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(BSP Tech. Rep. 4)

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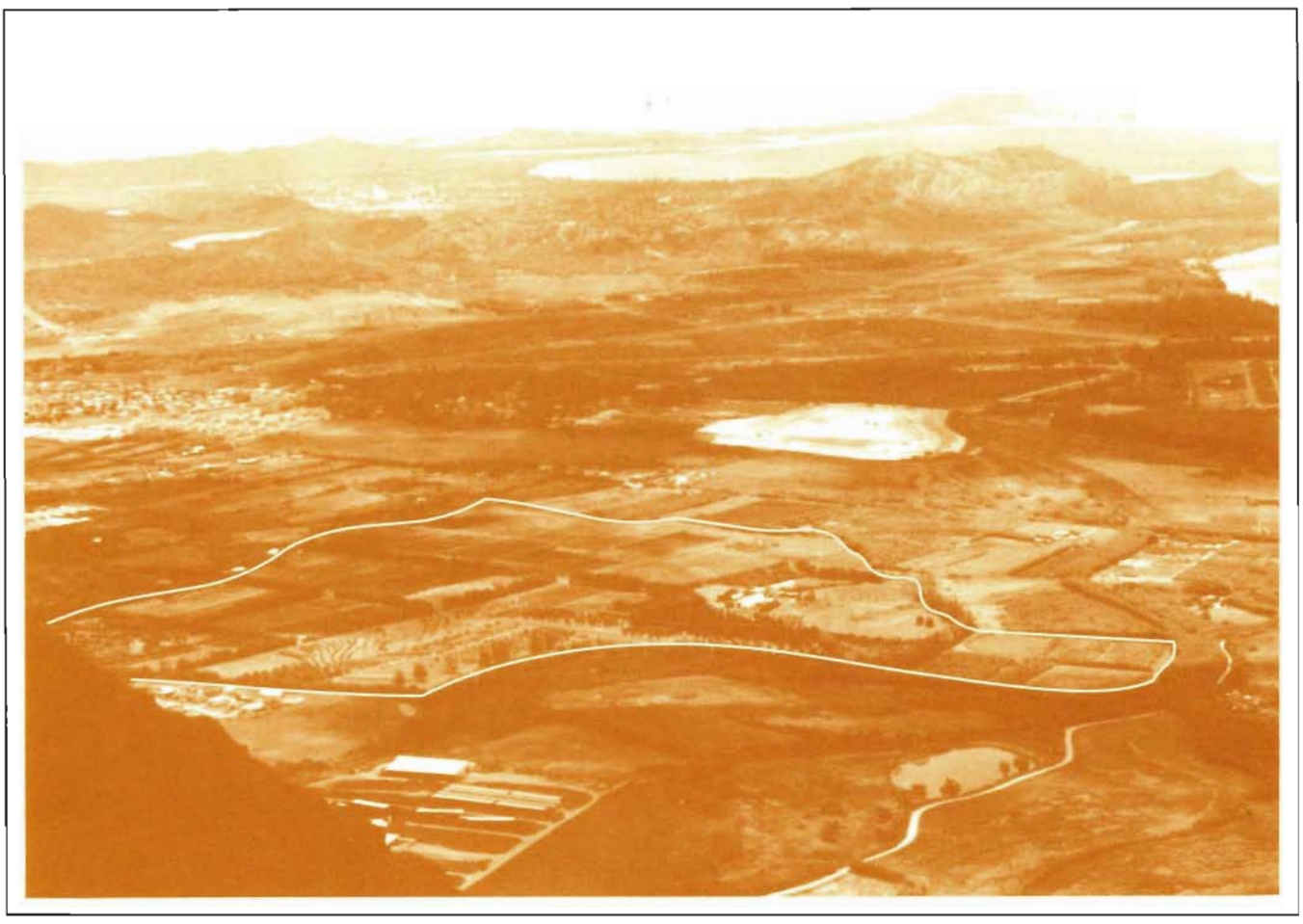

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**On the cover:** View of Waimanalo Experiment Station, one of 16 research sites of the Hawaii Agricultural Experiment Station, University of Hawaii.

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# Foreword

The research for this publication was a cooperative effort between the Hawaii Agricultural Experiment Station, College of Tropical Agriculture and Human Resources, University of Hawaii, and the Soil Conservation Service, U.S. Department of Agriculture.

The manuscript was originally submitted for publication in April 1974 and has not been changed substantially since then. Final editing and production was handled through the Benchmark Soils Project (UH/AID ta-C-1108).

# Abstract

There are 16 experiment stations of the Hawaii Agricultural Experiment Station, College of Tropical Agriculture and Human Resources, located throughout the State of Hawaii. Detailed soil survey maps of each site were prepared by the Honolulu-based Soil Survey Staff of the Soil Conservation Service, U.S. Department of Agriculture; then, soil samples were collected for each dominant soil series at each station and were analyzed in the laboratory at the University of Hawaii, Manoa Campus. This report is an inventory of the basic soil resources of these experiment stations.

**Key words:** Experiment station, soil survey, soil classification, soil-resource inventory

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# Preface

The State of Hawaii, which comprises a chain of volcanic islands in the central Pacific Ocean, is isolated from other land masses and lies athwart the prevailing northeast trade winds. The northeastern sides of the islands receive heavy rainfall; the southeastern sides and the tops of the high mountains, which project above the rainbearing clouds, are dry. (The islands rise to more than 4000 meters [13,125 feet] above sea level.) Wide variations in rainfall, temperature, and cloudiness engender many microclimates superimposed upon a general tropical marine climate with a mean summer to mean winter temperature range of less than 5°C (9°F). Mean annual rainfall ranges from 12 cm (5 inches) to more than 12 meters (470 inches). Mean annual temperatures decrease from 24°C (75°F) at the coast to 8°C (47°F) at the summit of the tallest mountain.

Variations in the nature and range of soil parent materials, in combination with the many microclimates, have produced 190 separate soil series in a land area of only 4 million acres, 1 million of which is rock land.

With so much variation in so small an area, where two places 5 miles apart may have average annual rainfalls differing by 2000 cm (80 inches) and mean annual temperatures differing by 3°C (5°F), it is difficult for researchers, given normal financial constraints, to provide accurate information applicable to all Hawaii's agriculture.

