DISTRIBUTION OF AVAILABLE [illegible]

analysis is done in the same way in the same laboratory and the yield figures are also determined in the same manner for the whole area. A general pattern in the nutrient status of the area is evident. Available potassium and silicon and to a certain extent also phosphorus decrease with increasing elevation. The low lying areas - makai fields - in general have twice the quantity of available nutrients in the soil as the mauka fields, in spite of the heavier fertilizer applications in the mauka fields. This significant difference in nutrient status can be explained in two ways: Soils occurring in the lower regions are characterized by clayey texture and some of them contain montmorillonite. The cation exchange capacity for these soils is about twice as much as that of the highly weathered soils of the mauka fields (Cline, 1955). The phosphorus-fixing capacity of these "bauxitic" soils has been a subject of many studies and Dedatta, Fox and Sherman (1963) report that maximum yields on these soils are not obtained unless 1000 to 1200 lb P_2O_5/ acre are applied. The availability of phosphorus in some Hawaiian soils was the subject of a study by Ayres (1952). He found only 30 ppmP in Wahiawa top soil, 71 ppmP in Lahaina top soil and 700 ppmP in Lualualei (all determinations were made by the "modified Truog technique*)

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* Modified Truog technique uses 0.02 N sulfuric acid + $(NH_4)_2SO_4$ (3g/l) at a soil: extractant ratio of 1:100 and addition of a small amount of activated carbon to remove organic matter.

The subsoil of Wahiawa and Lahaina (45 cm plus) has only 7 to 10 ppm available P. The low silica and potassium content are also characteristic for these highly weathered soils. In addition, it should be noted that the mauka fields are irrigated with mountain water, which contains less than 1 ppm Si, while the low lying areas receive pump water for irrigation, containing more than 30 ppm Si. Fox et al. (1967) observed a marked change in soluble Si at an elevation of 150-180 m in a study of a sequence of soils in the Waialua transect and related this to the source of irrigation water (see also Figure 16).

The second explanation for this distribution pattern is to take into account the fact that these soils have been intensively cultivated for many years. Lower yields are generally observed in the low lying areas compared to the areas of higher elevation. The removal of nutrients from the soil will accordingly be greater in the higher producing areas. Although no exact data are available for this area Humbert (1968) reports that one ton of millable cane contains around 0.54 kg N, 0.63 kg P_2O_5 and 2.5 kg K_2O. Innes (1960) concludes that in the case of potash the correct policy should be to tend to overfertilize, rather than underfertilize.

In order to illustrate the relation between yield and available nutrients (P and K) after harvest, regression equations have been calculated and the linear regression

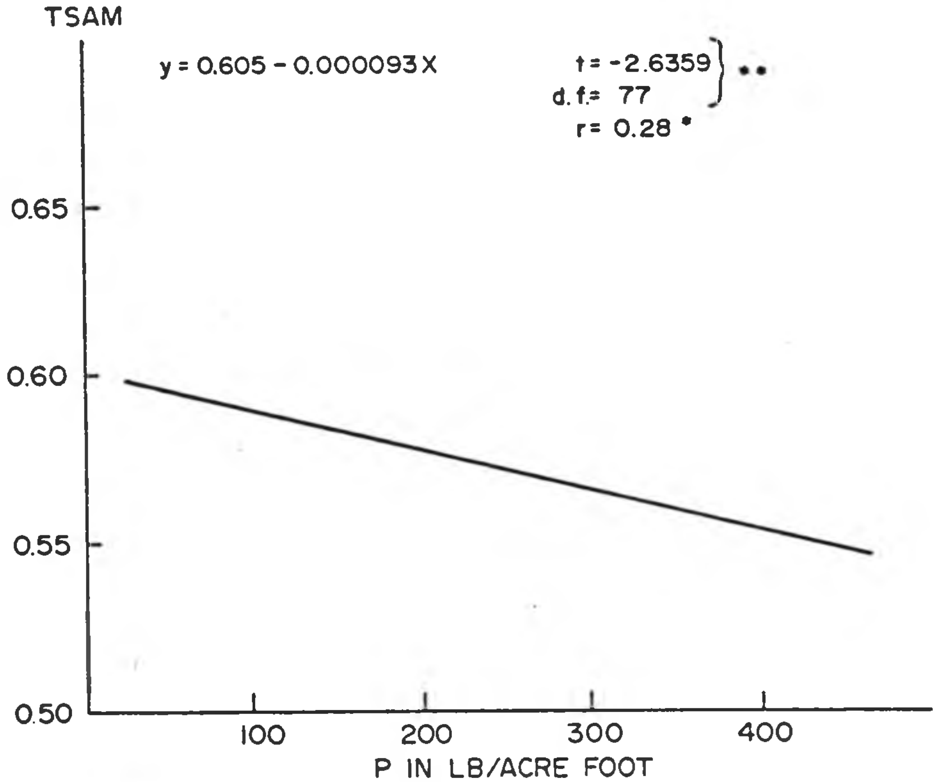


FIGURE 17. RELATION BETWEEN AVAILABLE P AND TSAM

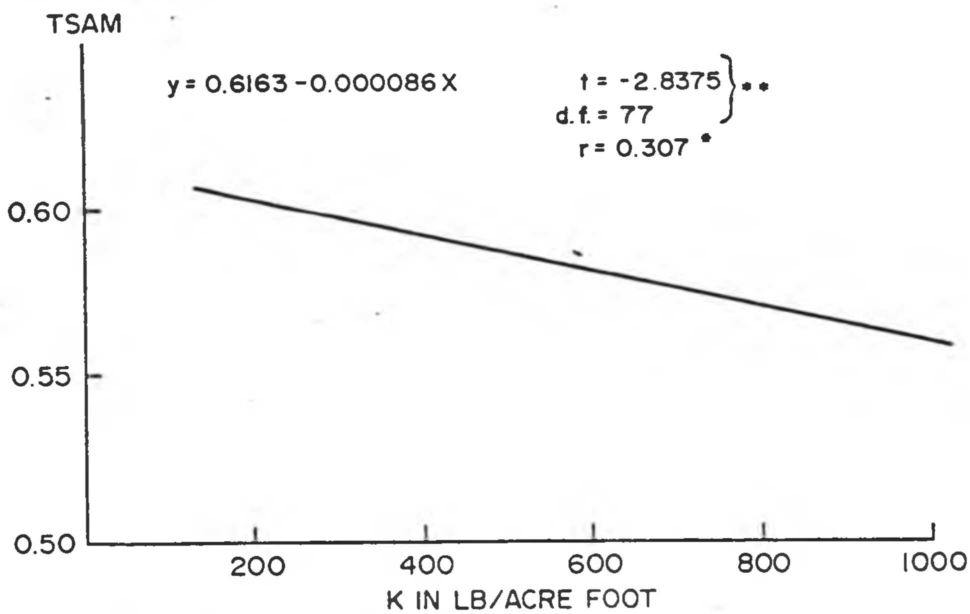


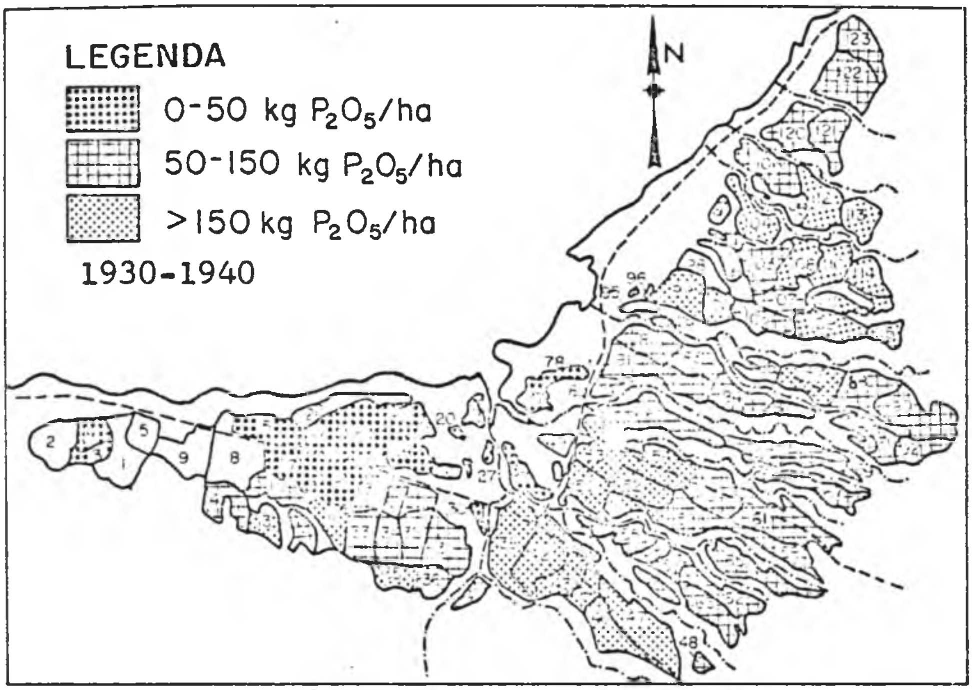
FIGURE 18. RELATION BETWEEN AVAILABLE K AND TSAM

lines are represented in Figure 17 and 18. The regression equations and the t value to test the significance of the regression coefficients are as follows:

TSAM = 0.605 - 0.000093 P/foot (t = -2.636 with 77 d.f.)

TSAM = 0.616 - 0.000086 lb K/acre foot (t = -2.837 with 77 d.f.)

both regression coefficients are highly significant (P=0.01). To understand these negative regression coefficients, other factors have to be related to yield. Fertilizer practices seem to be the logical interfering factor since they are based on soil analysis. Figures 19 and 20 show the fertilizer application distribution for P_2O_5 and K_2O during 1930-1940 and 1960-1970. If the selected group of yield data (see Chapter III, Section 2) are related to the amount of fertilizers given, no significant correlation is obtained. This does not mean that there is no response to added P and K, but merely that the recommendations for fertilizer practices based on soil analysis are satisfactory. Another way of looking at this result is that only a small range of possible applications are tested. The majority of fields received 400-500 kg K_2O/ha and 150-200 kg P_2O_5/ha within this selected group. In order to test a wider range of applications, a group of fields was selected in the makai-mauka areas with data on yield and fertilizer applications since 1930. Although the concept of homogeneity is sacrificed with respect to varieties, the results as shown in Figure 21 and 22 clearly demonstrate the positive effect of increased



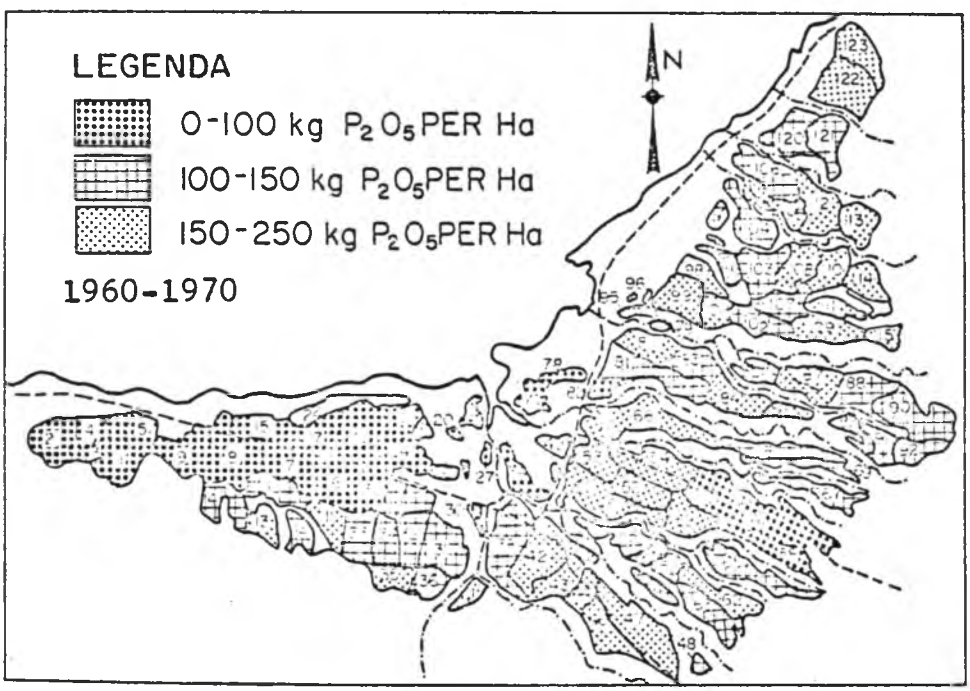
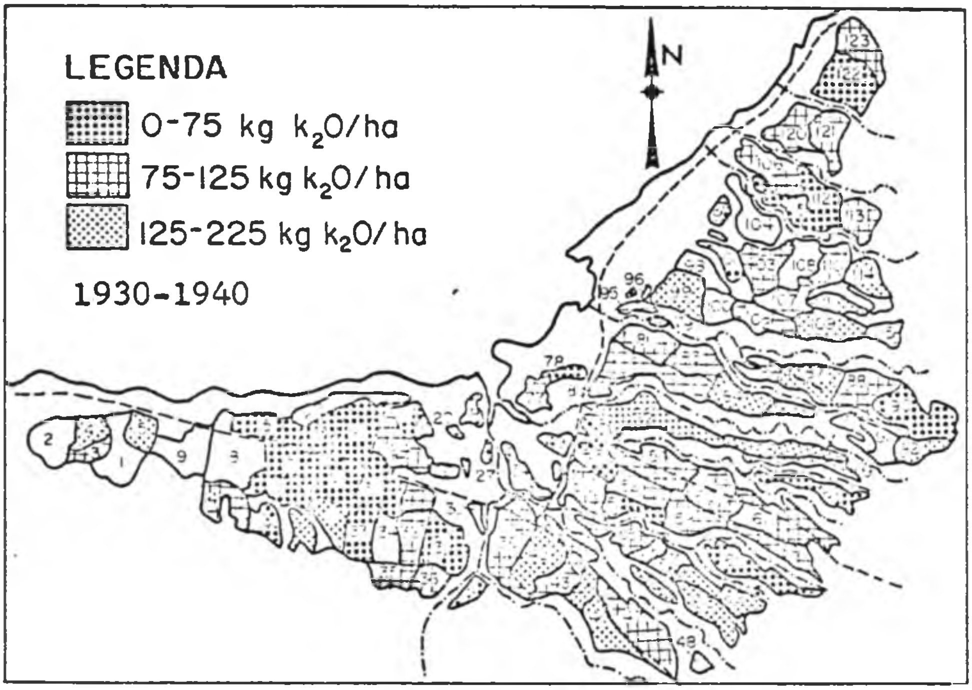


FIGURE 19. APPLICATION OF P_2O_5 DURING THE 1930's AND 1960's



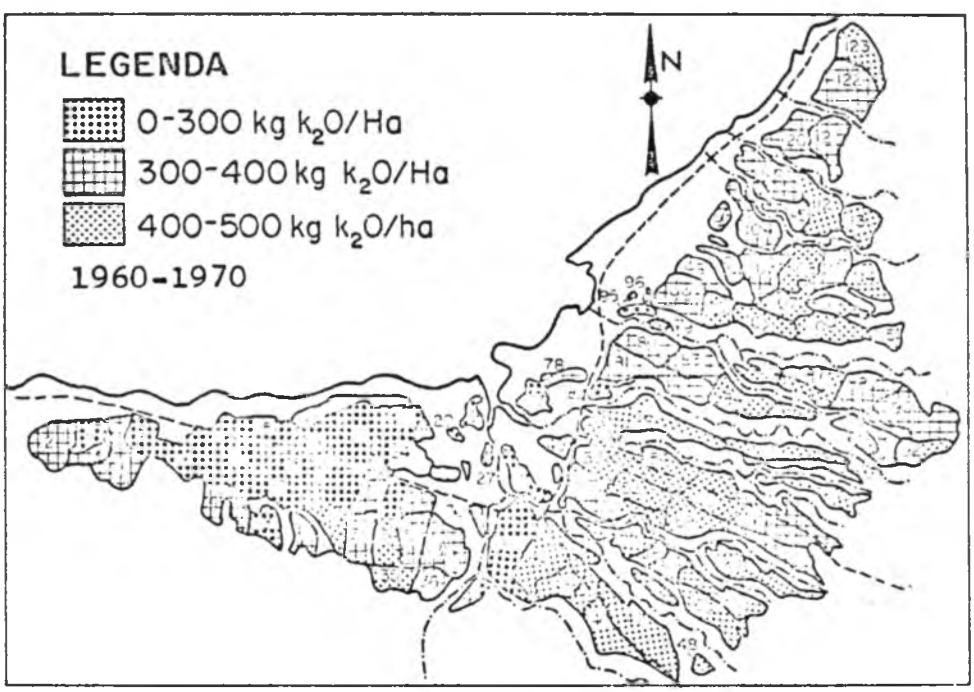


FIGURE 20. DISTRIBUTION OF K_2O DURING 1930's AND 1960's

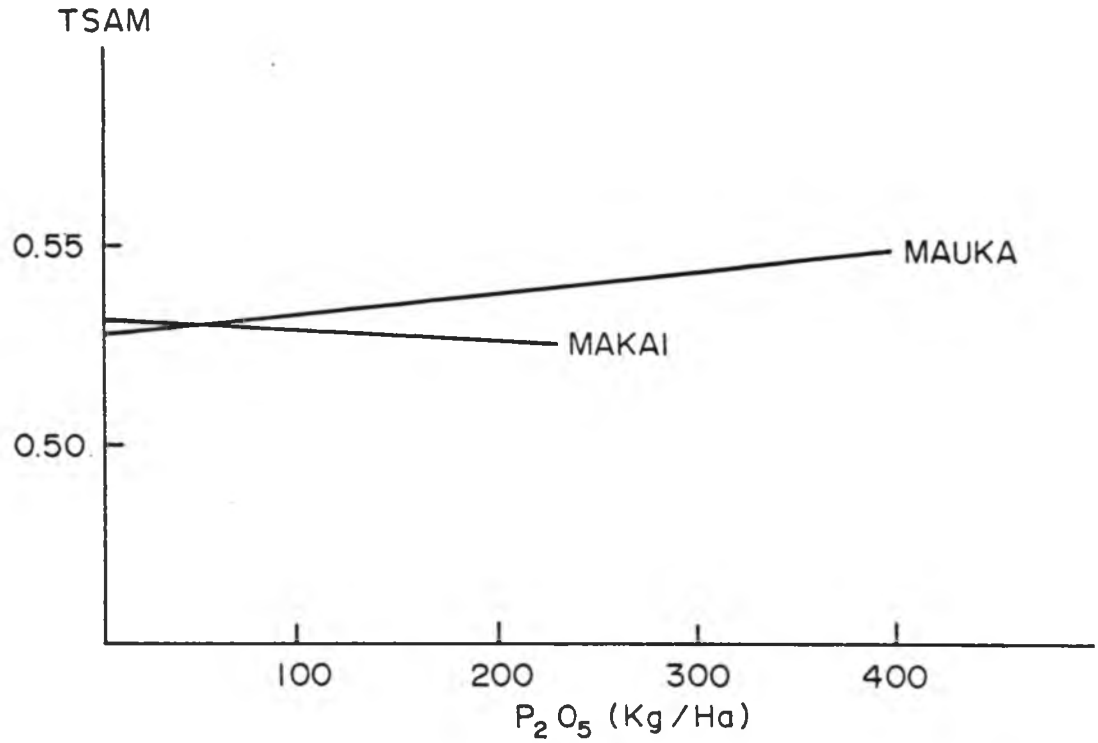


FIGURE 21. RELATION BETWEEN P_2O_5 AND SUGAR YIELD IN MAKAI AND MAUKA SECTIONS OF WACO

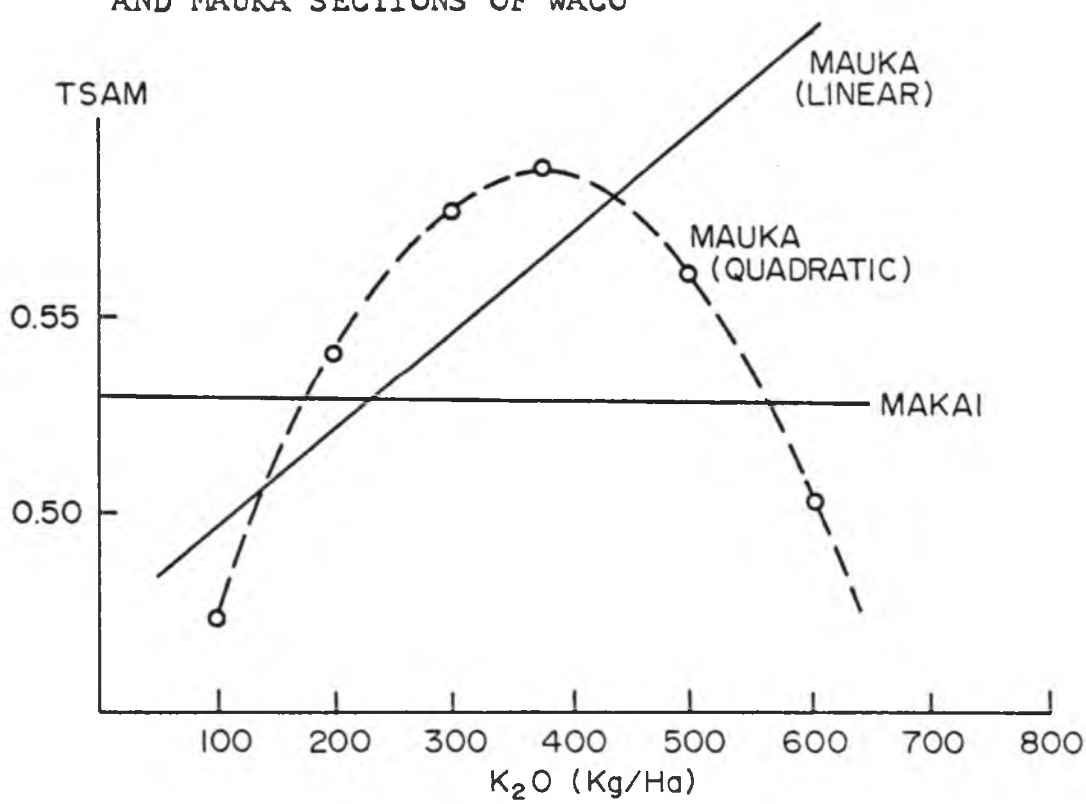


FIGURE 22. RELATION BETWEEN K_2O AND SUGAR YIELD IN MAUKA AND MAKAI SECTIONS OF WACO

potash applications in the mauka fields. The regression equations and the t-value to test the significance of the regression coefficient are as follows:

Makai Fields (162 degrees of freedom)

TSAM = 0.532 - 0.000034 kg P_2O_5/ha (t=0.47; r <0.01; N.S.)

TSAM = 0.530 + 0.000001 kg K_2O/ha (t=0.02; r <0.01; N.S.)

Mauka Fields (186 degrees of freedom)

TSAM = 0.529 + 0.000045 kg P_2O_5/ha (t=0.49; r <0.01; N.S.)

TSAM = 0.473 + 0.000245 kg K_2O/ha (t=6.76; r=0.44; P<0.01)

These results indicate that increased applications of K_2O in particular significantly increased the yield in the Mauka fields up to 375 kg/ha. Beyond that point the yields tend to decrease. The quadratic regression equation is also significant at 1%-r = 0.58 and is as follows:

$$TSAM = 0.378 + 0.001105X - 0.000147X^2 \quad (X = \text{kg } K_2O/\text{ha})$$

This curvilinearity does not necessarily mean that high amounts of potash are responsible for lower yield. As was pointed out earlier (see Table XIII) higher amounts of potash were generally applied during the later part of the 1960's, when the yield was declining.

The total set of data since 1930 has been split up in four groups by decades. Linear regression equations have been calculated for applications of P, N and K and also for total rainfall received during the growing period. The results are shown in Figure 23 while the statistical data are given in Table XV.

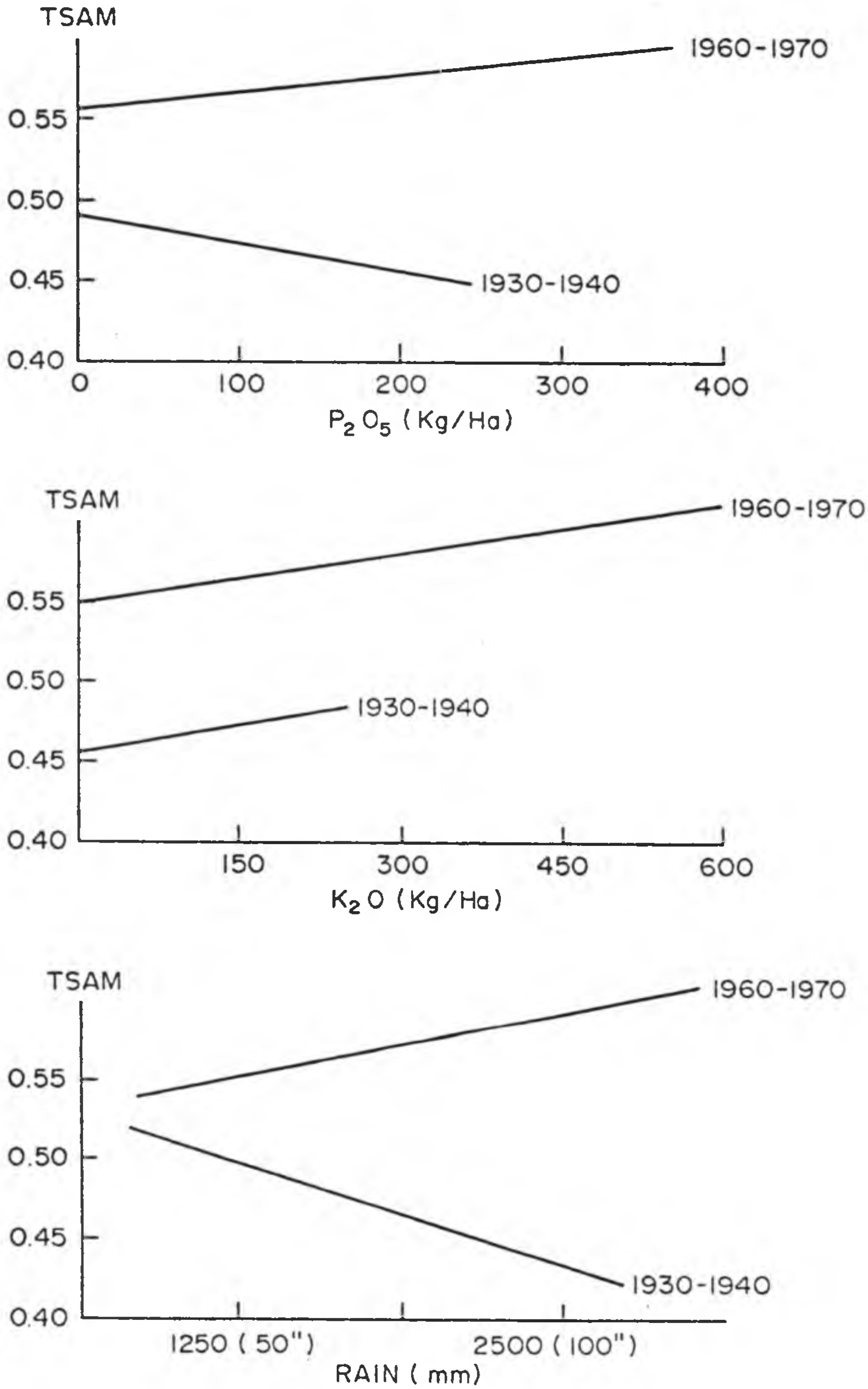


FIGURE 23. RESPONSE OF SUGAR YIELD TO APPLICATIONS OF K_2O AND P_2O_5 AND TO TOTAL RAINFALL DURING THE 1930's AND THE 1960's

TABLE XV

AVERAGE APPLICATION OF P, N AND K, AVERAGE TOTAL RAINFALL IN mm, THE t-VALUE FOR THE LINEAR REGRESSION COEFFICIENT AND THE AVERAGE YIELD DURING THE FOUR DECADES+

	1930-40	1940-50	1950-60	1960-70
n (number of records)	167	353	244	666
P_2O_5 (kg/ha)	131.01	99.2	147.89	118.35
t	-2.99**	0.26 N.S.		4.80**
K_2O (kg/ha)	98.16	118.1	275.79	304.1
t	1.49 N.S.	-0.64 N.S.	-2.14*	5.78**
N (kg/ha)	225.5	195.09	279.09	308.4
t	-2.53**	-4.45**	-1.94*	3.54**
Rain (mm)	2000	1580	2060	1960
t	-3.68**	-0.62 N.S.	-1.74 NS	4.21**
Yield (TSAM)	0.46	0.53	0.57	0.58

+ Excluded are: Period 1940-1945, strike years and exceptional management practices.

** Means significant at 1% level.

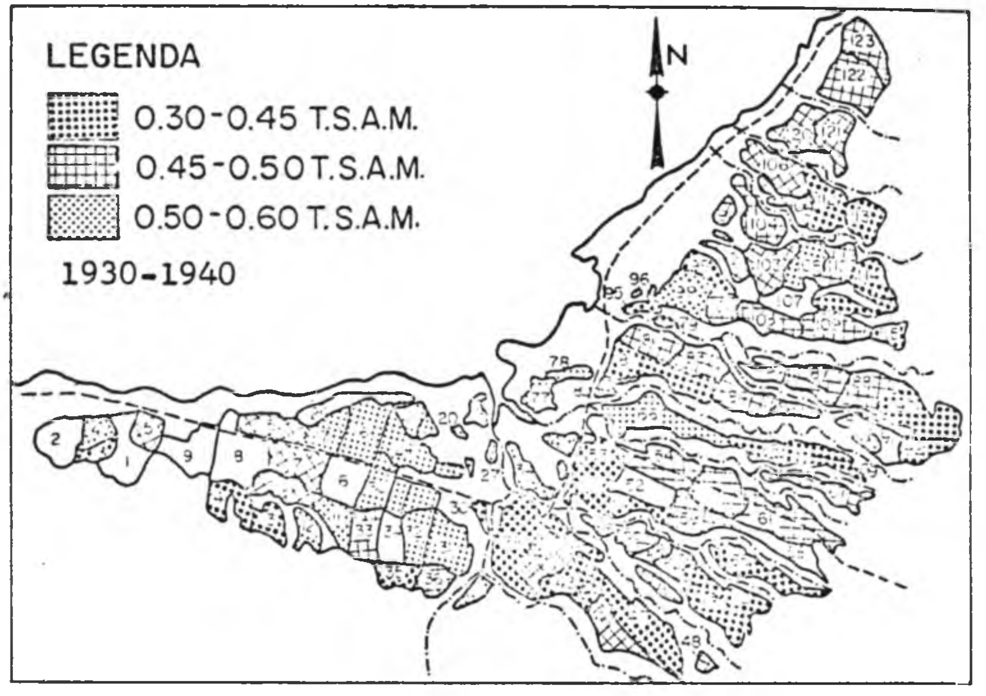
* Means significant at 5% level.

N.S. Means non significant.

Finally yield distribution maps were constructed. Figure 24 shows the average yield for each field during 1930-1940 and during 1960-1970, while Figure 25 shows the trend surfaces for the same periods. It is now possible to explain the foregoing results in a satisfactory manner.

The most significant change in fertilizer practices is definitely the potash application which tripled since 1930-1940. The highly significant positive correlation between potash and yield in the mauka fields compared to the non-significant correlation in the makai fields demonstrates that fertility has been a limiting factor in the upland section. This explains the lower yields in the mauka fields during the 1930's, demonstrated by the yield distribution maps as well as by the rainfall-yield relation, which was negatively correlated. (Total rainfall increases towards the mountains as can be seen in Figure 26)

Increasing fertilizer applications, potash - as well as Si, during the 1960's have apparently diminished the limiting fertility factor in the mauka fields. This resulted in higher sugar production in the mauka fields than in the makai fields during the 1960's. Table XVI summarizes the fertilizer application and sugar yield in both sections during 1930-1940 and 1960-1970.



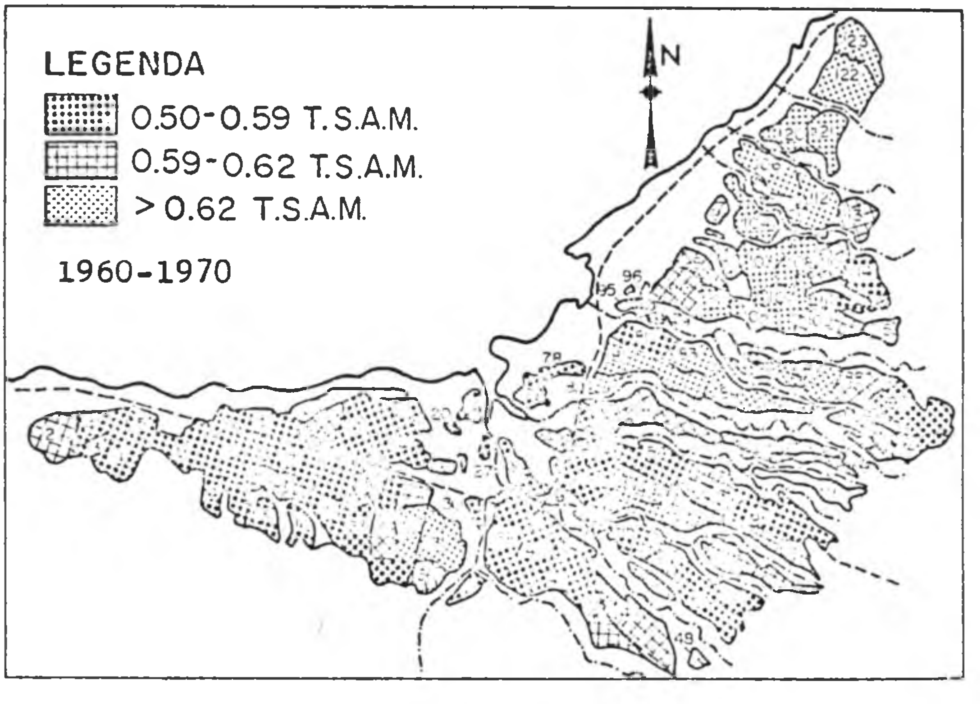
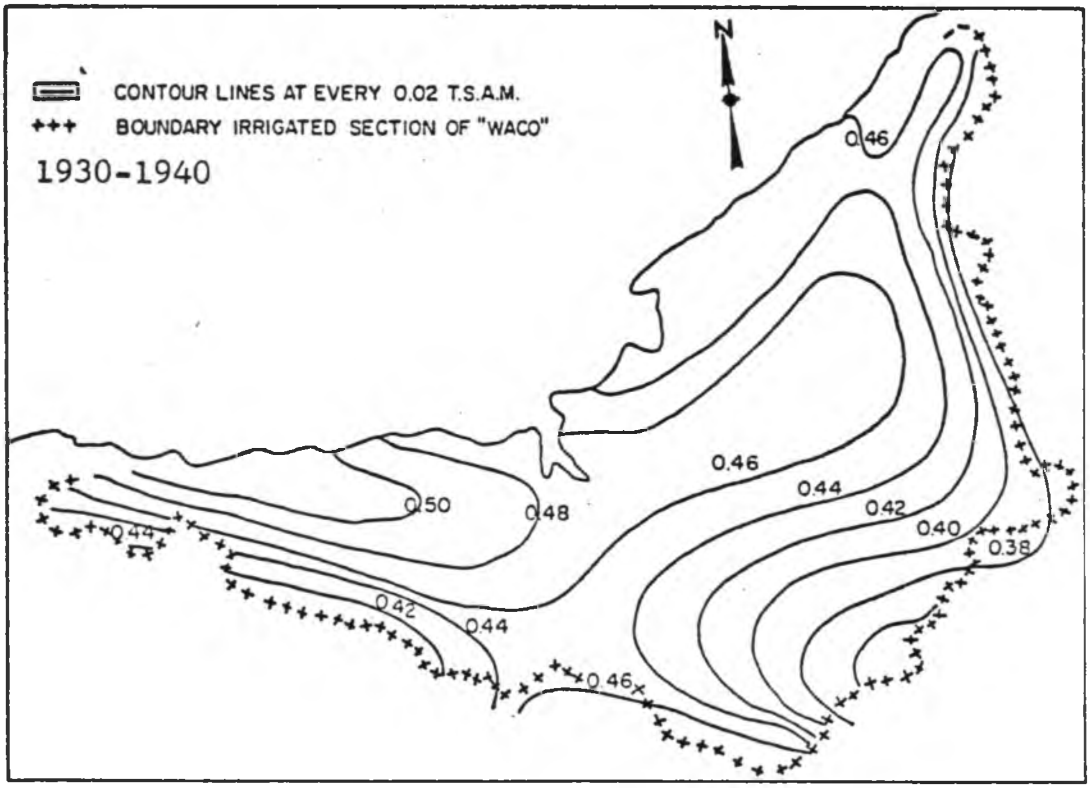


FIGURE 24. AVERAGE YIELD DISTRIBUTION DURING THE 1930's AND THE 1960's



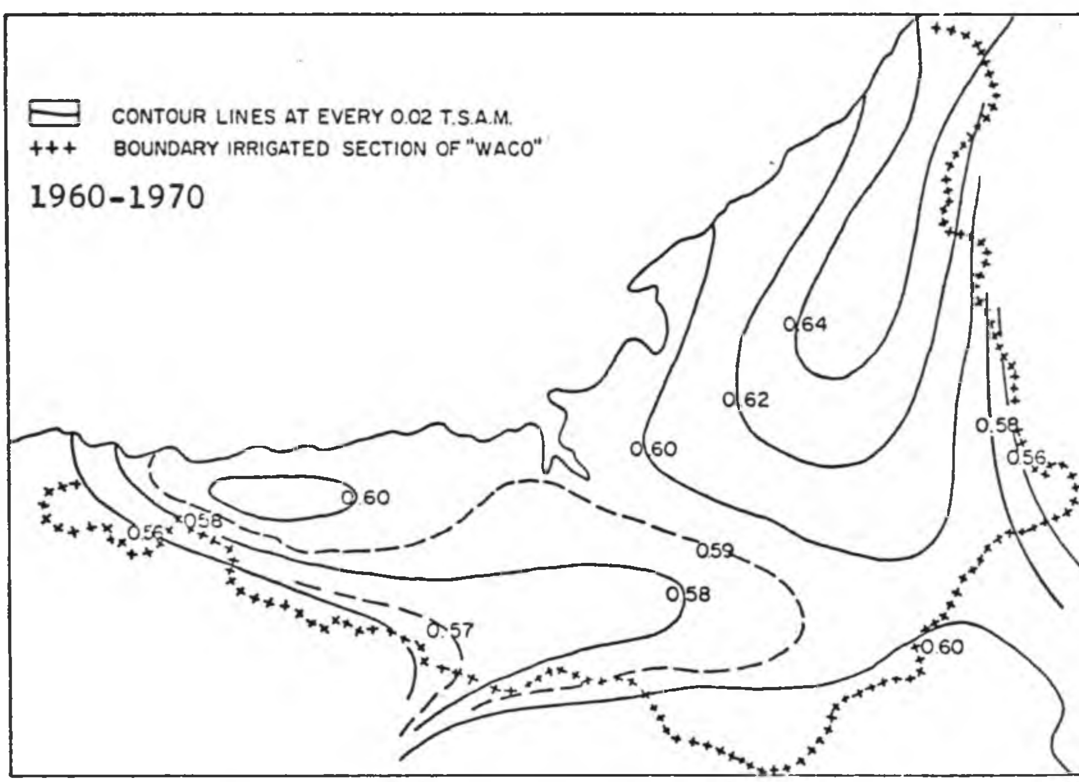


FIGURE 25. TREND SURFACE OF YIELD DISTRIBUTION DURING THE 1930's AND THE 1960's

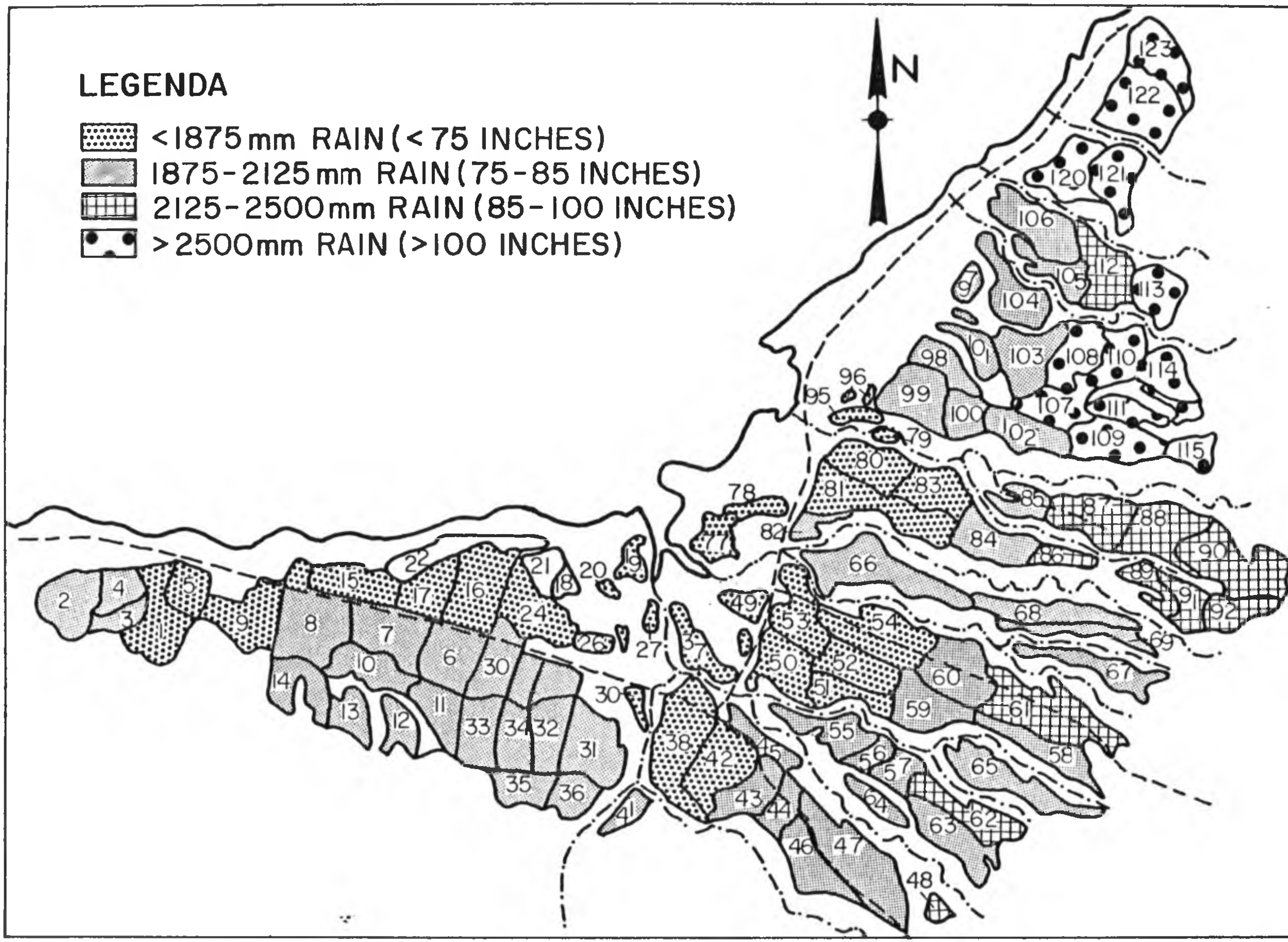


FIGURE 26. DISTRIBUTION OF TOTAL RAINFALL FOR GROWING PERIOD IN [illegible]

TABLE XVI

AVERAGE YIELD, N, P_2O_5 AND K_2O APPLICATION FOR 20 REPRESENTATIVE FIELDS IN THE MAKAI AND MAUKA SECTIONS OF THE PLANTATION DURING 1930-1940 AND 1960-1970

	1930-1940				1960-1970			
	TSAM	K_2O kg/ha	P_2O_5 kg/ha	N kg/ha	TSAM	K_2O kg/ha	P_2O_5 kg/ha	N kg/ha
Makai	0.501	76	66	233	0.558	174	39	292
Mauka	0.469	114	157	231	0.621	365	145	317

This discussion however does not solve the question of why makai fields with high natural fertility and a favorable climatic setting produce significantly less than the fields at higher elevation. What are the limiting factors in this low lying area?