The Hawaii Agricultural Experiment Station of the College of Tropical Agriculture and Human Resources, University of Hawaii, has 16 permanent field experimental facilities in 12 of the agriculturally important microenvironments in the State. Although they are not sufficient to encompass all Hawaii's microenvironments, these facilities do constitute an environmental network for studying plant and animal response to natural factors that probably cannot be equaled elsewhere in the tropics, or perhaps even in the continental United States.

This report provides information about the soils and microclimates at these facilities. I hope that it will be used by agricultural researchers in planning their field experiments, so that the full potential of this network can be realized and information gained at the facilities can be correctly and safely applied in many of the other microclimates where agriculture is practiced in Hawaii or other tropical areas.

**L. D. Swindale**
Former Associate Director
Hawaii Agricultural Experiment Station
April 1974

# Introduction

Tropical soils are often considered infertile and unproductive; however, much research conducted over the past years at the Hawaii Agricultural Experiment Station, College of Tropical Agriculture and Human Resources, University of Hawaii, has proven that these soils produce high crop yields under proper management. In addition, the sugar and pineapple industries in Hawaii have made many important contributions to soil research that can be incorporated in the use of this natural resource.

Because of the diversity of soil-forming factors and the relatively rapid formation of soils caused by high temperatures and high rainfall, soils in Hawaii differ greatly within short distances. Therefore, experiment stations were established throughout the State to make more precise predictions. Table 1 classifies the major soils at each location according to Soil Taxonomy (Soil Survey Staff, 1975); Table 2 shows the general research projects of each station; and Table 3 lists the locations, sizes, and general climatic data of the 16 experiment stations of the Hawaii Agricultural Experiment Station.

**Table 1. Classification of major soil series at the experiment stations of the Hawaii Agricultural Experiment Station**

| Experiment station | Soil Taxonomy | | |
|---|---|---|---|
| | Soil series | Order | Subgroup and family |
| *Kauai* | | | |
| Wailua | Halii | Oxisols | Typic Gibbsihumox<br>clayey, ferritic, isothermic |
| Kauai Field | Hanalei | Entisols | Tropic Fluvaquents<br>very-fine, oxidic, nonacid, isohyperthermic |
| *Oahu* | | | |
| Poamoho | Wahiawa | Oxisols | Tropeptic Eutrustox<br>clayey, kaolinitic, isohyperthermic |
| Waialee | Kaena | Vertisols | Typic Pelluderts<br>very-fine, montmorillonitic, isohyperthermic |
| | Waialua | Mollisols | Vertic Haplustolls<br>very-fine, kaolinitic, isohyperthermic |
| Waimanalo | Waialua[a] | Mollisols | Vertic Haplustolls<br>very-fine, kaolinitic, isohyperthermic |
| | Kawaihapai | Mollisols | Cumulic Haplustolls<br>fine, mixed, isohyperthermic |
| *Maui* | | | |
| Haleakala | Makawao | Ultisols | Humoxic Tropohumults<br>clayey, oxidic, isothermic |
| Kula | Kula | Inceptisols | Typic Eutrandepts<br>medial, isothermic |
| *Hawaii* | | | |
| Lalamilo | Waimea | Inceptisols | Typic Eutrandepts<br>medial, isothermic |
| Pukalani | Waimea[a] | Inceptisols | Typic Eutrandepts<br>medial, isomesic |
| | Kikoni[a] | Inceptisols | Typic Eutrandepts<br>medial, isomesic |
| Mealani | Maile | Inceptisols | Hydric Dystrandepts<br>thixotropic, isomesic |

*—Continued*

**Table 1.** *Continued.*

| Experiment station | Soil Taxonomy | | |
|---|---|---|---|
| | Soil series | Order | Subgroup and family |
| Hamakua | Maile | Inceptisols | Hydric Dystrandepts thixotropic, isomesic |
| | Honokaa | Inceptisols | Typic Hydrandepts thixotropic, isothermic |
| Kona | Honuaulu | Inceptisols | Hydric Dystrandepts thixotropic over fragmental, isothermic |
| Kulani | Puukala | Inceptisols | Hydric Lithic Dystrandepts thixotropic, isomesic |
| Volcano | Puaulu | Inceptisols | Typic Hydrandepts medial over thixotropic, isomesic |
| Malama-Ki | Malama | Histosols | Typic Tropofolists dysic, isohyperthermic |
| | Opihikao | Histosols | Lithic Tropofolists dysic, isohyperthermic |
| Waiakea | Papai | Histosols | Typic Tropofolists euic, isohyperthermic |
| | Keaukaha | Histosols | Lithic Tropofolists dysic, isohyperthermic |

a. Variant.

**Table 2. General research programs of the experiment stations of the Hawaii Agricultural Experiment Station**

| Experiment station | Program |
|---|---|
| *Kauai* | |
| Wailua | Fruit, vegetable, nut, root, and rice crops—nutrition, varietal evaluation, weed and disease control; pasture productivity and forage production; herbicide screening and evaluation. |
| Kauai Field | Rice and taro. |
| *Oahu* | |
| Poamoho | Fruit, vegetable, and nut crops; weed and disease control. |
| Waialee | Beef and dairy cattle, swine, and poultry—nutrition, physiology, breeding, and disease control. |
| Waimanalo | Fruit, vegetable, nut, and forage crops; weed control; irrigation. |
| *Maui* | |
| Haleakala | Fruit and nut crops; pasture management and tropical legumes. |
| Kula | Fruit, vegetable, and nut crops; ornamentals; pasture management and tropical legumes. |
| *Hawaii* | |
| Lalamilo | Vegetable crops; irrigation. |
| Pukalani | Beef cattle—breeding and reproduction; forage crops. |
| Mealani | Beef cattle—breeding, nutrition, and reproduction; agronomic crops; windbreaks. |
| Hamakua | Fruit and nut crops; forestry; agronomic crops. |
| Kona | Fruit and nut crops. |
| Kulani | Beef cattle; forage crops. |
| Volcano | Vegetable and agronomic crops. |
| Malama-Ki | Fruit and nut crops—production, breeding, nutrition, and disease control; forestry. |
| Waiakea | Fruit and nut crops—breeding, nutrition, and disease control; ornamentals; forestry; livestock nutrition; agronomic crops. |

SOURCE: Office of the Associate Director, HITAHR.

Table 3. Location, acreage, and climatic data of the experiment stations of the Hawaii Agricultural Experiment Station

| Experiment station | Island | Location | Approx. acres | Elevation (ft) | Annual rainfall (inches) | Average temperature (°F) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Min. | Max. |
| Wailua | Kauai | Wailua | 250 | 532 | 98 | 68 | 78 |
| Kauai Field[a] | Kauai | Wailua | 14 | < 10 | 50 | 69 | 81 |
| Poamoho | Oahu | Poamoho | 50 | 545-705 | 44 | 67 | 82 |
| Waialee | Oahu | Waialee | 135 | 10-50 | 40[b] | | |
| Waimanalo | Oahu | Waimanalo | 127 | 65-95 | 60 | 68 | 82 |
| Haleakala | Maui | Makawao | 38 | 2000 | 79 | 54 | 76 |
| Kula | Maui | Kula | 19 | 3000 | 30 | 52 | 78 |
| Lalamilo | Hawaii | Waimea | 18 | 2500 | 30 | 59 | 73 |
| Pukalani | Hawaii | Waimea | 200 | 3000 | 25 | 55[b] | 69[b] |
| Mealani | Hawaii | Waimea | 195 | 2800 | 56 | 55 | 69 |
| Hamakua | Hawaii | Honokaa | 180 | 2200-2800 | 100 | 57 | 70 |
| Kona[c] | Hawaii | Kainaliu | 18 | 1465-1672 | 71 | 60 | 78 |
| Kulani | Hawaii | Kulani | 700 | 5000-7000 | 100[b] | | |
| Volcano | Hawaii | Volcano | 30 | 4000 | 183 | 63 | 79 |
| Malama-Ki | Hawaii | Malama-Ki | 190 | 250 | 127 | 67 | 80 |
| Waiakea | Hawaii | Waiakea | 195 | 525 | 183 | 63 | 79 |

SOURCE: Office of the Associate Director, HITAHR.

a. An additional 14 acres comprise the Kauai Rice Experimental Field at Wailua.
b. Estimated.
c. An additional 3 acres are at Captain Cook.

# General Description of the Hawaii Soils

## Kauai

At the Wailua Experiment Station on the oldest of the Hawaiian Islands, highly weathered Oxisols are predominant. The Halii and Kapaa soils are so highly weathered that a study on the feasibility of mining bauxite, the oxides of aluminum, from Kauai was considered by major aluminum companies in the United States and Canada. Reclamation trials show that, with high levels of fertilization and liming, these soils can be used efficiently for crops and pasture.

The Kauai Rice Experimental Field in Wailua is devoted to research on taro and rice production. Although this type of paddy soil accounts for only a small area in Hawaii, the soil is important in the production of these specialty crops.

## Oahu

The soils of the Oahu experiment stations (Poamoho, Waialee, and Waimanalo) were formed from residual or alluvial basaltic minerals. These soils are not as highly weathered and, therefore, are inherently more fertile than the soils at the Kauai station. The Island of Oahu consists of approximately 19,000 acres of the Wahiawa soil series, 50 of which occur at the Poamoho Experiment Station. This soil, as well as the other Oxisols, is used extensively for sugarcane and pineapple production in Hawaii. Soils of the coastal plains and alluvial areas are represented at the Waialee and Waimanalo Experiment Stations. Although their inherent fertility is high, these soils, especially the Vertisols at Waialee, are difficult to manage because of their physical properties.

## Maui

On the Island of Maui there are soils derived from andesitic and basic lava rocks as well as from volcanic ash. The Makawao soil at the Haleakala Experiment Station is not fertile and requires adequate fertilization and liming. The Kula soils at the Kula Experiment Station, on the other hand, is very fertile and, with proper water management, can produce many of the vegetables as well as ornamental crops grown in Hawaii.

## Hawaii

On the Island of Hawaii, where large acreages of volcanic ash soil or lava lands are devoted to agriculture, there are nine experiment stations. Three of them, Malama-Ki, Waiakea, and Kulani, represent a unique type of agricultural land: on recently cleared forest lands, which are really geologically young lava, many acres of shallow, tropical organic soils classified as Tropofolists (Histosols) are used

for the production of papaya, macadamia, avocado, guava, sugarcane, truck crops, pasture, and other crops. This Island, which is larger than all the other islands combined, has at least 400,000 acres of these Tropofolists. Research has been underway to determine the characteristics of these soils (Yaibuathes, 1971) and their potential for more crops and other uses (Periaswamy, 1973).

Contrasting with the stony and shallow Tropofolists are the volcanic ash soils, collectively called the Andepts. In areas of low rainfall (less than 30 inches mean annual rainfall), such as at the Lalamilo and Pukalani Experiment Stations, these Andepts are classified as Typic Eutrandepts because of their high base status. In higher rainfall areas (50 to 100 inches)—for example, at the Mealani, Hamakua, and Kona Experiment Stations—the soils become less fertile because the bases and the silica are leached out. These Andepts are classified as Dystrandepts. In areas of still greater rainfall (over 100 inches), as represented by the Volcano Experiment Station, the soils are almost devoid of bases and silica. These soils, which dehydrate irreversibly into sand and gravel fragments, are called Hydrandepts. They are very similar to those found in the high rainfall belt of the Hilo and Hamakua coasts.

Rainfall affects not only the chemical properties, as shown in the subsequent tables in this report, but also the mineralogical and physical properties. As rainfall increases, the intensity of weathering increases, causing the decomposition of volcanic glass (the primary constituent of volcanic ash) and the primary minerals. High rainfall also increases the water content in the soils, which is related to the very smeary consistency. Only field examination can fully show the unique morphological properties of these soils.

## Other Research on Hawaii Soils

The results of the soil survey and the laboratory data of the dominant soils are presented in the following sections. Additional information may be found in Soil Survey of the Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii (Foote et al., 1972) and Soil Survey of the Island of Hawaii, State of Hawaii (Sato et al., 1973). Much research has been conducted on the different soils of Hawaii. It cannot be overemphasized that the results of the research—for example, in terms of crop yield under similar management—can be extended to similar soils in other parts of the State. There is even the possibility that these results can be applied to other tropical areas through Soil Taxonomy, the latest system of soil classification (Soil Survey Staff, 1975). When predictions such as these can be made, the utility of this study will have been fulfilled.