To understand this we need to see what other management practices have been changed during these forty years.

Aside from fertilizer applications, the degree of mechanization changed considerably. A review of the management at Waialua (Dupuy, 1966) cites this change as follows:

> "Up to the year 1936 there was little mechanization in the harvesting operation. The cane was all cut and loaded by hand and much of it was hauled from the field by mule teams, which drew the cars over portable rails to main lines of the railroad. In 1937 the use of large mobile crawler-type cranes was introduced to grab the cane loose from its growing position in the field and load it directly into rail cars."

In 1953 railroad hauling was converted to truck hauling, and in 1963 the plantation introduced the 40-ton hauling truck. Although mechanization reduced the number of employees from 2516 in 1913 to 641 in 1968, the introduction of heavy machinery may have affected the physical conditions of the soil in a negative manner. Unfortunately, few quantitative data are available on the physical properties of the soils. It is known that the aggregate stability of soils with a high content of sesquioxides is much greater than that of soil of montmorillonitic or mixed mineralogical composition. Bennema (1967), in describing the agricultural possibilities of latosols, states that these soils have reasonably good physical conditions for plant growth, because of their great depth and high porosity favorable to root development; their stable structure which causes them to be less susceptible to erosion; and, their friable conditions which make them easy to work.

Uehara, Flach and Sherman (1962) state that the Low Humic Latosols in Hawaii possess excellent physical properties and have withstood the use of heavy agricultural equipment because of their stable structure. The high aggregate stability of these soils according to Cagauan and Uehara (1965) is mainly a result of the minerological composition of the system: A kaolin-free iron oxide mixture and the history of development of the aggregates: the highest degree of particle orientation was found in samples from areas with relatively high rainfall, but having a pronounced dry season.

Under wet conditions the soils in the low lying areas lose much of their structure and become very plastic, sticky and compact, while the upland soils of high aggregate stability remain very permeable and keep their structure under wet conditions.

Although no quantitative data are available to underline this point, observations from harvest operators confirm that the makai section, including soil series like Pearl Harbor, Haleiwa, Pulehu and Waialua, is more difficult to work with under wet conditions, and they have restricted drainage compared to the mauka section of the plantation, Wahiawa, Ewa and Lahaina soil series. Poor physical conditions are aggravated by the use of heavy machinery. Since the same equipment is used over the entire area, the fields most affected will be those that have less favorable physical soil characteristics.

Trouse and Humbert (1961) and Trouse (1959) report an elaborate investigation on the effect of compaction on the growth of sugar cane. They compared the increase in bulk density after heavy traffic for the Lahaina and Wahiawa series in WACO. Their results show that the bulk density of the surface soil increased from 1.11 g/cc to 1.71 g/cc for Lahaina and from 1.07 g/cc to 1.62 g/cc for Wahiawa. The effect of heavy traffic was still observed at 40 cm depth. Although no comparison is made for the heavy clay soils in the makai section of WACO, it may be assumed that compaction resulting from heavy traffic will be even more significant there. In a separate study they related the growth of roots under different levels of compaction. (Different soils were compacted in soil cores, then placed in Mitscherlich pots and surrounded with loose soil of the same kind. Single eye cuttings of sugar cane were planted in the loose soil above the core and root growth was determined by rubidium 85 activity) The results of this experiment show that root growth was severely restricted for Low Humic Latosols at 1.45 g/cc, for Gray Hydromorphic soils at 1.83 g/cc and for alluvial soils at 1.54 g/cc. With increasing bulk density the roots encounter greater mechanical resistance, but also the water and gas permeability are greatly reduced which may seriously affect the growth of sugar cane. In profile studies, made at several locations in the plantation, it was obvious that the bulk of roots was concentrated in the first 25 cm of the soil.

Because of the absence of quantitative data on the physical properties of the soil, soil mapping units were compared in relation to yield. They are to a large degree described by their visible morphological properties. An analysis of variance was carried out to determine if a significant difference in yield exists among the soil series:

Pearl Harbor	(0.576)	Average of 13 observations
Haleiwa	(0.569)	Average of 12 observations
Waialua	(0.580)	Average of 41 observations

Pulehu-Kawaihapai	(0.588)	Average of 21 observations
Ewa (level phase)	(0.618)	Average of 19 observations
Ewa (sloping phase)	(0.565)	Average of 15 observations
Lahaina	(0.602)	Average of 77 observations
Wahiawa	(0.616)	Average of 127 observations
Leilehua	(0.558)	Average of 9 observations
Total	(0.599)	Average of 334 observations

The statistical analysis is as follows:

TABLE XVII

ANALYSIS OF VARIANCE TO TEST THE SIGNIFICANCE OF YIELD DIFFERENCE AMONG NINE SOIL MAPPING UNITS

Source	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio
Total	333	0.91727		
Between soils	8	0.10775	0.01347	5.431**
Within soils	325	0.80951	0.00248	

** Significant at 1% level.

There exists a highly significant difference in yield among these mapping units. In order to find out which soils differ significantly from each other an analysis of variance was carried out between every pair of soil units. Table XVIII gives the F-ratios calculated in the upper half, while

TABLE XVIII

F-RATIO AND ITS SIGNIFICANCE FOR NINE PAIRS OF SOIL MAPPING UNITS
(SOILS ARE ARRANGED IN ORDER OF THE AVERAGE YIELD)

Soil Units	1	2	3	4	5	6	7	8	9
1 Leilehua	--	0.16	0.34	0.62	1.72	2.52	4.77	13.6	15.3
2 Ewa (slope)	N.S.	--	0.05	0.30	1.14	1.89	5.26	16.4	13.6
3 Haleiwa	N.S.	N.S.	--	0.08	0.47	0.99	3.27	11.0	9.2
4 Pearl Harbor	N.S.	N.S.	N.S.	--	0.06	0.34	2.08	8.2	5.6
5 Waialua	N.S.	N.S.	N.S.	N.S.	--	0.31	4.07	18.2	9.2
6 Pulehu	N.S.	N.S.	N.S.	N.S.	N.S.	--	1.02	6.6	4.6
7 Lahaina	5	5	10	N.S.	5	N.S.	--	3.6	1.4
8 Wahiawa	1	1	1	1	1	5	10	--	0.1
9 Ewa (level)	1	1	1	5	1	5	N.S.	N.S.	--
Average TSAM	0.56	0.56	0.57	0.58	0.58	0.59	0.60	0.62	0.62

Figure V-3. Lysogeny of USDA194 revealed by plaque formation on control plates without added phage.

in the lower half it is indicated which F-ratios are significant at 1% (1), 5% (5) and 10% (10) level. (N.S. = non significant)

This table shows clearly that Haleiwa, Pearl Harbor, Waialua and Pulehu alluvial soils are significantly different from Wahiawa and Ewa (level phase), but there is no significant difference in yield response within these two groups. Lahaina is intermediate between these two groups and is only significantly different from Waialua, Haleiwa, and Leilehua.

While there was only a minute difference in yield between the level and gently sloping phase of the Wahiawa and the Lahaina series, a highly significant difference in yield is observed between the two phases of the Ewa soil series. The Ewa soil series in this area located at the foot of the Waianae range whose slope is much steeper than that of the Koolau range on which the Wahiawa and Lahaina series are located (see Figure 27). Consequently, colluvial material, consisting of stones and large boulders, characterize the sloping phase of the Ewa series. In addition, this area is also subject to occasional erosion, damaging the cane. These factors contribute to the low yields of Ewa-sloping phase.

Another soil series with very low yields is Leilehua. It is located at the highest elevation in the plantation and classified as Tropohumult. Aside from very poor chemical conditions, these soils have an illuvial B horizon and

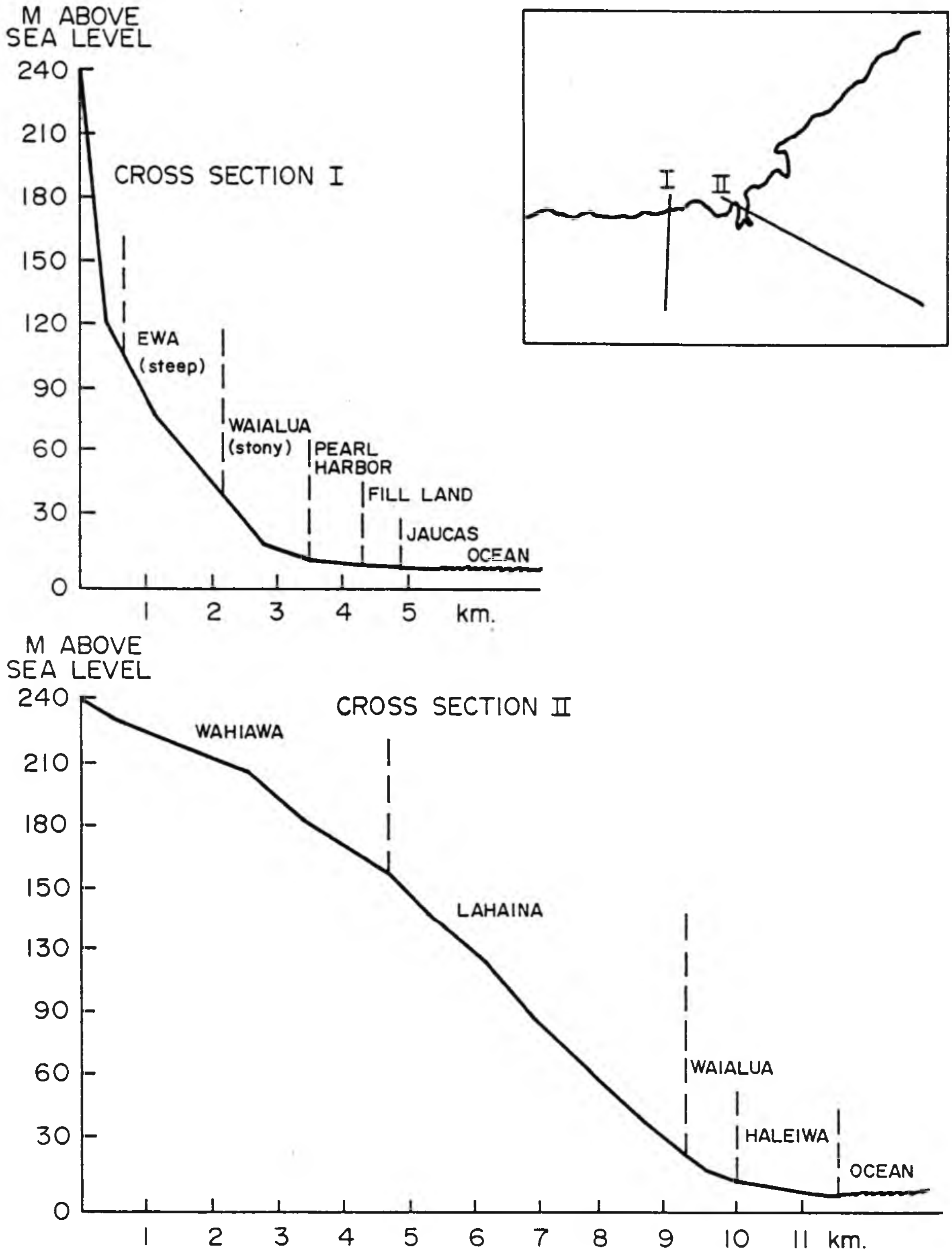


FIGURE 27. CROSS-SECTION AT TWO LOCATIONS IN WACO

increasing amounts of rain and the degree of cloudiness may be another limiting factor in its yield. However, only two fields in the plantation (Opaeula 16 and Opaeula 18) are located on these soils so that one must be cautious with their interpretation.

Although the foregoing discussion indicates that the poor physical condition of the soil may be one of the limiting factors in sugar production, the detrimental effect of compaction theoretically should be overcome by good soil preparation. As indicated in Chapter II, Section 1, the soils are subsoiled and turned over by disc plows before planting a crop. However, little soil preparation is carried out in the case of ratoon crops. Therefore, if compaction is a determining factor in sugar production, it should show up when plant crop yields are compared with yields of ratoon crops. Figure 28 shows the effect of ratooning on the yield expressed as TSAM, TSA and TCAM.

All three expressions of crop production show a steep drop in yield with subsequent ratooning. Although the entire field is replanted, the effect of deteriorating soil conditions is obvious. In order to test the significance of this drop in yield, an analysis of variance test was carried out between plant crop and first ratoon crop, and between first and second ratoon crop. Table XIX gives the results.

There is a highly significant decrease in yield between plant crop and first ratoon, but the decrease in yield

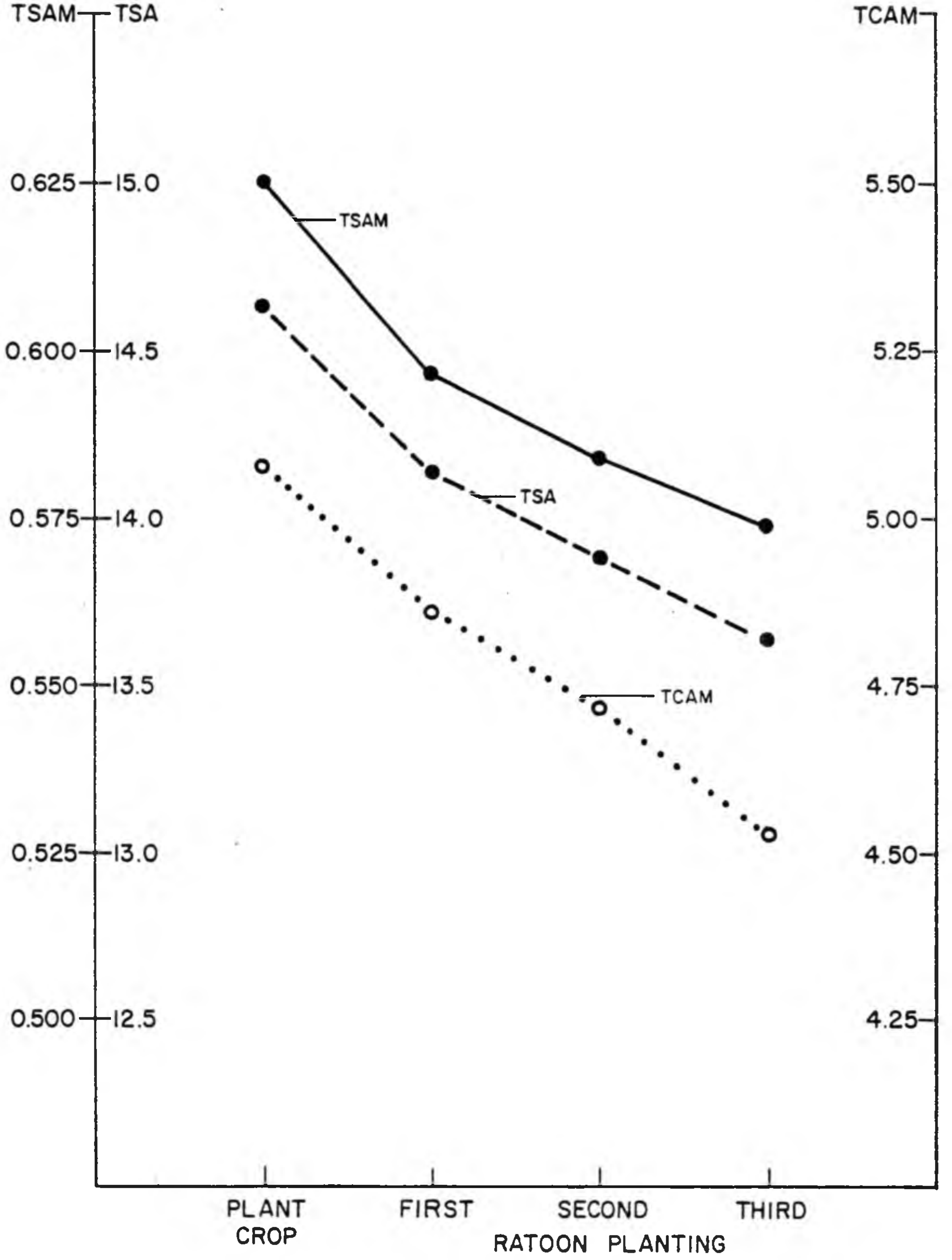


FIGURE 28. INFLUENCE OF RATOONING ON THE YIELD

TABLE XIX

ANALYSIS OF VARIANCE BETWEEN PLANT CROP AND FIRST RATOON AND BETWEEN FIRST RATOON AND SECOND RATOON

		Plant Crop and First Ratoon		
Source	D.F.	Sum Squares	Mean Square	F-ratio
Total	165	0.45786		
Between	1	0.03197	0.03197	12.309**
Within	164	0.42589	0.00260	

		First Ratoon and Second Ratoon		
Source	D.F.	Sum Squares	Mean Square	F-ratio
Total	139	0.34303		
Between	1	0.00563	0.00563	2.3029 N.S.
Within	138	0.33740	0.00244	

** Significant at 1% level

N.S. Non significant

between first and second ratoon is not significant at the 5% level. Although it would be tempting to compare this decrease in yield due to ratooning during the four decades, the results are not directly comparable because the plantation changed its method of ratooning from mechanical ratooning-only those areas replanted where regrowth is poor-to ratoon planting-100% of the field replanted. This last method is certainly a major step towards reducing the loss due to damaged cane during harvest operations. As Figure 29 demonstrates ratooning has always been a factor in lowering the yields. While it may have been the result of damaged stools before 1960, the decrease in the last decade is most probably due to compaction. Also varietal differences may be of importance. This is demonstrated during 1950-1960. Variety 37-1933 gave higher yields in the first ratoon cycle.

Since it is concluded that compaction may be the main reason for yield decrease, a separate comparison was made of the effect of ratooning between different soil groups. In order to have sufficient data for a reliable average, only two groups were compared: Wahiawa, Lahaina and Ewa (level phase) versus Waialua, Haleiwa, Pulehu and Pearl Harbor. Table XX gives the average yield for these two groups for plant crop, first ratoon and second ratoon.

TABLE XX

INFLUENCE OF RATOON CROPPING ON THE SUGAR YIELD (TSAM) FOR UPLAND SOILS (WAHIAWA, LAHAINA AND EWA) AND LOWLAND SOILS (WAIALUA, HALEIWA, PULEHU AND PEARL HARBOR)

Soils	Plant Crop	First Ratoon	Second Ratoon	Difference Pl-2nd rt.
Upland soils	0.629	0.605	0.597	0.032
Lowland soils	0.613	0.574	0.555	0.058
Difference between Upland and Lowland	0.016	0.031	0.042	

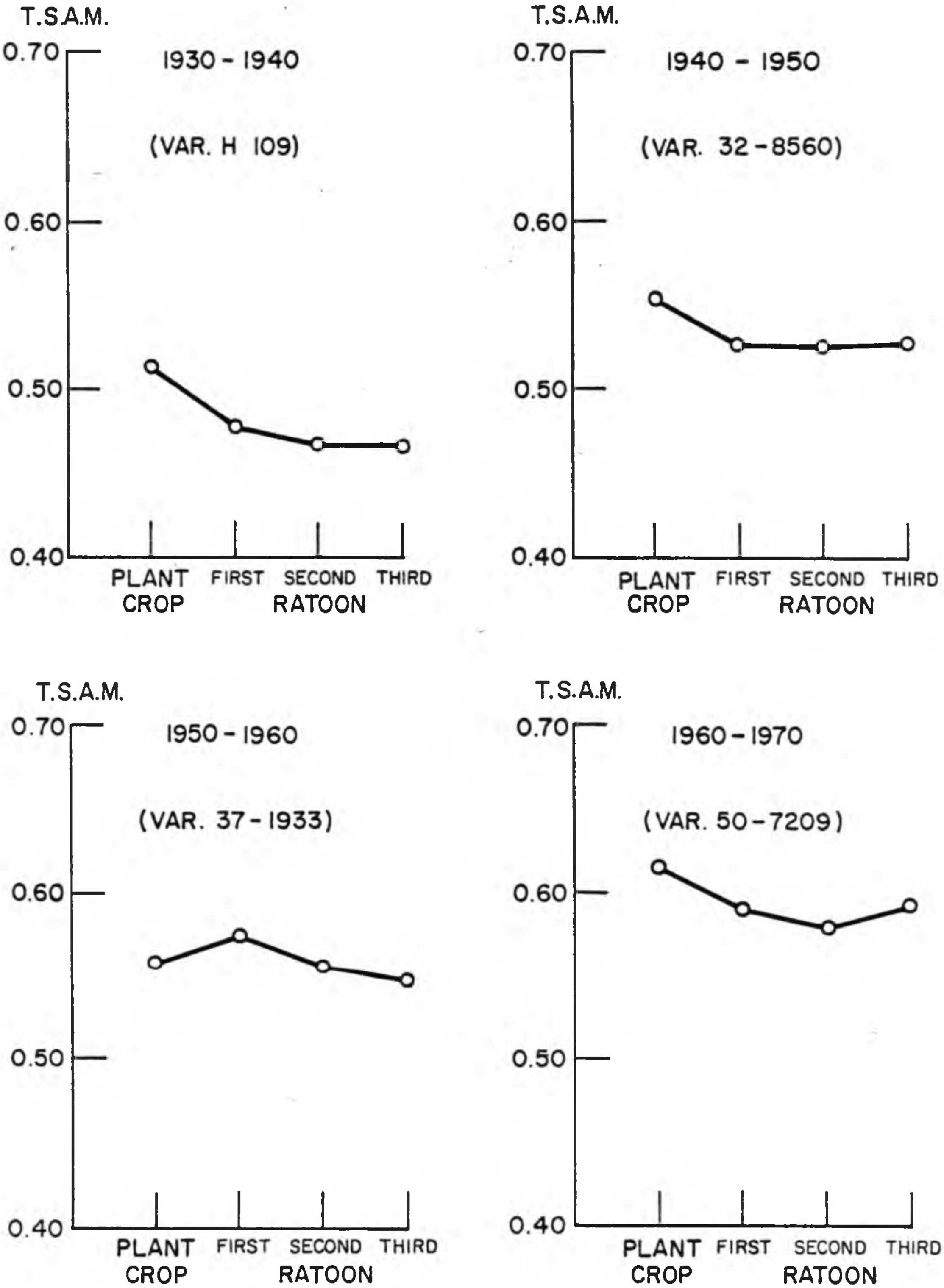


FIGURE 29. INFLUENCE OF RATOONING ON FOUR VARIETIES

While ratooning affected the yields in both soil groups, the decrease in yield is almost twice as much in the alluvial soils than in the soils at higher altitude. This difference supports the aforementioned belief that compaction is more pronounced in soils with poorer structured stability.

Ratooning is a practice generally accepted in the major sugar growing areas of the world. Tang (1965, 1969) reports on a study of eight, and nine consecutive ratoon crops in Taiwan, that no significant loss in cane was found as long as the soil productivity is properly maintained; Yamasaki (1956) concludes in studies carried out in sugar cane fields on the Hilo coast that poor cane growth of ratoon crops results from one of the following conditions:

a. A very shallow surface soil.

b. Soil compaction.

c. Shallow tillage depth.

d. Poor field preparation.

Also, Trouse (1955) indicates that ratoon fields will give a poorer yield because of compacted areas especially on the infield roads.

However, soil compaction does not seem to be the only reason for poor yields. After two to three ratoon crops, the fields are tilled again following the same schedule as in the case of the first plant crop. In this way, the original soil structure is more or less restored. This second plant crop never reaches the same sugar tonnage as the first plant crop and the ratoon crops in the second cycle are even worse than those in the first crop cycle as is illustrated in Figure 30. A statistical analysis of the difference between these two cycles of planted cane is given in Table XXI.

TABLE XXI

ANALYSIS OF VARIANCE OF THE DIFFERENCE IN SUGAR YIELD BETWEEN FIRST AND SECOND CYCLE PLANT CROP

Source	D.F.	Sum Squares	Mean Square	F-ratio
Total	129	0.36192		
Between	1	0.01491	0.01491	5.4989*
Within	128	0.34702	0.00271	

* Significant at 5% level

There exists a significant difference in yield ($P=0.05$) between cane planted in the first cycle and cane planted in the second cycle.

In order to see if this yield decline occurs in the whole area, the data were separated into three soil groups and the average yield was calculated for the two plant cycles within each group. Table XXII shows the result.

A substantial yield decline is apparent within the alluvial soils as well as the Lahaina series, while the same average yield is maintained within the area of the Wahiawa series.

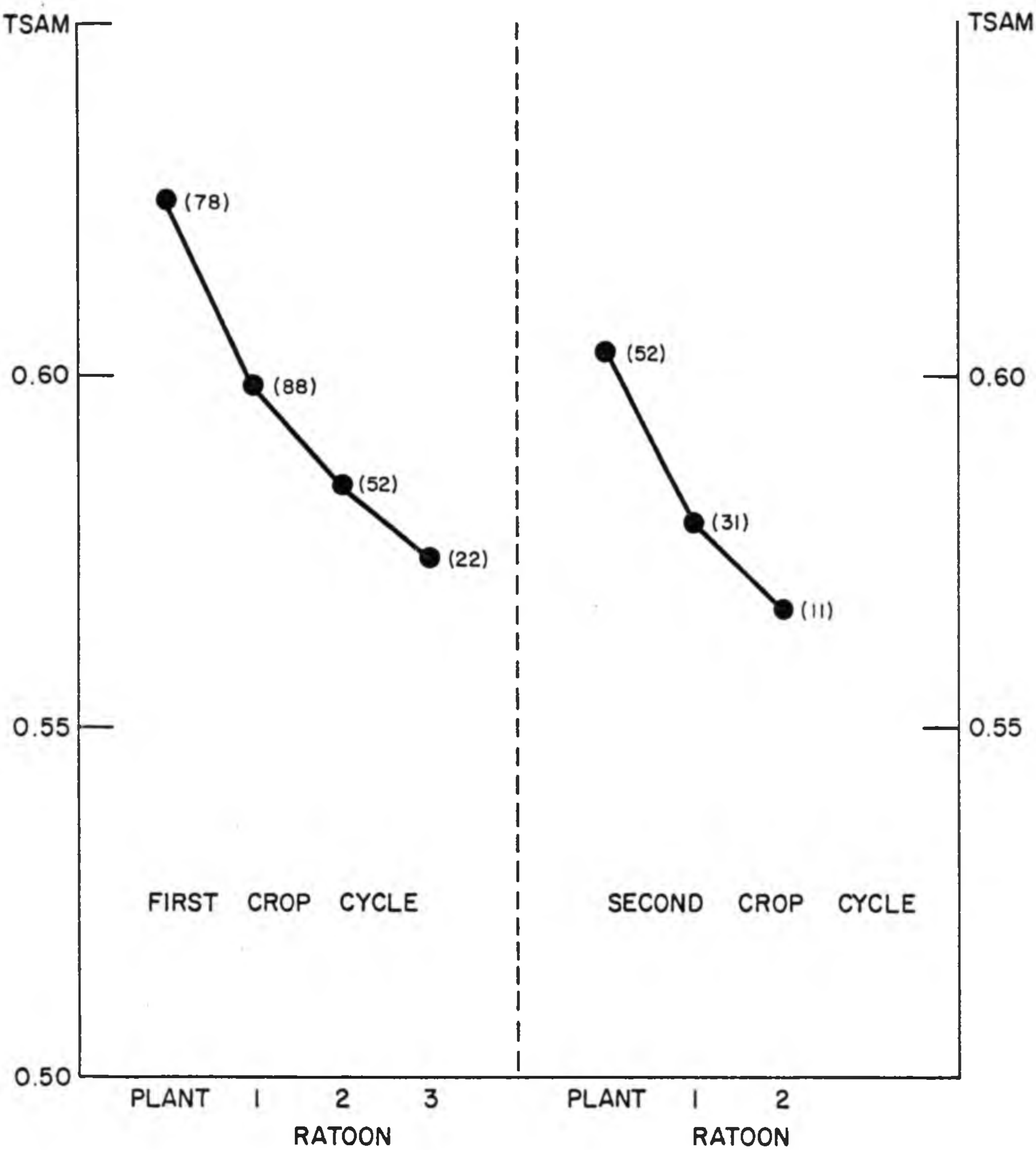


FIGURE 30. RELATION BETWEEN YIELD AND RATOONING FOR FIRST AND SECOND PLANT CYCLE

TABLE XXII

AVERAGE YIELD FOR PLANT CROP-FIRST AND SECOND CYCLE-FOR THE WHOLE PLANTATION, THE FIELDS ON WAHIAWA SOIL, LAHAINA SOIL AND ALLUVIAL SOILS

Soils	First cycle TSAM	(n)	Second cycle TSAM	(n)	Yield Decline
All fields	0.625	(78)	0.603	(52)	0.022
Wahiawa	0.628	(29)	0.628	(16)	0.000
Lahaina	0.634	(23)	0.591	(14)	0.043
Alluvial	0.613	(21)	0.587	(11)	0.026

This yield decline as observed in WACO is also reported from other plantations and areas. Hsia and Ou-Yang (1969) reported this yield decline in Taiwan, and they concluded that the main cause would be the presence of the nymphs of "Magannia hebes Walkers." Their studies showed that the buds on the nymph-invested stumps lost their germinating ability temporarily after the former crop was harvested.

However it is dubious if this situation exists in WACO because fresh seed pieces are planted even in ratoon crops. Mills and Vlitos (1965) isolated fungi from a heavy clay soil and found that the "fungal genera in the rhizosphere of the young ratoons were generally those which utilize sugar substrates rather than cellulose." To which extent these fungi may cause this yield decline is not known.

Figure 31 shows the average yield in the mauka and makai

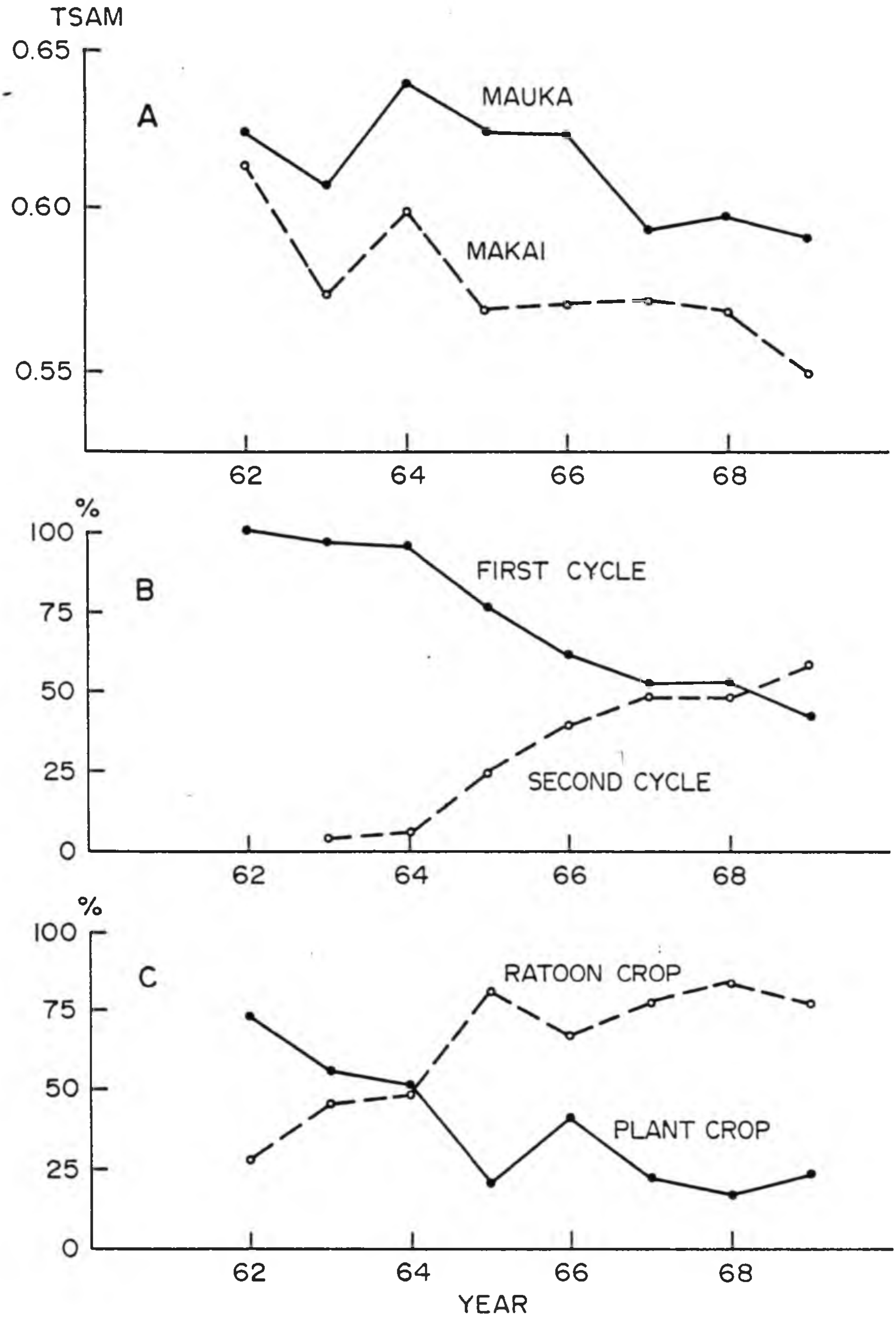


FIGURE 31. AVERAGE YIELD IN MAUKA AND MAKAI SECTION (A) PERCENTAGE PLANTED IN FIRST AND SECOND CYCLE (B) PERCENTAGE PLANT CROP AND RATOON CROP (C) BASED ON FIELDS HARVESTED EVERY YEAR SINCE 1962.

section of the plantation for each harvest year since 1962, the percentage of the yield data for first crop cycle versus second crop cycle, as well as for plant crop versus ratoon crop during the same year.

After 1964 the number of fields in ratooning and planted for the second time increased. This augmentation coincides with a drop in yield, most strongly felt in the makai area. A second drop in yield most strongly felt in the mauka section occurred in 1967. In this year only 25% of the fields were plant crop, while in 1966 50% of the fields were plant crop. The third decline was observed in 1969 in the makai fields, despite that almost 50% of the fields in that area were replanted.

From these observations it can be concluded that the increase in ratoon cropping in the later part of the 1960's as well as the increase in fields planted for the second time resulted in a decrease in yield in the late 1960's. While ratoon cropping seems to be the major factor in yield decline, in the mauka fields, a genuine yield decline-not caused by ratooning, as well as a ratoon yield decline, is observed in the makai section.

Finally, it should be mentioned that the nutrient status in the soil shows an opposite trend. The lowest amount of available potassium was found after the 1965 harvest, while the potassium reserve steadily increased thereafter.

3. CLIMATE AND MANAGEMENT IN RELATION TO CROP PRODUCTION

The atmosphere influences crop growth in many ways: It provides energy in the form of sunlight necessary for photosynthesis, it regulates the rate of photosynthesis, and respiration through air temperature and the rate of nutrient uptake by the roots through soil temperature, it provides CO_2 and O_2, which are essential in biochemical processes and finally it provides water in the form of rainfall which is an important constituent of all processes in the plant that influence growth.

The processes of photosynthesis and respiration can be expressed in the following simplified equations (Chang, 1968):

Photosynthesis: $CO_2 + H_2O + \text{Energy} \longrightarrow (CH_2O) + O_2 - 2000$ cal.

Respiration: $(CH_2O) + O_2 \longrightarrow H_2O +$ heat of combustion.

From these two equations it becomes apparent that plant growth depends on the excess of dry matter production from photosynthesis over the loss of dry matter due to respiration. This net gain is called net photosynthesis. While photosynthesis only takes place during daylight hours, respiration is a 24-hour process. Since respiration increases with increasing temperature, it is obvious that areas with a high diurnal temperature difference and a low night temperature are potentially high-producing areas. In Hawaii, the sugar cane plantations with a large diurnal temperature range and a low night temperature are known to have a better juice quality, according to Das (1931).

The correlation between photosynthesis and radiation is high for a dense crop with a minimal loss of light. Sugar cane in Hawaii, according to Chang (1968), intercepts a good deal of sunlight throughout its growing season, with radiation playing an important role in the final yield in areas of adequate water supply. He reports a straight line relationship ($Y = -17.77 + 0.055X$) between radiation in langleys per day and yield in Ton Sugar per Acre at Pepeekeo plantation.

However, without an adequate water supply, crop production will be reduced. Water, available for plant growth can be supplied in three ways: by rainfall, irrigation or ground water. Since the roots of the cane plant are considered to be the most important mechanisms of water uptake, most attention is given to the availibility of water in the soil. Irrigation practices are largely governed by the soil moisture capacity (see Chapter II). To what extent the leaves may absorb water is not known, but Chang (1968) mentions that many plants can directly absorb moisture from unsaturated air of high humidity. In this context Hudson (1969) observed a marked response in growth due to a shower of less than 1 mm at night for eight-month old cane in a commercial field. He found that growth responded better to a light shower in the evening than to 50 mm (2 inches) surface irrigation the next day. Another climatic factor, directly related to irrigation management is evaporation. Evaporation and evapotranspiration are closely related and according to Chang (1968), the ratio approaches 1.0 for sugar cane six months after planting. The evaporation pan is therefore used in computing the water needs for the crop. This 1 : 1 ratio is strongly criticized by Ewart (1965), who found under controlled test conditions for the same cane variety a correlation coefficient between evaporation and evapotranspiration of 0.39. He states that yields and rate of growth per unit area is influenced largely by field operating conditions and not solely by the energy potential available in the atmosphere. The evaporation pan registers this potential high level of optimum growth and water extraction. However different fields would only grow and utilize water at a below optimum level. Therefore, consumptive use under 1 : 1 ratio concept is based on the assumption of absolute storage capacity (of the soil), complete utilization (of water) and optimum yield potential.

The results of yield-climate relationships in WACO will be presented in the form of regression equations. Since the plantation has 29 rainfall stations scattered over the area, the yield-rainfall relationship will be discussed in more detail. However, the interactions among factors like rainfall, radiation and evaporation have to be considered first. Three stations have complete monthly records over the last ten years, while radiation measurements in Kawaihapai were temporarily stopped as reported earlier. Evaporation can not be considered a completely independent climatic factor; the evaporative power of the air is determined by temperature, wind humidity and especially radiation (Chang, 1968). Figure 32 shows the high correlation between evaporation and radiation at the three sites, based on monthly averages. Ekern (1970) however, reports that the correlation between daily radiation and daily evaporation is not very significant. Strong positive advection of heat from surroundings makes evaporation greater than the full net radiation. The relation of monthly rainfall and radiation is however curvilinear as Figure 33 demonstrates. High rainfall usually occurs during short periods and, therefore, radiation levels off in months of high rainfall. If the total rainfall for a given crop season is compared with total radiation for the same period, no relation is observed, while the relation between total radiation and total evaporation is apparent (Figure 34). The effect of rainfall on yield should, therefore, be considered independent of the effect of radiation and evaporation on yield. In this area high rainfall does not necessarily coincide with low radiation, which in other areas might be one of the unfavorable growth factors. There are, however, other direct effects of rainfall that influence yield. The total rainfall for the growing period is split up in total rainfall received during

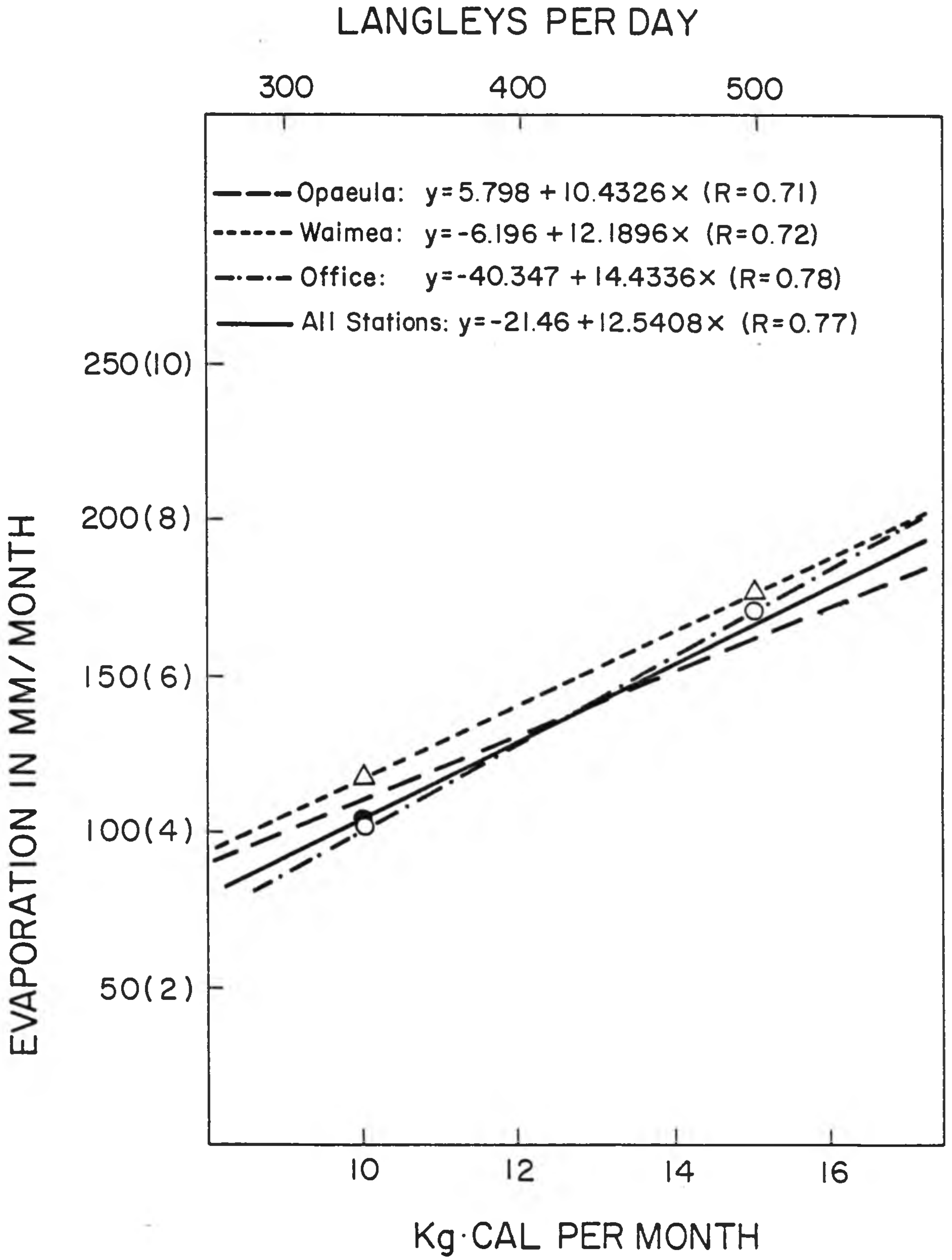


FIGURE 32. RELATIONSHIP BETWEEN MONTHLY RADIATION, AND MONTHLY EVAPORATION FOR THREE SITES IN WACO

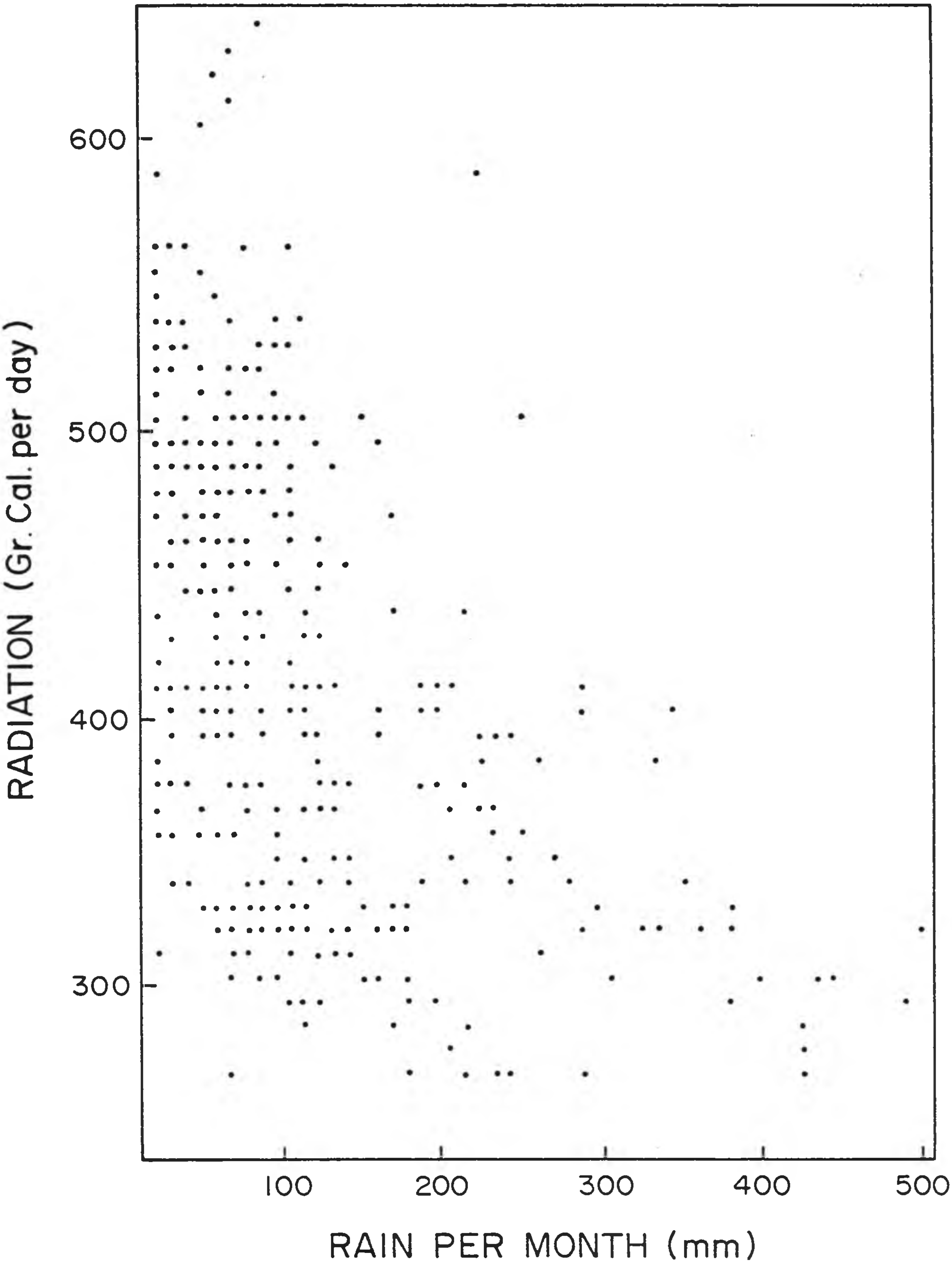


FIGURE 33. RELATION BETWEEN MONTHLY RAINFALL AND MONTHLY RADIATION

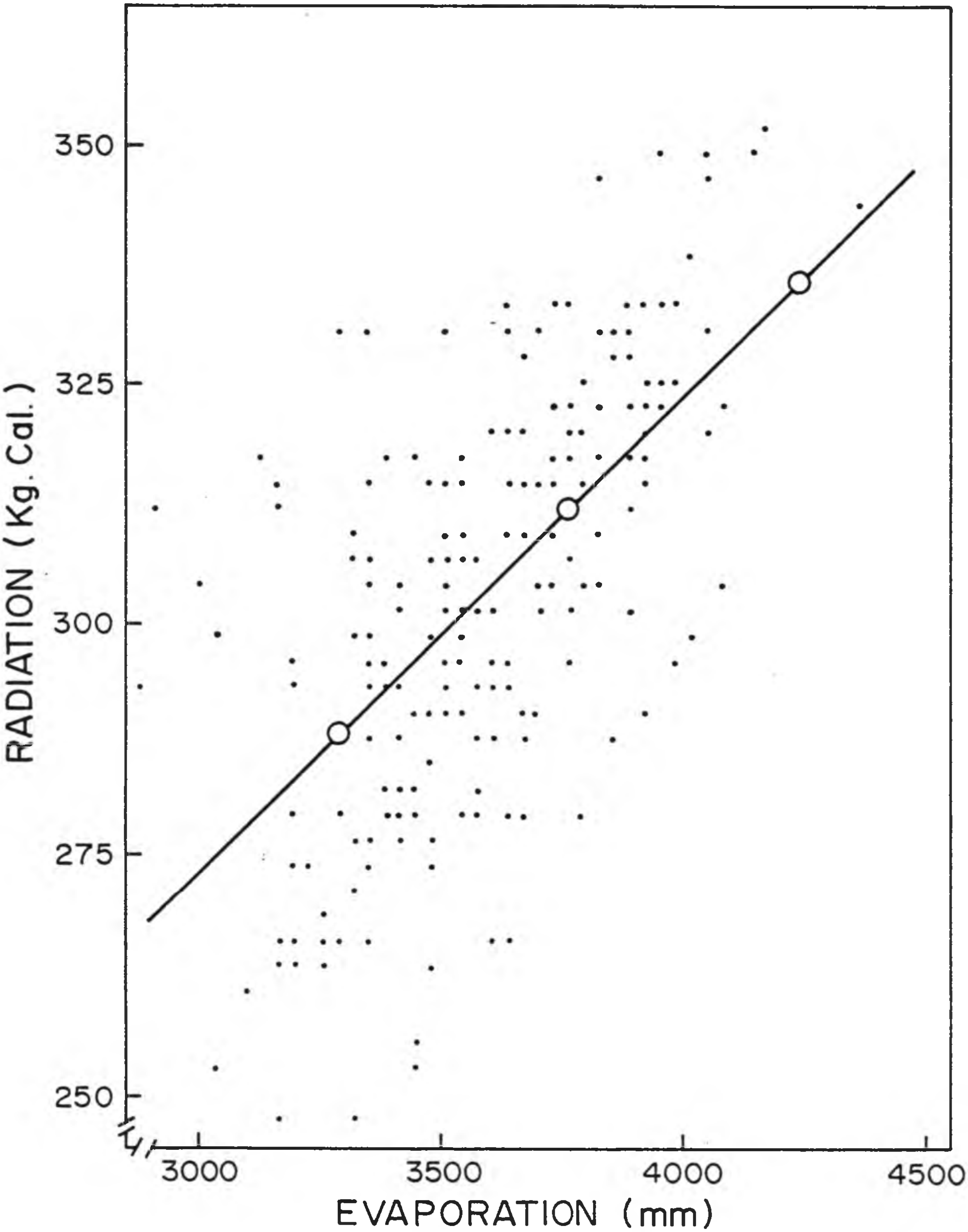
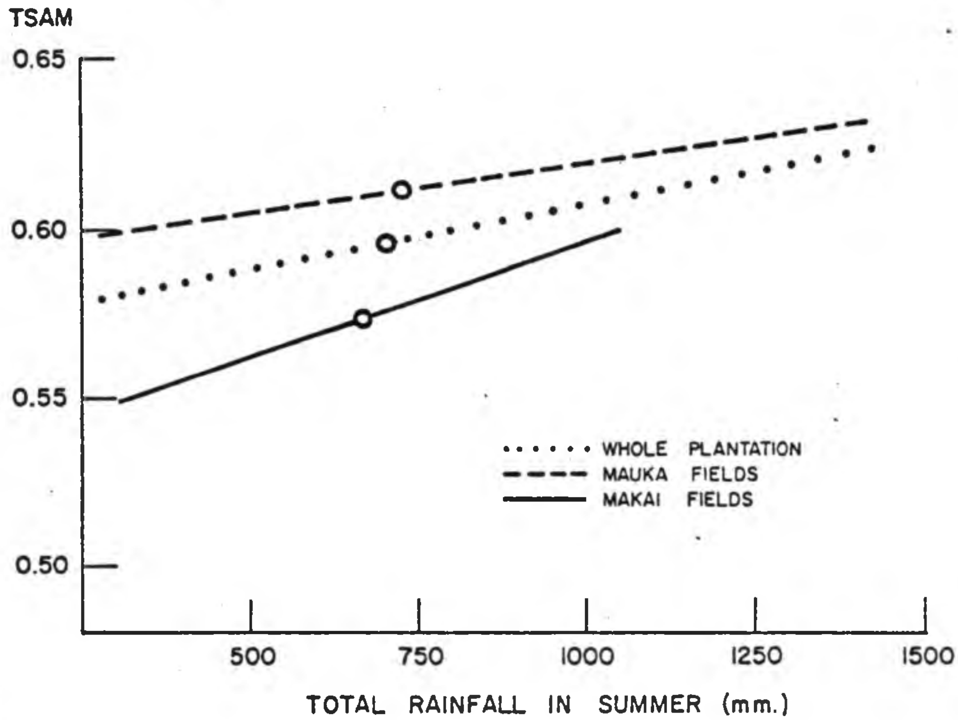


FIGURE 34. RELATION BETWEEN TOTAL EVAPORATION AND TOTAL RADIATION DURING GROWTH PERIOD.

summer and total amount received during winter. Figure 35 illustrates the unfavorable effect of winter rainfall in comparison with the favorable effect of summer rainfall.

The negative effect of rainfall during the winter period (October through March) can be explained in many ways: Heavy rain storms cause erosion on sloping land to such an extent that furrows, following the contour lines, overflow and young cane is washed away. In the low lying areas significant drainage problems arise during winter, which may seriously affect the growth of cane. On the other hand, rain during the summer will be more effectively used by the crop because heavy storms are infrequent during the summer. According to Leopold (1948) hours of maximum rainfall in summer are between 9 p.m. and 7 a.m. at Waimea and Opaeula. The beneficial effect of rainfall at night has been pointed out earlier.

The effect of the seasonal variation in climate on the sugar yield can also be seen when the average yield for the month in which the cane is planted or harvested is calculated. Table XXIII summarizes the general climate in spring, summer and fall, for the low lying areas, represented by Office station and the mountain fields represented by Opaeula station.



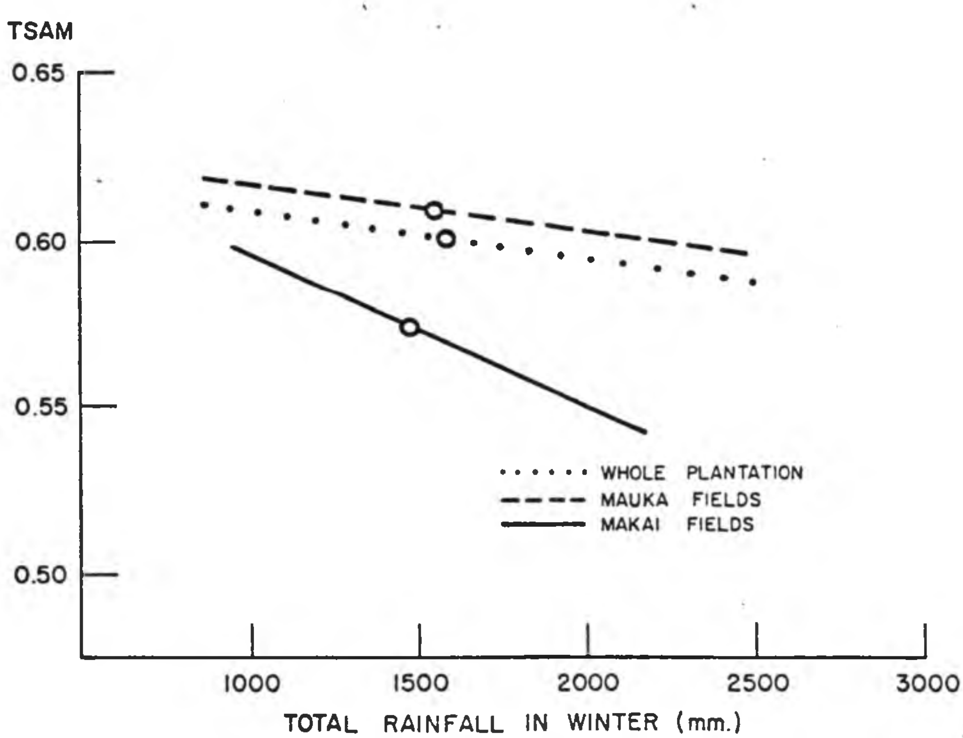


FIGURE 35. SUGAR YIELD IN RELATION TO TOTAL RAINFALL IN SUMMER AND TOTAL RAINFALL IN WINTER

TABLE XXIII

MEDIAN MONTHLY RAINFALL, RADIATION, MAX. TEMPERATURE, MIN. TEMPERATURE AND DIURNAL TEMPERATURE DIFFERENCE FOR OFFICE AND OPAEULA DURING SPRING (MARCH, APRIL), SUMMER (MAY THROUGH AUGUST) AND FALL (SEPTEMBER THROUGH NOVEMBER)

	Spring		Summer		Fall	
	Office	Opaeula	Office	Opaeula	Office	Opaeula
Rain (mm)	65	85	22	40	37	60
Radiation (gr.C)	420	396	511	455	429	408
Max. Temp.	79.6	77.7	84.8	81.2	83.5	81.1
Min. Temp.	61.9	64.8	65.5	68.7	64.9	68
Diurnal (Diff.)	18.0	12.6	19.3	12.1	18.8	11.8

Except under special conditions, no planting or harvest operations are carried out during winter. Figures 36 and 37 show the yield fluctuation as a function of the month of planting and harvest. The fluctuations generally coincide with the climatic fluctuations. Since the age of the crop fluctuates between 23 and 24 months, the general trend of the planting month should coincide with that of the month of harvest. The higher yields during the summer months can be explained by the high radiation, low rainfall and high diurnal difference in temperature. These conditions are considered favorable for high juice quality. By decreasing the moisture content of the stalks, cane growth stops and dehydration enhances the conversion of reducing sugars to

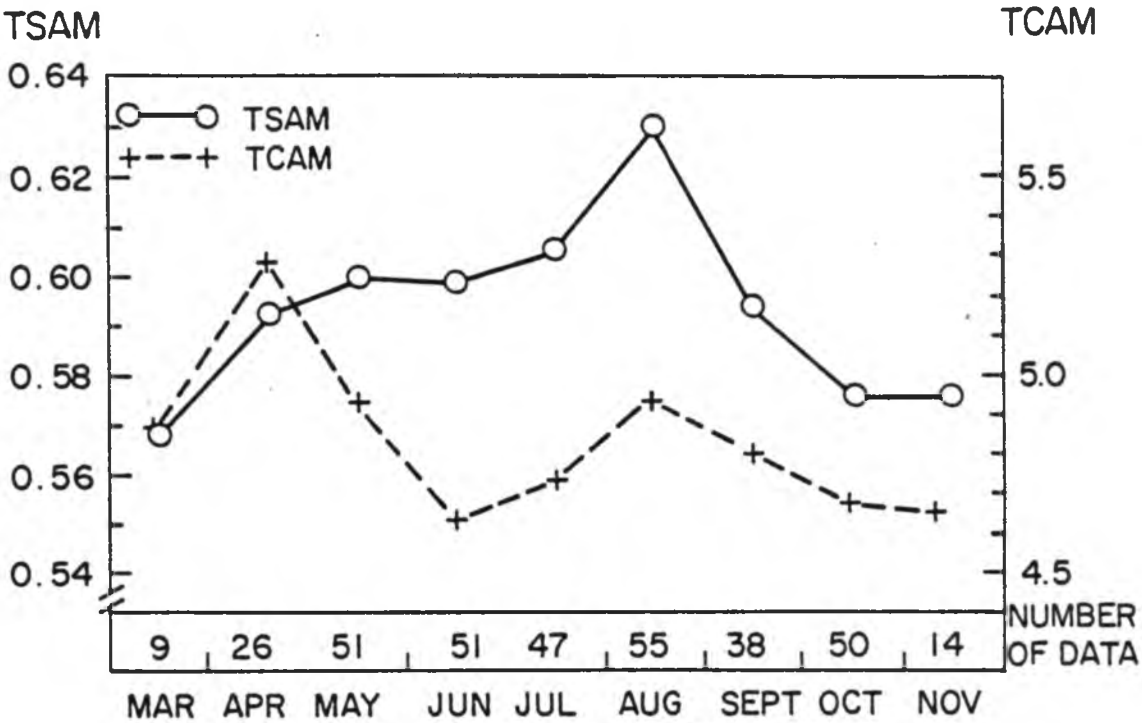


FIGURE 36. RELATION BETWEEN MONTH OF PLANTING AND YIELD

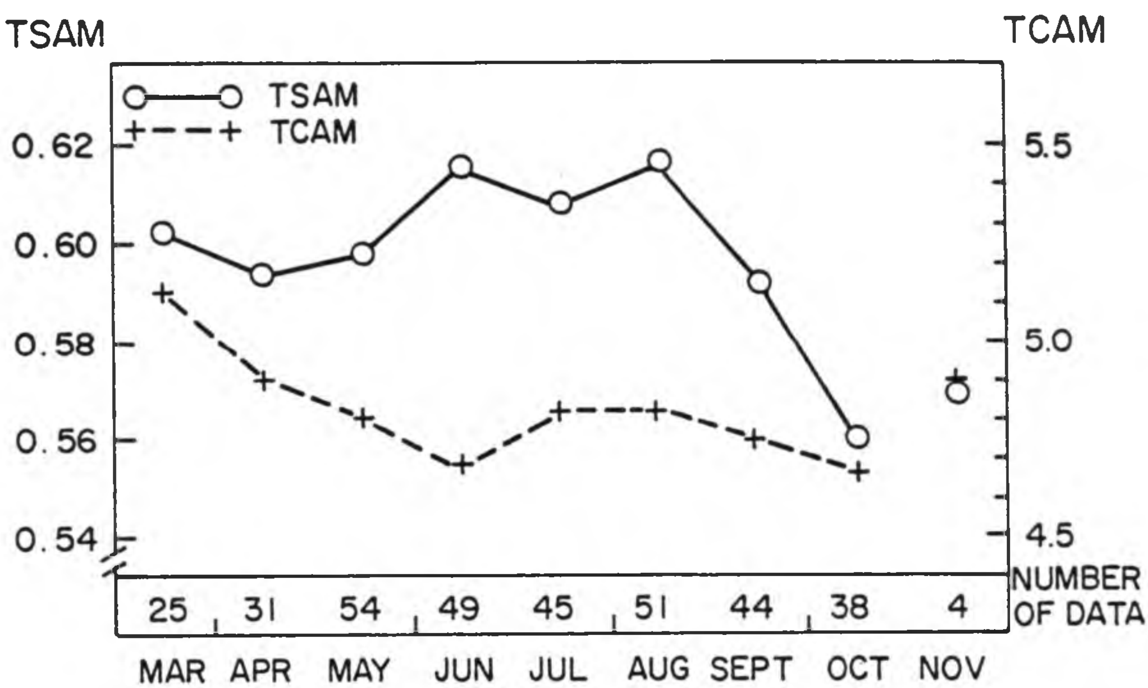


FIGURE 37. RELATION BETWEEN MONTH OF HARVEST AND YIELD

sucrose (Humbert, 1968). Therefore, many sugar plantations stop irrigation two to three months before harvest.

Cane harvested in early spring cannot adequately ripen because of the rainy winter months. This explains the lower yields during spring harvest. In addition the uptake of P and N by the roots is severely restricted at soil temperature below 70°F. If it is assumed that the air temperature equals the root temperature under a full canopy, cane growth in winter will be much lower than during the summer. Hart (1965) presents definite evidence that low root temperature on sunny days do actually retard transloca-tion of sucrose from the leaf. This leads to accumulation of sucrose in the blade, which may in turn depress the rate of photosynthesis and thus decrease yield. Burr (1952) points out that in cold, wet soils germination is often slow and requires replanting. In addition increasing night temperature has a negative effect on the total sugars as reported by Humbert (1968). This may affect the drop in sugar yield observed in September, when other climatic conditions are still optimal. The cane yield shows more or less a reverse trend being high in spring and low in summer. This underlines the above statement by Humbert. Shoji (1965) reports that low minimum temperature is significantly correlated with high sucrose content in Puerto Rico and he cites Capo (1962) who found a significant correlation of the difference between the daily maximum and minimum temperature one month before harvest. High diurnal difference in temperature is observed in summer months in the low lying areas and may favorably influence the sugar yield. However, if the sugar yields from the makai fields are compared with those of the mauka fields, where a significant lower diurnal difference in temperature exists, it becomes apparent that the regional variation in temperature is not limiting the growth of cane because mauka fields still give higher yields than makai fields (see Figure 38).

Another observation from this figure is the drop in yield in fields harvested in July, compared to June and August. This drop in yield coincides with a rainfall peak during this month (see Figure 3), which may negatively affect harvest operations.

Finally, some discrepancies between the yield and month of planting compared to month of harvest should be discussed. The relatively high sugar yield observed in March-harvests might be related to the age of the cane. The same arguments can be put forward when the very low sugar yields, if planted in March, are considered. Sugar cane planted in March is 23.9 months on the field (varying from 23.4 to 25.3 months) while sugar cane harvested in March is 22.8 months on the field (varying from 21.9 to 23.9 months). While Ton Sugar per Acre increases with age, Ton Sugar per Acre per Month decreases with age (see Figure 39). From this figure it is evident that increasing age reduces TSAM, while TSA levels

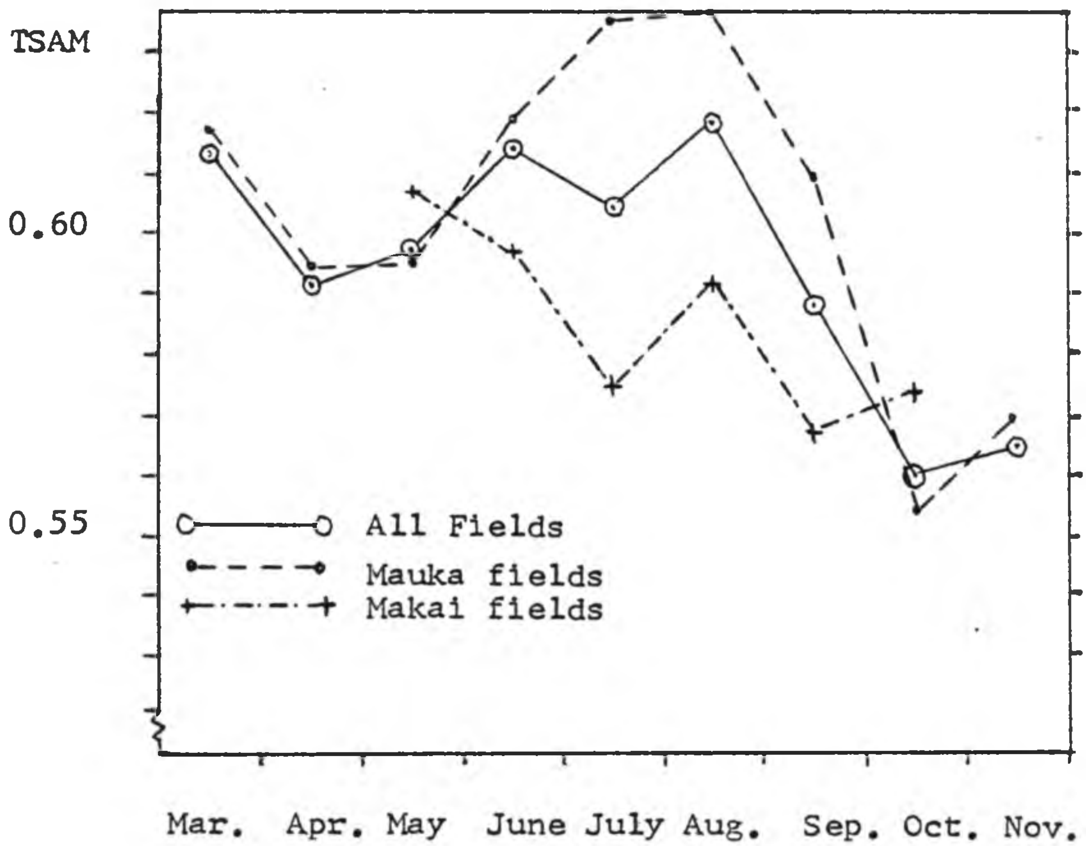


FIGURE 38. RELATION BETWEEN MONTH OF HARVEST AND SUGAR YIELD IN MAKAI AND MAUKA SECTION OF WACO

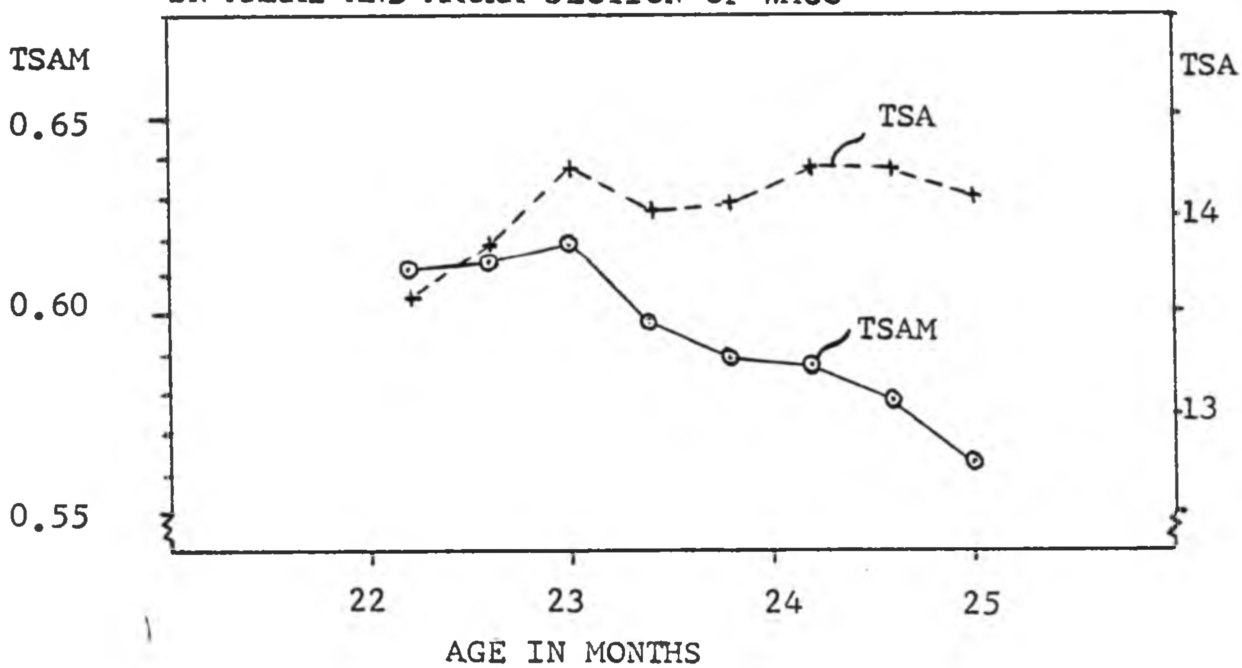


FIGURE 39. RELATION BETWEEN AGE OF CROP AND SUGAR YIELD

off at 23 to 24 months. The relation between TSAM and age is best expressed by a quadratic regression equation at 1% level:

$$Y = -0.1326 + 0.0829X - 0.0022X^2 \text{ , (age between 21 and 26 months).}$$

The low yields obtained when planted in October or November may be reflected by the increasing rainfall in this period, which often hampers the planting and harvest operations. In addition, the seed pieces will germinate slowly because of low temperatures in winter and the young cane is very susceptible to adverse conditions caused by rain storms during winter. Also, cane harvested in October has been at least 24 months on the field.