# Procedure

## Soil Surveys and Mapping

A detailed *soil survey* was made to determine the soils at the experimental farms. The steepness, length, and shape of slopes, the kinds of rock, and many characteristics of the soils were observed. Holes were dug to expose **soil profiles.** A profile is the sequence of natural layers, or horizons, in a soil, extending from the surface down into the parent material that has not been changed by leaching or by the action of plant roots. Comparisons were then made among the profiles, and these soils were classified and named according to nationwide, uniform procedures. The soil series and soil phase are the categories of soil classification most used in local surveys.

Soils that have almost similar profiles make up a **soil series.** Except for different textures in the surface layer, all soils of a series have major horizons that are similar in thickness, arrangement, and other important characteristics. The soils series may be named for a town or other geographic feature near the place where that series was first observed and mapped. Wahiawa and Waimea, for example, are the names of two soils series in Hawaii. All soils in the United States with the same soil series name are essentially alike in those characteristics that affect their behavior in the undisturbed landscape.

Soils of one series can differ in texture of the surface soil and in slope, stoniness, or other characteristics that affect their use. On the basis of such differences, a soil series is divided into **soil phases.** The name of a soil phase indicates a feature that affects management; for example, Waimea silt loam, 0 to 3 percent slopes, is a phase of the Waimea series.

The **soil maps** in this report were prepared from aerial photographs that show woodlands, buildings, field borders, trees, and other details to help in drawing soil boundaries accurately. Symbols, as shown in the Soil Survey Manual (Soil Survey Staff, 1951) and as used by the Soil Survey Staff, were used to denote areas such as swamps, quarries, and sample sites on the soil maps.

The areas shown on a soil map are called **mapping units.** A mapping unit is nearly equivalent to a soil phase, but not completely, since it is not practical to show on a map all the small, scattered bits of other soils within an area that is dominantly of a recognized soil phase.

Some areas are closely related to another soil series but depart from it in at least one differentiating characteristic. These units are called **variants;** they are really a separate soil series but too small in known extent to justify establishing a new series. Another kind of mapping unit consists of soil material that is so rocky, shallow, or steep that

it cannot be classified as a soil series. These areas are called **miscellaneous land types** and are given descriptive names, such as rough broken land, stony land, and rock land.

## Capability Groupings

The capability grouping shows, in a general way, the suitability of soils for most kinds of crops (Soil Survey Staff, 1961). The groups are made according to the limitations of the soils when used for crops, the risk of damage when they are used, and the way they respond to treatment. The soils are grouped at two levels, the capability class and the subclass. **Capability classes,** the broadest groups, are designated by Roman numerals I through VIII, which indicate progressively greater limitations and narrower choices for practical use. **Capability subclasses** are soil groups within each class and are designated by adding a small letter—e, w, s, or c—to the class numeral, for example, IIe. The letter **e** shows that the main limitation is risk of *erosion* unless close-growing plant cover is maintained; **w** shows that *water* in or on the soil interferes with plant growth or cultivation; **s** shows that the soil is limited mainly because it is *shallow,* droughty, or stony; and **c** shows that the chief limitation is *climate* that is too cold or too dry.

In class I there are no subclasses because the soils of this class have few limitations. Class V can contain, at the most, only the subclasses indicated by w, s, and c, because the soils in class V are subject to little or no erosion, although they have other limitations that restrict their use largely to pasture or range, woodland, wildlife habitat, or recreation. The eight classes in the capability system and the subclasses represented in Hawaii are further described by Foote et al. (1972).

## Laboratory Data and Descriptions

Laboratory data were collected according to the procedures described in the Soil Survey Investigations Report No. 1 (Soil Survey Staff, 1972).

The acidity of the soils was obtained in both 1 *N* KCl and distilled water by means of a Beckman Expandomatic pH Meter; in each case, a 1:1 paste or suspension, on a volume basis, was prepared. Delta pH was calculated by the difference between the two methods:

$$pH_{KCl} - pH_{H_2O}$$

Organic C was determined volumetrically after oxidation with a $K_2Cr_2O_7 - H_2SO_4$ mixture and by back titration with a standard $FeSO_4$ solution. Organic matter was then calculated by multiplying the value of the organic C by a factor of 1.724. Total N was determined by Kjeldahl digestion. Extractable Fe was determined by the dithionite-citrate extraction method described by Jackson (1958). Cation-exchange capacity values were obtained by ammonium acetate extraction adjusted to pH 7.0, using NaCl as the exchange solution before distillation of the ammonia on the Kjeldahl apparatus. The extractable Ca and Mg were determined by atomic absorption spectrophotometry, whereas the extractable Na and K were determined by flame photometry. Base saturation was calculated by dividing the sum of the bases by the cation-exchange capacity value. Extractable Mn was also determined by atomic absorption spectrophotometry.

# Soil Maps, Soil Descriptions, and Laboratory Data

## Island of Kauai

### Description of the Soils of the Wailua Experiment Station

Fig. 1 shows the soils of the Wailua Station.

HALII SERIES

The Halii series consists of well- and moderately well-drained silty clay soils developed in material weathered from basic igneous rock and probably mixed with volcanic ash and ejecta. These soils occur on gently sloping to steep uplands. The annual rainfall is 100 to 200 inches. Mean annual soil temperature is about 71°F. Halii soils are geographically associated with the Kapaa and Hanamaulu soils.

Halii soils are used for water supply, wildlife, sugarcane, and pasture.

***Halii gravelly silty clay, 3 to 8 percent slopes*** **(HfB).**

This soil occupies ridge tops and side slopes in the uplands. The surface layer is gravelly due to iron stone concretions.

In a representative profile, the surface layer is a very dark grayish-brown gravelly silty clay about 6 inches thick. The upper subsoil is dark reddish-brown and strong brown subangular blocky silty clay and clay loam; red bands up to 2 inches are common. The lower subsoil continues to below 60 inches. The substratum is soft weathered rock. The surface layer is very strongly acid, and the subsoil is very strongly to extremely acid.

Permeability is moderately rapid, runoff is slow, and erosion hazard is slight. Roots may penetrate to 5 feet or more.