Although the seasonal variation in climate has an important influence on the sugar yield, it was not possible to relate the regional variation in climate to sugar production. The most important draw-back is the few observation stations in this area. The three stations, where radiation is measured do not satifactorily represent the regional variation in climate. In addition, the grouping of fields per station as practiced by WACO most probably does not represent the actual climatic situation of the fields. The "Office group" includes mauka fields, while the "Opaeula group" includes makai fields. However, even if only yields on the fields around the three stations are related to total radiation, no significant correlation is observed. The regression line tends to have a negative slope, meaning that the area with higher radiation (Office) gives lower yields than those fields with lower radiation (Opaeula). This same trend has been observed earlier with the nutrient status of the soil. As stated before this does not imply that radiation, respectively nutrient status have a negative effect on yield, but that other factors dominate in this area.

It can be pointed out that the radiation figures should be corrected to account for the slope factor and the exposure to the sun. Sellers (1965) outlines the calculations involved. The ratio of solar radiation on a sloping plane ($I_{pl.}$) and solar radiation on a horizontal surface ($I_{hor.}$) can be expressed as follows:

$$\frac{I_{pl.}}{I_{hor.}} = \frac{\cos B}{\sin E} = \frac{\cos i \sin E + \sin i \cos E \cos A}{\sin E} =$$

$$\cos i + \sin i \operatorname{cotg} E \cos A$$

in which:

i = angle of the sloping surface

A = Azimuth angle at noon

E = Solar elevation = (90° - latitude - declination of the sun)

The ratio has been calculated for two-week intervals for a 5% and 10% slope for S, SE, E, NE, N, NW, W, and SW facing slopes at noon. Figure 40 illustrates the seasonal variation of this ratio.

South facing slopes generally receive more radiation than North facing slopes during the winter months which difference increases with the angle of the slope. During the summer months (from May until August) the ratio is approximately 1.0, which means that neither slope nor exposure influences the amount of sunlight received at this latitude. In WACO, the majority of the fields have slopes around 5% and are facing NW. Radiation in those areas are just below 1 throughout the year. It is questionable if this difference is measurable. From these calculations it can be concluded that corrections for slope and exposure will not change the reported radiation measurements significantly. Even the North facing fields on the steeper slopes will at the most receive 10% less sunlight than the horizontal fields and this only during December and January. Another factor, that might add to a reduced radiation in this particular section is the shadow effect of the Waianae range, whose North slope is very steep (see e.g. Figure 27). Although no actual radiation data are available for this section, sunlight may become limiting in that area. Yields are generally lower there. The same trend can be observed in the highest section of the plantation located on the Wahiawa

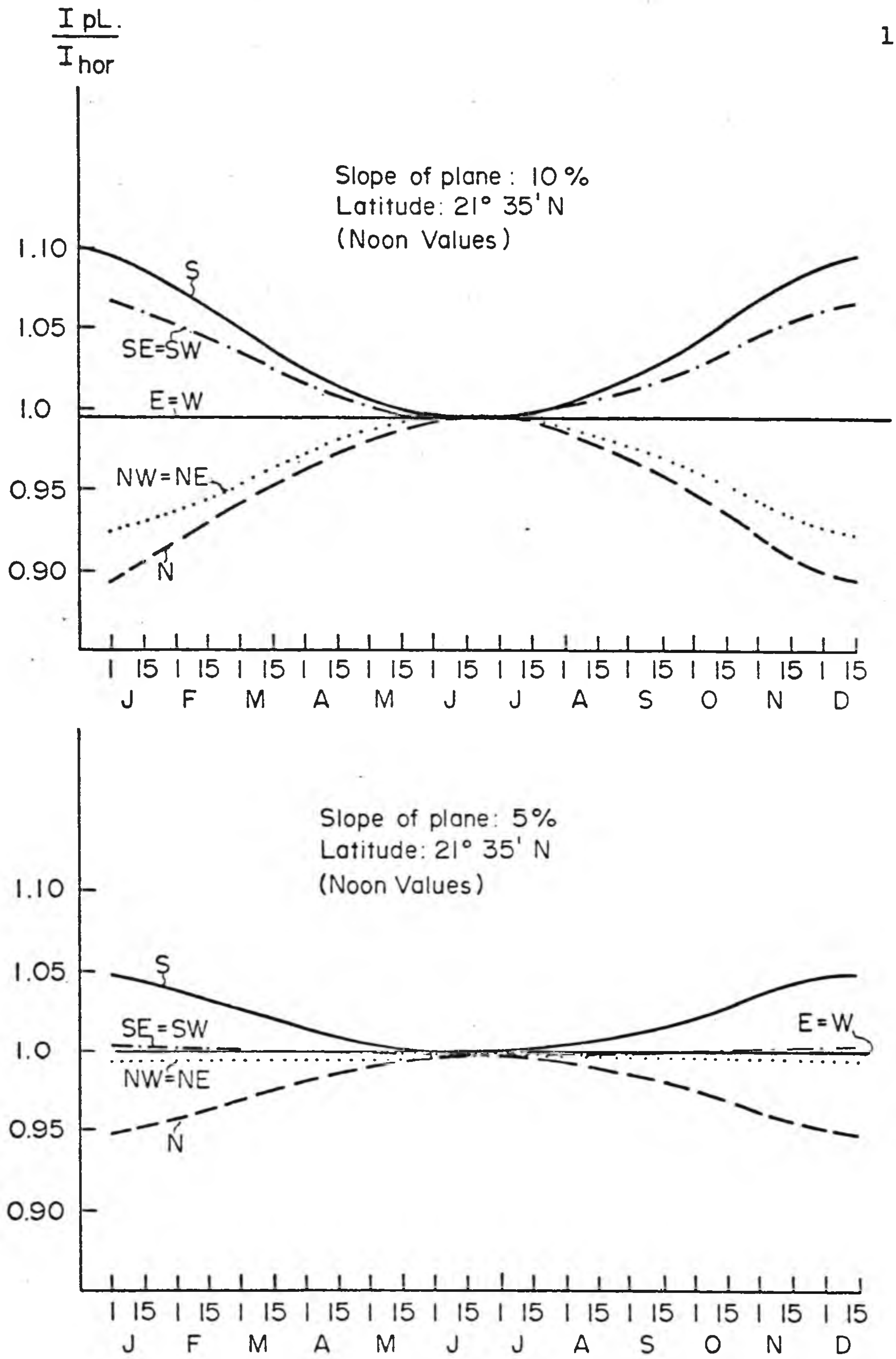


FIGURE 40. SEASONAL VARIATION OF THE RATIO OF SOLAR RADIATION BETWEEN SLOPING AND HORIZONTAL SURFACES FOR TWO DIFFERENT SLOPES AND EIGHT ASPECTS.

and Leilehua soil series, which decrease in yield with increasing elevation might be correlated with increasing cloudiness.

4. YIELD ESTIMATION

The ultimate goal of any research dealing with crop production is to estimate the yield based on measurable variables. In the previous sections some of the more important variables have been discussed in relation to crop growth. However, most of the analyses were based on the relationship between yield and single variables, although in some instances the records were grouped in an attempt to remove one of the interacting variables (e.g. crop cycle, mauka versus makai section). In this section all variables are interpreted simultaneously in relation to yield by using the technique of stepwise multiple regression.

The following variables have been used:

A. Climatic Variables

1. RAINS (rainfall in summer) measured in mm
2. RAINW (rainfall in winter) measured in mm
3. RAINH (rainfall at month of harvest) measured in mm
4. RAINB (rainfall one month before harvest) " " "
5. EVAP (pan evaporation on monthly basis)
6. RADI (radiation on monthly basis) gr. cal/100
7. MAXT (max. temp. at harvest) in degree Fahrenheit

8. MINT (min. temp. at harvest) in degree Fahrenheit
9. DIFT (diurnal difference in temperature at harvest)

B. Management Variables

1. HARM (month of harvest) coded
2. AGE (age in months)
3. CRCY (crop cycle) coded
4. WATM (monthly application of irrigation water) in mm
5. NITR (total nitrogen applied) in kg/ha
6. P_2O_5 (total P_2O_5 applied) in kg/ha
7. K_2O (total K_2O applied) in kg/ha
8. RIPD (days after last round of irrigation)

Coding of the harvest month and crop cycle was done according to the average yield for that month or cycle, which was determined by using all data. Although it is realized that a certain bias is involved in this practice, it is believed to be the most satisfactory way of coding these two variables. The coding is as follows:

Month of harvest	Code	Crop Cycle	Code
March	6.13	Plant crop (1st cycle)	6.25
April	5.92	1st ratoon (1st cycle)	5.97
May	5.97	2nd ratoon (1st cycle)	5.84
June	6.14	3rd ratoon (1st cycle)	5.74
July	6.04	plant crop (2nd cycle)	6.03
August	6.18	1st ratoon (2nd cycle)	5.79

Month of Harvest	Code	Crop Cycle	Code
September	5.88	2nd ratoon (2nd cycle)	5.67
October	5.60		
November	5.65		

C. <u>Soils</u>

The soil factor was introduced by splitting the data in five groups according to the mapping units (see Figure 41). The following groups were selected:

1. Montmorillonitic group (Pearl Harbor; Kaena; Haleiwa).

2. Alluvial group (Kawaihapai; Pulehu; Waialua (level phase)).

3. Lahaina group (Lahaina series, all phases).

4. Ewa, Wahiawa group (Wahiawa (all phases); Ewa (level phase)).

5. Sloping group (Ewa and Waialua (sloping and stony phases))

In subsequent sections three sets of variables will be correlated with sugar yield. First management variables are used, secondly management + climatic variables, while the third step combines these variables with the above mentioned soil groups.

1. <u>Management Factors in Relation to Yield</u>

Table XXIV shows which management variables are

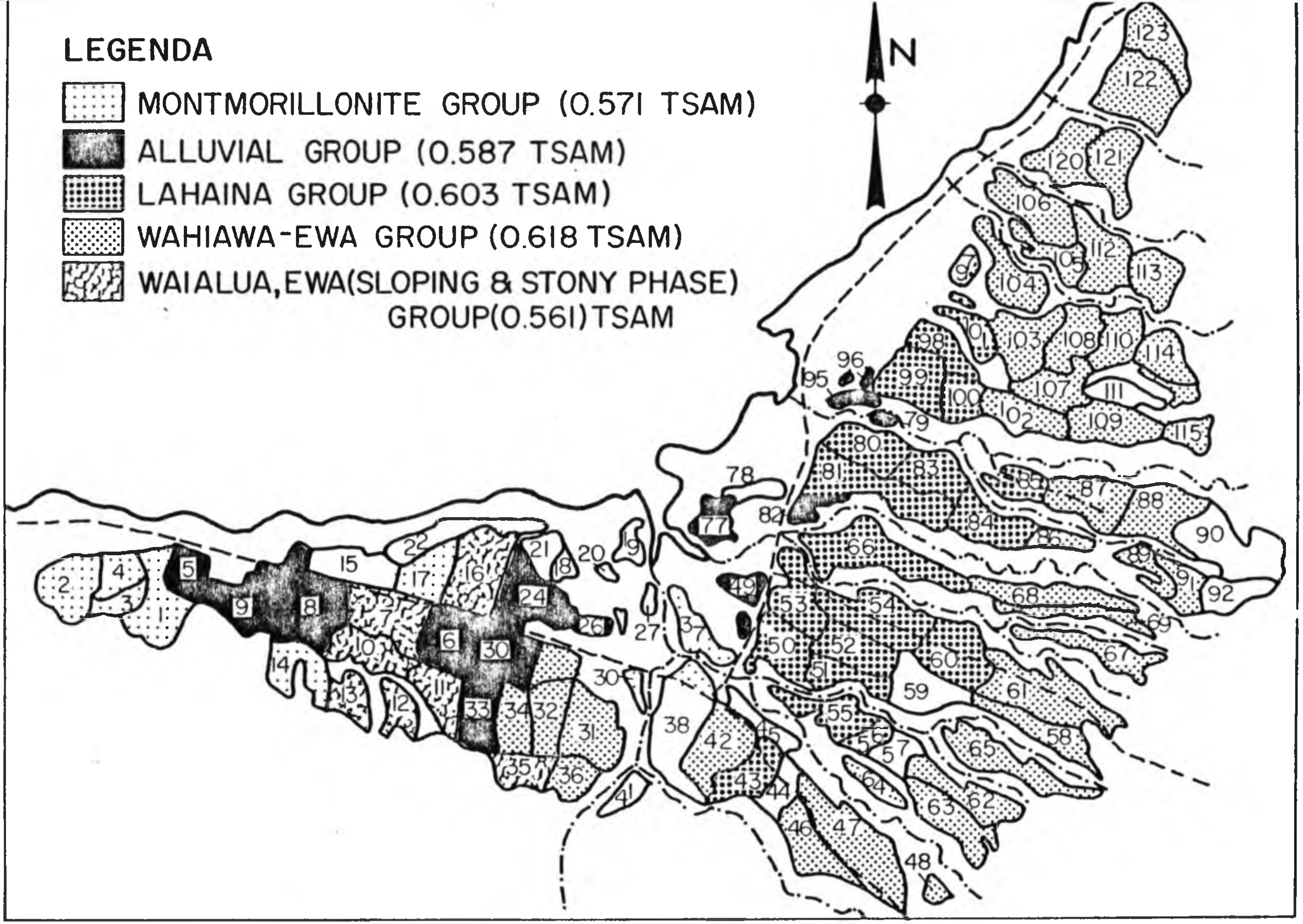

LEGENDA
MONTMORILLONITE GROUP (0.571 TSAM)
ALLUVIAL GROUP (0.587 TSAM)
LAHAINA GROUP (0.603 TSAM)
WAHIAWA-EWA GROUP (0.618 TSAM)
WAIALUA, EWA(SLOPING & STONY PHASE) GROUP(0.561) TSAM
N

FIGURE 41.

TABLE XXIV

CORRELATION MATRIX FOR MANAGEMENT VARIABLES AND TSAM

		1	2	3	4	5	6	7	8	9
1.	HARM		5	NS	5 +	NS	NS	NS	NS *	1 **
2.	AGE	-0.14		5	NS	NS	NS	NS	NS	1
3.	CRCY	0.06	-0.16		NS	1	5	1	NS	1
4.	WATM	-0.14	0.06	-0.12		5	5	NS	NS	NS
5.	NITR	0.00	0.09	-0.31	0.16		5	1	NS	NS
6.	P_2O_5	-0.03	0.08	0.14	0.15	0.16		1	5	NS
7.	K_2O	-0.02	-0.08	-0.28	0.07	0.49	0.21		1	NS
8.	RIPD	0.10	-0.04	0.07	-0.04	0.11	0.15	0.21		NS
9.	TSAM	0.38	-0.30	0.32	0.04	0.04	0.04	0.09	-0.00	

* NS = Non significant ($r < 0.14$)

\+ 5 = Significant at 5% level ($0.14 < r < 0.18$)

** 1 = Significant at 1% level ($r > 0.18$)

significantly correlated with each other and with yield. It is obvious from this Table that month of harvest, age of the crop, and crop cycle are highly correlated with yield. None of the other factors are of significance in relation to yield. However, it should be noticed that fertilizer application interacts significantly with crop cycle.

Nitrogen and potash applications are negatively, but phosphorus application is positively correlated with crop cycle. This means that more N and K is applied to the first ratoon crop, while more P is given to the plant crop. Table XXV shows the average amount of fertilizers applied to plant crop and ratoon crop for the mauka and makai section of the plantation.

TABLE XXV

AVERAGE AMOUNT OF N, P_2O_5 AND K_2O APPLIED FOR DIFFERENT CROP CYCLES IN MAUKA AND MAKAI SECTION OF WACO (ALL DATA IN kg/ha)

Crop Cycle	Mauka			Makai		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
First plant crop	348	202	364	309	109	205
1st ratoon	360	89	412	336	25	209
2nd ratoon	363	119	431	327	65	250
3rd ratoon	358	198	438	350	149	310
2nd plant crop	353	169	429	330	149	273

Table XXVI shows the cumulative R^2 and the regression coefficient for each variable. The negative sign for ripening days can be explained by the low yields of crops harvested in spring. For such crops, the last round of irrigation was in late fall, which in turn resulted in the high number of ripening days since normally no extra water is applied during the winter months. The management factors used explain 33.7% of the yield variation. Figure 43 shows how the actual yield is related to the estimated values. The regression line, based on these values is:

$$Y_{est} = 0.400 + 0.340\ Y_{obs}$$

TABLE XXVI

LINEAR REGRESSION COEFFICIENTS AND R^2 (CUMULATIVE) AT EACH STEP FOR MANAGEMENT VARIABLES IN RELATION TO TSAM

Step	Variable	R^2(cum)	Regression Coefficient
1	HARM	0.1483	0.09375
2	CRCY	0.2354	0.09643
3	AGE	0.2800	-0.01251
4	K_2O	0.3048	0.00006
5	WATM	0.3208	0.00013
6	RIPD	0.3311	-0.00009
7	NITR	0.3366	0.00014
8	P_2O_5	0.3374	-0.00002
	CONSTANT		-0.32390

2. Management + Climatic Variables in Relation to Yield

Although it is realized as pointed out earlier, that the radiation and evaporation data for each crop yield do not satisfactorily represent the actual radiation and evaporation pertaining to that yield, they are included in the subsequent multiple correlations mainly to stress the point of possible interactions between climatic and management variables. Table XXVII shows the significance of interactions among those variables that are highly correlated with yield.

The most significant interaction between management and climatic factors is the happenstance negative correlation between crop cycle and evaporation as well as radiation. This means that the plant crop received less sunlight than the ratoon crop. This relation can be explained by means of Figures 31 and 42. The radiation during the summer generally increased since 1964, the land area under ratooning increased but the yield declined during the same period. Table XXVIII demonstrates that through stepwise regression techniques it is possible to account for this interaction. Radiation, which was negatively correlated with yield as a single variable, is now positively correlated.

The cumulative R^2 shows that by including the climatic variables 45.46% of the yield variation can be explained. The actual plot of observed versus estimated values (see Figure 43) clearly indicates that the scattered points tend

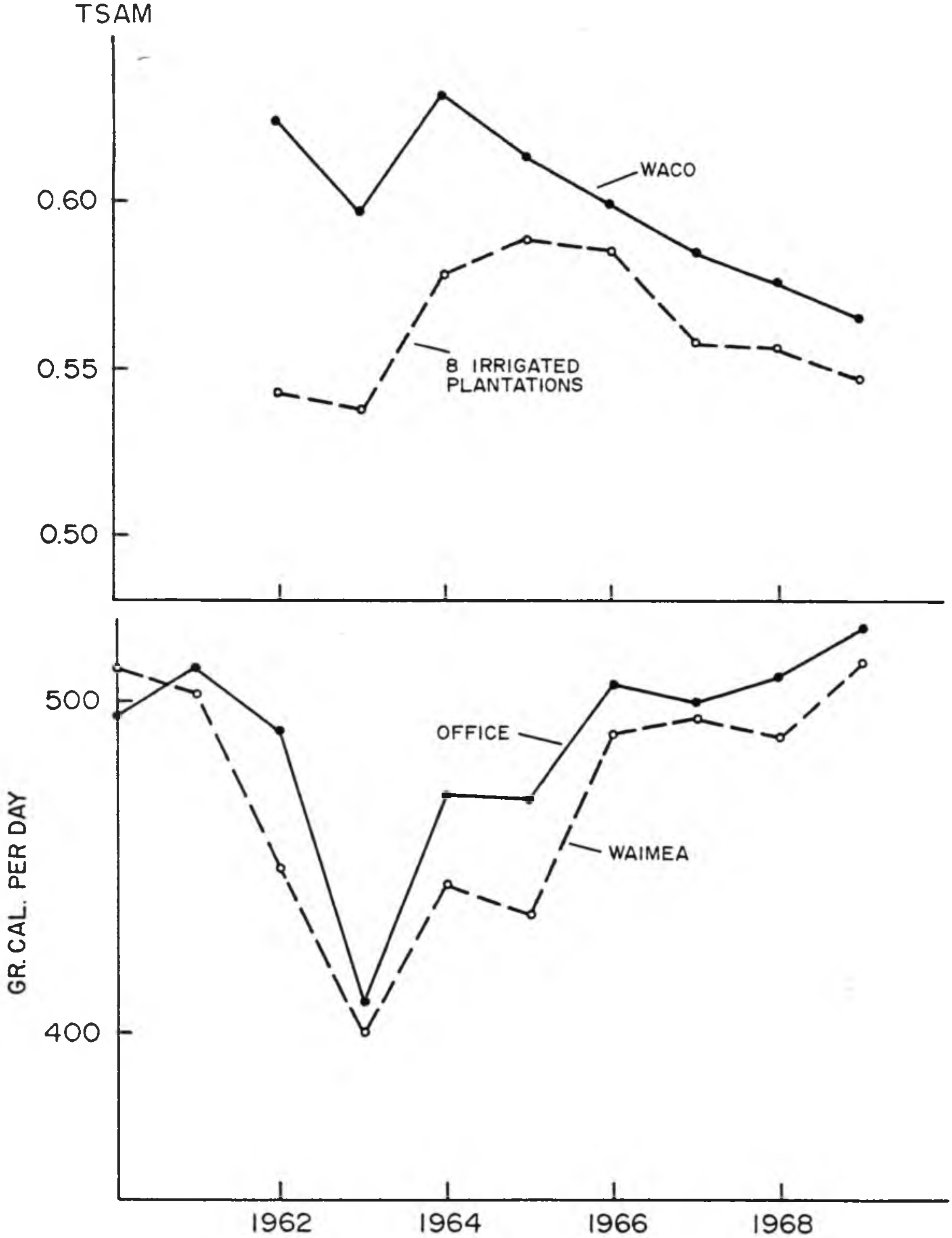


FIGURE 42. RELATION BETWEEN YEAR OF HARVEST AND YIELD AND MONTHLY RADIATION DURING SUMMER MONTHS

TABLE XXVII

CORRELATION MATRIX FOR THOSE CLIMATIC AND MANAGEMENT VARIABLES, THAT ARE HIGHLY CORRELATED WITH TSAM

	1	2	3	4	5	6	7	8	9
1. HARM		5	NS	1	NS	NS	NS	5	1
2. AGE	-0.14		5	5	NS	1	1	NS	1
3. CRCY	0.06	-0.16		1	1	1	1	1	1
4. RAINS	0.27	0.14	0.25		NS	1	1	1	1
5. EVAP	-0.04	0.01	-0.37	0.03		1	1	1	1
6. RADI	-0.09	0.19	-0.35	-0.39	0.49		1	1	1
7. MAXT	-0.09	0.20	-0.27	-0.28	0.24	0.29		1	1
8. DIFT	-0.14	0.11	-0.28	-0.46	0.26	0.39	0.64		1
9. TSAM	0.38	-0.30	0.32	0.27	-0.25	-0.27	-0.27	-0.33	

NS = Non significant ($r < 0.138$)

5 = Significant at 5% level ($0.138 < r < 0.181$)

1 = Significant at 1% level ($r > 0.181$)

TABLE XXVIII

LINEAR REGRESSION COEFFICIENTS AND CUMULATIVE R^2 AT EACH STEP FOR CLIMATIC AND MANAGEMENT VARIABLES IN RELATION TO TSAM

Step	Variable	R^2 (cum)	Regression Coefficient
1	HARM	0.1483	0.07043
2	CRCY	0.2354	0.05483
3	DIFT	0.2908	-0.00294
4	AGE	0.3293	-0.01729
5	RAINB	0.3507	-0.00014
6	NITR	0.3780	0.00021
7	WATM	0.3906	0.00017
8	RAINS	0.4079	0.00006
9	EVAP	0.4318	-0.00014
10	K_2O	0.4369	0.00003
11	RADI	0.4396	0.00090
12	P_2O_5	0.4435	-0.00004
13	MINT	0.4472	-0.00208
14	RAINH	0.4528	-0.00007
15	RIPD	0.4542	-0.00004
16	RAINW	0.4546	-0.00000
	CONSTANT		0.36978

to concentrate more along the expected line than when management variables were correlated alone. The regression equation, based on these points is as follows:

$$Y_{est} = 0.326 + 0.454\ Y_{obs}$$

3. <u>Soils, Climate and Management in Relation to Yield</u>

In order to introduce the soil factor in the yield estimation equation, the fields were divided on the basis of soil series. Five groups were formed.

a. The "Montmorillonite" Group

Within this lowland group evaporation turned out to be the most significant factor, positively correlated with yield. Significant negative correlation was found with the amount of water supplied, rainfall at harvest time, rainfall during winter and rainfall one month before harvest. This means that in spite of the relatively low rainfall in this area, all factors that contribute to more water to the plant are negative. Poor drainage and stickiness of the soil may be the main causes for this observation. The average yield of the data in this group is 0.571 TSAM (Standard deviation 0.0352) and the regression coefficients as well as the cumulative R^2 are given in Table XXIX. Within this group we can explain 84% of the yield variation.

b. The "Alluvial" Group

This group is also located in the makai side of the

TABLE XXIX

LINEAR REGRESSION COEFFICIENTS AND CUMULATIVE R^2 AT EACH STEP FOR CLIMATIC AND MANAGEMENT VARIABLES IN THE "MONTMORILLONITE" GROUP IN RELATION TO TSAM

Step	Variable	R^2 (cum)	Regression Coefficient
1	EVAP	0.2829	0.00115
2	WATM	0.3830	-0.00028
3	RAINH	0.4906	-0.00042
4	RAINW	0.6401	-0.00019
5	RADI	0.6704	0.00285
6	DIFT	0.7564	-0.00264
7	AGE	0.7845	0.03453
8	K_2O	0.7996	-0.00008
9	P_2O_5	0.8116	0.00011
10	CRCY	0.8430	0.04385
	CONSTANT		-0.64097

plantation. Excluded from the alluvial group are those fields that are stony or very shallow. Table XXX gives the regression coefficient and cumulative R^2.

In this group evaporation again plays a major role but is now negatively correlated, while the factors that supply water to the cane are positively correlated. Month of harvest and age of the crop seem to be more important factors to the final yield.

TABLE XXX

LINEAR REGRESSION COEFFICIENTS AND CUMULATIVE R^2 FOR CLIMATIC AND MANAGEMENT VARIABLES AT EACH STEP IN THE "ALLUVIAL" GROUP IN RELATION TO TSAM

Step	Variable	R^2 (cum)	Regression Coefficient
1	EVAP	0.3314	-0.00224
2	AGE	0.4227	-0.02643
3	NITR	0.4987	0.00036
4	HARM	0.5583	0.06705
5	RAINW	0.5770	-0.00000
6	RAINS	0.5843	0.00005
7	RAINH	0.5921	0.00016
8	MINT	0.5959	-0.00239
9	WATM	0.6022	0.00006
	CONSTANT		1.15015

More than 60% of the yield variation can be explained. The average yield for this group is 0.587 TSAM (Standard deviation is 0.0413).

c. The "Lahaina" Group

This group occupies the lower part of the upland soils. The crop cycle which did not play an important role in the previous groups is one of the main management factors in the Lahaina group together with the age of the crop. Radiation is the most important factor and is negatively correlated

TABLE XXXI

LINEAR REGRESSION COEFFICIENTS AND CUMULATIVE R^2 AT EACH STEP FOR CLIMATIC AND MANAGEMENT VARIABLES IN THE "LAHAINA" GROUP IN RELATION TO TSAM

Step	Variable	R^2 (cum)	Regression Coefficient
1	RADI	0.2911	-0.00148
2	CRCY	0.4454	0.14298
3	RAINB	0.6279	-0.00010
4	DIFT	0.6774	-0.00573
5	AGE	0.7018	-0.01185
6	RIPD	0.7203	-0.00015
7	RAINH	0.7320	-0.00008
8	NITR	0.7365	0.00014
	CONSTANT		0.28602

with the yield. Table XXXI gives the statistics for this group. Within the Lahaina group 73.65% of the yield variation is explained. The average yield for this group is 0.603 TSAM (Standard deviation is 0.0486).

d. The "Ewa-Wahiawa" Group

This group occupies the major mauka part of the plantation. The close similarity in soil characteristics between the Wahiawa and the Ewa series and their same yielding capacity were the reasons to group these soils together, although it is realized that their parent material is different. Because of the large number of data, it was possible to split the group up according to crop cycle.

d-1. "Ewa-Wahiawa" (Plant crop only)

The month of harvest and amount of water applied were the most significant management factors, both positively correlated. The amount of P_2O_5 is also positively correlated, but nitrogen application is negatively correlated. Evaporation and radiation are positively correlated, but they do not contribute significantly to the cumulative R^2. The increase in R^2 is given in Table XXXII and the regression coefficients are tabulated in Table XXXIII

d-2. "Ewa-Wahiawa" (First ratoon planting)

While age of the crop was not significantly correlated with yield of the plant crop, it is one of the most important factors in the first ratoon and is negatively correlated. Total water applied is again an important factor, but P_2O_5 as well as K_2O are now negatively correlated. That P_2O_5 is important in the case of a plant crop, can be explained by the fact that the soil preparation methods preceding planting bring the subsoil, which has a very high fixing capacity, to the surface. Therefore, more fertilizer is needed for the plant crop. All the climatic factors are negatively correlated with the yield except summer rainfall (see Tables XXXII and XXXIII for the statistics).

d-3. Other ratoons in the "Ewa-Wahiawa" group

The month of harvest plays a major role in this group.

TABLE XXXII

ACCUMULATIVE R SQUARE FOR CLIMATIC AND MANAGEMENT VARIABLES IN THREE CROP CYCLE GROUPS OF THE "EWA-WAHIAWA" GROUP

PLANT CROP (BOTH CYCLES)			FIRST RATOON (FIRST CYCLE)			OTHER RATOONS		
STEP	VARIABLE	R SQ	STEP	VARIABLE	R SQ	STEP	VARIABLE	R SQ
1	M.HARV	0.09	1	WATER	0.22	1	M.HARV.	0.45
2	WATER	0.18	2	AGE	0.34	2	K2O	0.50
3	SUM.RAIN	0.23	3	RAIN BEF	0.43	3	SUM.RAIN	0.53
4	P2O5	0.27	4	MAX.TEMP	0.49	4	EVAP.	0.55
5	MIN.TEMP	0.30	5	RIP.DAYS	0.52	5	RAIN HAR	0.56
6	WIN.RAIN	0.34	6	P2O5	0.53	6	RAIN BEF	0.58
7	NITR.	0.35	7	SUM.RAIN	0.54	7	RIP.DAYS	0.60
8	MAX.TEMP	0.37	8	MIN.TEMP	0.56	8	MAX.TEMP	0.60
9	EVAP.	0.38	9	WIN.RAIN	0.58	9	NITR.	0.61
10	RAIN HAR	0.39	10	K2O	0.59	10	WATER	0.61

TABLE XXXIII

REGRESSION COEFFICIENTS AND AVERAGE VALUES FOR CLIMATIC AND MANAGEMENT VARIABLES IN THREE CROP CYCLE GROUPS OF THE "EWA-WAHIAWA" GROUP

	PLANT CROP (BOTH CYCLES)		FIRST RATOON (FIRST CYCLE)		OTHER RATOONS	
VARIABLE	REGR.CO.	AVERAGE	REGR.CO.	AVERAGE	REGR.CO.	AVERAGE
M.HARVEST	0.10579				0.18535	
AGE MONTH		23.4	-0.01136	23.7		23.6
WATER MM.	0.00046	185	0.00027	178	0.00011	185
NITR.	-0.00051	350		361	-0.00044	360
P2O5	0.00020	185	-0.00016	89		143
K2O		378	-0.00007	393	0.00017	441
SUM.RAIN	0.00003	863	0.00005	877	0.00003	687
WIN.RAIN	-0.00002	1507	-0.00003	1485		1736
RAIN HAR.	0.00016	40		73	0.00032	48
RAIN BEF.		64	-0.00016	87	-0.00021	71
EVAP.	0.00072	147		148	0.00086	151
RADIATION		125		125		130
MAX.TEMP.	-0.00234	82	-0.00441	82	-0.00165	83
MIN.TEMP.	-0.00435	69	-0.00282	68		68
CONSTANT	0.43900		1.46291			
TSAM	0.631		0.619		0.606	

Since the average crop age is 23.6 months, most probably lower yield is related more to late planting than to late harvesting. Increasing Potash application also increases yield significantly, summer rain and evaporation are also positively correlated to crop yield. The statistics for this group are also summarized in Tables XXXII and XXXIII.

The three selections of the "Ewa-Wahiawa" group explained respectively 39%, 59% and 61% of the yield variation.

e. "Ewa-Sloping Phase, Waialua-Stony Phase" group

The fields belonging to this group are all located in the Western part of the plantation. The average yield is only 0.561 TSAM. Winter rainfall alone explains more than 23% of the variation and is negatively correlated. This confirms an earlier statement about the erosion hazard in this area.

The final regression equation however does not include winter rainfall, because at subsequent steps in the stepwise regression winter rainfall lost its importance and was overshadowed by such factors as age, temperature difference, and nitrogen application. The regression equation explains almost 83% of the yield variation and reads as follows:

Yield estimated = -1.09755 - 0.02361 AGE + 0.08123 CRCY + 0.00112 NITR - 0.00008 P_2O_5 - 0.00006 K_2O + 0.00049 RIPD - 0.00004 SUMR + 0.00036 RAINH + 0.00440 EVAP - 0.00297 RADI + 0.01479 MAXT - 0.01112 DIFT.

Although interaction among different variables in some instances defy satisfactory explanation, the grouping of fields according to soil type increased the explained variation significantly. Figure 43 shows the relation between the actual yield and the estimated yield. The regression line, based on these values is as follows:

$$Y_{est} = 0.216 + 0.642\ Y_{obs}$$

This discussion does not include stepwise regression between TSAM and climatic variables alone, because it is questionable to which extent the yield is related to these variables, radiation in particular. It was observed, however, that diurnal difference in temperature during the harvest month was negatively correlated with yield ($r = 0.334$), rainfall during summer was positively correlated with yield ($r = 0.269$), as was minimum temperature during the harvest month ($r = 0.169$). For the sake of uniformity Figure 43 also includes the relation between the actual yield and estimated yield based on climatic variables alone.

The most important conclusion that can be drawn from Figure 43 is that the yield can be estimated satisfactorily only if management, climate and soil are involved together. Although it will never be possible to estimate all the yield data exactly as observed ($Y_{est} = Y_{obs}$) the linear regression equations calculated on the basis of the observed and

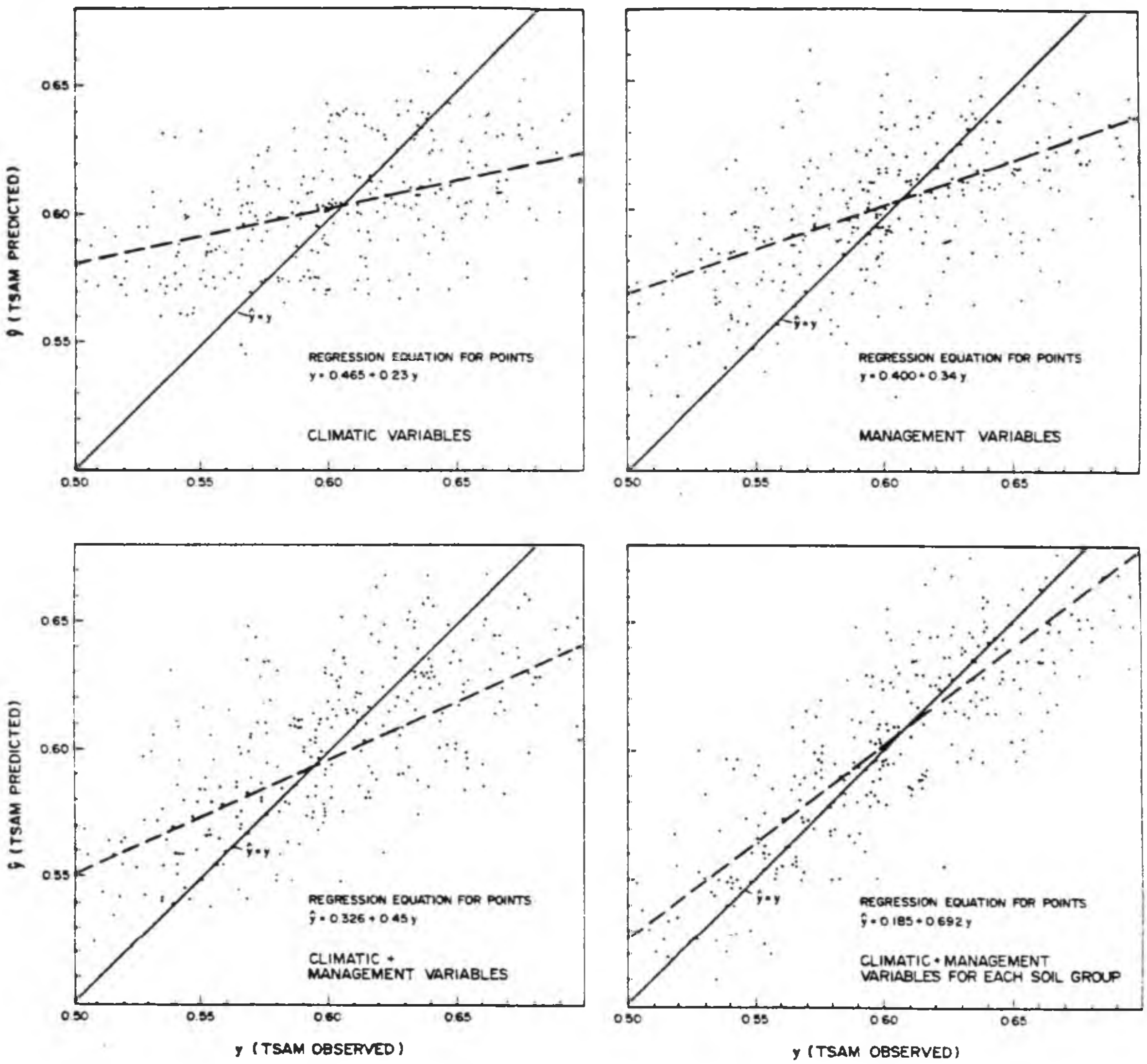


FIGURE 43. RELATION BETWEEN OBSERVED AND ESTIMATED YIELDS BASED ON FOUR SETS OF VARIABLES

estimated values demonstrate clearly that the equation that approaches this estimation line most closely is the one based on all three systems.

To what extent are these prediction equations practical? The difference between actual and estimated yield can be expressed as a percentage of the actual yield. Table XXXIV tabulates the percentage of yield data, whose estimated values differ more than 10%, 5 to 10%, 1 to 5% and less than 1% from the observed values.

TABLE XXXIV

PERCENTAGE OF DATA, WHOSE ESTIMATED VALUES DIFFER MORE THAN 10%, 5 TO 10%, 1 TO 5% AND LESS THAN 1% FROM THE OBSERVED VALUES

$\frac{Y_{est} - Y_{obs}}{Y_{obs}}$	Management Variables	Climate + Management	Climate + Management + Soil
More than 10%	12.6%	7.6	2.1
5 to 10%	30.0%	29.9	19.9
1 to 5%	44.7%	49.4	56.1
Less than 1%	12.7%	13.1	21.9

This Table illustrates that on the basis of the variables considered and the soil map, one can predict 80% of the yield within 5% error. Expressed in terms of TSAM this is equivalent to a value of 0.03 TSAM based on an average yield of 0.60 TSAM.

The difference between estimated and observed yield can also be expressed in a frequency histogram as shown in Figure 44. These Figures were compiled by setting up class intervals of the difference between estimated and observed values. The Figures indicate that the standard deviation is significantly reduced when the three systems are combined.

From this discussion it also has become clear that it is very hazardous to prepare a yield potential map, because so many unmappable climatic and management variables influence yield. All that can be said is that under the present system of management, the highest average yields can be obtained from fields on the "Ewa-Wahiawa" soil complex, while the lowest yields are obtained from the "Montmorillonite" complex.

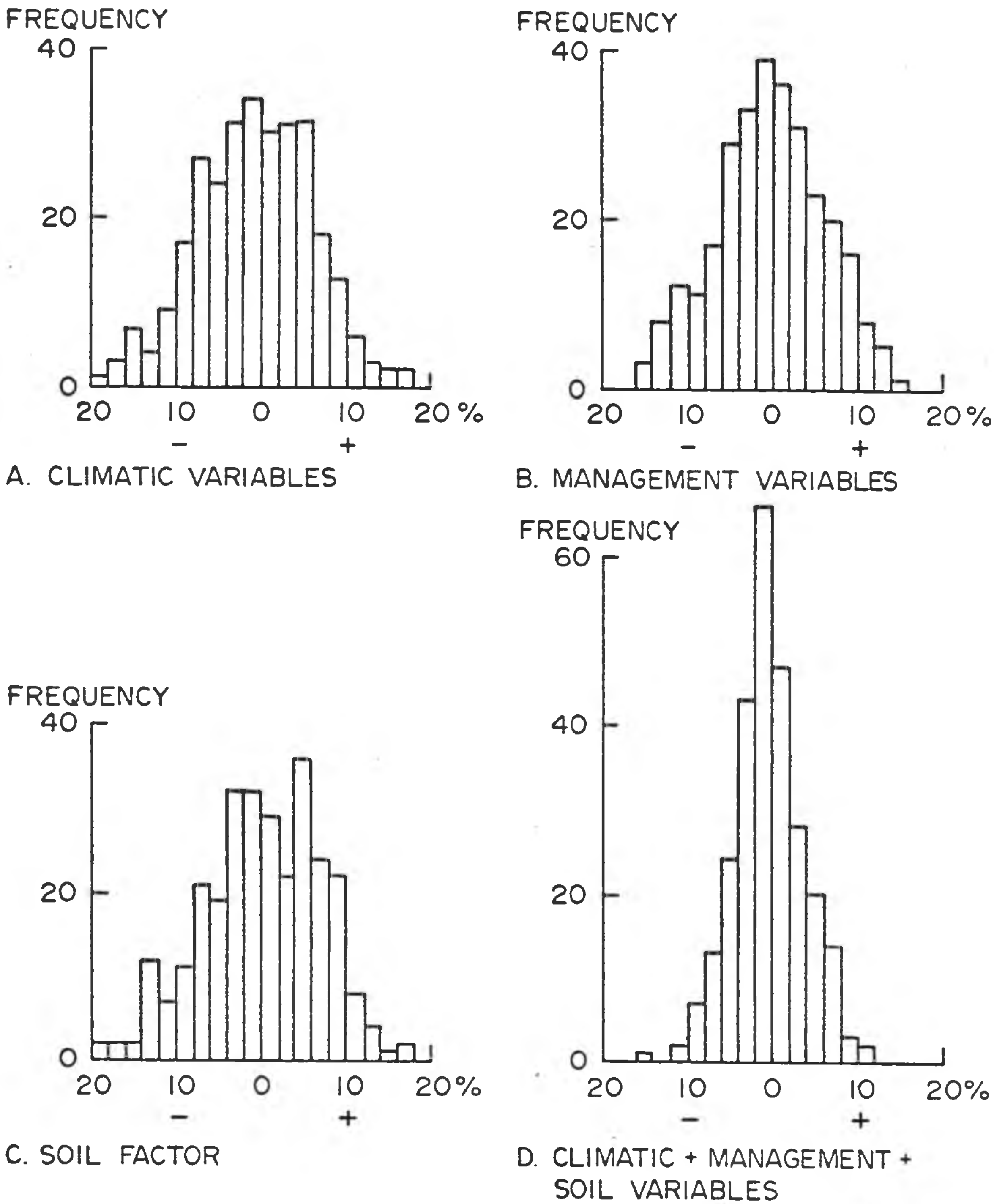


FIGURE 44. FREQUENCY HISTOGRAM OF THE DIFFERENCE BETWEEN ESTIMATED AND OBSERVED YIELD EXPRESSED AS A PERCENTAGE OF THE OBSERVED YIELD FOR FOUR SETS OF VARIABLES.

CHAPTER V

SUMMARY AND CONCLUSIONS

A study has been undertaken to analyze the yield of sugar cane in relation to climate, soils and management. The Waialua Sugar Company Inc., located in the northern part of Oahu, Hawaii, was selected for this purpose. Some 4200 ha of irrigated sugar cane is presently cultivated and complete files on yield and management practices for around 80 fields are available since 1930. In addition it maintains 28 rainfall stations and four meteorological observation posts, where besides rainfall, evaporation, global radiation, maximum and minimum temperature are measured. A detailed soil survey has been carried out for the State of Hawaii by the U.S. Soil Conservation Service and additional soil data are collected by the company.

Sugar cane cultivation is mechanized to the fullest extent. A single variety normally covers about 75% of the total area. In addition to the plant crop, two to three ratoon crops are generally harvested before intensive soil preparation - subsoiling and deep plowing - is carried out again. While reshaping the furrows and spot replanting was the general practice for ratoon cropping before 1960, in the last decade 100% of the field is replanted.

Fertilizer practices are based on soil analysis in the case of P, K and Si, and on the variety grown in the case of

N application. While Si is broadcasted before plowing operations and P is applied in bands at the time of planting, K and N are given in several applications by means of irrigation water within nine months after planting. The main form of irrigation is through furrow application. The furrows are connected with the flumes in a so called "Herring bone system". Timing of irrigation is based on weekly evaporation and rainfall measurements and the soil moisture capacity, which is determined for each field. Harvest operations are scheduled from early March to November with peaks during July and August. Since the abandonment of railroad hauling in 1953, cane is hauled from the field by large trucks and transported to the mill.

The climate in this area is characterized by rainy winters with up to 100 mm of rain per month from November until March and dry summers with less than 25 mm of rain per month from June until September. A distinct rainfall pattern can be observed with higher amounts of rainfall at higher altitude. Radiation and evaporation follow the same monthly pattern as rainfall, but the regional variation is not as clear, mainly because of the lack of observation sites. It is known to decrease with elevation, however. Temperature fluctuation during the year is not as pronounced as the other climatic factors. The maximum temperature varies from $75^{o}F$ in winter to $86^{o}F$ in summer and is 3 to $4^{o}F$ less at 200 m altitude. The minimum temperature fluctuates between

$60^{\circ}F$ in winter and $72^{\circ}F$ in summer and is 3 to 4 degrees higher at 200 m altitude. Therefore, the median diurnal difference is most pronounced at low elevations during the summer months. In general, it can be concluded that the fields at low elevation have a more favorable climatic environment for sugar production than the mauka fields.

The geomorphological setting of this area is characterized by gentle sloping upland, and a level to nearly level coastal area. The upland is intersected by steep gulches, widening towards the coast.

Almost 60% of the area is classified as Oxisols (Ustox and Torrox) and 30% as Mollisols (Haplustolls). The remaining 10% belongs to Inceptisols (Tropaquepts) and Vertisols (Pelluderts). Two important sets of characteristics divide these groups: Chemical properties and physical properties. The soils at higher elevations, Oxisols, are characterized by a low nutrient status but favorable physical conditions for plant growth compared to the soils at lower elevation.

Using field records as basic material, a management data bank has been set up and the yields were statistically analyzed: Linear and quadratic regression equations between sugar yield and independent quantitative variables; F-tests for independent qualitative variables; stepwise regression to study interactions among various independent variables, and trend surface calculations to study certain distribution patterns. The sets of data were grouped in various ways to obtain homogeneous sets with respect to certain management practices.

Most of the following conclusions are based on sugar yield expressed as Ton Sugar per Acre per Month for a single variety: H 50-7209.

1. Sugar yield increased from 0.45 TSAM in 1930 to 0.57 TSAM in the late 1960's. This increase is mainly the result of improved varieties, increasing amounts of fertilizers, particularly potash, reducing the number of ratoons, and changing from mechanical ratooning to ratoon planting.

2. Most sugar cane varieties undergo a yield decline that cannot be explained by any of the studied variables (see also point 6).

3. Seasonal climatic variation plays an important role in sugar yield. Cane harvested during June, July and August gives highest yields. This can be explained by the favorable climate during these months: High radiation favors the ripening of the cane. Low rainfall is also favorable to ripening, but may be less important than the improved field conditions offered by dry weather. The opposite situation exists during early spring. Low yields during September and October may be caused more by the time of planting, which occurs during the same months (average age of the crop is 23.7 months). When cane is planted in

the fall, its initial growth is very slow because of low winter temperature and heavy rainstorms in winter may cause impeded drainage in the low lying areas and erosion hazards in the fields that are located at the foot of the steep slopes of the Waianae range. Both factors can damage young cane seriously.

4. Field location is an important factor in sugar production. Areas at lower elevation produced significantly less sugar than most of the upland fields during the last decade, while the reverse situation occurred during the 1930's. This explains the negative correlation with total rainfall during the 1930's and the positive correlation during the 1960's, since rainfall is strongly correlated with location. The areas at low altitude are characterized by a high natural fertility and favorable climatic setting, but poor physical conditions especially with regard to soil structure and soil consistency. It can be concluded that the pattern of yield distribution in the 1930's is mainly caused by the fertility level of the soils in this area. Increasing amounts of fertilizers - especially potash and silicate - have overcome this limiting factor. Introduction of heavy machinery and high degree of mechanization alters the physical properties of the soil in a negative manner. It can be stated therefore that the limiting factor in sugar production during the last decade is the physical condition of the soil. An analysis of variance of the yield among

different soil mapping units emphasizes this conclusion. Soils of the Haleiwa, Pearl Harbor, Waialua, Kawaihapai and Pulehu series give significantly lower yields than those of the Wahiawa, Ewa or Lahaina series.

5. Ratooning reduces sugar production significantly in spite of the fact that 100% of the field is replanted. Soil compaction is considered the main reason for this yield reduction. This is most strongly expressed in the soils with poor physical properties.

6. There exists a genuine yield decline, not to be confused with a drop in sugar yield as a result of ratooning. An analysis of variance to test the difference between the first and second plant crop (in both cases a thorough and identical soil preparation was carried out before planting) showed a significant decline in yield. The second plant crop generally occurred after the first plant crop was ratooned two to three times. This yield decline was more pronounced in the alluvial soils than in the Wahiawa series.

7. The technique of stepwise regression to estimate yield has been used successfully, and observations based on relationships between yield and single variables have been substantiated with this technique. Climatic variables or management variables used alone could not explain more than 30% of the yield variation. Combining all the variables except the soil factor explained 45% of the variation, but dividing the yield data according to their soil mapping unit

resulted in an increase in R^2 from 45% to 82%. The practical result is that using the available information, 80% of the yield data can be estimated within 5% from the actual yield.

8. An important finding is that in spite of the higher evaporation and lower rainfall in the makai areas, increased amounts of water-either as irrigation or as winter rainfall or rainfall at harvest- are negatively correlated with yield. Poor physical soil conditions is obviously one of the major problems in this area.

9. The stepwise regression also pointed out the interactions among variables. Radiation aside from its obvious strong correlation with evaporation was also correlated to crop cycle, fertilizer application, age of the crop and other variables. It is, therefore, not possible in this type of study to place too much emphasis on correlations between single variables and yield, because many hidden interactions confound the relationship.

APPENDIX I

TABLES OF MANAGEMENT, YIELD, CLIMATIC, AND SOIL DATA USED

T A B L E I

MANAGEMENT PRACTICES AND YIELD DATA FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CYCLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	FERTILIZER IN KG/HA. P2O5	FERTILIZER IN KG/HA. K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
1	1962	10	10	23.7	0	24.3	3274	59	348	0	277	0.635	15.05	5.38	8.5
1	1966	10	9	23.2	2	20.1	2718	72	366	0	423	0.541	12.54	4.47	8.3
1	1968	9	10	24.4	3	28.2	4244	54	339	232	435	0.592	14.45	5.32	9.0
2	1963	9	10	24.5	1	19.8	2861	68	274	0	194	0.605	14.84	5.35	8.8
2	1965	10	9	23.8	2	24.6	3487	95	348	0	412	0.597	14.20	5.00	8.4
2	1967	10	8	22.4	3	17.4	3210	57	350	178	468	0.636	14.22	5.50	8.6
2	1969	9	9	23.8	4	23.4	4124	75	335	0	503	0.558	13.27	4.41	7.9
3	1963	9	10	24.6	1	20.1	2768	82	251	0	139	0.664	16.36	5.40	8.1
3	1965	10	10	23.7	2	25.8	2876	100	360	0	423	0.586	13.91	4.82	8.2
3	1967	10	9	22.1	3	19.8	2118	55	346	183	436	0.598	13.22	4.82	8.1
3	1969	9	9	23.6	4	24.9	4531	79	341	0	391	0.493	11.66	3.80	7.7
4	1963	10	10	23.1	0	17.8	2242	80	251	0	139	0.607	14.05	5.03	8.3
4	1965	10	10	23.8	1	25.1	2842	99	352	0	416	0.541	12.90	4.69	8.7
4	1969	10	9	23.2	4	26.2	4257	86	297	178	286	0.554	12.83	4.32	7.8
5	1964	11	10	23.3	0	26.7	6040	70	278	0	190	0.616	14.35	5.31	8.6
5	1966	10	10	23.5	1	21.5	5240	79	307	0	303	0.566	13.31	4.96	8.8
5	1968	10	10	24.4	2	31.5	8504	65	347	257	259	0.544	13.28	5.10	9.4
6	1964	8	8	23.4	0	22.3	2887	70	294	0	0	0.599	14.01	4.63	7.7
6	1966	7	7	23.7	1	21.7	3602	65	314	0	301	0.573	13.57	4.38	7.6
6	1968	8	8	24.8	2	32.6	3757	56	335	0	275	0.542	13.43	4.33	8.0
7	1963	7	6	23.5	1	24.8	3502	187	287	0	94	0.564	13.25	5.15	9.1
7	1967	7	6	23.5	1	27.0	4292	56	350	0	0	0.543	12.75	4.77	8.8
7	1969	8	7	22.6	4	26.3	3609	80	284	71	71	0.574	12.97	4.26	7.4
7	1969	6	6	23.9	2	28.8	4809	59	344	71	71	0.533	12.75	4.28	8.0
8	1963	9	7	22.3	0	20.3	2385	78	175	0	89	0.576	12.86	5.28	9.2
8	1965	7	7	24.0	1	30.6	5102	70	316	0	0	0.598	14.36	5.61	9.4
8	1967	8	7	23.3	2	21.7	3933	77	318	0	89	0.594	13.83	5.53	9.3

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CYCLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
8	1969	9	8	22.8	4	21.9	5146	84	350	0	0	0.610	13.89	5.37	8.8
8	1969	7	8	24.3	3	27.5	5204	87	349	0	0	0.504	12.22	4.30	8.5
9	1969	9	9	24.0	2	23.9	3883	95	358	0	0	0.580	13.92	5.13	8.8
9	1969	9	9	24.0	2	23.9	3883	95	274	0	67	0.516	12.38	4.10	7.9
9	1969	10	9	23.1	4	22.4	6439	114	232	0	0	0.539	12.46	5.20	9.6
10	1964	8	7	23.2	0	28.9	5628	65	349	203	207	0.647	15.02	4.89	7.6
10	1966	7	7	23.8	1	24.9	4282	48	350	0	277	0.595	14.17	4.83	8.1
10	1968	7	8	24.6	3	34.6	6746	44	355	211	278	0.547	13.46	4.66	8.5
11	1965	5	3	22.5	0	37.9	5410	92	365	228	408	0.572	12.86	5.26	9.2
11	1967	3	3	23.7	1	28.6	4289	143	347	157	419	0.551	13.05	5.14	9.3
11	1969	4	4	23.9	4	36.8	5639	166	361	203	445	0.598	14.32	4.80	8.0
12	1962	10	9	22.5	0	26.8	4006	65	343	206	296	0.688	15.51	5.74	8.3
12	1964	9	9	23.6	1	30.6	4873	57	385	0	294	0.622	14.69	4.67	7.5
12	1966	9	10	25.1	2	28.8	5983	57	365	122	394	0.543	13.62	4.53	8.3
12	1966	10	10	24.5	4	28.8	5933	62	362	125	399	0.544	13.30	4.87	9.0
12	1968	10	10	24.3	6	36.4	8772	42	363	259	551	0.536	13.02	5.19	9.7
13	1963	10	10	24.0	1	26.1	4189	60	341	173	176	0.549	13.20	4.76	8.7
14	1963	10	10	23.8	0	21.0	3244	74	273	201	277	0.535	12.76	4.51	8.4
14	1965	10	10	23.7	1	25.6	3711	75	367	0	397	0.514	12.19	4.53	8.8
14	1969	9	9	24.0	3	23.9	3877	69	357	183	240	0.469	11.26	3.79	8.1
16	1964	9	8	22.8	0	21.0	3044	75	271	0	232	0.561	12.80	4.30	7.7
17	1962	8	8	23.5	0	20.3	2968	68	246	0	198	0.602	14.17	4.75	7.9
17	1964	8	8	24.1	1	21.4	3097	76	322	0	167	0.602	14.51	4.73	7.9
17	1966	9	8	22.9	4	19.7	3102	67	324	0	283	0.660	15.14	5.01	7.6
19	1968	6	7	24.8	2	38.1	5743	54	314	0	0	0.486	12.07	4.35	9.0
21	1968	8	7	22.8	2	18.0	3077	69	66	0	0	0.525	11.97	4.30	8.2
25	1962	7	5	22.7	0	27.5	4619	178	257	193	265	0.595	13.48	5.51	9.3

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CYCLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	FERTILIZER IN KG/HA. P205	FERTILIZER IN KG/HA. K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
25	1964	5	5	23.7	1	26.2	3504	81	329	0	397	0.590	13.99	5.18	8.8
25	1966	5	7	25.3	2	27.5	4929	91	340	115	241	0.535	13.53	4.42	8.3
26	1962	7	6	22.7	0	29.6	7274	213	267	250	246	0.637	14.44	5.67	8.9
26	1964	6	5	23.8	1	31.0	6540	79	342	0	416	0.611	14.53	5.54	9.1
26	1966	5	7	25.2	2	34.7	6306	83	351	116	241	0.520	13.09	4.50	8.7
26	1968	8	7	22.9	4	35.0	7875	78	338	0	187	0.634	14.54	5.57	8.8
28	1963	9	8	23.6	0	23.6	2578	66	335	191	100	0.624	14.74	5.27	8.4
28	1965	8	8	24.0	1	32.0	5583	95	355	0	402	0.590	14.18	4.99	8.5
28	1967	9	7	22.8	2	22.2	2314	81	348	159	470	0.615	14.04	5.17	8.4
28	1969	8	7	23.5	3	29.0	2356	55	342	173	305	0.561	13.19	4.25	7.6
29	1964	10	9	23.9	0	28.3	2603	60	316	0	0	0.585	13.99	4.53	7.7
29	1966	9	9	23.4	1	23.9	2443	68	344	99	342	0.537	12.56	4.33	8.1
29	1968	9	9	24.2	2	36.7	3302	56	342	229	234	0.580	14.02	4.75	8.2
30	1962	8	8	24.3	1	22.5	2188	66	353	172	165	0.582	14.14	4.69	8.1
30	1962	8	8	23.8	0	22.5	2188	60	327	219	167	0.652	15.51	5.05	7.7
30	1964	8	8	24.1	1	25.8	2457	68	321	0	201	0.601	14.46	4.66	7.8
30	1964	9	8	23.2	4	25.8	2457	63	282	0	227	0.576	13.37	4.41	7.7
30	1966	8	8	23.5	2	20.2	3277	87	350	98	434	0.615	14.45	4.78	7.8
30	1966	8	8	23.7	5	20.2	3277	83	346	0	406	0.598	14.20	4.74	7.4
30	1968	8	8	24.3	3	31.0	2580	51	296	0	377	0.623	15.15	4.78	7.7
30	1968	8	8	24.5	6	31.0	2580	51	339	0	425	0.519	12.71	4.06	7.8
31	1963	8	9	24.8	1	25.8	5108	65	369	145	193	0.662	16.41	4.98	7.5
31	1963	9	8	24.3	4	25.8	5108	73	360	180	180	0.666	16.16	5.05	7.6
31	1965	9	9	23.8	4	28.5	5764	97	365	255	365	0.639	15.22	5.04	7.9
31	1965	9	9	24.4	5	28.5	5764	97	365	0	359	0.593	14.44	4.78	8.1
31	1967	9	8	22.8	6	22.4	4507	81	367	0	436	0.627	14.27	5.10	8.1
32	1963	8	8	24.4	0	27.3	4013	66	344	193	202	0.669	16.35	5.36	8.0

T A B L E 1 (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CY-CLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
32	1965	8	8	24.0	1	31.3	5422	83	359	0	387	0.677	16.26	5.57	8.2
32	1967	8	7	22.5	2	23.9	3519	66	355	174	468	0.646	14.52	5.34	8.3
32	1969	7	7	23.9	3	30.7	5073	61	376	161	367	0.550	13.12	4.24	7.7
33	1962	9	8	23.8	0	25.8	4353	56	346	197	264	0.603	14.34	4.84	8.0
33	1964	8	8	24.0	1	28.2	4878	64	334	0	405	0.572	13.74	4.79	8.4
33	1966	9	8	22.6	4	24.2	4065	53	360	127	443	0.600	13.58	4.98	8.3
33	1968	8	9	24.2	5	35.6	4921	57	367	253	446	0.554	13.42	4.52	8.2
34	1966	10	9	22.3	0	24.6	4083	58	374	131	419	0.611	13.62	5.15	8.4
35	1962	9	9	23.4	1	27.3	3835	52	368	176	278	0.528	12.36	4.61	8.7
35	1964	9	8	23.8	2	29.0	4212	65	370	179	428	0.554	13.18	4.61	9.3
35	1964	10	9	22.8	4	29.0	4212	66	353	182	381	0.585	13.33	4.76	8.1
35	1966	10	10	24.8	4	28.1	5079	81	359	127	445	0.506	12.53	4.13	8.2
35	1966	9	10	25.1	5	28.1	5079	81	360	105	442	0.553	13.87	4.47	8.1
35	1968	11	11	24.1	5	40.0	5719	55	387	327	495	0.549	13.21	5.39	9.8
36	1963	7	8	25.1	1	28.8	4658	68	361	218	204	0.601	15.08	4.93	8.2
36	1963	8	8	24.3	4	28.8	4658	64	329	189	197	0.621	15.07	5.17	8.3
36	1965	8	8	24.0	2	34.5	5968	79	371	0	396	0.654	15.67	5.57	8.5
36	1965	8	8	24.0	5	34.5	5968	77	371	0	396	0.596	14.32	5.24	8.8
37	1969	10	10	24.1	2	30.2	5753	75	348	0	247	0.528	12.70	4.51	8.5
38	1963	8	9	24.4	4	26.0	4068	72	208	0	101	0.666	16.28	5.31	8.0
38	1963	8	9	24.9	1	26.3	4010	67	275	175	101	0.512	12.74	4.41	8.6
38	1969	10	10	24.7	6	30.9	6102	65	351	180	405	0.524	12.94	4.14	7.9
39	1966	10	10	23.9	0	25.8	4482	75	327	0	347	0.566	13.52	5.30	9.4
39	1968	10	10	24.4	1	39.5	6784	43	351	0	471	0.466	11.38	4.90	10.5
40	1963	10	9	23.5	0	22.9	4156	102	266	0	183	0.637	14.98	5.21	8.2
40	1969	10	10	24.6	3	37.0	7853	76	363	190	204	0.539	13.25	4.57	8.5
41	1962	8	9	24.3	1	31.3	4115	55	414	181	451	0.487	11.84	4.18	8.6

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CY-CLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
42	1966	7	10	23.3	5	30.7	3376	59	350	164	496	0.547	12.74	4.61	8.4
43	1963	5	5	23.4	0	31.9	4226	223	357	198	393	0.607	14.22	5.20	8.6
43	1963	4	5	24.7	1	34.3	3875	217	355	217	398	0.535	13.21	4.79	9.0
43	1966	11	10	23.4	4	33.1	4576	75	367	160	441	0.528	12.34	4.11	7.8
45	1963	5	5	23.5	0	30.8	4550	211	355	213	390	0.560	13.16	4.71	9.4
45	1966	11	10	23.0	4	32.5	4891	64	367	150	422	0.450	10.36	3.43	7.6
46	1963	7	7	24.3	0	26.5	4206	134	369	225	400	0.593	14.39	4.68	7.9
46	1965	7	6	22.9	1	35.7	4578	90	361	0	506	0.613	14.02	4.71	7.7
46	1967	6	5	23.3	2	29.8	4499	122	367	184	524	0.573	13.36	4.74	8.3
46	1969	6	5	23.4	3	30.0	4049	202	391	388	512	0.599	13.99	4.15	6.9
47	1965	7	5	23.0	2	33.1	4394	92	355	225	432	0.591	13.60	4.26	7.2
47	1965	8	5	21.8	5	33.1	4394	92	355	225	432	0.632	13.76	4.85	7.7
47	1967	6	5	23.9	6	29.7	4232	130	349	0	444	0.581	13.87	4.50	7.7
48	1963	6	7	25.3	1	34.9	4755	56	357	199	407	0.557	14.08	4.58	8.2
48	1965	7	6	22.9	2	35.1	3817	81	362	0	384	0.613	14.01	4.37	7.1
48	1967	7	6	23.1	4	31.4	4741	100	361	146	479	0.697	16.12	5.03	7.2
48	1969	6	6	23.3	5	30.2	4001	42	383	185	407	0.593	13.81	4.10	6.9
49	1969	10	10	24.0	6	31.0	4812	50	324	133	291	0.509	12.21	4.17	8.2
50	1962	4	4	23.8	0	36.5	5073	164	370	287	299	0.612	14.56	5.46	8.9
50	1962	4	4	23.8	0	36.5	5073	164	370	287	299	0.587	13.98	5.35	9.1
50	1965	10	11	24.1	2	32.9	4819	77	449	0	464	0.568	13.68	5.22	9.2
50	1967	11	10	23.5	3	34.9	4650	69	381	195	433	0.540	12.68	4.52	8.4
50	1969	11	10	23.6	4	32.4	7241	73	356	171	416	0.584	13.77	4.13	7.1
51	1964	4	3	23.3	0	38.6	4110	106	352	206	506	0.656	15.29	5.57	8.5
52	1962	4	3	23.0	0	31.4	4144	162	386	203	288	0.720	16.59	6.91	9.6
52	1964	4	4	23.6	0	36.4	4386	120	351	199	404	0.629	14.83	5.56	8.8
52	1966	4	3	22.3	4	36.1	3799	148	347	147	389	0.702	15.64	5.86	8.3

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CY-CLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
52	1958	3	3	23.7	2	37.5	5390	100	355	198	425	0.555	13.17	4.82	8.7
53	1962	4	4	24.3	0	33.0	3935	190	366	287	288	0.552	13.42	4.96	9.0
53	1965	11	11	24.0	2	36.9	5498	71	424	0	450	0.565	13.57	5.33	9.4
53	1967	11	11	23.1	3	33.0	4347	71	337	183	414	0.583	13.44	4.97	8.5
53	1969	11	11	23.9	3	30.8	5782	43	342	183	423	0.559	13.37	4.08	7.3
53	1969	11	10	23.6	5	30.8	5782	43	425	241	423	0.588	13.89	4.68	8.0
53	1969	10	10	24.1	4	30.8	5782	43	283	0	423	0.551	13.29	5.58	10.1
54	1963	4	5	24.4	0	32.9	4959	201	324	188	302	0.541	13.21	4.80	8.9
54	1965	5	3	22.2	1	36.7	4128	121	404	0	579	0.576	12.81	5.12	8.9
54	1967	4	5	24.4	4	26.1	4541	195	361	179	464	0.553	13.52	4.90	8.9
54	1969	5	4	22.5	5	35.6	4930	146	357	267	368	0.569	12.81	4.35	7.6
54	1969	5	4	22.5	5	35.6	4930	146	357	267	368	0.527	11.87	4.43	8.4
55	1963	6	5	23.5	0	33.0	5139	223	344	193	391	0.520	12.20	4.97	9.6
55	1963	5	5	24.4	1	35.8	3848	212	350	217	378	0.518	12.65	4.65	9.0
55	1965	5	3	22.0	2	38.7	4624	136	432	0	505	0.568	12.48	4.94	8.7
55	1967	4	4	24.4	3	33.5	4103	166	343	128	424	0.472	11.52	4.69	9.9
55	1969	4	4	24.0	6	38.9	5047	168	412	174	567	0.531	12.75	4.16	7.8
56	1963	6	5	23.6	0	33.0	3786	218	342	195	391	0.569	13.42	4.68	8.2
56	1965	5	5	23.2	1	39.0	3548	170	415	0	500	0.592	13.72	5.36	9.1
56	1967	6	4	22.5	4	29.4	3660	176	369	162	442	0.582	13.11	4.81	8.3
56	1969	4	4	24.2	5	39.0	3090	171	416	180	464	0.563	13.61	4.21	7.5
58	1964	7	6	23.1	0	33.5	4254	50	339	198	291	0.634	14.63	4.59	7.2
58	1966	6	6	23.9	1	32.8	3279	130	366	0	435	0.595	14.24	4.17	7.0
60	1962	6	7	25.0	0	34.1	4279	83	367	217	393	0.602	15.06	4.74	7.9
60	1964	7	6	22.7	1	31.9	4338	52	356	0	405	0.641	14.54	4.83	7.5
60	1966	6	6	23.3	4	31.9	3947	235	353	123	456	0.607	14.17	4.11	6.8
60	1968	6	5	23.7	5	34.7	5317	81	349	0	575	0.601	14.26	4.65	7.7

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T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CYCLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
61	1962	5	6	25.6	1	34.9	4362	53	384	174	379	0.587	15.02	4.88	8.3
61	1964	7	6	23.1	0	29.4	3807	56	353	187	369	0.661	15.25	4.75	7.2
61	1964	6	6	24.2	2	32.8	4403	57	357	0	275	0.607	14.67	4.32	7.1
61	1966	6	6	24.2	1	31.6	4613	257	362	0	397	0.476	11.52	3.46	7.3
61	1966	7	6	23.0	4	31.6	4613	250	367	120	443	0.605	13.91	3.87	6.4
62	1963	5	5	24.4	1	31.9	3341	238	371	209	404	0.557	13.59	4.60	8.3
63	1963	10	9	23.5	0	26.5	3776	61	327	197	408	0.599	14.09	4.70	7.8
63	1965	9	9	23.5	1	35.9	5017	75	397	0	399	0.611	14.37	4.48	7.3
63	1967	9	10	25.0	2	34.2	4257	80	352	178	470	0.512	12.82	4.27	8.3
63	1969	10	10	23.3	3	27.0	4029	60	351	169	407	0.557	13.00	3.82	6.9
64	1963	10	9	23.4	0	24.6	3634	60	333	197	405	0.539	12.62	4.02	7.5
64	1965	9	9	23.6	1	35.0	4943	77	383	0	413	0.587	13.88	4.22	7.2
64	1967	9	10	25.0	2	34.8	5393	66	352	169	472	0.525	13.13	4.10	7.8
64	1969	11	10	23.5	3	31.0	4363	57	343	163	501	0.516	12.12	3.75	7.3
65	1964	6	5	22.8	0	29.0	4465	155	356	200	415	0.606	13.84	4.32	7.1
65	1966	5	5	24.3	1	35.0	4409	222	391	39	471	0.597	14.52	4.50	7.5
65	1968	6	6	23.9	0	36.3	4437	108	359	180	542	0.602	14.38	4.18	6.9
66	1962	5	4	23.1	0	31.9	3628	170	361	220	378	0.651	15.06	5.93	9.1
66	1964	4	3	23.0	1	32.3	3859	95	358	178	503	0.632	14.51	5.45	8.6
66	1966	4	4	24.1	4	29.6	3307	198	349	138	435	0.627	15.12	5.36	8.5
66	1968	4	4	23.7	5	30.0	4544	149	352	200	536	0.566	13.42	5.10	9.0
67	1962	10	10	24.6	0	31.4	5283	62	339	206	404	0.654	16.08	5.30	8.1
67	1964	10	9	23.2	1	31.7	4263	71	347	118	384	0.681	15.77	5.00	7.3
67	1966	10	8	22.9	2	29.9	4746	59	355	88	523	0.600	13.74	4.37	0.7
67	1968	9	9	24.4	0	34.4	5314	53	349	188	439	0.570	13.92	4.12	7.2
[illegible]	[illegible]	5	6	24.1	0	31.2	3553	208	375	258	376	0.638	15.39	5.86	9.2

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CYCLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P205	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
68	1966	3	4	25.3	2	33.7	3959	203	383	0	474	0.598	15.10	4.82	8.1
68	1966	4	5	24.4	4	30.8	3857	211	356	132	413	0.568	13.84	4.68	8.2
68	1968	5	4	22.8	4	32.8	5789	151	355	184	562	0.596	13.60	5.29	8.9
68	1968	5	4	23.3	5	32.8	5789	151	356	191	565	0.552	12.85	4.89	8.9
69	1963	11	9	22.7	0	28.0	3345	70	281	199	404	0.637	14.45	5.17	8.1
69	1965	10	9	23.8	1	36.7	4147	62	377	0	403	0.647	15.39	5.15	8.0
69	1969	10	8	22.1	0	26.2	3327	80	346	203	492	0.542	11.96	3.81	7.0
77	1964	7	6	22.7	0	25.0	3406	137	337	0	0	0.641	14.56	4.91	7.7
77	1964	7	6	23.7	1	30.0	4289	139	335	0	0	0.530	12.55	4.47	8.4
79	1966	10	9	23.1	0	27.0	4832	94	330	151	311	0.543	12.53	5.26	9.7
80	1963	3	3	23.4	1	36.8	4139	182	341	167	296	0.531	12.41	5.06	9.5
80	1965	5	3	22.2	4	37.4	4338	146	348	227	404	0.636	14.09	5.49	8.6
80	1967	3	3	23.6	5	36.8	4783	145	329	303	471	0.580	13.71	5.41	9.3
81	1962	7	7	23.6	0	32.6	4865	67	333	227	297	0.693	16.38	5.31	7.7
81	1964	7	7	23.7	1	30.0	4649	71	350	0	403	0.633	15.00	4.71	7.4
81	1966	7	5	21.7	4	26.7	4165	102	349	110	406	0.690	14.95	4.94	7.2
81	1968	5	6	24.8	5	39.8	5999	103	349	198	437	0.566	14.03	4.77	8.4
82	1964	8	6	22.9	0	31.5	5685	55	337	193	202	0.727	16.67	5.71	7.9
82	1966	6	5	22.8	1	27.8	5351	117	337	0	360	0.632	14.43	5.20	8.2
83	1962	7	7	24.1	0	31.4	4874	65	344	254	300	0.627	15.10	4.94	7.9
83	1964	7	7	23.5	1	29.3	4805	58	348	0	398	0.652	15.33	4.88	7.5
83	1966	7	6	22.9	2	28.4	4622	86	348	85	432	0.653	14.96	4.82	7.4
83	1968	6	6	24.0	3	37.1	5954	102	359	225	451	0.598	14.37	4.71	7.9
34	1966	6	4	22.5	0	26.7	4385	208	350	120	431	0.725	16.35	5.33	7.4
84	1968	5	5	24.2	1	38.0	4816	180	341	202	443	0.629	15.24	5.23	8.3
85	1962	8	8	23.7	0	32.5	4679	66	335	184	279	0.720	17.08	5.41	7.5
85	1964	8	7	23.5	1	29.7	4677	57	347	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CYCLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
85	1966	8	6	22.0	0	24.3	3863	65	355	119	422	0.730	16.04	4.98	6.8
85	1968	6	6	24.4	1	37.4	5030	85	361	231	470	0.616	15.01	4.63	7.5
86	1964	6	6	23.8	1	27.3	4627	74	377	0	396	0.617	14.68	4.39	7.1
86	1964	6	5	23.2	0	27.2	4610	74	353	197	396	0.647	14.98	4.81	7.4
86	1966	6	5	23.1	1	26.7	3511	210	399	0	460	0.615	14.22	4.69	7.6
86	1968	5	5	24.3	2	38.2	4975	184	360	199	455	0.592	14.36	4.93	8.3
87	1963	6	7	24.6	1	27.3	3658	139	344	157	395	0.600	14.79	4.75	7.9
87	1965	8	7	23.6	4	32.8	4960	77	351	221	412	0.666	15.69	5.05	7.6
87	1967	8	6	22.2	5	24.4	3312	101	353	148	503	0.622	13.82	4.65	7.5
88	1962	5	6	25.1	1	33.0	3720	68	367	187	301	0.604	15.16	4.85	8.0
88	1964	6	6	23.8	2	26.8	3872	97	352	0	292	0.599	14.25	4.09	6.8
88	1964	7	6	23.3	0	26.8	3872	95	347	204	300	0.631	14.68	4.52	7.2
88	1966	6	6	23.5	2	25.8	3857	237	365	111	416	0.602	14.15	4.25	7.1
89	1964	6	6	23.2	0	28.0	4080	96	350	208	393	0.638	14.80	4.57	7.2
89	1966	6	5	22.9	0	25.6	3123	221	376	139	405	0.580	13.26	4.43	7.6
89	1966	6	5	23.2	1	25.6	3123	192	353	0	421	0.589	13.65	4.62	7.8
89	1968	5	5	24.3	2	34.2	3932	117	341	185	423	0.553	13.45	4.41	8.0
90	1963	7	7	24.0	1	20.2	2570	253	353	120	355	0.546	13.11	4.45	8.2
90	1963	8	7	23.4	4	20.0	3099	245	337	210	355	0.593	13.90	4.60	7.8
90	1965	8	7	23.4	4	28.9	4349	76	348	226	385	0.579	13.53	4.45	7.7
90	1965	7	7	24.1	5	28.9	4349	80	348	0	385	0.595	14.33	4.77	8.0
90	1967	7	7	23.1	6	22.0	3030	99	359	144	437	0.573	13.24	4.19	7.3
91	1962	5	6	25.2	1	33.2	4457	60	368	185	288	0.604	15.20	4.87	8.1
91	1964	6	6	23.8	2	27.0	3820	119	351	0	390	0.607	14.44	4.29	7.1
91	1966	7	5	22.6	4	21.8	4087	130	353	117	442	0.575	12.97	3.85	6.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5679	114	342	230	356	0.519	12.36	3.86	7.4