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**Profile description of Halii gravelly silty clay:**

Island of Kauai, Wailua Experiment Station (Table 4).

| | |
|---|---|
| Ap S69Ha-2-1-1 | 0 to 33 cm (0–13 inches), dark brown (10YR 3/3) gravelly silty clay; strong medium, fine and very fine granular structure; friable, slightly sticky and slightly plastic; no roots; many fine pores; many fine and medium iron concretions; few saprolite fragments from lower horizons; abrupt wavy boundary. |
| B21 S69Ha-2-1-2 | 33 to 58 cm (13–23 inches), dark yellowish-brown (10YR 3/4) silty clay; moderate medium and coarse subangular blocky structure; friable, sticky, plastic, and weakly smeary; no roots; many fine and very fine pores; about 10 to 20 percent saprolite about 2.5 to 7.5 cm (1–3 inches) in diameter; common fine and medium iron concretions; common fine gibbsite concretions; clear wavy boundary. |
| C1 S69Ha-2-1-3 | 58 to 76 cm (23–30 inches), dark brown (7.5YR 4/4) and reddish-brown (5YR 4/4) silty clay; moderate medium subangular blocky structure; friable, sticky, plastic, and moderately smeary; no roots; many very fine pores; about 50 percent soft saprolites; common fine gibbsite concretions; gradual wavy boundary. |
| C2 S69Ha-2-1-4 | 76 to 112 cm (30–44 inches), variegated colors of reddish-brown (5YR 4/4) and dark reddish-brown (5YR 3/4) silty clay; moderate medium and fine subangular blocky structure; friable, sticky, plastic, and strongly smeary; no roots; many medium and fine pores; about 80 to 90 percent soft to hard saprolites. |

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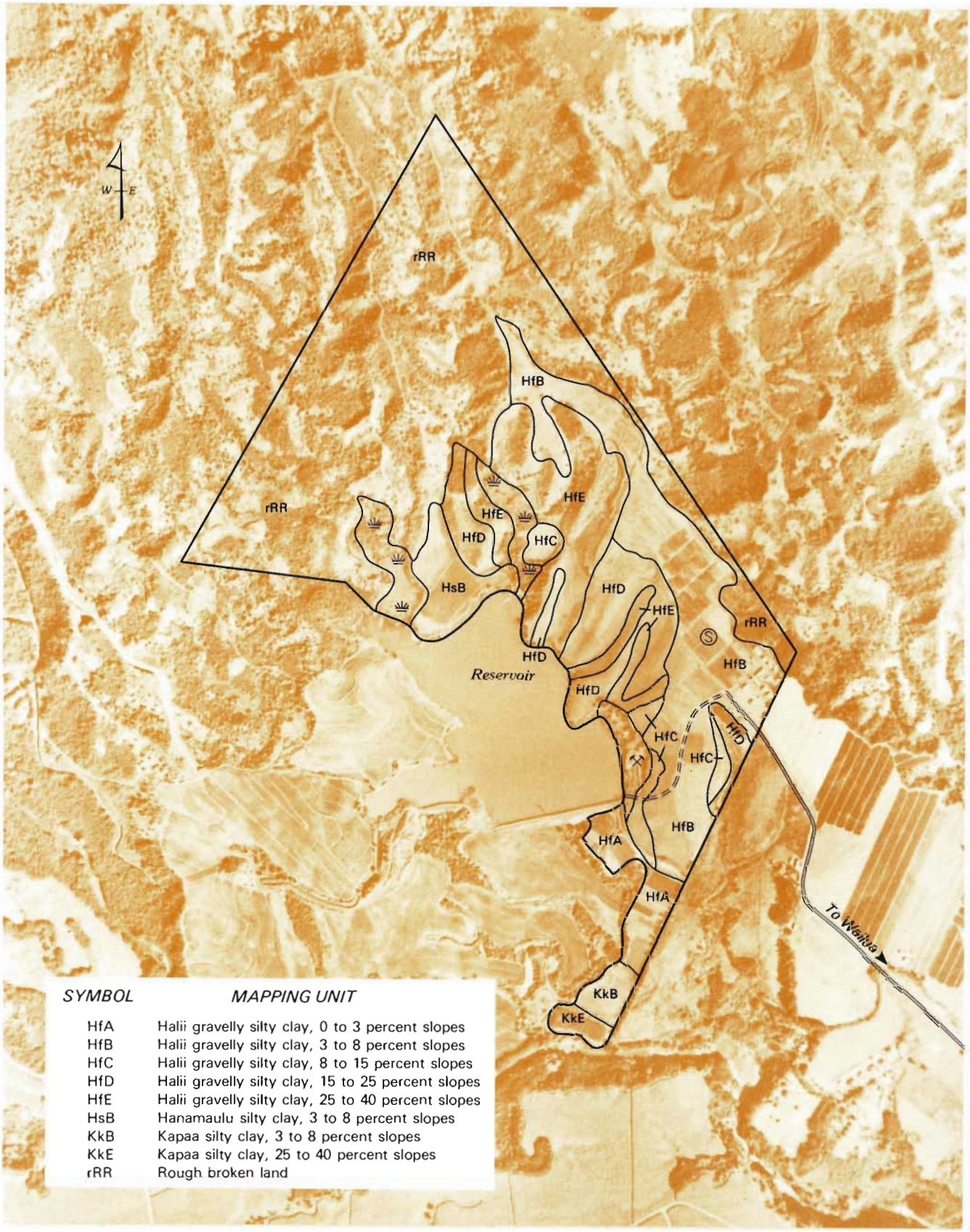


Fig. 1. Soil map of the Wailua Experiment Station, Wailua, Kauai. Approximate scale: 1:13000. For general location, see Sheet 29, Soil Survey by Foote et al. (1972), lat. 22°04′30″N; long. 159°24′45″W.