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CY-CLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
102	1965	6	5	23.1	1	31.1	4556	185	361	0	492	0.644	14.89	5.31	8.2
102	1967	6	5	23.1	2	30.8	4327	189	343	198	511	0.661	15.26	5.39	8.2
102	1969	5	5	24.2	3	36.6	4913	186	352	190	501	0.668	16.16	4.82	7.2
103	1963	5	6	24.7	0	33.0	4652	195	335	209	302	0.655	16.19	5.33	8.1
103	1965	6	4	21.7	1	32.4	4114	156	351	0	389	0.663	14.41	5.29	8.0
103	1967	4	4	24.1	2	30.7	4198	179	340	181	340	0.576	13.87	5.06	8.8
103	1969	5	5	24.2	3	37.7	4872	178	367	180	377	0.617	14.96	4.50	7.3
104	1962	6	5	22.5	1	29.8	4075	182	356	174	190	0.611	13.72	4.99	8.2
104	1964	5	5	23.5	0	31.6	4368	159	347	203	503	0.693	16.31	5.11	7.4
104	1966	5	4	23.1	1	30.2	4265	187	350	0	363	0.668	15.43	5.27	7.9
104	1968	4	5	24.2	4	34.8	5211	168	351	190	409	0.628	15.20	5.11	8.1
105	1964	8	7	22.9	0	26.8	4368	60	349	209	199	0.614	14.07	4.84	7.9
105	1966	8	6	22.3	4	25.8	4456	61	353	133	416	0.697	15.52	4.93	7.1
105	1968	7	7	24.0	5	33.9	4178	67	355	232	341	0.546	13.11	4.30	7.9
106	1964	9	7	22.7	0	27.1	4593	60	348	203	202	0.637	14.46	4.71	7.4
106	1966	8	7	23.1	1	25.6	4505	63	356	0	372	0.678	15.67	4.87	7.2
106	1968	7	7	24.0	2	30.2	4907	64	356	206	350	0.588	14.09	4.46	7.6
107	1963	6	6	24.2	0	28.9	4074	236	337	147	403	0.680	16.43	5.27	7.7
107	1965	7	6	22.8	1	31.5	4307	186	363	0	403	0.676	15.42	5.43	8.0
107	1967	6	5	23.1	2	28.9	3988	211	341	172	548	0.626	14.45	5.15	8.2
107	1969	5	5	24.0	3	36.3	4564	193	360	200	403	0.653	15.69	4.72	7.2
108	1964	10	9	22.7	0	32.8	4723	62	341	195	309	0.666	15.11	5.01	7.5
108	1966	9	8	23.5	1	26.2	4643	97	352	118	480	0.639	15.04	5.28	8.3
108	1968	8	8	23.5	2	37.8	4545	57	359	195	516	0.681	16.02	4.96	7.3
109	1963	5	4	23.3	1	27.8	3600	200	367	170	391	0.564	13.12	4.83	8.6
109	1965	6	6	24.1	4	34.6	4800	73	350	211	428	0.649	15.63	5.47	8.4
109	1967	6	5	23.1	5	25.8	3734	100	341	153	502	0.570	13.18	4.81	8.4

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CY-CLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
92	1965	7	7	24.0	1	29.8	4566	71	346	0	525	0.573	13.73	4.65	8.1
92	1967	7	6	23.1	2	21.4	2814	94	349	124	428	0.538	12.44	4.07	7.6
95	1962	11	10	22.8	0	31.0	4804	64	360	199	201	0.654	14.94	5.15	7.9
95	1964	10	9	23.3	1	30.0	5587	65	330	0	0	0.644	14.98	5.06	7.9
95	1966	10	9	23.2	4	27.4	6267	94	330	150	297	0.607	14.07	5.05	8.3
96	1962	11	10	23.0	0	32.9	4951	58	362	206	201	0.640	14.73	5.20	8.1
96	1964	10	9	23.3	1	29.0	4813	69	346	0	0	0.576	13.41	4.23	7.3
96	1966	10	9	23.2	4	20.8	3561	91	332	145	303	0.655	15.21	5.08	7.8
96	1968	10	9	23.6	5	38.1	7248	46	347	159	356	0.617	14.59	5.40	8.8
97	1963	5	5	24.9	0	33.0	5296	91	347	166	299	0.618	15.37	5.43	8.8
97	1965	5	3	21.9	1	33.8	4841	158	356	0	394	0.620	13.56	4.98	8.0
97	1967	5	4	22.9	4	31.6	4431	165	346	200	327	0.598	13.67	5.46	9.1
97	1969	4	5	24.4	5	39.1	5239	169	357	187	390	0.570	13.90	4.16	7.3
98	1964	5	4	22.6	0	32.9	4836	137	348	207	397	0.634	14.32	5.37	8.5
98	1966	4	3	23.0	1	34.4	5383	155	348	147	334	0.634	14.58	5.32	8.4
98	1968	3	3	23.9	2	38.1	6829	132	347	207	383	0.588	14.08	4.75	8.1
99	1963	4	3	23.8	0	39.8	5333	169	324	222	302	0.644	15.33	5.50	8.5
99	1965	5	5	23.4	4	37.0	4763	194	348	220	417	0.595	13.94	5.20	8.7
99	1967	5	3	22.3	5	35.9	4469	158	363	185	310	0.577	12.84	4.60	8.0
100	1964	5	5	24.0	0	33.2	4805	153	349	203	403	0.734	17.66	5.56	7.6
100	1966	5	3	22.4	1	32.0	5200	161	350	139	423	0.604	13.53	5.02	8.3
100	1968	3	3	23.4	2	38.2	6847	140	357	201	383	0.627	14.66	4.97	7.9
101	1963	5	6	24.7	0	32.7	4684	184	335	202	302	0.662	16.36	5.68	8.6
101	1965	6	3	21.9	1	32.9	4803	161	361	0	493	0.635	13.91	5.02	7.9
101	1967	5	4	22.7	4	29.9	4313	172	342	183	344	0.565	12.82	4.94	8.7
101	1969	4	5	24.2	5	36.8	4848	172	353	182	404	0.598	14.46	4.20	7.0
102	1963	6	6	24.2	0	27.6	4747	200	351	167	395	0.673	16.30	5.40	8.0

T A B L E I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CY-CLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P205	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
109	1969	5	5	24.0	6	32.0	4583	209	377	183	505	0.619	14.88	4.31	7.0
110	1962	10	10	23.7	1	28.1	3814	62	368	185	362	0.635	15.07	4.78	7.5
110	1964	10	9	23.3	2	27.7	3767	57	361	0	403	0.594	13.83	4.43	7.5
110	1966	10	9	22.6	4	23.8	4159	80	352	139	423	0.572	12.90	4.35	7.6
111	1963	5	5	23.2	1	28.0	3850	208	360	183	390	0.505	11.74	4.32	8.6
111	1965	6	6	24.4	4	35.1	4835	77	353	211	407	0.598	14.57	4.90	8.2
111	1967	6	5	23.2	5	25.8	4018	126	343	154	496	0.533	12.37	4.38	8.2
111	1969	6	6	24.1	6	32.0	4327	66	372	192	426	0.521	12.53	3.83	7.4
112	1963	8	8	23.8	1	25.8	3831	48	347	169	403	0.640	15.25	5.03	7.9
112	1965	9	8	23.4	4	29.5	5265	70	352	227	398	0.689	16.14	5.19	7.5
112	1967	9	8	23.4	5	25.6	3551	78	357	173	462	0.632	14.78	4.97	7.9
112	1969	8	8	23.2	6	31.0	4130	59	374	178	502	0.698	16.19	5.00	7.2
113	1963	8	8	23.8	1	24.1	3452	62	348	164	398	0.613	14.59	4.75	7.7
113	1965	8	8	24.3	2	33.9	6017	70	371	210	399	0.639	15.54	5.02	7.9
113	1967	10	8	22.4	4	21.7	2864	88	359	151	469	0.569	12.73	4.60	8.1
115	1963	6	6	24.6	1	26.5	3696	204	346	175	403	0.587	14.42	4.83	8.2
113	1969	9	8	23.1	5	29.6	4721	67	381	206	397	0.612	14.11	4.44	7.3
114	1963	6	5	23.5	1	24.7	3464	226	368	175	403	0.520	12.21	4.25	8.2
115	1965	7	6	23.6	0	31.6	5403	79	361	206	426	0.638	15.06	5.16	8.1
115	1967	6	5	23.4	1	24.1	3639	94	344	143	433	0.542	12.67	4.29	7.9
115	1969	7	6	23.3	4	26.5	3932	66	375	356	503	0.612	14.27	4.41	7.2
120	1963	8	7	24.0	1	25.0	4518	55	282	171	283	0.627	15.03	5.24	8.4
120	1963	8	7	23.3	0	25.6	4319	50	341	189	290	0.674	15.73	5.46	8.1
120	1965	7	8	24.3	2	29.5	5184	77	363	0	405	0.674	16.38	4.96	7.4
120	1965	7	8	24.3	1	29.5	5184	72	363	0	405	0.665	16.17	4.96	7.5
120	1967	8	7	23.1	4	24.5	4269	77	367	179	463	0.661	15.24	5.17	7.8

TABLE I (CONTINUED)
MANAGEMENT PRACTICES AND YIELD DATA
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	CROP YEAR	MONTH OF PL	MONTH OF HA	AGE IN MO.	CR. CYCLE *2	IRR. RNDS	TOTAL WATER APPL. (MM) *3	RIPENING DAYS *4	FERTILIZER IN KG/HA. N	P2O5	K2O	TON SUGAR ACRE MONTH	TON SUGAR ACRE	TON CANE ACRE MONTH	CANE SUGAR RATIO
121	1963	8	8	23.4	0	25.3	3896	48	358	203	291	0.678	15.86	5.57	8.2
121	1965	8	8	24.3	1	32.6	5753	73	369	0	423	0.622	15.12	5.06	8.1
121	1967	8	7	23.2	2	26.5	4339	78	367	185	451	0.626	14.54	4.94	7.9
121	1969	8	8	23.3	3	29.4	4373	55	372	178	421	0.643	15.01	4.80	7.5
122	1964	10	8	22.5	0	23.2	3607	58	335	191	301	0.622	13.97	5.15	8.3
122	1966	8	7	23.1	1	24.3	4100	59	355	78	437	0.703	16.26	5.40	7.7
122	1968	8	7	23.6	2	30.9	2804	49	347	210	453	0.650	15.34	5.14	7.9
123	1962	9	9	23.8	0	27.2	4107	67	358	195	302	0.610	14.52	5.19	8.5
123	1964	9	8	23.3	1	27.0	4623	64	353	0	501	0.618	14.41	5.18	8.4
123	1966	9	8	22.7	4	23.4	4328	75	353	115	440	0.667	15.14	5.17	7.8

* :YIELD DATA ARE SELECTED ACCORDING TO:
VARIETY---:50-7209
AGE-------:21-26 MONTHS
PLANTED---:MARCH-NOVEMBER
HARVESTED-:MARCH-NOVEMBER
YEARS-----:1960-1969

*1:THE NUMBERS REFER TO THE PLANTATION FIELDS (SEE TABLE III FOR DECODING)

*2:THE CROP CYCLE IS DIVIDED AS FOLLOWS:
0 MEANS PLANT CROP (FIRST CYCLE)
1 MEANS FIRST RATOON CROP (FIRST CYCLE)
2 MEANS SECOND RATOON CROP (FIRST CYCLE)
3 MEANS THIRD RATOON CROP (FIRST CYCLE)
4 MEANS PLANT CROP (SECOND CYCLE)
5 MEANS FIRST RATOON CROP (SECOND CYCLE)
6 MEANS SECOND RATOON CROP (SECOND CYCLE)
7 MEANS THIRD RATOON CROP (SECOND CYCLE)
8 MEANS PLANT CROP (THIRD CYCLE)

*3:TOTAL WATER APPLIED = ROUNDS OF IRR. X ACRE INCHES X 25 MM.

*4:DAYS AFTER LAST IRRIGATION

TABLE II

CLIMATOLOGICAL OBSERVATIONS FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER	RAINFALL IN MM.				EVAPORATION IN MM.			RADIATION IN KG.CALORIES			GR.C	TEMP.(FAH) AT HARVEST		TON SUGAR	TON CANE
*1	TOTAL	SUMMER *2	WINTER *3	AFTER RIP. *4	TOTAL	SUMMER *2	WINTER *3	TOTAL	SUMMER *2	WINTER *3	PER DAY	MAX.	MIN.	ACRE MONTH	ACRE MONTH
1	1419	469	950	0	2965	1807	1157	306	171	136	431	87.3	66.9	0.635	5.38
1	2154	647	1507	76	3463	2067	1395	297	176	121	426	87.6	68.1	0.541	4.47
1	2034	450	1584	93	3972	2305	1667	347	197	151	474	88.6	69.1	0.592	5.32
2	2359	932	1429	76	3580	2125	1455	281	158	123	382	82.4	70.8	0.605	5.35
2	1582	559	1022	113	3420	2027	1392	276	159	117	386	86.9	66.3	0.597	5.00
2	1932	427	1554	117	3290	1947	1342	301	167	134	448	86.3	68.9	0.636	5.50
2	2032	375	1657	47	3905	2382	1522	336	201	135	471	84.5	68.1	0.558	4.41
3	2362	932	1429	83	3580	2125	1455	281	158	123	380	82.4	70.8	0.664	5.40
3	1577	559	1019	113	3550	2027	1522	288	159	129	405	83.2	67.8	0.586	4.82
3	1797	442	1357	106	3477	2135	1342	316	182	134	476	88.2	67.4	0.598	4.82
3	2034	375	1659	60	3905	2382	1522	336	201	135	475	84.5	68.1	0.493	3.80
4	2244	925	1319	82	3430	1975	1455	264	141	123	381	82.4	70.8	0.607	5.03
4	1712	553	1152	282	3550	2027	1522	288	159	129	403	83.2	67.8	0.541	4.69
4	2029	359	1669	58	3715	2192	1522	322	186	135	462	84.5	68.1	0.554	4.32
5	1862	769	1092	33	3392	2010	1382	256	140	116	365	82.4	66.5	0.616	5.31
5	2154	647	1507	89	3607	2067	1540	312	176	136	441	85.2	68.7	0.566	4.96
5	2029	432	1597	106	3815	2147	1667	332	182	151	454	88.6	69.1	0.544	5.10
6	2067	892	1175	58	3585	2190	1392	268	152	116	382	85.7	67.0	0.599	4.63
6	2284	657	1627	36	3650	2255	1395	306	185	121	430	85.2	68.0	0.573	4.38
6	2029	429	1600	30	3800	2332	1527	336	198	138	451	90.3	68.8	0.542	4.33
7	2432	909	1522	0	3222	1897	1325	267	155	112	378	82.4	70.3	0.564	5.15
7	2079	439	1639	369	3447	2105	1342	315	180	134	446	86.5	65.8	0.543	4.77
7	2039	394	1644	69	3695	2172	1522	319	184	135	471	85.4	68.0	0.574	4.26
7	2039	439	1600	52	3882	2360	1522	334	199	135	465	85.5	65.0	0.553	4.28
8	2437	904	1532	252	3120	1795	1325	245	133	112	360	83.5	71.6	0.576	5.28
8	1744	609	1134	100	3617	2225	1392	282	165	117	391	85.5	67.7	0.598	5.61
8	2032	394	1637	254	3435	2092	1342	316	181	134	451	87.3	69.1	0.594	5.53

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	RAINFALL SUMMER *2	RAINFALL WINTER *3	RAINFALL AFTER RIP. *4	EVAPORATION IN MM. TOTAL	EVAPORATION SUMMER *2	EVAPORATION WINTER *3	RADIATION IN KG.CALORIES TOTAL	RADIATION SUMMER *2	RADIATION WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	TEMP.(FAH) AT HARVEST MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
8	1369	347	1622	72	3738	2215	1522	322	187	135	471	85.7	67.5	0.610	5.37
8	2039	457	1582	64	4090	2567	1522	353	217	135	483	85.7	67.5	0.504	4.30
9	2050	375	1675	102	3905	2382	1522	336	201	135	467	84.5	68.1	0.580	5.13
9	2050	375	1675	102	3905	2382	1522	336	201	135	467	84.5	68.1	0.516	4.10
9	2044	359	1684	84	3715	2192	1522	322	186	135	464	84.5	68.1	0.539	5.20
10	2092	909	1182	19	3397	2005	1392	254	138	116	365	84.5	67.9	0.647	4.89
10	2247	739	1597	16	3650	2255	1395	306	185	121	428	85.2	68.0	0.595	4.83
10	2372	532	1539	31	4057	2505	1527	352	214	138	477	90.3	68.8	0.547	4.66
11	1559	409	1150	542	3285	1892	1392	247	131	117	366	79.5	61.5	0.572	5.26
11	2104	704	1400	667	3542	2067	1475	322	176	146	452	79.4	64.7	0.551	5.14
11	2202	467	1734	859	3830	2307	1522	330	195	135	460	81.0	65.9	0.598	4.80
12	1637	532	1104	0	2813	1807	1005	295	171	125	437	90.4	68.9	0.688	5.74
12	2139	914	1225	84	3567	2175	1392	269	152	116	379	85.9	66.8	0.622	4.67
12	2287	712	1575	69	3767	2227	1540	325	189	136	431	85.2	68.7	0.543	4.53
12	2297	704	1592	69	3607	2067	1540	312	176	136	423	85.2	68.7	0.544	4.87
12	2039	439	1600	87	3815	2147	1667	332	182	151	456	88.6	69.1	0.536	5.19
13	2650	1022	1639	67	3430	1975	1455	264	141	123	367	82.4	70.8	0.549	4.76
14	2625	1022	1604	67	3430	1975	1455	264	141	123	370	82.4	70.8	0.535	4.51
14	1779	619	1159	207	3550	2027	1522	288	159	129	405	83.2	67.8	0.514	4.53
14	2139	379	1759	57	3905	2382	1522	336	201	135	467	84.5	68.1	0.469	3.79
16	2022	879	1142	62	3407	2013	1392	255	139	116	373	85.7	67.0	0.561	4.30
17	1754	484	1269	0	2902	1900	1005	313	188	125	443	90.8	69.5	0.602	4.75
17	2069	892	1177	0	3585	2190	1392	268	152	116	371	85.7	67.0	0.602	4.73
17	2334	622	1712	77	3463	2067	1395	295	174	121	429	86.1	69.1	0.660	5.01
19	1950	479	1469	27	3965	2647	1317	351	214	138	472	88.4	66.8	0.486	4.35
21	1839	392	1447	37	3505	2188	1317	319	181	138	466	83.4	66.8	0.525	4.30
25	1534	457	1127	0	3145	1932	1210	304	167	137	446	82.4	63.9	0.595	5.51

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T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	SUMMER *2	WINTER *3	AFTER RIP. *4	EVAPORATION IN MM. TOTAL	SUMMER *2	WINTER *3	RADIATION IN KG.CALORIES TOTAL	SUMMER *2	WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
25	1857	794	1062	204	3775	2350	1422	306	173	133	429	82.0	63.2	0.590	5.18
25	2177	597	1579	50	3602	2180	1422	291	158	133	407	86.1	67.2	0.535	4.42
26	1584	469	1114	0	3350	2140	1210	319	182	137	469	85.6	65.3	0.637	5.07
26	1359	722	1137	197	4280	2932	1347	345	218	127	454	82.0	63.2	0.611	5.54
26	2177	597	1579	47	4280	2932	1347	345	218	127	456	86.1	67.2	0.520	4.50
26	1842	392	1450	37	3505	2188	1317	319	181	138	464	88.4	66.8	0.634	5.57
28	2616	972	1644	47	3470	2157	1313	294	163	131	414	86.3	65.2	0.624	5.27
28	1842	662	1179	134	3825	2470	1355	313	182	131	434	86.4	64.5	0.590	4.99
28	2139	394	1744	139	3420	2080	1340	301	167	134	440	85.6	68.2	0.615	5.17
28	2327	432	1894	32	3660	2202	1457	319	184	135	453	85.6	67.5	0.561	4.25
29	1979	825	1154	22	3638	2215	1422	291	158	133	405	85.8	66.1	0.585	4.53
29	2427	675	1752	102	3820	2475	1347	318	191	127	453	87.2	65.6	0.537	4.33
29	2257	539	1717	44	3670	2350	1317	334	197	138	460	88.4	67.8	0.580	4.75
30	1877	544	1332	0	3590	2377	1210	335	198	137	459	85.6	66.1	0.582	4.69
30	1869	544	1325	0	3590	2377	1210	335	198	137	469	85.6	66.1	0.652	5.05
30	2119	892	1227	77	3838	2415	1422	303	170	133	419	85.7	66.3	0.601	4.66
30	2087	677	1209	75	3625	2202	1422	289	156	133	414	85.7	66.3	0.576	4.41
30	2422	664	1757	119	3867	2520	1347	319	192	127	452	86.8	66.9	0.615	4.78
30	2417	664	1752	112	3867	2520	1347	319	192	127	448	86.8	66.9	0.598	4.74
30	2239	527	1712	37	3715	2395	1317	336	198	138	460	89.1	67.7	0.623	4.78
30	2239	527	1712	37	3715	2395	1317	336	198	138	456	89.1	67.7	0.519	4.06
31	2625	1027	1602	47	3852	2540	1313	324	193	131	436	85.1	65.2	0.662	4.98
31	2625	972	1647	47	3470	2157	1313	294	163	131	403	86.3	65.2	0.666	5.05
31	1809	657	1152	139	3797	2442	1355	314	182	131	439	86.5	65.2	0.639	5.04
31	1847	657	1169	139	3797	2442	1355	314	182	131	428	86.5	65.2	0.593	4.78
31	2175	454	1719	167	3607	2270	1340	316	182	134	462	85.0	58.6	0.627	5.10
32	2725	934	1634	52	3677	2365	1313	311	180	131	424	86.3	65.2	0.669	5.36

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	RAINFALL SUMMER *2	RAINFALL WINTER *3	RAINFALL AFTER RIP. *4	EVAPORATION IN MM. TOTAL	EVAPORATION SUMMER *2	EVAPORATION WINTER *3	RADIATION IN KG.CALORIES TOTAL	RADIATION SUMMER *2	RADIATION WINTER *3	RADIATION GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	TEMP.(FAH) AT HARVEST MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
32	1844	662	1182	132	3825	2470	1355	313	182	131	434	86.4	64.5	0.677	5.57
32	2067	442	1625	82	3632	2292	1340	316	181	134	467	85.6	68.2	0.646	5.34
32	2377	509	1867	29	3857	2397	1457	335	199	135	467	85.6	67.5	0.550	4.24
33	1867	522	1344	0	3400	2190	1210	319	182	137	447	85.6	66.1	0.603	4.84
33	2119	892	1227	69	3838	2415	1422	303	170	133	420	85.7	66.3	0.572	4.79
33	2412	652	1759	97	3640	2292	1347	303	176	127	447	86.8	66.9	0.600	4.98
33	2237	575	1662	59	3888	2570	1317	350	213	138	482	88.4	67.8	0.554	4.52
34	2392	664	1727	164	3630	2282	1347	303	176	127	452	87.2	65.6	0.611	5.15
35	1934	584	1350	0	3582	2370	1210	333	196	137	473	84.3	65.0	0.528	4.61
35	2114	877	1237	72	3625	2202	1422	289	156	133	404	85.7	66.3	0.554	4.61
35	1987	825	1162	72	3638	2215	1422	291	158	133	424	85.8	66.1	0.585	4.76
35	2482	664	1817	87	3772	2282	1490	318	176	142	426	85.2	65.8	0.506	4.13
35	2487	675	1812	87	3965	2475	1490	333	191	142	442	85.2	65.8	0.553	4.47
35	2294	517	1777	122	3610	2170	1440	329	182	147	455	85.0	66.0	0.549	5.39
36	2500	1014	1639	0	3877	2565	1313	326	195	131	432	86.3	65.2	0.601	4.93
36	2600	984	1625	50	3677	2365	1313	311	180	131	426	86.3	65.2	0.621	5.17
36	1839	662	1177	127	3825	2470	1355	313	182	131	434	86.4	64.5	0.654	5.57
36	1852	662	1189	127	3825	2470	1355	313	182	131	434	86.4	64.5	0.596	5.24
37	1925	307	1617	62	3813	2200	1613	334	186	148	461	85.0	63.8	0.528	4.51
38	2225	850	1375	62	3852	2540	1313	324	193	131	443	86.1	65.2	0.666	5.31
38	2225	850	1375	102	3852	2540	1313	324	193	131	434	86.1	65.2	0.512	4.41
38	2175	350	1825	59	3813	2200	1613	334	186	148	450	85.0	63.8	0.524	4.14
39	2197	537	1659	107	3772	2282	1490	318	176	142	443	85.2	65.8	0.566	5.30
39	1964	412	1552	94	3632	2170	1463	332	182	151	454	87.0	67.9	0.466	4.90
40	2250	825	1400	112	3485	2172	1313	292	161	131	414	86.1	65.2	0.637	5.21
40	2200	350	1825	59	3813	2200	1613	334	186	148	452	85.0	63.8	0.539	4.57
41	1875	607	1267	0	3770	2560	1210	348	212	137	478	84.3	65.0	0.487	4.18

TABLE II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	RAINFALL SUMMER *2	RAINFALL WINTER *3	RAINFALL AFTER RIP. *4	EVAPORATION IN MM. TOTAL	EVAPORATION SUMMER *2	EVAPORATION WINTER *3	RADIATION IN KG.CALORIES TOTAL	RADIATION SUMMER *2	RADIATION WINTER *3	RADIATION GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	TEMP.(FAH) AT HARVEST MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
42	2300	650	1650	69	4413	2922	1490	363	221	142	520	85.2	65.8	0.547	4.51
43	2150	900	1250	0	3660	2347	1313	319	188	131	454	81.1	63.1	0.607	5.20
43	2225	950	1300	0	3800	2488	1313	333	202	131	450	81.1	63.1	0.535	4.79
43	2300	550	1750	84	3635	2282	1352	305	176	129	434	85.2	65.8	0.528	4.11
45	2250	875	1350	0	3660	2347	1313	319	188	131	452	81.1	63.1	0.560	4.71
45	2225	575	1650	89	3635	2282	1352	305	176	129	441	85.2	65.8	0.450	3.43
46	2225	850	1375	0	3688	2375	1313	312	181	131	427	85.1	66.0	0.593	4.68
46	1600	500	1125	0	3595	2240	1355	296	165	131	430	84.5	63.9	0.613	4.71
46	2075	400	1675	377	3665	2325	1340	315	180	134	450	84.5	65.5	0.573	4.74
46	2325	475	1850	839	3680	2222	1457	318	182	135	452	83.0	63.5	0.599	4.15
47	1575	500	1075	0	3370	2015	1355	280	149	131	405	82.7	64.7	0.591	4.26
47	1575	475	1100	0	3172	1817	1355	268	137	131	409	82.7	64.7	0.632	4.85
47	2100	400	1700	377	3665	2325	1340	315	180	134	438	84.5	65.5	0.581	4.50
48	2575	875	1700	64	3863	2550	1313	327	196	131	430	85.1	66.0	0.557	4.58
48	1900	625	1275	300	3595	2240	1355	296	165	131	430	84.5	63.9	0.613	4.37
48	2575	500	1675	437	3650	2310	1340	315	180	134	454	86.4	65.3	0.697	5.03
48	2775	575	2200	19	3867	2410	1457	334	199	135	477	86.1	65.0	0.593	4.10
49	2000	350	1650	52	3813	2200	1613	334	186	148	463	85.0	63.8	0.509	4.17
50	1475	425	1025	0	3463	2252	1210	331	195	137	464	82.3	62.4	0.612	5.46
50	1475	425	1025	0	3463	2252	1210	331	195	137	464	82.3	62.4	0.587	5.35
50	1800	475	1300	212	3860	2267	1590	321	169	153	444	80.0	64.4	0.568	5.22
50	1625	450	1200	39	3625	2282	1342	317	182	136	450	86.5	66.5	0.540	4.52
50	2000	350	1650	67	3667	2200	1467	320	186	134	452	85.0	63.8	0.584	4.13
51	1850	825	1025	222	3595	2172	1422	294	161	133	421	79.5	61.8	0.656	5.57
52	1450	375	1075	0	3320	2110	1210	317	181	137	460	77.5	60.9	0.720	6.91
52	1900	875	1050	297	3730	2307	1422	305	172	133	431	80.6	61.9	0.629	5.56
52	2150	475	1675	904	3615	2267	1347	296	169	127	442	80.4	58.6	0.702	5.36

TABLE II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	SUMMER *2	WINTER *3	AFTER RIP. *4	EVAPORATION IN MM. TOTAL	SUMMER *2	WINTER *3	RADIATION IN KG.CALORIES TOTAL	SUMMER *2	WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
52	1900	450	1450	677	3750	2282	1467	332	182	150	466	77.9	62.9	0.555	4.82
53	1475	425	1050	0	3463	2252	1210	331	195	137	454	82.3	62.4	0.552	4.96
53	1800	475	1300	209	3715	2267	1447	308	169	139	428	80.0	64.4	0.565	5.33
53	1400	450	950	34	3745	2282	1463	328	182	146	473	81.4	66.0	0.583	4.97
53	2000	350	1650	37	3790	2200	1590	330	186	143	459	80.9	64.1	0.559	4.08
53	2000	350	1650	37	3667	2200	1467	320	186	134	452	85.0	63.8	0.588	4.68
53	2000	350	1650	37	3813	2200	1613	334	186	148	461	85.0	63.8	0.551	5.58
54	2100	950	1150	0	3800	2488	1313	333	202	131	455	81.1	63.1	0.541	4.80
54	1525	375	1125	689	3442	2088	1355	279	148	131	418	79.2	57.6	0.576	5.12
54	2150	650	1500	772	3932	2592	1340	339	205	134	463	84.5	65.5	0.553	4.90
54	2050	450	1600	784	3647	2190	1457	316	181	135	468	78.6	63.3	0.569	4.35
54	2050	450	1600	784	3647	2190	1457	316	181	135	468	78.6	63.3	0.527	4.43
55	1750	875	875	0	3472	2160	1313	303	172	131	429	81.1	63.1	0.520	4.97
55	2425	950	1475	0	3660	2347	1313	319	188	131	435	81.1	63.1	0.518	4.65
55	1575	375	1200	787	3442	2088	1355	279	148	131	422	79.2	57.6	0.568	4.94
55	2500	700	1800	889	3763	2425	1340	324	190	134	442	80.3	62.1	0.472	4.69
55	2550	600	1975	932	3790	2332	1457	330	195	135	458	78.6	63.3	0.531	4.16
56	2425	875	1550	0	3472	2160	1313	303	172	131	427	81.1	63.1	0.569	4.68
56	1750	700	1050	1017	3710	2357	1355	303	172	131	435	82.7	64.7	0.592	5.36
56	2225	400	1825	889	3495	2155	1340	300	165	134	443	80.3	62.1	0.582	4.81
56	2550	600	1975	919	3790	2332	1457	330	195	135	454	78.6	63.3	0.563	4.21
58	1975	725	1225	32	3317	1945	1372	278	149	130	461	81.5	69.1	0.634	4.59
58	2325	525	1775	225	3572	2192	1380	296	174	122	412	82.7	71.3	0.595	4.17
60	1600	525	1100	0	3297	2202	1095	332	204	128	442	81.1	69.4	0.602	4.74
60	1975	725	1225	37	3317	1945	1372	278	149	130	468	81.5	69.1	0.641	4.83
60	2325	525	1775	1025	3572	2192	1380	296	174	122	423	82.7	71.3	0.607	4.11
60	2350	625	1750	352	3317	1997	1320	295	168	127	415	83.5	69.7	0.601	4.65

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	SUMMER *2	WINTER *3	AFTER RIP. *4	EVAPORATION IN MM. TOTAL	SUMMER *2	WINTER *3	RADIATION IN KG.CALORIES TOTAL	SUMMER *2	WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
61	1675	575	1100	0	3250	2155	1095	331	203	128	430	82.0	67.7	0.587	4.38
61	1975	725	1225	17	3317	1945	1372	278	149	130	401	81.5	69.1	0.661	4.75
61	1975	750	1225	17	3470	2097	1372	291	161	130	401	81.5	69.1	0.607	4.32
61	2325	525	1775	1019	3572	2192	1380	296	174	122	407	82.7	71.3	0.476	3.46
61	2300	525	1775	1014	3405	2025	1380	284	162	122	411	82.7	71.3	0.605	3.87
62	2425	550	1500	0	3317	2045	1275	304	180	125	415	78.4	66.7	0.557	4.60
63	2425	875	1550	102	3165	1890	1275	275	150	125	389	82.2	70.2	0.599	4.70
63	1925	575	1350	79	3495	2160	1335	296	169	126	419	84.8	70.0	0.611	4.48
63	2375	525	1850	117	3592	2125	1465	321	182	138	427	85.8	72.1	0.512	4.27
63	2400	375	2025	59	3595	2050	1545	316	175	141	452	82.2	66.7	0.557	3.82
64	2425	875	1550	97	3165	1890	1275	275	150	125	391	82.2	70.2	0.539	4.02
64	1925	575	1350	79	3495	2160	1335	296	169	126	417	84.8	70.0	0.587	4.22
64	2375	525	1850	42	3592	2125	1465	321	182	138	427	85.8	72.1	0.525	4.10
64	2425	375	2025	59	3463	2050	1413	304	175	129	431	82.2	66.7	0.516	3.75
65	1975	750	1225	369	3302	1930	1372	279	150	130	408	78.5	66.8	0.606	4.32
65	2225	550	1775	1012	3545	2165	1380	294	172	122	403	82.4	67.6	0.597	4.50
65	2325	625	1700	425	3505	2185	1320	310	183	127	432	85.2	72.7	0.602	4.18
66	1600	475	1125	0	2970	1875	1095	306	178	128	441	78.9	65.5	0.651	5.93
66	1900	825	1075	250	3263	1890	1372	280	150	130	405	76.7	65.1	0.632	5.45
66	2300	550	1750	967	3520	2140	1380	290	169	122	401	77.1	63.7	0.627	5.36
66	2275	650	1625	962	3460	2141	1319	308	181	127	432	81.5	69.3	0.566	5.10
67	1675	450	1250	0	3130	1897	1230	313	172	140	423	81.6	67.4	0.654	5.30
67	1850	750	1100	67	3325	1952	1372	278	149	130	400	83.0	70.7	0.681	5.00
67	1875	600	1275	122	3272	1892	1380	272	150	122	395	83.4	71.9	0.600	4.37
67	2275	600	1700	132	3488	2167	1320	309	182	127	421	87.0	73.1	0.570	4.12
68	1675	550	1125	0	3097	2002	1095	318	190	128	439	79.2	66.7	0.638	5.86
68	1825	750	1075	319	3142	1770	1372	268	138	130	407	76.7	65.1	0.662	5.73

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	SUMMER *2	WINTER *3	AFTER RIP. *4	EVAPORATION IN MM. TOTAL	SUMMER *2	WINTER *3	RADIATION IN KG.CALORIES TOTAL	SUMMER *2	WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
68	2425	550	1875	977	3650	2140	1510	302	169	133	397	77.1	63.7	0.598	4.82
68	2300	575	1725	987	3677	2297	1380	305	183	122	416	82.4	67.6	0.568	4.68
68	2275	625	1650	957	3313	1995	1320	296	169	127	432	81.5	69.3	0.596	5.29
68	2275	625	1650	957	3313	1995	1320	296	169	127	423	81.5	69.3	0.552	4.89
69	2125	825	1325	84	3060	1890	1170	263	150	113	385	82.2	70.2	0.637	5.17
69	1725	550	1175	57	3327	1992	1335	283	157	126	396	84.8	70.0	0.647	5.15
69	2175	350	1825	64	3307	1900	1405	290	161	129	437	81.8	69.9	0.542	3.81
77	1775	700	1075	189	3317	1945	1372	278	149	130	408	84.8	70.8	0.641	4.91
77	1775	700	1075	189	3317	1945	1372	278	149	130	391	85.7	66.1	0.530	4.47
79	2000	550	1450	139	3430	2050	1380	286	164	122	412	85.7	66.1	0.543	5.26
80	1625	450	1175	0	3285	1897	1388	310	172	138	441	78.0	64.8	0.531	5.06
80	1450	325	1125	717	3172	1838	1335	266	139	126	398	77.8	62.5	0.636	5.49
80	2225	600	1625	737	3510	2050	1460	303	164	138	427	78.5	66.7	0.580	5.41
81	1575	500	1075	0	3135	2040	1095	317	189	128	447	81.1	69.4	0.693	5.31
81	1750	700	1050	25	3495	2125	1372	292	163	130	411	81.5	71.0	0.633	4.71
81	2100	475	1625	207	3222	1842	1380	269	147	122	412	82.4	67.6	0.690	4.94
81	2375	650	1725	359	3663	2342	1320	324	197	127	435	85.2	72.7	0.566	4.77
82	1775	675	1100	17	3130	1757	1372	264	134	130	383	81.5	69.1	0.727	5.71
82	1950	475	1500	197	3392	2010	1380	281	159	122	410	82.4	67.6	0.632	5.20
83	1525	500	1025	0	3135	2040	1095	317	189	128	437	81.1	69.4	0.627	4.94
83	1750	700	1050	25	3495	2125	1372	292	163	130	414	81.5	71.0	0.652	4.88
83	2125	475	1650	44	3405	2025	1380	284	162	122	413	82.7	71.3	0.653	4.82
83	2350	625	1725	357	3505	2185	1320	310	183	127	430	85.2	72.7	0.598	4.71
84	2125	450	1650	927	3235	1852	1380	266	145	122	394	77.1	63.7	0.725	5.33
84	2350	625	1725	967	3475	2155	1320	310	183	127	426	83.5	69.7	0.629	5.23
85	1650	525	1100	0	3142	2047	1095	316	188	128	444	82.0	69.6	0.720	5.41
85	1900	775	1125	44	3307	1935	1372	278	148	130	393	81.5	71.0	0.700	5.00

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	RAINFALL IN MM. SUMMER *2	RAINFALL IN MM. WINTER *3	RAINFALL IN MM. AFTER RIP. *4	EVAPORATION IN MM. TOTAL	EVAPORATION IN MM. SUMMER *2	EVAPORATION IN MM. WINTER *3	RADIATION IN KG.CALORIES TOTAL	RADIATION IN KG.CALORIES SUMMER *2	RADIATION IN KG.CALORIES WINTER *3	RADIATION GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	TEMP.(FAH) AT HARVEST MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
85	2725	525	2200	100	3227	1847	1380	270	148	122	409	82.7	71.3	0.730	4.98
85	2575	725	1850	137	3505	2185	1320	310	183	127	423	85.2	72.7	0.616	4.63
86	1900	775	1125	127	3470	2097	1372	291	161	130	407	81.5	69.1	0.617	4.39
86	1900	750	1150	127	3302	1930	1372	279	150	130	401	78.5	66.8	0.647	4.81
86	2800	550	2250	1112	3392	2010	1380	281	159	122	405	82.4	67.6	0.615	4.69
86	2600	775	1825	1072	3475	2155	1320	310	183	127	424	83.5	69.7	0.592	4.93
87	2300	900	1375	0	3490	2215	1275	312	187	125	422	81.8	70.1	0.600	4.75
87	2225	525	1700	0	3332	1997	1335	282	156	126	398	81.7	68.9	0.666	5.05
87	2250	550	1700	392	3155	1820	1332	281	155	126	422	84.8	69.7	0.622	4.65
88	2150	825	1325	0	3250	2155	1095	331	203	128	439	82.0	67.7	0.604	4.85
88	1875	925	950	134	3470	2097	1372	291	161	130	407	81.5	69.1	0.599	4.09
88	1875	875	1000	132	3317	1945	1372	278	149	130	398	81.5	69.1	0.631	4.52
88	2850	900	1950	1152	3572	2192	1380	296	174	122	419	82.7	71.3	0.602	4.25
89	1900	925	975	177	3470	2097	1372	291	161	130	418	81.5	69.1	0.638	4.57
89	2800	850	1950	1114	3392	2010	1380	281	159	122	408	82.4	67.6	0.580	4.43
87	2800	850	1950	1114	3392	2010	1380	281	159	122	403	82.4	67.6	0.589	4.62
89	3025	925	2100	625	3475	2155	1320	310	183	127	424	83.5	69.7	0.553	4.41
90	2225	1025	1200	0	3340	2065	1275	296	172	125	411	81.8	70.1	0.546	4.45
90	2200	950	1250	0	3152	1880	1275	281	156	125	399	81.8	70.1	0.593	4.60
90	2200	825	1375	0	3332	1997	1335	282	156	126	401	81.7	68.9	0.579	4.45
90	2275	900	1375	0	3515	2180	1335	294	168	126	406	81.7	68.9	0.595	4.77
90	2550	825	1800	292	3522	2190	1332	309	183	126	446	84.1	72.2	0.573	4.19
91	2175	825	1350	0	3250	2155	1095	331	203	128	437	82.0	67.7	0.604	4.87
91	1900	925	975	219	3470	2097	1372	291	161	130	407	81.5	69.1	0.607	4.29
91	2800	825	1975	322	3222	1842	1380	269	147	122	396	82.4	67.6	0.575	3.85
91	3000	900	2100	600	3505	2185	1320	310	183	127	433	85.2	72.7	0.519	3.36
92	2200	1025	1175	0	3340	2065	1275	296	172	125	422	81.8	70.1	0.540	4.25

TABLE II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	RAINFALL IN MM. SUMMER *2	RAINFALL IN MM. WINTER *3	RAINFALL IN MM. AFTER RIP. *4	EVAPORATION IN MM. TOTAL	EVAPORATION IN MM. SUMMER *2	EVAPORATION IN MM. WINTER *3	RADIATION IN KG.CALORIES TOTAL	RADIATION IN KG.CALORIES SUMMER *2	RADIATION IN KG.CALORIES WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	TEMP.(FAH) AT HARVEST MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
92	1975	900	1075	0	3515	2180	1335	294	168	126	408	81.7	68.9	0.573	4.65
92	2075	700	1975	259	3342	2010	1332	295	169	126	426	84.8	69.7	0.538	4.07
95	1575	550	1025	0	3017	1897	1120	300	172	128	439	81.6	67.4	0.654	5.15
95	1875	775	1100	84	3325	1952	1372	278	149	130	398	83.0	70.7	0.644	5.06
95	2450	750	1700	232	3430	2050	1380	286	164	122	410	84.8	70.8	0.607	5.05
96	1600	550	1050	0	3017	1897	1120	300	172	128	435	81.6	67.4	0.640	5.20
96	1875	775	1100	87	3325	1952	1372	278	149	130	393	83.0	70.7	0.576	4.23
96	2450	750	1700	227	3430	2050	1380	286	164	122	410	84.8	70.8	0.655	5.08
96	2275	575	1700	69	3330	2013	1320	295	168	127	416	87.0	73.1	0.617	5.40
97	2250	975	1250	0	3317	2045	1275	304	180	125	407	78.4	66.7	0.618	5.43
97	1575	425	1150	819	3172	1838	1335	266	139	126	404	77.8	62.5	0.620	4.98
97	2225	700	1525	797	3392	2060	1332	292	166	126	424	78.9	65.7	0.598	5.46
97	2275	650	1625	775	3717	2310	1405	324	196	129	443	78.8	62.1	0.570	4.16
98	1850	800	1050	362	3275	1902	1372	278	148	130	410	78.4	67.0	0.634	5.37
98	2325	600	1725	887	3372	1992	1380	278	157	122	403	79.1	64.3	0.634	5.32
98	2175	625	1525	882	3442	1990	1455	307	168	139	428	78.6	68.4	0.588	4.75
99	2000	550	1475	0	3172	1897	1275	297	172	125	415	78.0	64.8	0.644	5.50
99	1825	700	1100	1069	3455	2120	1335	288	162	126	410	81.4	68.4	0.595	5.20
99	2150	575	1575	707	3270	1938	1332	279	153	126	417	78.5	66.7	0.577	4.60
100	1950	825	1125	394	3430	2057	1372	291	162	130	404	78.5	66.8	0.734	5.56
100	2300	575	1725	889	3240	1860	1380	268	146	122	398	79.1	64.3	0.604	5.02
100	2625	625	1975	647	3442	1990	1455	307	168	139	437	78.6	68.4	0.627	4.97
101	2250	1025	1225	0	3482	2207	1275	315	190	125	424	80.7	68.7	0.662	5.68
101	1575	275	1300	794	3017	1682	1335	254	127	126	386	77.8	62.5	0.635	5.02
101	2225	700	1525	797	3392	2060	1332	292	166	126	428	78.9	65.7	0.565	4.94
101	2275	650	1625	789	3717	2310	1405	324	196	129	446	78.8	62.1	0.598	4.20
102	2225	925	1300	0	3307	2032	1275	300	175	125	412	80.7	68.7	0.673	5.40

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	RAINFALL SUMMER *2	RAINFALL WINTER *3	RAINFALL AFTER RIP. *4	EVAPORATION IN MM. TOTAL	EVAPORATION SUMMER *2	EVAPORATION WINTER *3	RADIATION IN KG.CALORIES TOTAL	RADIATION SUMMER *2	RADIATION WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	TEMP.(FAH) AT HARVEST MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
102	1700	575	1125	0	3300	1965	1335	276	150	126	398	81.4	68.4	0.644	5.31
102	2250	600	1650	859	3365	2030	1332	295	169	126	425	83.0	69.4	0.661	5.39
102	2275	525	1750	792	3595	2188	1405	312	183	129	429	78.8	62.1	0.668	4.82
103	2250	1025	1225	0	3482	2207	1275	315	190	125	424	80.7	68.7	0.655	5.33
103	1700	450	1250	900	3130	1795	1335	265	139	126	407	78.8	66.2	0.663	5.29
103	2400	850	1550	807	3505	2172	1332	303	177	126	419	78.9	65.7	0.576	5.06
103	2275	525	1725	787	3595	2188	1405	312	183	129	429	78.8	62.1	0.617	4.50
104	1650	575	1050	0	3842	2335	1507	316	180	136	468	79.7	71.0	0.611	4.99
104	1875	825	1050	397	3715	2210	1505	296	165	131	419	78.1	69.7	0.693	5.11
104	2325	600	1725	917	3370	2015	1355	285	160	125	411	76.5	63.0	0.668	5.27
104	2425	750	1675	954	3635	2270	1365	333	201	132	458	81.9	66.9	0.628	5.11
105	2000	950	1025	97	3492	1985	1505	282	151	131	410	80.4	73.0	0.614	4.84
105	2375	650	1725	69	3177	1822	1355	275	150	125	410	80.6	61.3	0.697	4.93
105	2525	800	1750	42	3560	2195	1365	321	189	132	446	86.4	75.6	0.546	4.30
106	1975	900	1075	84	3305	1800	1505	267	137	131	392	80.4	73.0	0.637	4.71
106	2425	825	1600	72	3372	2017	1355	290	165	125	418	80.5	61.2	0.678	4.87
106	2525	800	1750	39	3560	2195	1365	321	189	132	446	86.4	75.6	0.568	4.46
107	3025	1350	1650	0	3960	2370	1590	300	174	125	412	79.8	70.8	0.680	5.27
107	2500	1050	1475	0	3375	2020	1355	283	157	131	420	73.5	72.4	0.676	5.43
107	2950	825	2125	884	3365	2047	1317	303	171	132	437	81.4	64.0	0.626	5.15
107	3325	950	2350	1217	3838	2247	1588	323	190	133	448	81.5	65.9	0.653	4.72
108	2450	1175	1275	162	3515	2007	1505	283	152	131	416	86.4	73.9	0.666	5.01
108	3200	1150	2075	337	3405	2047	1355	291	166	125	412	81.9	69.0	0.639	5.28
108	3150	925	2225	112	3615	2250	1365	322	190	132	457	85.5	70.0	0.681	4.96
109	2000	1250	1625	0	3852	2263	1590	293	167	125	418	77.4	63.4	0.564	4.83
109	2575	1100	1475	0	3545	2190	1355	298	167	131	412	73.5	72.4	0.649	5.47
109	2975	825	2150	444	3365	2047	1317	303	171	132	437	81.4	64.0	0.570	4.91

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	RAINFALL SUMMER *2	RAINFALL WINTER *3	RAINFALL AFTER RIP. *4	EVAPORATION IN MM. TOTAL	EVAPORATION SUMMER *2	EVAPORATION WINTER *3	RADIATION IN KG.CALORIES TOTAL	RADIATION SUMMER *2	RADIATION WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	TEMP.(FAH) AT HARVEST MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
109	3300	950	2325	1222	3838	2247	1568	323	190	133	448	81.5	65.9	0.619	4.31
110	2425	900	1525	0	3982	2307	1677	321	172	149	450	80.5	72.3	0.635	4.78
110	2500	1175	1325	144	3515	2007	1505	283	152	131	405	86.4	73.9	0.594	4.43
110	3075	1100	1975	294	3405	2047	1355	291	166	125	429	82.8	66.7	0.572	4.35
111	2875	1400	1475	0	4000	2407	1590	304	179	125	437	78.0	69.9	0.505	4.32
111	2575	1100	1475	0	3545	2190	1355	298	167	131	407	73.5	72.4	0.598	4.90
111	2975	825	2150	477	3365	2047	1317	303	171	132	436	81.4	64.0	0.533	4.38
111	3300	925	2350	112	3877	2290	1588	324	191	133	447	83.8	68.2	0.521	3.83
112	2775	1275	1500	82	3905	2315	1590	296	170	125	414	81.6	73.0	0.640	5.03
112	2450	1000	1450	197	3380	2025	1355	288	157	131	410	81.7	71.2	0.689	5.19
112	2700	725	1975	197	3292	1975	1317	308	176	132	439	81.2	68.8	0.632	4.97
112	2775	750	2050	137	3925	2338	1588	326	193	133	468	83.1	72.3	0.698	5.00
113	2750	1275	1475	114	3905	2315	1590	296	170	125	414	81.6	73.0	0.613	4.75
113	2475	1000	1475	197	3563	2210	1355	303	172	131	415	81.7	71.2	0.639	5.02
113	2575	700	1875	200	3152	1832	1317	294	162	132	436	81.2	68.8	0.569	4.60
113	3025	1350	1650	0	3772	2185	1588	312	179	133	450	83.1	72.3	0.587	4.83
113	2775	650	2125	144	3790	2200	1590	289	164	125	410	78.0	69.9	0.612	4.44
114	2950	1300	1650	0	3960	2370	1590	300	174	125	406	79.8	70.8	0.520	4.25
115	2525	1050	1475	0	3375	2020	1355	288	157	131	406	73.5	72.4	0.638	5.16
115	2975	825	2150	362	3365	2047	1317	303	171	132	432	81.4	64.0	0.542	4.29
115	3250	875	2375	122	3715	2127	1588	308	175	133	440	83.8	68.2	0.612	4.41
120	3025	1425	1575	0	3720	2130	1590	281	156	125	390	80.0	72.6	0.627	5.24
120	2925	1425	1475	150	3720	2130	1590	281	156	125	402	80.0	72.6	0.674	5.46
120	2500	1200	1300	194	3745	2390	1355	315	184	131	432	81.7	71.2	0.674	4.96
120	2400	1200	1200	184	3745	2390	1355	315	184	131	432	81.7	71.2	0.665	4.96
120	2850	850	2000	167	3322	2005	1317	308	176	132	445	81.2	67.8	0.661	5.17
120	3025	925	2100	69	3890	2302	1588	324	191	133	460	82.8	69.6	0.640	4.67

T A B L E II (CONTINUED)
CLIMATOLOGICAL OBSERVATIONS
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO.LTD." *

NUMBER *1	RAINFALL IN MM. TOTAL	SUMMER *2	WINTER *3	AFTER RIP. *4	EVAPORATION IN MM. TOTAL	SUMMER *2	WINTER *3	RADIATION IN KG.CALORIES TOTAL	SUMMER *2	WINTER *3	GR.C PER DAY	TEMP.(FAH) AT HARVEST MAX.	MIN.	TON SUGAR ACRE MONTH	TON CANE ACRE MONTH
121	2950	1450	1500	150	3905	2315	1590	296	170	125	421	81.6	73.0	0.678	5.57
121	2500	1100	1400	197	3563	2210	1355	303	172	131	415	81.7	71.2	0.622	5.06
121	2850	850	2000	177	3322	2005	1317	308	176	132	443	81.2	67.8	0.626	4.94
121	3000	900	2100	122	3925	2338	1588	326	193	133	466	83.1	72.3	0.643	4.80
122	2500	1275	1250	179	3315	1807	1505	269	138	131	398	84.0	73.5	0.622	5.15
122	3000	1150	1825	297	3372	2017	1355	290	165	125	418	60.5	61.2	0.703	5.40
122	2875	850	2050	82	3365	2000	1365	306	174	132	432	86.4	75.6	0.650	5.14
123	2550	1050	1500	0	4000	2492	1507	324	188	136	454	81.7	71.4	0.610	5.19
123	2550	1325	1225	172	3510	2002	1505	282	152	131	404	84.0	73.5	0.618	5.18
123	3000	1150	1850	327	3405	2047	1355	291	166	125	426	81.9	69.0	0.667	5.17

* :YIELD DATA ARE SELECTED ACCORDING TO:
VARIETY---:50-7209
AGE-------:21-26 MONTHS
PLANTED---:MARCH-NOVEMBER
HARVESTED-:MARCH-NOVEMBER
YEARS-----:1960-1969
*1:THE NUMBERS REFER TO THE PLANTATION FIELDS (SEE TABLE III FOR DECODING)
*2:SUMMER MONTHS: APRIL,MAY,JUNE,JULY,AUGUST,SEPTEMBER
*3:WINTER MONTHS: OCTOBER,NOVEMBER,DECEMBER,JANUARY,FEBRUARY,MARCH
*4:RAINFALL AFTER LAST IRRIGATION ROUND IS APPLIED

T A B L E III (CONTINUED)
SOIL DATA, ELEVATION AND SLOPE
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO. LTD." *

FIELD NAME	NUMBER	SIZE IN AC.	MAIN SOIL SE-RIES *1	% OF TO-TAL	MIN. SOIL SE-RIES *1	% OF TO-TAL	K IN LB ACRE	P PER FOOT	PH	MOISTURE STO-RAGE *2	PERMEABILITY *3	DRAINAGE *4	ELEVATION M.	SLOPE IN %	MEAN TON SUGAR AC/MO
KEMOO 1	42	155	170	72	60	19	178	111	6.4	2.97	4	5	36	2- 4	0.584
KEMOO 2A	43	75	60	81	170	13	130	78	6.0	2.90	4	5	100	5-13	0.557
KEMOO 4	46	93	150	82	62	17	243	73	5.5	3.07	5	5	153	2-10	0.594
KEMOO 5	47	198	150	80	152	12	363	99	5.2	3.14	5	5	166	4-10	0.605
KEMOO 9	48	30	152	73	150	26	275	73	6.2	3.17	5	5	226	7-10	0.615
HELEMANO 2A	50	133	60	86	1000	7	621	69	6.6	3.04	4	5	40	3- 7	0.578
HELEMANO 2B	51	53	60	81	62	18	369	52	6.6	2.97	4	5	86	4- 5	0.588
HELEMANO 4	52	113	60	75	62	24	404	83	6.8	2.90	4	5	43	4- 5	0.633
HELEMANO 4A	53	113	60	61	162	15	429	62	7.0	2.90	4	5	86	4-10	0.569
HELEMANO 4B	54	146	62	94		0	267	44	6.4	2.90	4	5	83	4- 8	0.553
HELEMANO 5A	55	90	60	68	62	22	225	39	6.4	2.87	4	5	90	6-14	0.522
HELEMANO 5B	56	25	62	88		0	225	37	6.4	2.94	4	5	120	5- 8	0.576
HELEMANO 6	58	94	150	95		0	306	71	5.8	3.23	5	5	196	3- 6	0.614
HELEMANO 6B	60	120	60	91	62	8	311	82	5.6	3.01	4	5	140	3- 6	0.613
HELEMANO 6C	61	200	150	53	152	33	300	81	6.1	3.27	5	5	190	3- 7	0.587
HELEMANO 7	62	128	150	60	152	39	311	65	5.2	3.17	5	5	203	4- 8	0.557
HELEMANO 7D	63	139	150	76	152	23	343	67	5.1	3.17	5	5	206	3-13	0.570
HELEMANO 8	65	151	150	78	152	21	321	77	5.2	3.27	5	5	193	4- 8	0.602
HELEMANO 9	66	205	60	75	170	12	420	78	6.5	3.04	4	5	63	4-10	0.609
HELEMANO 10	67	125	150	100		0	303	61	5.1	3.30	5	5	190	4-10	0.626
HELEMANO 11	68	110	150	89	60	10	336	61	5.5	3.10	5	5	170	4- 6	0.600
HELEMANO 11A	69	78	150	100		0	213	107	5.3	3.27	5	5	196	4- 5	0.609
PAALAA 1	77	64	160	75	1000	25	591	166	7.8	3.56	4	5	3	0- 1	0.585
OPAEULA 1	80	90	62	57	60	42	261	36	6.8	2.84	4	5	40	5- 8	0.582
OPAEULA 2	81	166	60	56	62	38	256	64	6.9	2.97	4	5	56	2- 7	0.645

T A B L E III

SOIL DATA, ELEVATION AND SLOPE FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO. LTD." *

FIELD NAME	NUMBER	SIZE IN AC.	MAIN SOIL SE-RIES *1	% OF TO-TAL	MIN. SOIL SE-RIES *1	% OF TO-TAL	K IN LB ACRE	P PER FOOT	PH	MOISTURE STO-RAGE *2	PERMEABILITY *3	DRAINAGE *4	ELEVATION M.	SLOPE IN %	MEAN TON SUGAR AC/MO
KAWAIHAPAI 1	1	135	600	74	760	25	370	273	6.9	3.07	1	1	16	2- 4	0.579
KAWAIHAPAI 2	2	129	1000	68	780	31	329	412	6.9	3.10	4	5	6	0- 3	0.597
KAWAIHAPAI 2A	3	27	600	59	780	40	324	324	6.9	2.90	1	1	11	2- 2	0.625
KAWAIHAPAI 2D	4	67	1000	53	600	34	339	397	7.6	3.14	4	5	3	0- 2	0.547
KAWAIHAPAI 3	5	64	780	57	770	25	419	280	7.0	3.20	4	5	3	0- 2	0.575
GAY 1	6	100	160	100		0	562	132	6.7	3.23	4	4	16	1- 6	0.571
GAY 2	7	105	162	69	160	30	1094	121	6.8	3.33	4	4	11	1- 6	0.560
GAY 3	8	183	780	79	162	16	1163	205	6.8	3.20	4	5	11	1- 2	0.576
GAY 4	9	145	780	98		0	1475	462	7.2	3.20	4	5	11	1- 2	0.545
GAY 5	10	106	162	83	172	11	606	171	6.9	3.17	4	4	40	3- 7	0.596
GAY 5A	11	77	172	94		0	287	70	6.7	3.20	4	5	40	3-10	0.574
GAY 6	12	85	172	83		0	375	85	6.4	3.04	4	5	66	4-10	0.561
GAY 7	13	72	172	59	760	40	421	109	6.6	3.00	4	5	60	6-13	0.539
GAY 8	14	79	600	46	760	31	455	255	7.0	3.07	1	1	43	5-17	0.506
MILL 2	19	40	160	65	102	35	1232	310	7.2	3.23	4	4	1	0- 2	0.486
MILL 10	25	32	160	75	190	25	279	90	7.0	3.30	4	4	10	0- 2	0.573
MILL 11	26	12	160	100		0	243	78	7.0	3.30	4	4	1	1- 2	0.600
RANCH 2	29	52	160	73	190	26	501	149	6.9	3.40	4	4	21	2- 3	0.567
RANCH 3	30	94	160	90		0	524	72	6.5	3.43	4	4	21	2- 3	0.596
RANCH 4	31	132	170	100		0	374	40	6.9	3.20	4	5	46	3- 5	0.636
RANCH 5	32	73	170	73	190	26	326	50	6.8	3.43	4	5	46	2- 4	0.635
RANCH 7	34	88	170	54	160	32	480	123	6.7	3.27	4	5	45	2- 4	0.621
RANCH 10B	36	58	170	93		0	211	45	6.6	3.14	4	5	76	5-17	0.614
VALLEY 1	37	99	1000	100		0	481	111	6.5	3.53	4	5	3	0- 4	0.528
VALLEY 3	39	36	1000	94		0	445	114	6.9	3.86	4	5	10	0- 5	0.516

T A B L E III (CONTINUED)
SOIL DATA, ELEVATION AND SLOPE
FOR EACH PLANTATION FIELD IN "WAIALUA SUGAR CO. LTD." *

FIELD NAME		NUMBER	SIZE IN AC.	MAIN SOIL SE-RIES *1	% OF TO-TAL	MIN. SOIL SE-RIES *1	% OF TO-TAL	K IN LB PER ACRE FOOT	P IN LB PER ACRE FOOT	PH	MOISTURE STO-RAGE *2	PERMEABILITY *3	DRAINAGE *4	ELEVATION M.	SLOPE IN %	MEAN TON SUGAR AC/MO
OPAEULA	3	82	43	160	55	105	23	318	201	6.8	3.23	4	5	13	1-13	0.679
OPAEULA	5	83	94	62	84	60	15	278	45	6.5	2.84	4	5	76	4- 8	0.632
OPAEULA	6	84	103	60	50	152	33	350	39	6.6	3.00	4	5	123	5- 8	0.662
OPAEULA	7	85	61	62	86	155	13	209	49	6.2	3.04	4	5	120	5-10	0.691
OPAEULA	8	86	59	150	89		0	310	68	5.5	3.10	5	5	166	4- 7	0.616
OPAEULA	9	87	114	150	95		0	243	79	5.2	3.27	5	5	170	4-13	0.626
OPAEULA	12	88	116	150	100		0	380	70	5.2	3.43	5	5	210	3- 7	0.609
OPAEULA	16	90	183	570	61	150	38	317	47	5.2	3.32	5	5	255	2- 5	0.580
OPAEULA	17	91	56	150	100		0	368	75	5.8	3.30	5	5	235	2- 6	0.576
OPAEULA	18	92	110	570	68	150	31	286	76	5.2	3.50	5	5	261	1-10	0.550
KAWAILOA	1A	97	47	62	100		0	538	39	7.0	2.90	4	5	63	6-10	0.601
KAWAILOA	1B	98	76	60	100		0	490	49	6.5	2.94	4	5	40	3- 8	0.595
KAWAILOA	2	99	115	60	89		0	413	37	6.8	2.81	4	5	68	2- 3	0.608
KAWAILOA	3	100	98	60	59	150	30	595	50	6.5	2.84	4	5	108	4- 8	0.655
KAWAILOA	4	101	54	60	100		0	505	30	7.0	2.97	4	5	60	5- 8	0.615
KAWAILOA	5	102	110	150	100		0	296	29	6.2	3.04	5	5	108	4- 8	0.661
KAWAILOA	6	103	114	152	55	150	44	606	46	7.0	2.90	5	5	100	4- 6	0.628
KAWAILOA	7	104	120	152	80	62	19	389	50	6.8	2.94	5	5	91	3- 7	0.617
KAWAILOA	8A	105	55	152	85	62	14	299	36	6.3	3.04	5	5	83	3- 9	0.619
KAWAILOA	8B	106	139	152	53	60	39	340	30	6.5	3.07	5	5	75	3- 9	0.634
KAWAILOA	11	109	140	150	89	152	10	381	62	5.7	3.10	5	5	158	5-10	0.600
KAWAILOA	12	110	102	150	100		0	294	65	5.6	3.14	5	5	161	4- 8	0.600
KAWAILOA	13	111	42	152	57	150	42	256	38	5.5	3.14	5	5	198	4- 9	0.539
KAWAILOA	15	113	95	150	75	155	24	278	63	5.0	3.33	5	5	161	4- 8	0.608
KAWAILOA	18	114	61	150	100		0	287	80	5.4	3.38	5	5	198	3-13	0.520

T A B L E III (CONTINUED)
SOIL DATA, ELEVATICN AND SLOPE
FOR EACH PLANTATION FIELC IN "WAIALUA SUGAR CO. LTD." *

FIELD NAME	NUMBER	SIZE IN AC.	MAIN SCIL SE-RIES *1	% OF TC-TAL	MIN. SOIL SE-RIES *1	% OF TO-TAL	K IN LB PER ACRE FOOT	P	PH	MOISTURE STO-RAGE *2	PERMEABILITY *3	CRAINAGE *4	ELEVATION M.	SLOPE IN %	MEAN TON SUGAR AC/MO
KAWAILOA 19	115	101	150	88	152	11	226	87	5.5	3.27	5	5	201	4- 7	0.595
WAIMEA 1	120	106	150	66	152	26	316	40	5.4	3.10	5	5	86	2-20	0.657
WAIMEA 2	121	114	150	93		C	238	28	6.1	3.23	5	5	120	3-10	0.642
WAIMEA 3	122	179	150	67	155	32	268	56	5.9	3.27	5	5	108	4-17	0.658
WAIMEA 4	123	120	150	60	155	40	240	41	5.7	3.11	5	5	100	3-10	0.632

* :THE FIELDS THAT ARE OCCUPIEC BY LESS THAN 60% OF ONE SOIL SERIES OR NOT PLANTED WITH VARIETY 50-7209 ARE NOT INCLUDED IN THIS TABLE

*1:SEE TABLE IV FOR LOCAL NAME AND CLASSIFICATION

*2:MOISTURE STORAGE CAPACITY IS EXPRESSEC IN INCHES OF WATER

*3:PERMEABILITY 1=VERY SLOW; 2=SLOW; 3=MOD.SLOW; 4=MODERATE; 5=MOD.RAPID
*4:DRAINAGE 1=VERY POOR; 2=POOR; 3=IMPERFECT; 4=MOD.WELL; 5=WELL

TABLE IV

SOIL SERIES AND THEIR CLASSIFICATION (ACCORDING TO "SOIL CONSERVATION SERVICE) THAT OCCUR IN "WAIALUA SUGAR CO. LTD."

NUMBER ON MAP	SOIL SERIES NAME	CLASSIFICATION U.S.D.A. COMPREHENSIVE SYSTEM OF SOIL CLASSIFICATION				
600	PEARL HARBOUR	VERY FINE	MONTMORILL.	ISOHYPERTHERMIC	TYPIC	TROPAQUEPT
1000	HALEIWA	FINE	MIXED	ISOHYPERTHERMIC	TYPIC	HAPLUSTOLL
160	WAIALUA	VERY FINE	KAOLINITIC	ISOHYPERTHERMIC	TYPIC	HAPLUSTOLL
170	EWA	FINE	KAOLINITIC	ISOHYPERTHERMIC	ARIDIC	HAPLUSTOLL
190	WAIPAHU	VERY FINE	KAOLINITIC	ISOHYPERTHERMIC	TORRERTIC	HAPLUSTOLL
780	PULEHU	FINE LOAM	MIXED	ISOHYPERTHERMIC	CUMULIC	HAPLUSTOLL
570	LEILEHUA	CLAYEY	OXIDIC	ISOTHERMIC	HUMOXIC	TROPOHUMULT
60	LAHAINA	CLAYEY	KAOLINITIC	ISOHYPERTHERMIC	TYPIC	TORROX
150	WAHIAWA	CLAYEY	KAOLINITIC	ISOTHERMIC	TROPEPTIC	EUTRUSTOX

TABLE V
CLIMATOLOGICAL INFORMATION FOR STATION: KAWAIHAPAI
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAINFALL MM.	EVAPORATION IN MM.	MOISTURE DEFICIT	RADIATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1960				
JAN.	55	79	-24	10.21	79.1	64.4	71.7	14.7
FEB.	85	77	8	8.94	78.5	64.7	71.6	13.8
MAR.	135	65	70	11.46	77.9	64.3	71.1	13.6
APR.	20	122	-102	11.38	80.9	65.4	73.1	15.5
MAY.	32	113	-81	14.04	85.3	67.4	76.3	17.9
JUNE	17	138	-121	14.04	87.7	69.4	78.5	18.3
JULY	13	145	-132	14.63	88.9	71.0	79.9	17.9
AUG.	13	141	-129	15.35	89.3	70.5	79.9	18.8
SEP.	30	115	-86	14.37	87.9	69.5	78.7	18.4
OCT.	135	88	47	12.32	84.9	69.1	77.0	15.8
NOV.	42	57	-15	12.27	80.2	66.2	73.2	14.0
DEC.	75	43	32	10.05	77.3	64.0	70.6	13.3
ANN.	652	1185	-533	149.05	83.2	67.2	75.2	16.0
				YEAR: 1961				
JAN.	107	64	43	10.87	77.1	62.1	69.6	15.0
FEB.	35	63	-28	10.54	77.3	64.4	70.8	12.9
MAR.	40	106	-66	14.61	81.9	64.1	73.0	17.8
APR.	52	123	-71	14.23	80.4	64.4	72.4	16.0
MAY.	102	136	-33	16.20	84.0	66.3	75.1	17.7
JUNE	17	108	-90	15.29	82.1	65.8	73.9	16.3
JULY	15	151	-136	16.15	83.0	65.6	74.3	17.4
AUG.	5	139	-134	16.30	85.3	66.2	75.7	19.1
SEP.	7	149	-141	16.49	84.7	62.9	73.8	21.8
OCT.	22	109	-87	11.52	82.4	64.9	73.6	17.5
NOV.	105	85	20	8.48	77.8	62.1	69.9	15.7
DEC.	42	89	-47	9.01	77.9	57.8	67.8	20.1
ANN.	552	1322	-769	159.71	81.2	63.9	72.5	17.3
				YEAR: 1962				
JAN.	107	94	14	7.98	76.1	58.2	67.1	17.9
FEB.	120	95	25	8.45	72.8	55.2	64.0	17.6
MAR.	235	110	125	8.45	74.5	58.5	66.5	16.0
APR.	70	131	-61	11.52	81.9	62.1	72.0	19.8
MAY.	113	165	-53	12.21	82.9	63.0	72.9	19.9
JUNE	20	168	-149	12.91	86.9	66.1	76.5	20.8
JULY	7	195	-187	13.75	89.2	68.3	78.7	20.9
AUG.	15	177	-162	13.21	90.8	69.5	80.1	21.3
SEP.	45	165	-120	12.64	90.4	68.9	79.6	21.5
OCT.	80	152	-73	10.99	87.3	66.9	77.1	20.4
NOV.	5	149	-144	9.04	81.7	68.6	75.1	13.1
DEC.	55	101	-47	8.89	77.6	66.0	71.8	11.6
ANN.	872	1704	-832	130.06	82.7	64.3	73.5	18.4

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: KAWAIHAPAI 60-64
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO-RATION IN MM.	MOIS-TURE DEFICIT	RADI-ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1963				
JAN.	285	84	201	9.14	77.7	64.9	71.3	12.8
FEB.	82	125	-43	9.14	78.7	65.2	71.9	13.5
MAR.	257	129	128	11.14	78.6	67.2	72.9	11.4
APR.	352	118	234	9.02	78.7	69.2	73.9	9.5
MAY.	202	158	44	10.41	79.9	68.1	74.0	11.8
JUNE	13	181	-169	9.98	82.4	70.3	76.3	12.1
JULY	17	186	-169	10.90	83.5	71.6	77.5	11.9
AUG.	42	170	-128	12.31	84.4	71.1	77.7	13.3
SEP.	27	160	-132	12.25	83.3	71.5	77.4	11.8
OCT.	15	130	-115	10.93	82.4	70.8	76.6	11.6
NOV.	25	118	-93	9.38	81.1	68.4	74.7	12.7
DEC.	135	60	75	9.00	79.6	63.4	71.5	16.2
ANN.	1455	1622	-167	123.61	80.9	68.5	74.7	12.4
				YEAR: 1964				
JAN.	88	105	-18	8.93	79.6	63.5	71.5	16.1
FEB.	5	111	-106	8.80	79.6	61.3	70.4	18.3
MAR.	105	127	-22	11.03	79.4	63.2	71.3	16.2
APR.	25	128	-103	10.02	80.7	63.8	72.2	16.9
MAY.	10	170	-160	12.39	82.1	63.9	73.0	18.2
JUNE	5	194	-189	11.92	84.7	67.0	75.8	17.7
JULY	52	195	-142	12.82	84.5	67.9	76.2	16.6
AUG.	13	187	-174	14.12	85.7	67.0	76.3	18.7
SEP.	10	161	-151	13.68	85.9	66.8	76.3	19.1
OCT.	70	142	-72	10.56	82.4	66.5	74.4	15.9
NOV.	60	113	-53	8.64	80.2	66.3	73.5	13.4
DEC.	310	82	228	8.39	79.6	66.3	72.9	13.3
ANN.	752	1715	-962	131.28	82.0	65.3	73.7	16.7
				YEAR: 1965				
JAN	145	128	17	0.0	78.5	64.2	71.3	14.3
FEB	60	144	-84	0.0	75.3	62.6	68.9	12.7
MAR	7	132	-125	0.0	79.5	61.5	70.5	18.0
APR	225	125	100	0.0	79.9	64.4	72.1	15.5
MAY	100	139	-39	0.0	82.7	66.8	74.7	15.9
JUN	10	215	-205	0.0	84.7	67.2	75.9	17.5
JUL	67	195	-127	0.0	85.5	67.7	76.6	17.8
AUG.	27	182	-155	0.0	85.5	68.0	76.8	17.5
SEP	15	135	-120	0.0	86.9	66.3	76.6	20.6
OCT	190	130	60	0.0	83.2	67.8	75.5	15.4
NOV.	322	96	226	0.0	79.7	66.5	73.1	13.2
DEC	117	93	25	0.0	76.9	63.6	70.2	13.3
ANN.	1287	1715	-428	0.0	81.5	65.5	73.5	16.0

T A B L E V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: KAWAIHAPAI 60-64
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO-RATION IN MM.	MOIS-TURE DEFICIT	RADI-ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1966				
JAN	25	103	-78	0.0	78.0	59.9	68.9	18.1
FEB.	192	92	101	0.0	76.4	62.6	69.5	13.8
MAR	30	139	-109	0.0	80.2	62.3	71.2	17.9
APR	70	158	-89	0.0	79.1	62.4	70.7	16.7
MAY	25	163	-138	0.0	83.6	65.1	74.3	18.5
JUN	10	201	-191	0.0	85.2	68.4	76.8	16.8
JUL	55	198	-143	0.0	85.2	68.0	76.6	17.2
AUG	25	195	-170	0.0	86.1	69.1	77.6	17.0
SEP	17	159	-142	0.0	87.6	68.1	77.8	19.5
OCT	35	145	-110	0.0	85.2	68.7	76.9	16.5
NOV	285	110	175	0.0	82.0	67.1	74.5	14.9
DEC	72	105	-32	0.0	79.4	65.6	72.5	13.8
ANN	842	1770	-927	0.0	82.3	65.6	74.0	16.7
				YEAR: 1967				
JAN	50	106	-56	0.0	78.1	63.5	70.8	14.6
FEB	22	106	-83	0.0	80.2	63.6	71.9	16.6
MAR	215	116	99	0.0	79.4	64.7	72.0	14.7
APR	27	146	-119	0.0	80.4	64.5	72.4	15.9
MAY	80	171	-91	0.0	84.0	66.8	75.4	17.2
JUNE	7	199	-192	0.0	86.5	65.8	76.1	20.7
JUL	60	184	-124	0.0	87.3	69.1	78.2	18.2
AUG.	50	171	-121	0.0	86.3	68.9	77.6	17.4
SEP	15	189	-174	0.0	88.2	67.4	77.8	20.8
OCT.	27	180	-153	0.0	87.0	68.4	77.7	18.6
NOV	70	141	-71	0.0	80.8	66.8	73.8	14.0
DEC	230	104	126	0.0	78.3	67.3	72.8	11.0
ANN.	855	1814	-959	0.0	83.0	66.4	74.7	16.6
				YEAR: 1968				
JAN	197	133	65	0.0	78.9	64.1	71.5	14.8
FEB	145	163	-18	0.0	80.5	62.5	71.5	18.0
MAR	185	118	67	0.0	77.8	64.1	70.9	13.7
APR	102	148	-45	0.0	83.6	66.8	75.2	16.8
MAY	25	177	-152	0.0	86.1	66.1	76.1	20.0
JUN	13	197	-184	0.0	87.9	68.4	78.1	19.5
JUL	20	197	-177	0.0	90.0	69.3	79.6	20.7
AUG	5	199	-194	0.0	90.3	68.8	79.5	21.5
SEP	27	169	-141	0.0	90.3	69.2	79.7	21.1
OCT	77	139	-62	0.0	88.6	69.1	78.8	19.5
NOV	102	117	-15	0.0	86.1	66.5	76.3	19.6
DEC	265	81	183	0.0	80.2	65.9	73.0	14.3
ANN	1165	1838	-673	0.0	85.0	66.7	75.9	18.3