**Table 4. Laboratory data of Halii gravelly silty clay**

Soil name: Halii — Classification: Typic Gibbsihumox, clayey, ferritic, isothermic
Soil no.: S69Ha-2-1-(1-4) — Location: Wailua Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ----------pct---------- | |
| 0-33 | Ap | 24.5 | 21.8 | 53.7 | 1.40 | | | 17.7 | 2.87 | | | 25.8 | 36.9 |
| 33-58 | B21 | 9.3 | 15.6 | 75.1 | 1.22 | | | 21.3 | 1.91 | | | 27.5 | 39.3 |
| 58-76 | C1 | 27.5 | 28.9 | 43.6 | 1.15 | | | 22.3 | 1.31 | | | 26.5 | 37.9 |
| 76-112 | C2 | 26.3 | 32.3 | 41.4 | 1.15 | | | 20.6 | 0.99 | | | 24.7 | 35.3 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-33 | 3.04 | 0.45 | 0.15 | 0.15 | 3.79 | | 16.01 | | 0.1 | 24 | | 4.98 | 4.59 | -0.39 |
| 33-58 | 1.16 | 0.18 | 0.12 | 0.07 | 1.53 | | 12.97 | | 0.1 | 12 | | 5.27 | 5.07 | -0.20 |
| 58-76 | 0.37 | 0.04 | 0.06 | 0.05 | 0.52 | | 8.12 | | < 0.1 | 6 | | 5.23 | 5.28 | 0.05 |
| 76-112 | 0.28 | 0.03 | 0.07 | 0.06 | 0.44 | | 6.97 | | < 0.1 | 6 | | 5.00 | 5.22 | 0.22 |

Hue of the A horizon ranges from 7.5YR to 2.5Y. Texture of the A horizon ranges from gravelly silty clay loam to gravelly silty clay. Hue of the B horizon ranges from 2.5 YR to 10 YR. Value of the B horizon ranges from 3 to 5 and chroma ranges from 2 to 6. Capability classification IVs, nonirrigated.

***Halii gravelly silty clay, 0 to 3 percent slopes* (HfA).**

This soil is similar to Halii gravelly silty clay, 3 to 8 percent slopes, except slopes are nearly level. Runoff is slow and erosion hazard is none to slight. Capability classification IVs, nonirrigated.

***Halii gravelly silty clay, 8 to 15 percent slopes* (HfC).**

This soil is similar to Halii gravelly silty clay, 3 to 8 percent slopes, except it is moderately sloping. Runoff is slow and erosion hazard is slight to moderate. Capability classification IVe, nonirrigated.

***Halii gravelly silty clay, 15 to 25 percent slopes* (HfD).**

This soil is similar to Halii gravelly silty clay, 3 to 8 percent slopes, except it is moderately steep. Runoff is medium and erosion hazard is moderate. Capability classification IVe, nonirrigated.

***Halii gravelly silty clay, 25 to 40 percent slopes* (HfE).**

This soil is similar to Halii gravelly silty clay, 3 to 8 percent slopes, except for steep slopes. Runoff is rapid and erosion hazard is severe. Capability classification VIe, nonirrigated.

HANAMAULU SERIES

The Hanamaulu series consists of well-drained silty clay soils developed in alluvium washed from upland soils. These soils are on nearly level to strongly sloping stream terraces and steep terrace breaks. Elevations range from 200 to 700 feet. The annual rainfall is 60 to 100 inches. Mean annual soil temperature is about 73°F. Hanamaulu soils are geographically associated with Halii, Kapaa, and Hihimanu soils.

Hanamaulu soils are used for sugarcane, pasture, wildlife, and water supply. The natural vegetation consists of guava, pandanus, glenwoodgrass, ricegrass, and hau.

***Hanamaulu silty clay, 3 to 8 percent slopes* (HsB).**

This soil is on terraces.

In a representative profile, the surface layer is brown and very dark grayish-brown granular silty clay, about 11 inches thick. The subsoil is dark brown and dark reddish-brown subangular blocky silty clay over silty clay loam, about 60 inches thick. The substratum is slightly to strongly weathered pebbles, stones, and boulders. The surface layer is extremely acid, and the subsoil is very strongly acid.

Permeability is moderately rapid, runoff is slow, and erosion hazard is none to slight. Available water-holding capacity is about 1.4 inches per foot of soil. Roots may penetrate to 5 feet or more. Capability classification IIe, nonirrigated.

KAPAA SERIES

The Kapaa series consists of well-drained silty clay soils developed in material weathered from basic igneous rock. These soils are on gently sloping to extremely steep uplands. Elevations range from 200 to 800 feet. The annual rainfall is 80 to 120 inches. Mean annual soil temperature is about 72°F. Kapaa soils are geographically associated with the Halii and Puhi soils.

Kapaa soils are used for sugarcane, pasture, pineapple, orchard, truck crops, woodland, wildlife, and water supply. Natural vegetation consists of ricegrass, hilograss, yellow foxtail, Christmas berry, false staghorn fern, guava, rhodomyrtus, and melastoma.

***Kapaa silty clay, 3 to 8 percent slopes* (KkB).**

This soil is on broad ridges on the uplands.

In a representative profile, the surface layer is dark brown to dark yellowish-brown granular silty clay about 10 inches thick. The subsoil is a yellowish-red and reddish-brown subangular blocky silty clay, about 60 inches thick. The substratum is soft weathered rock. The surface layer is strongly to very strongly acid, and the subsoil is medium to very strongly acid.

Permeability is moderately rapid, runoff is slow, and erosion hazard is slight. Roots may penetrate to 5 feet or more. Capability classification IIIs, nonirrigated.

***Kapaa silty clay, 25 to 40 percent slopes* (KkE).**

This soil is similar to Kapaa silty clay, 3 to 8 percent slopes, but with steeper slopes. Runoff is rapid and erosion hazard is moderate to severe. Part of the surface layer has been removed by erosion.

This soil is used for pasture, wildlife habitat, and woodland. Capability classification VIe, nonirrigated.

ROUGH BROKEN LAND

***Rough broken land* (rRR).**

This unit consists of very steep land that is broken by numerous intermittent drainage channels. It occurs as gulches and mountainsides with slopes ranging from 40 to 70 percent. Local relief is generally between 25 to 500 feet. Runoff is rapid and geologic erosion is active. Elevations range from near sea level to about 8000 feet. The annual rainfall is 25 to more than 200 inches. Dominant vegetation in the drier areas is guava, lantana, Natal redtop, bermudagrass, koa haole, and molassesgrass. Ohia, kukui, koa, and ferns are dominant in the wetter areas.

The soils are variable and are 20 to more than 50 inches deep over soft weathered rock. Usually there are some weathered rock fragments mixed with the soil material. Small areas of rock outcrop, stones, and soil slips are common. Included are colluvium and alluvium along gulch bottoms.

This soil is used principally for watershed and wildlife. In places it is also used for pasture and woodland. Capability classification VIIe, nonirrigated.

## Description of the Soil of the Kauai Rice Experimental Field

HANALEI SERIES

***Hanalei silty clay, 0 to 2 percent slopes.***

The soil throughout the Kauai Rice Experimental Field is an intergrade between the Hanalei and Pearl Harbor series. Both the Hanalei and Pearl Harbor series are poorly drained. The former is classified as a Tropic Fluvaquents while the latter is classified as a Typic Tropaquepts.

The soil is formed from alluvium deposited over peat and muck. The upper 20 inches is a silty clay and is typical of the Hanalei series. The peat and muck at depths below 20 inches is typical of the Pearl Harbor series.

---

**Profile description of Hanalei silty clay:**

Kauai Rice Experimental Field (Table 5, page 20.)

| | |
|---|---|
| Ap S70Ha-2-1-1 | 0 to 15 cm (0–6 inches), very dark grayish-brown (10YR 3/2) silty clay with common fine prominent yellowish-red and dark reddish-brown mottles; cloddy structure; very firm when moist, sticky and plastic when wet; many roots; clear smooth boundary. |
| B21 S70Ha-2-1-2 | 15 to 33 cm (6–13 inches), very dark gray (10YR 3/1) silty clay with common fine prominent yellowish-red and dark reddish-brown mottles; massive; firm when moist, sticky and plastic when wet; many roots; common very fine pores; gradual smooth boundary. |
| B22 S70Ha-2-1-3 | 33 to 51 cm (13–20 inches), similar to above horizon except common fine, faint black mottles; many roots; water table at 40 cm (16 inches); clear smooth boundary. |
| IIC S70Ha-2-1-4 | 51 to 165 cm (20–65 inches), black peat and muck. |

---

**Table 5. Laboratory data of Hanalei silty clay**

Soil name: Hanalei — Classification: Tropic Fluvaquents, very-fine, oxidic, nonacid, isohyperthermic
Soil no.: S70Ha-2-1-(1-4) — Location: Kauai Rice Experimental Field, Wailua

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-15 | Ap | 6.8 | 39.7 | 53.6 | 1.51 | | | 27.2 | 6.64 | | | 4.7 | 6.7 |
| 15-33 | B21 | 8.8 | 35.9 | 55.3 | 0.98 | | | 30.5 | 5.20 | | | 5.0 | 7.1 |
| 33-51 | B22 | 7.6 | 47.4 | 45.0 | 0.70 | | | 32.7 | 9.43 | | | 2.2 | 3.1 |
| 51-165 | IIC | | | | 0.33 | | | | 22.00 | | | 3.8 | 5.4 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | ---------pct--------- | | | | |
| 0-15 | 7.44 | 11.10 | 6.03 | 0.33 | 24.90 | | 37.46 | | 0.3 | 66 | | 4.60 | 4.00 | -0.60 |
| 15-33 | 7.92 | 12.04 | 6.32 | 0.18 | 26.46 | | 36.68 | | 0.2 | 72 | | 4.45 | 3.85 | -0.60 |
| 33-51 | 11.58 | 13.58 | 6.51 | 0.22 | 31.89 | | 43.84 | | 2.8 | 73 | | 3.78 | 3.35 | -0.43 |
| 51-165 | 16.85 | 14.60 | 6.77 | 0.08 | 38.30 | | 52.37 | | | 73 | | 2.75 | 2.60 | -0.15 |

# Island of Oahu

## Description of the Soils of the Poamoho Experiment Station

Fig. 2 shows the soils of the Poamoho Station.

WAHIAWA SERIES

The Wahiawa series consists of well-drained silty clay soils developed in residum and alluvium weathered from basic igneous rocks. They are on uplands on slopes ranging from nearly level to moderately steep. Elevations range from 500 to 1200 feet. Mean annual rainfall is 40 to 60 inches. Most of the rain occurs between November and April. Mean annual soil temperature is 72°F. Wahiawa soils are geographically associated with the Kunia, Lahaina, Leilehua, and Manana soils.

The Wahiawa soils are used for sugarcane, pineapple, pasture, truck crops, orchard, and homesites. Natural vegetation consists of bermudagrass, guava, koa haole, and lantana.

***Wahiawa silty clay, 3 to 8 percent slopes* (WaB).**

This is a smooth nearly level soil.

In a representative profile, the surface layer is very dusky-red and dusky-red silty clay about 12 inches thick. The subsoil is dark reddish-brown silty clay with subangular blocky structure, 3 to 4 feet thick. The substratum is weathered basic igneous rock. The surface layer is medium acid, and the subsoil is medium acid to neutral.

Permeability is moderately rapid. Runoff is slow and erosion hazard is slight. Available water-holding capacity is about 1.3 inches per foot in the surface layer and 1.6 inches per foot in the subsoil. Roots can penetrate to 5 feet or more.

---

**Profile description of Wahiawa silty clay:**

Island of Oahu, Poamoho Experiment Station (Table 6).

The site is in Field G, about 150 feet southwest of the quonset warehouse.

| | |
|---|---|
| Ap1 S70Ha-7-2-1 | 0 to 25 cm (0–10 inches), very dusky-red (2.5YR 2/2) silty clay; cloddy due to tillage; firm when moist, sticky and plastic when wet; common roots; common pores; violent effervescence with $H_2O_2$; compacted by machinery; upper 1 inch consists of loose granular material; gradual smooth boundary. |
| Ap2 S70Ha-7-2-2 | 25 to 41 cm (10–16 inches), very dusky-red (2.5YR 2/2) light silty clay; weak very fine granular structure; friable when moist, sticky and plastic when wet; common roots; many very fine pores; violent effervescence with $H_2O_2$; clear abrupt boundary. |
| B21 S70Ha-7-2-3 | 41 to 86 cm (16–34 inches), dark reddish-brown (2.5YR 2/4) silty clay; moderate and strong very fine subangular blocky structure; friable when moist, sticky and very plastic when wet; few roots; many very fine and common fine pores; many black concretions (1/8 inch) and stains; violent effervescence with $H_2O_2$; gradual wavy boundary. |
| B22 S70Ha-7-2-4 | 86 to 127 cm (34–50 inches), dark reddish-brown (2.5YR 3/4) silty clay; moderate very fine subangular blocky structure; friable when moist, sticky and plastic when wet; few roots; many very fine pores; common black concretions (1/8 inch) and stains; strong effervescence with $H_2O_2$. |

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Fig. 2. Soil map of the Poamoho Experiment Station, Poamoho, Oahu. Approximate scale: 1:9000. For general location, see Sheets 39–40, Soil Survey by Foote, et al. (1972), lat. 21°32′30″N; long. 158°05′15″W.