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: KAWAIHAPAI 60-64
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO-RATION IN MM.	MOIS-TURE DEFICIT	RADI-ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
YEAR: 1969								
JAN	235	113	122	0.0	77.7	64.6	71.1	13.1
FEB	107	100	7	0.0	79.4	67.1	73.2	12.3
MAR.	72	131	-59	0.0	80.0	63.0	71.5	17.0
APR	27	161	-134	0.0	81.0	65.9	73.4	15.1
MAY.	27	189	-162	0.0	83.9	64.1	74.0	19.8
JUN	20	180	-160	0.0	85.5	65.0	75.3	20.5
JUL	30	196	-166	0.0	85.4	68.0	76.7	17.4
AUG.	13	213	-200	0.0	85.7	67.5	76.6	18.2
SEP	50	167	-117	0.0	84.5	68.1	76.3	16.4
OCT.	40	168	-128	0.0	85.2	66.3	75.7	18.9
NOV.	135	193	-58	7.04	83.2	67.1	75.1	16.1
DEC.	70	111	-42	7.41	80.7	63.5	72.1	17.2
ANN	827	1924	-1097	0.0	82.7	65.8	74.3	16.8
YEAR: 1970								
JAN.	185	126	59	8.66	79.1	61.5	70.3	17.6
FEB.	75	137	-62	11.14	78.8	57.8	68.3	21.0
MAR.	5	160	-155	13.37	79.9	56.0	67.9	23.9
APR.	38	164	-126	17.34	79.5	61.0	70.3	18.5
MAY.	10	182	-172	16.17	83.0	63.2	73.1	19.8
JUNE	5	193	-188	16.51	84.4	64.8	74.6	19.6
JULY	55	206	-151	21.76	84.2	64.5	74.3	19.7
AUG.	10	204	-194	17.00	85.3	64.2	74.7	21.1
SEP.	10	164	-154	14.19	85.1	63.7	74.4	21.4
OCT.	52	150	-97	15.90	83.4	64.7	74.0	18.7
NOV.	120	94	26	8.22	80.2	63.5	71.8	16.7
DEC.	38	114	-77	10.13	77.3	62.0	69.6	15.3
ANN.	602	1895	-1291	170.39	81.7	62.2	72.0	19.4

TABLE V
CLIMATOLOGICAL INFORMATION FOR STATION: OFFICE
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAINFALL MM.	EVAPORATION IN MM.	MOISTURE DEFICIT	RADIATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
			YEAR: 1960					
JAN.	20	92	-73	11.32	78.0	60.6	69.3	17.4
FEB.	90	98	-8	10.05	78.2	59.7	68.9	18.5
MAR.	102	127	-25	12.31	77.5	61.2	69.3	16.3
APR.	17	140	-123	12.42	79.0	61.9	70.4	17.1
MAY.	35	160	-125	14.97	83.0	64.7	73.8	18.3
JUNE	15	189	-174	14.86	84.8	66.0	75.4	18.8
JULY	47	203	-155	15.16	85.0	66.7	75.8	18.3
AUG.	13	188	-175	15.78	85.2	67.0	76.1	18.2
SEP.	40	161	-121	14.66	85.1	66.3	75.7	18.8
OCT.	195	127	67	13.26	83.9	66.4	75.1	17.5
NOV.	52	99	-47	12.22	80.7	64.5	72.6	16.2
DEC.	75	77	-2	10.46	79.0	60.6	69.8	18.4
ANN.	702	1663	-960	157.46	81.6	63.8	72.7	17.8
			YEAR: 1961					
JAN.	115	93	22	11.40	78.8	58.8	68.8	20.0
FEB.	40	89	-49	10.81	78.8	62.0	70.4	16.8
MAR.	22	137	-115	14.30	81.0	60.8	70.9	20.2
APR.	42	140	-98	14.42	81.0	62.3	71.6	18.7
MAY.	85	188	-103	16.15	82.9	65.1	74.0	17.8
JUNE	17	174	-156	15.29	83.8	65.6	74.7	18.2
JULY	42	199	-156	14.90	85.2	65.2	75.2	20.0
AUG.	13	207	-195	16.95	86.4	65.7	76.0	20.7
SEP.	15	160	-145	14.97	87.2	64.8	76.0	22.4
OCT.	52	108	-56	12.20	84.2	66.4	75.3	17.8
NOV.	105	93	12	10.76	80.6	64.3	72.4	16.3
DEC.	60	85	-25	9.85	79.9	61.7	70.8	18.2
ANN.	610	1674	-1064	162.00	82.5	63.6	73.0	18.9
			YEAR: 1962					
JAN.	102	92	11	10.04	79.5	62.1	70.8	17.4
FEB.	105	91	14	11.11	77.9	58.9	68.4	19.0
MAR.	225	117	108	10.55	77.5	60.9	69.2	16.6
APR.	70	143	-73	13.96	82.3	62.4	72.3	19.9
MAY.	72	171	-98	14.86	82.4	63.9	73.1	18.5
JUNE	13	207	-194	15.38	85.6	65.3	75.4	20.3
JULY	5	229	-224	16.32	85.3	65.6	75.4	19.7
AUG.	10	211	-201	14.40	85.6	66.1	75.8	19.5
SEP.	35	180	-145	13.50	84.3	65.0	74.6	19.3
OCT.	77	147	-70	12.94	83.4	63.0	73.2	20.4
NOV.	2	144	-141	10.84	81.7	63.6	72.6	18.1
DEC.	57	91	-34	9.57	79.0	60.5	69.8	18.5
ANN.	775	1825	-1050	153.48	82.0	63.1	72.6	18.9

T A B L E V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: OFFICE
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO- RATION IN MM.	MOIS- TURE DEFICIT	RADI- ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1963				
JAN.	302	88	214	9.99	79.2	60.7	69.9	18.5
FEB.	57	120	-63	10.84	80.7	59.7	70.2	21.0
MAR.	267	135	132	12.35	79.9	62.2	71.0	17.7
APR.	338	126	212	9.97	79.4	64.9	72.1	14.5
MAY.	172	151	22	11.36	81.1	63.1	72.1	18.0
JUNE	7	190	-182	11.76	84.2	65.0	74.6	19.2
JULY	22	199	-176	12.20	85.1	66.0	75.5	19.1
AUG.	45	190	-145	14.03	86.3	65.2	75.7	21.1
SEP.	40	175	-135	13.71	86.1	65.2	75.6	20.9
OCT.	20	144	-125	13.04	84.9	64.7	74.8	20.2
NOV.	13	123	-110	11.40	83.3	62.5	72.9	20.8
DEC.	82	73	9	10.25	80.2	61.4	70.8	18.8
ANN.	1367	1715	-348	140.89	82.5	63.4	73.0	19.1
				YEAR: 1964				
JAN.	72	105	-33	9.91	79.6	62.4	71.0	17.2
FEB.	13	116	-104	9.64	80.0	58.7	69.3	21.3
MAR.	170	135	35	12.15	79.5	61.8	70.6	17.7
APR.	27	134	-107	11.00	80.6	61.9	71.2	18.7
MAY.	7	188	-180	14.11	82.0	63.2	72.6	18.8
JUNE	2	223	-220	13.67	85.7	66.1	75.9	19.6
JULY	55	221	-166	14.83	84.9	67.2	76.0	17.7
AUG.	15	226	-211	15.58	85.7	66.3	76.0	19.4
SEP.	7	191	-184	15.44	85.8	66.1	75.9	19.7
OCT.	63	138	-76	12.90	82.7	64.6	73.6	18.1
NOV.	85	98	-14	10.07	80.2	66.0	73.1	14.2
DEC.	397	77	320	8.53	80.1	63.8	71.9	16.3
ANN.	915	1854	-939	147.83	82.2	64.0	73.1	18.2
				YEAR: 1965				
JAN.	132	103	29	9.93	77.8	61.9	69.8	15.9
FEB.	92	108	-16	10.49	74.8	57.6	66.2	17.2
MAR.	10	132	-122	12.73	79.2	57.6	68.4	21.6
APR.	172	115	57	12.14	80.3	61.5	70.9	18.8
MAY.	102	153	-51	12.31	82.7	64.7	73.7	18.0
JUNE	5	225	-220	15.98	84.5	63.9	74.2	20.6
JULY	35	214	-179	14.36	85.1	64.8	74.9	20.3
AUG.	55	213	-158	14.49	86.4	64.5	75.4	21.9
SEP.	13	164	-151	14.84	86.5	65.2	75.8	21.3
OCT.	177	141	36	12.39	83.9	64.2	74.0	19.7
NOV.	350	95	255	9.05	80.0	64.4	72.2	15.6
DEC.	152	104	49	8.85	77.0	62.3	69.6	14.7
ANN.	1297	1769	-471	147.58	81.5	62.7	72.1	18.8

T A B L E V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: OFFICE
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO-RATION IN MM.	MOIS-TURE DEFICIT	RADI-ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1966				
JAN.	25	104	-79	10.48	78.1	56.5	67.3	21.6
FEB.	160	96	64	9.49	75.9	58.9	67.4	17.0
MAR.	22	149	-126	12.19	80.4	58.6	69.5	21.8
APR.	20	164	-144	13.03	79.4	59.0	69.2	20.4
MAY.	20	176	-156	15.07	84.6	62.5	73.5	22.1
JUNE	5	224	-219	15.96	86.2	66.9	76.5	19.3
JULY	82	234	-152	16.28	86.1	67.2	76.6	18.9
AUG.	20	218	-199	16.18	86.8	66.9	76.8	19.9
SEP.	7	181	-173	14.98	87.2	65.6	76.4	21.6
OCT.	52	144	-91	14.88	85.2	65.8	75.5	19.4
NOV.	263	105	157	12.28	81.9	65.8	73.8	16.1
DEC.	60	95	-35	11.48	79.7	62.6	71.1	17.1
ANN.	737	1890	-1153	162.30	82.6	63.0	72.8	19.6
				YEAR: 1967				
JAN.	42	89	-46	10.84	77.6	60.1	68.8	17.5
FEB.	45	100	-55	10.80	79.3	61.3	70.3	18.0
MAR.	210	117	93	11.67	78.7	63.3	71.0	15.4
APR.	50	142	-92	14.00	80.3	62.1	71.2	18.2
MAY.	27	170	-142	15.05	84.5	65.5	75.0	19.0
JUNE	22	210	-188	16.10	86.4	65.3	75.8	21.1
JULY	38	196	-159	15.49	85.6	68.2	76.9	17.4
AUG.	75	189	-114	14.94	86.0	68.6	77.3	17.4
SEP.	7	177	-170	14.70	87.5	66.7	77.1	20.8
OCT.	27	146	-118	13.64	86.5	66.5	76.5	20.0
NOV.	107	120	-13	10.39	81.4	66.0	73.7	15.4
DEC.	197	80	118	8.83	79.0	64.8	71.9	14.2
ANN.	850	1736	-886	156.45	82.7	64.9	73.8	17.9
				YEAR: 1968				
JAN.	215	99	116	11.00	78.6	61.6	70.1	17.0
FEB.	80	123	-43	11.32	79.7	60.7	70.2	19.0
MAR.	172	100	72	10.48	77.9	62.9	70.4	15.0
APR.	90	139	-49	13.44	80.2	64.2	72.2	16.0
MAY.	27	168	-140	15.03	83.8	64.5	74.1	19.3
JUNE	5	194	-189	15.42	86.1	66.6	76.3	19.5
JULY	22	202	-180	16.14	88.4	66.8	77.6	21.6
AUG.	2	209	-206	16.64	89.1	67.7	78.4	21.4
SEP.	45	174	-129	14.69	88.4	67.8	78.1	20.6
OCT.	80	144	-64	13.17	87.0	67.9	77.4	19.1
NOV.	120	121	-1	11.52	85.0	66.0	75.5	19.0
DEC.	235	123	112	11.02	80.6	63.8	72.2	16.8
ANN.	1095	1797	-702	159.87	83.7	65.0	74.4	18.7

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: OFFICE
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO-RATION IN MM.	MOIS-TURE DEFICIT	RADI-ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1969				
JAN.	197	144	54	10.28	75.6	60.9	68.2	14.7
FEB.	120	114	6	9.79	77.6	64.5	71.0	13.1
MAR.	67	143	-76	14.03	78.1	60.3	69.2	17.8
APR.	27	161	-134	13.07	78.6	63.3	70.9	15.3
MAY.	15	202	-187	16.63	83.0	63.5	73.3	19.5
JUNE	10	188	-178	16.17	86.1	65.0	75.5	21.1
JULY	17	199	-181	16.99	85.6	67.5	76.5	18.1
AUG.	13	210	-198	17.72	85.8	66.4	76.1	19.4
SEP.	32	153	-120	14.14	84.3	65.7	75.0	18.6
OCT.	20	155	-135	12.23	85.0	63.8	74.4	21.2
NOV.	88	122	-35	9.39	80.9	64.1	72.5	16.8
DEC.	57	103	-45	9.88	80.2	61.5	70.8	18.7
ANN.	665	1895	-1230	160.37	81.7	63.9	72.8	17.9
				YEAR: 1970				
JAN.	165	97	68	7.97	78.5	61.0	69.8	17.5
FEB.	65	137	-72	9.84	78.2	59.0	68.6	19.2
MAR.	2	168	-166	12.48	80.6	59.9	70.2	20.7
APR.	42	178	-136	16.72	81.1	63.2	72.2	17.9
MAY.	10	198	-188	15.31	84.1	64.9	74.5	19.2
JUNE	2	208	-206	15.31	85.2	66.0	75.6	19.2
JULY	55	224	-169	19.18	86.1	66.5	76.3	19.6
AUG.	10	232	-222	16.00	86.7	67.7	77.2	19.0
SEP.	10	188	-178	13.20	86.4	66.0	76.2	20.4
OCT.	38	151	-113	18.42	85.1	66.4	75.7	18.7
NOV.	100	97	3	8.76	81.7	64.3	73.0	17.4
DEC.	42	111	-69	11.15	78.9	64.2	71.5	14.7
ANN.	542	1990	-1447	164.36	82.7	64.1	73.4	18.6

TABLE V
CLIMATOLOGICAL INFORMATION FOR STATION: OPAEULA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO- RATION IN MM.	MOIS- TURE DEFICIT	RADI- ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
YEAR: 1960								
JAN.	65	78	-13	10.08	75.5	62.5	69.0	13.0
FEB.	100	100	0	9.06	75.1	61.6	68.3	13.5
MAR.	110	111	-1	11.56	75.2	62.3	68.7	12.9
APR.	45	122	-77	12.29	75.2	64.8	70.0	10.4
MAY.	88	142	-54	13.83	78.5	66.9	72.7	11.6
JUNE	45	161	-117	15.05	80.3	68.2	74.2	12.1
JULY	47	173	-126	14.71	80.5	69.1	74.8	11.4
AUG.	47	163	-116	15.11	81.4	69.5	75.4	11.9
SEP.	60	143	-84	14.91	80.8	68.8	74.8	12.0
OCT.	97	111	-13	12.35	80.5	68.0	74.3	12.5
NOV.	95	85	10	12.35	76.6	66.7	71.6	9.9
DEC.	100	69	31	9.88	76.5	63.4	69.9	13.1
ANN.	900	1459	-559	151.19	78.0	66.0	72.0	12.0
YEAR: 1961								
JAN.	107	76	31	11.07	75.7	62.0	68.8	13.7
FEB.	105	80	25	9.85	75.4	65.5	70.4	9.9
MAR.	70	113	-43	13.18	78.0	64.2	71.1	13.8
APR.	45	123	-79	13.65	77.6	64.6	71.1	13.0
MAY.	100	175	-75	15.14	79.0	67.7	73.3	11.3
JUNE	72	148	-76	15.18	79.1	68.4	73.7	10.7
JULY	60	187	-127	15.64	81.1	68.3	74.7	12.8
AUG.	35	192	-157	16.01	81.3	69.4	75.3	11.9
SEP.	50	147	-97	16.43	82.2	68.2	75.2	14.0
OCT.	80	104	-24	11.97	80.5	69.0	74.8	11.5
NOV.	138	85	52	10.15	76.4	66.7	71.5	9.7
DEC.	115	83	32	9.63	76.5	65.0	70.8	11.5
ANN.	977	1514	-537	157.89	78.6	66.6	72.6	12.0
YEAR: 1962								
JAN.	97	80	18	9.02	77.9	64.3	71.1	13.6
FEB.	110	90	20	9.18	76.1	61.6	68.8	14.5
MAR.	282	118	164	9.28	75.1	63.6	69.3	11.5
APR.	77	119	-41	12.29	78.9	65.5	72.2	13.4
MAY.	55	127	-73	12.10	79.2	66.7	72.9	12.5
JUNE	50	152	-102	12.72	82.0	67.7	74.8	14.3
JULY	15	189	-174	14.84	81.1	69.4	75.2	11.7
AUG.	30	180	-150	14.30	82.0	69.6	75.8	12.4
SEP.	32	157	-125	13.92	81.2	69.3	75.2	11.9
OCT.	100	137	-37	12.54	81.6	67.4	74.5	14.2
NOV.	10	126	-116	11.21	79.3	68.1	73.7	11.2
DEC.	75	87	-12	9.76	76.7	63.0	69.8	13.7
ANN.	935	1563	-628	141.16	79.3	66.3	72.8	12.9

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: OPAEULA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO- RATION IN MM.	MOIS- TURE DEFICIT	RADI- ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1963				
JAN.	307	92	215	9.97	77.0	62.5	69.8	14.5
FEB.	77	132	-55	10.12	78.9	63.2	71.0	15.7
MAR.	242	139	103	11.69	78.0	64.8	71.4	13.2
APR.	410	115	295	9.45	77.7	67.5	72.6	10.2
MAY.	113	154	-42	11.81	78.4	66.7	72.5	11.7
JUNE	35	163	-128	10.48	80.7	68.7	74.7	12.0
JULY	55	182	-127	11.86	81.8	70.1	75.9	11.7
AUG.	13	183	-171	13.81	83.4	70.3	76.8	13.1
SEP.	67	166	-99	12.61	82.2	70.2	76.2	12.0
OCT.	42	139	-97	12.48	80.4	68.5	74.4	11.9
NOV.	27	119	-91	11.38	80.0	66.4	73.2	13.6
DEC.	90	54	36	9.81	78.3	64.2	71.2	14.1
ANN.	1480	1641	-161	135.47	79.7	66.9	73.3	12.8
				YEAR: 1964				
JAN.	130	100	30	9.71	77.0	65.7	71.3	11.3
FEB.	55	116	-61	9.48	76.0	64.2	70.1	11.8
MAR.	127	129	-2	11.50	76.7	65.1	70.9	11.6
APR.	67	133	-65	10.48	78.4	67.0	72.7	11.4
MAY.	17	154	-137	13.33	78.5	66.8	72.6	11.7
JUNE	20	168	-148	11.88	81.5	69.1	75.3	12.4
JULY	55	178	-123	13.96	81.5	71.0	76.3	10.5
AUG.	47	197	-149	14.81	82.7	70.7	76.7	12.0
SEP.	40	158	-118	14.24	83.0	70.7	76.8	12.3
OCT.	52	139	-87	12.56	80.2	69.1	74.6	11.1
NOV.	142	109	33	9.44	78.8	68.8	73.8	10.0
DEC.	395	70	325	8.15	78.9	68.6	73.7	10.3
ANN.	1150	1652	-502	139.54	79.4	68.1	73.7	11.4
				YEAR: 1965				
JAN.	140	113	27	9.30	77.6	65.0	71.3	12.6
FEB.	167	118	50	10.11	73.8	61.5	67.6	12.3
MAR.	25	128	-103	12.35	77.8	62.5	70.1	15.3
APR.	185	113	72	11.21	78.8	66.2	72.5	12.6
MAY.	217	169	49	11.05	81.4	68.4	74.9	13.0
JUNE	20	189	-169	14.28	81.2	69.2	75.2	12.0
JULY	89	189	-101	14.16	81.7	68.9	75.3	12.8
AUG.	50	209	-159	13.35	82.6	69.5	76.0	13.1
SEP.	42	136	-94	13.96	84.8	70.0	77.4	14.8
OCT.	202	139	63	11.40	81.7	68.6	75.1	13.1
NOV.	397	115	282	8.94	79.3	68.8	74.0	10.5
DEC.	213	117	95	8.47	75.7	65.1	70.4	10.6
ANN.	1747	1735	12	138.58	79.7	67.0	73.3	12.7

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: OPAEULA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO- RATION IN MM.	MOIS- TURE DEFICIT	RADI- ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1966				
JAN.	45	99	-55	10.04	76.8	62.9	69.8	13.9
FEB.	165	97	68	9.29	75.6	63.2	69.4	12.4
MAR.	30	134	-104	11.51	79.1	64.3	71.7	14.8
APR.	42	147	-105	11.94	77.1	63.7	70.4	13.4
MAY.	50	157	-107	14.30	82.4	67.6	75.0	14.8
JUNE	35	182	-147	15.17	82.7	71.3	77.0	11.4
JULY	140	187	-47	15.13	82.6	71.5	77.0	11.1
AUG.	45	214	-170	15.70	83.4	71.9	77.6	11.5
SEP.	20	157	-137	13.97	84.8	70.8	77.8	14.0
OCT.	157	124	33	14.19	83.1	70.6	76.8	12.5
NOV.	310	111	199	11.60	81.6	69.3	75.4	12.3
DEC.	135	97	38	10.26	78.2	67.3	72.7	10.9
ANN.	1175	1709	-534	153.09	80.6	67.9	74.2	12.8
				YEAR: 1967				
JAN.	65	93	-28	9.66	77.0	64.7	70.8	12.3
FEB.	95	98	-3	9.81	78.4	66.0	72.2	12.4
MAR.	215	106	109	10.87	78.5	66.7	72.6	11.8
APR.	110	123	-13	12.87	78.9	65.7	72.3	13.2
MAY.	55	140	-85	13.82	83.0	69.4	76.2	13.6
JUNE	25	167	-142	14.90	84.8	69.7	77.2	15.1
JULY	130	179	-49	13.81	84.1	72.2	78.1	11.9
AUG.	110	177	-67	13.73	83.9	72.9	78.4	11.0
SEP.	27	158	-130	12.95	85.7	72.0	78.8	13.7
OCT.	45	132	-87	12.24	85.8	72.1	78.9	13.7
NOV.	152	116	37	9.94	81.0	71.2	76.1	9.8
DEC.	265	100	164	7.99	78.6	67.0	72.8	11.6
ANN.	1295	1590	-295	142.59	81.6	69.1	75.4	12.5
				YEAR: 1968				
JAN.	225	99	126	10.34	79.2	65.2	72.2	14.0
FEB.	97	106	-9	10.14	81.1	66.1	73.6	15.0
MAR.	357	136	222	10.09	78.6	68.4	73.5	10.2
APR.	145	151	-7	12.28	81.5	69.3	75.4	12.2
MAY.	22	162	-140	13.94	83.5	69.7	76.6	13.8
JUNE	30	186	-156	14.35	85.2	72.7	78.9	12.5
JULY	57	193	-136	15.26	87.9	73.6	80.7	14.3
AUG.	20	198	-179	15.83	87.4	73.9	80.6	13.5
SEP.	82	175	-93	13.80	87.0	73.1	80.0	13.9
OCT.	107	138	-30	12.33	87.4	72.4	79.9	15.0
NOV.	195	118	77	11.33	84.3	70.1	77.2	14.2
DEC.	332	99	234	10.48	80.4	67.7	74.0	12.7
ANN.	1672	1762	-90	150.17	83.6	70.2	76.9	13.4

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: OPAEULA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO- RATION IN MM.	MOIS- TURE DEFICIT	RADI- ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
YEAR: 1969								
JAN.	280	109	171	10.07	77.0	65.3	71.1	11.7
FEB.	245	104	141	9.59	71.8	63.1	67.4	8.7
MAR.	85	148	-64	14.25	72.6	59.7	66.1	12.9
APR.	57	142	-85	12.48	73.4	62.2	67.8	11.2
MAY.	38	157	-120	15.63	78.8	62.1	70.4	16.7
JUNE	30	166	-136	15.17	82.2	64.6	73.4	17.6
JULY	75	174	-99	15.77	80.7	68.9	74.8	11.8
AUG.	30	195	-165	16.94	81.8	69.9	75.8	11.9
SEP.	47	149	-101	13.31	80.4	69.3	74.8	11.1
OCT.	42	140	-97	12.57	82.2	66.7	74.4	15.5
NOV.	115	105	10	10.35	80.1	66.5	73.3	13.6
DEC.	122	100	22	10.64	77.3	63.8	70.5	13.5
ANN.	1167	1690	-523	156.77	78.2	65.2	71.7	13.0
YEAR: 1970								
JAN.	185	126	59	8.51	79.1	61.5	70.3	17.6
FEB.	70	124	-54	11.37	75.9	57.9	66.9	18.0
MAR.	13	158	-146	14.40	77.5	59.7	68.6	17.8
APR.	80	156	-76	19.22	77.1	62.5	69.8	14.6
MAY.	30	159	-129	16.40	79.9	64.7	72.3	15.2
JUNE	27	169	-142	17.12	80.1	65.4	72.7	14.7
JULY	205	199	6	17.80	80.7	65.5	73.1	15.2
AUG.	30	197	-167	15.30	81.5	67.6	74.5	13.9
SEP.	35	163	-128	12.42	81.7	65.0	73.3	16.7
OCT.	47	130	-82	18.92	79.9	65.6	72.7	14.3
NOV.	120	89	30	9.66	77.2	63.1	70.1	14.1
DEC.	102	117	-15	12.02	76.0	63.0	69.5	13.0
ANN.	972	1768	-795	173.14	78.6	63.3	70.9	15.3

TABLE V

CLIMATOLCGICAL INFORMATION FOR STATION: WAIMEA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO- RATION IN MM.	MOIS- TURE DEFICIT	RADI- ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1960				
JAN.	65	116	-52	11.19	79.6	62.7	71.1	16.9
FEB.	88	113	-25	9.89	79.2	65.8	72.5	13.4
MAR.	172	134	39	12.41	78.6	63.4	71.0	15.2
APR.	105	154	-49	13.20	79.8	65.4	72.6	14.4
MAY.	82	186	-104	15.34	83.3	66.0	74.6	17.3
JUNE	80	195	-116	15.76	84.9	68.4	76.6	16.5
JULY	38	223	-185	15.80	86.1	70.5	78.3	15.6
AUG.	95	215	-120	16.04	86.1	70.2	78.1	15.9
SEP.	75	186	-111	16.09	85.6	70.0	77.8	15.6
OCT.	110	134	-24	13.95	82.6	67.9	75.2	14.7
NOV.	107	138	-30	13.45	77.6	67.5	72.5	10.1
DEC.	100	102	-2	10.71	76.0	65.1	70.5	10.9
ANN.	1117	1897	-780	163.84	81.6	66.9	74.3	14.7
				YEAR: 1961				
JAN.	122	121	2	12.33	75.5	67.0	71.3	8.5
FEB.	132	127	5	10.69	75.6	66.4	71.0	9.2
MAR.	67	159	-92	14.65	78.2	66.6	72.4	11.6
APR.	95	167	-73	14.54	78.4	69.6	74.0	8.8
MAY.	110	209	-99	15.00	80.3	72.1	76.2	8.2
JUNE	97	192	-95	15.16	80.8	72.9	76.8	7.9
JULY	88	227	-140	15.63	82.9	74.2	78.5	8.7
AUG.	92	224	-131	14.77	83.3	75.2	79.2	8.1
SEP.	55	182	-127	15.63	84.0	74.7	79.3	9.3
OCT.	85	129	-44	11.13	82.7	72.4	77.5	10.3
NOV.	165	105	60	10.01	78.7	69.5	74.1	9.2
DEC.	97	111	-14	10.34	78.2	66.0	72.1	12.2
ANN.	1207	1955	-747	159.88	79.9	70.5	75.2	9.3
				YEAR: 1962				
JAN.	77	112	-35	9.28	78.0	65.8	71.9	12.2
FEB.	132	116	16	9.85	76.2	67.7	71.9	8.5
MAR.	350	152	198	9.95	75.8	67.0	71.4	8.8
APR.	97	159	-62	12.66	79.5	67.9	73.7	11.6
MAY.	110	155	-45	12.90	79.7	71.0	75.3	8.7
JUNE	47	197	-150	13.41	81.7	71.3	76.5	10.4
JULY	55	211	-156	14.47	81.3	71.6	76.4	9.7
AUG.	70	187	-117	14.37	82.1	72.9	77.5	9.2
SEP.	57	194	-137	13.43	81.7	71.4	76.5	10.3
OCT.	92	170	-77	12.23	80.5	72.3	76.4	8.2
NOV.	15	174	-159	11.09	80.0	70.3	75.1	9.7
DEC.	55	132	-77	10.19	76.1	69.5	72.8	6.6
ANN.	1160	1960	-800	143.84	79.4	69.9	74.6	9.5

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: WAIMEA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO- RATION IN MM.	MOIS- TURE DEFICIT	RADI- ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1963				
JAN.	263	106	156	9.95	76.1	68.6	72.3	7.5
FEB.	47	144	-96	10.04	77.7	66.7	72.2	11.0
MAR.	215	140	75	11.23	77.2	66.7	71.9	10.5
APR.	463	123	339	9.81	77.4	68.4	72.9	9.0
MAY.	225	146	79	11.90	78.0	69.9	73.9	8.1
JUNE	67	170	-102	10.22	79.8	70.8	75.3	9.0
JULY	97	180	-83	12.22	80.0	72.6	76.3	7.4
AUG.	25	184	-159	14.67	81.6	73.0	77.3	8.6
SEP.	80	159	-79	13.20	81.3	73.4	77.3	7.9
OCT.	65	137	-72	12.97	80.6	71.0	75.8	9.6
NOV.	50	115	-65	11.87	80.0	71.7	75.8	8.3
DEC.	95	58	37	9.93	78.1	68.5	73.3	9.6
ANN.	1692	1663	29	138.01	79.0	70.1	74.5	8.9
				YEAR: 1964				
JAN.	152	89	63	9.77	77.2	66.7	71.9	10.5
FEB.	65	106	-41	9.51	76.0	67.2	71.6	8.8
MAR.	145	135	10	11.98	76.9	68.3	72.6	8.6
APR.	52	137	-85	10.99	77.7	70.1	73.9	7.6
MAY.	42	164	-122	13.54	78.1	69.7	73.9	8.4
JUNE	55	168	-114	12.59	80.9	71.6	76.2	9.3
JULY	82	172	-90	14.11	80.4	73.0	76.7	7.4
AUG.	80	204	-124	15.01	84.0	73.5	78.8	10.5
SEP.	52	199	-147	14.25	86.4	73.9	80.1	12.5
OCT.	65	156	-91	12.81	82.0	73.4	77.7	8.6
NOV.	145	112	33	9.83	78.9	71.5	75.2	7.4
DEC.	413	79	334	9.30	76.5	68.2	72.3	8.3
ANN.	1350	1722	-372	143.69	79.6	70.6	75.1	9.0
				YEAR: 1965				
JAN.	90	106	-16	9.73	74.1	69.8	71.9	4.3
FEB.	132	120	12	10.45	72.3	69.4	70.8	2.9
MAR.	17	141	-123	12.70	76.5	69.7	73.1	6.8
APR.	217	119	99	12.00	76.6	70.6	73.6	6.0
MAY.	177	157	21	11.54	75.9	70.9	73.4	5.0
JUNE	50	176	-126	12.73	73.5	72.4	72.9	1.1
JULY	102	189	-87	13.02	73.8	73.4	73.6	0.4
AUG.	80	179	-99	14.44	81.7	71.2	76.4	10.5
SEP.	30	142	-112	14.63	82.8	73.7	78.2	9.1
OCT.	192	133	60	12.34	79.2	70.5	74.8	8.7
NOV.	455	89	366	9.21	76.7	68.9	72.8	7.8
DEC.	185	90	95	8.66	73.7	69.1	71.8	4.6
ANN.	1727	1641	86	141.25	76.4	70.6	73.5	5.8

T A B L E V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: WAIMEA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO-RATION IN MM.	MOIS-TURE DEFICIT	RADI-ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1966				
JAN.	52	98	-45	9.78	74.8	61.7	68.2	13.1
FEB.	177	92	86	9.12	73.9	59.6	66.7	14.3
MAR.	27	140	-113	11.48	77.6	60.3	68.9	17.3
APR.	40	144	-104	12.06	76.5	63.0	69.8	13.5
MAY.	40	152	-112	14.70	81.1	61.9	71.5	19.2
JUNE	63	161	-99	15.18	80.6	61.3	70.9	19.3
JULY	230	194	36	15.16	80.5	61.2	70.8	19.3
AUG.	63	235	-173	15.79	81.9	69.0	75.4	12.9
SEP.	32	199	-167	14.78	82.8	66.7	74.7	16.1
OCT.	142	166	-24	15.11	80.2	65.0	72.6	15.2
NOV.	322	122	200	12.22	77.7	65.6	71.6	12.1
DEC.	120	94	26	11.07	74.7	62.8	68.7	11.9
ANN.	1310	1799	-489	156.47	78.5	63.2	70.8	15.3
				YEAR: 1967				
JAN.	88	91	-3	10.60	74.1	60.2	67.1	13.9
FEB.	88	95	-7	10.83	75.3	59.7	67.5	15.6
MAR.	210	108	102	11.81	74.6	60.7	67.6	13.9
APR.	90	129	-39	13.93	80.3	68.5	74.4	11.8
MAY.	52	146	-93	15.01	81.4	64.0	72.7	17.4
JUNE	40	162	-122	15.64	83.0	67.7	75.3	15.3
JULY	88	160	-73	15.01	81.2	67.8	74.5	13.4
AUG.	97	151	-53	14.24	81.2	68.8	75.0	12.4
SEP.	65	145	-81	13.14	82.9	68.8	75.8	14.1
OCT.	65	127	-62	12.74	82.9	68.5	75.7	14.4
NOV.	167	100	68	9.24	78.3	66.2	72.2	12.1
DEC.	220	88	132	8.21	77.1	63.4	70.2	13.7
ANN.	1270	1501	-231	150.40	79.4	65.4	72.4	14.0
				YEAR: 1968				
JAN.	190	110	80	10.67	78.3	61.3	69.8	17.0
FEB.	90	128	-39	9.95	79.9	62.7	71.3	17.2
MAR.	375	136	239	9.36	75.6	67.9	71.7	7.7
APR.	177	139	39	12.07	80.1	62.8	71.4	17.3
MAY.	25	151	-126	14.40	81.9	66.9	74.4	15.0
JUNE	55	179	-124	14.64	82.8	66.8	74.8	16.0
JULY	60	202	-143	15.64	86.4	75.6	81.0	10.8
AUG.	35	250	-215	16.14	85.5	70.0	77.8	15.5
SEP.	47	222	-175	14.39	85.6	68.9	77.2	16.7
OCT.	155	187	-32	13.33	83.6	68.2	75.9	15.4
NOV.	172	154	18	12.51	81.8	67.0	74.4	14.8
DEC.	210	127	83	11.16	76.6	65.7	71.1	10.9
ANN.	1592	1987	-395	154.28	81.5	67.0	74.2	14.5

TABLE V (CONTINUED)
CLIMATOLOGICAL INFORMATION FOR STATION: WAIMEA
LOCATED IN "WAIALUA SUGAR COMPANY INC." ,OAHU,HAWAII

MONTH	RAIN FALL MM.	EVAPO-RATION IN MM.	MOIS-TURE DEFICIT	RADI-ATION KG.CAL	TEMPERATURE (FAHRENHEIT) MAX.	MIN.	MEAN	MAX-MIN
				YEAR: 1969				
JAN.	252	141	112	10.74	73.5	62.9	68.2	10.6
FEB.	235	124	111	10.48	74.9	62.1	68.5	12.8
MAR.	117	165	-48	14.64	75.3	63.5	69.4	11.8
APR.	80	154	-74	13.07	76.8	65.4	71.1	11.4
MAY.	55	186	-131	16.26	81.5	65.9	73.7	15.6
JUNE	40	186	-146	15.89	83.8	68.2	76.0	15.6
JULY	100	175	-75	16.39	82.8	69.6	76.2	13.2
AUG.	65	194	-129	17.05	83.1	72.3	77.7	10.8
SEP.	70	142	-72	13.79	82.2	71.7	76.9	10.5
OCT.	67	149	-81	12.35	83.6	70.0	76.8	13.6
NOV.	127	120	8	9.91	81.8	68.5	75.1	13.3
DEC.	157	120	37	10.17	79.3	65.3	72.3	14.0
ANN.	1367	1857	-490	160.74	79.9	67.1	73.5	12.8
				YEAR: 1970				
JAN.	195	113	81	8.12	78.3	64.6	71.4	13.7
FEB.	55	144	-89	8.12	77.8	63.4	70.6	14.4
MAR.	13	160	-147	12.64	79.1	65.2	72.1	13.9
APR.	92	165	-73	17.08	79.1	67.0	73.0	12.1
MAY.	32	165	-133	15.09	82.4	68.7	75.5	13.7
JUNE	60	192	-132	15.79	83.5	69.5	76.5	14.0
JULY	270	250	20	18.50	85.0	71.4	78.2	13.6
AUG.	42	247	-204	15.40	85.7	73.5	79.6	12.2
SEP.	47	210	-163	12.87	85.4	71.0	78.2	14.4
OCT.	57	149	-91	18.59	83.5	71.6	77.5	11.9
NOV.	142	96	47	9.25	80.3	69.6	74.9	10.7
DEC.	142	127	15	11.48	78.0	69.8	73.9	8.2
ANN.	1150	2019	-869	164.97	81.5	68.8	75.1	12.7

APPENDIX III

ABBREVIATIONS AND CONVERSION FACTORS

LIST OF ABBREVIATIONS

WACO	Waialua Sugar Company Inc.
HSPA	Hawaiian Sugar Planters' Association.
SCS	Soil Conservation Service.
TSA	Ton Sugar per Acre.
TCA	Ton Cane per Acre.
TSAM	Ton Sugar per Acre per Month.
TCAM	Ton Cane per Acre per Month.
"Makai"	Towards the ocean (Hawaiian).
"Mauka"	Towards the mountains (Hawaiian).

CONVERSION FACTORS

a. From c.g.s. system to American system

1 hectare (ha) = 2.47 acres

1 kilogram (kg) = 2.18 pounds (lb)

1 kg/ha = 1.13 lb/acre

1 meter (m) = 3.28 feet (ft) = 39.27" (inches)

1 centimeter (cm) = 0.39" (inches)

b. From American system to c.g.s. system

1 acre = 0.405 ha

1 pound = 0.453 kg

1 foot = 0.3 m

1 inch = 2.5 cm

1 Ton per Acre = 2240 kg/ha

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