**Table 6. Laboratory data of Wahiawa silty clay**

Soil name: Wahiawa — Classification: Tropeptic Eutrustox, clayey, kaolinitic, isohyperthermic
Soil no.: S70Ha-7-2-(1-4) — Location: Poamoho Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-25 | Ap1 | 18.6 | 37.7 | 43.7 | 1.31 | | | 24.1 | 1.50 | | | 8.9 | 12.7 |
| 25-41 | Ap2 | 20.9 | 37.8 | 41.3 | 1.15 | | | 25.6 | 1.22 | | | 8.4 | 12.0 |
| 41-86 | B21 | 14.2 | 15.9 | 69.9 | 1.42 | | | 23.4 | 0.12 | | | 9.0 | 12.9 |
| 86-127 | B22 | 5.3 | 21.2 | 73.5 | 1.37 | | | 25.1 | 0.28 | | | 11.0 | 15.7 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | ---------pct--------- | | | | |
| 0-25 | 4.94 | 1.41 | 0.26 | 0.78 | 7.39 | | 16.90 | | < 0.1 | 44 | | 5.20 | 4.55 | -0.65 |
| 25-41 | 3.96 | 0.78 | 0.18 | 0.53 | 5.45 | | 17.64 | | < 0.1 | 31 | | 5.15 | 4.18 | -0.97 |
| 41-86 | 6.24 | 1.55 | 0.19 | 0.51 | 8.49 | | 13.10 | | < 0.1 | 65 | | 6.10 | 5.40 | -0.70 |
| 86-127 | 5.46 | 1.65 | 0.28 | 0.16 | 7.55 | | 10.87 | | < 0.1 | 69 | | 6.65 | 5.90 | -0.75 |

Black concretions occur on the surface and to depths of 4 feet or more. Depth to bedrock is more than 5 feet. Depth to highly weathered rock varies from 5 feet to more than 10 feet. A few boulder cores may occur in the subsoil.

This soil is used for truck crops and orchards. Capability classification IIe, irrigated and nonirrigated.

***Wahiawa silty clay, 0 to 3 percent slopes* (WaA).**

This soil is on smooth, nearly level slopes. It is similar to Wahiawa silty clay, 3 to 8 percent slopes, except for slope. The erosion hazard is none to slight. Capability classification I, irrigated or IIc, nonirrigated.

***Wahiawa silty clay, 8 to 15 percent slopes* (WaC).**

This soil is similar to Wahiawa silty clay, 3 to 8 percent slopes, except for moderate slopes. The erosion hazard is slight to moderate. Capability classification IIIe, irrigated and nonirrigated.

***Wahiawa silty clay, 15 to 25 percent slopes, eroded* (WaD2).**

This soil is similar to Wahiawa silty clay 3 to 8 percent slopes, except for moderately steep slopes and erosion. Most of the surface layer and part of the subsoil have been removed by erosion. Depth to soft weathered rock ranges from 2 to 3 feet. The erosion hazard is severe. Workability is difficult because of slope. Capability classification IVe.

KOLEKOLE VARIANT

The Kolekole variant consists of well-drained silty clay loam soils on uplands. These soils developed in old gravelly alluvium mixed with volcanic ash. They occur on gently sloping to moderately steep uplands. Elevations range from 500 to 1200 feet. Mean annual rainfall is 35 to 50 inches, most of which occurs between November and April. Mean annual soil temperature is about 71°F. The Kolekole variant is geographically associated with the Kunia, Mahana, and Wahiawa soils.

Kolekole variant is used for sugarcane, pineapple, and orchards. Natural vegetation consists of guava, lantana, bermudagrass and Natal redtop.

***Kolekole silty clay loam variant, 6 to 12 percent slopes* (KuC).**

This soil occurs on moderate slopes.

In a representative profile, the surface layer is dark reddish-brown silty clay loam about 10 inches thick. The subsoil is a dark reddish-brown silty clay loam and silty clay, 38 to more than 52 inches thick. It is very friable in the surface layer and upper subsoil.

On the Poamoho Station, this soil differs from a typical Kolekole soil because it lacks the pan-like layer in the subsoil and old gravelly alluvium in the substratum.

Permeability is moderate and erosion hazard is slight to moderate. Available water-holding capacity is about 1.1 inches per foot of soil. Capability classification IIIe, irrigated and nonirrigated.

***Kolekole silty clay loam variant, 12 to 25 percent slopes* (KuD).**

This soil occurs on moderately steep side slopes adjacent to drainageways. It is similar to Kolekole silty clay loam variant, 6 to 12 percent slopes, except for slope. The erosion hazard is moderate to severe. Workability is difficult because of slope. Capability classification IVe, irrigated and nonirrigated.

## Description of the Soils of the Waialee Experiment Station

Fig. 3 shows the soils of the Waialee Station.

KAENA SERIES

The Kaena series consists of poorly drained clay soils developed from alluvium and colluvium. The soils occur on gently sloping to steep alluvial fans and talus slopes. Elevations range from 50 to 150 feet. Mean annual rainfall is 30 to 45 inches. Mean annual soil temperature is about 74°F. Kaena soils are geographically associated with the Waialua and Pulehu soils.

Kaena soils are used for pasture, sugarcane, truck crops, and homesites. Natural vegetation consists of kiawe, klu, lantana, koa haole, and fingergrass.

***Kaena very stony clay, 10 to 35 percent slopes* (KanE).**

This soil occurs on moderate to steep talus slopes. There are many stones and boulders on the surface and in the profile.

In a representative profile, the surface layer is very dark gray clay about 10 inches thick. The subsoil is dark gray and grayish-brown clay 36 to more than 48 inches thick. The substratum is highly weathered gravel. These soils are very sticky and very plastic and are mottled because of poor drainage. In places they are affected by seepage. The soil reaction is slightly acid to neutral.

Permeability is slow. Runoff is slow to medium and erosion hazard is moderate to severe. Available water-holding capacity is about 1.4 inches per foot in the surface layer and about 1.7 inches per foot in the subsoil. Workability is difficult because of stoniness, steep slopes, and very sticky and very plastic clays. The shrink-swell potential is high. Roots may penetrate to 5 feet or more.

The amount of stones in the profile increases with depth. Hue ranges from 10YR to 7.5YR. In the A hori-

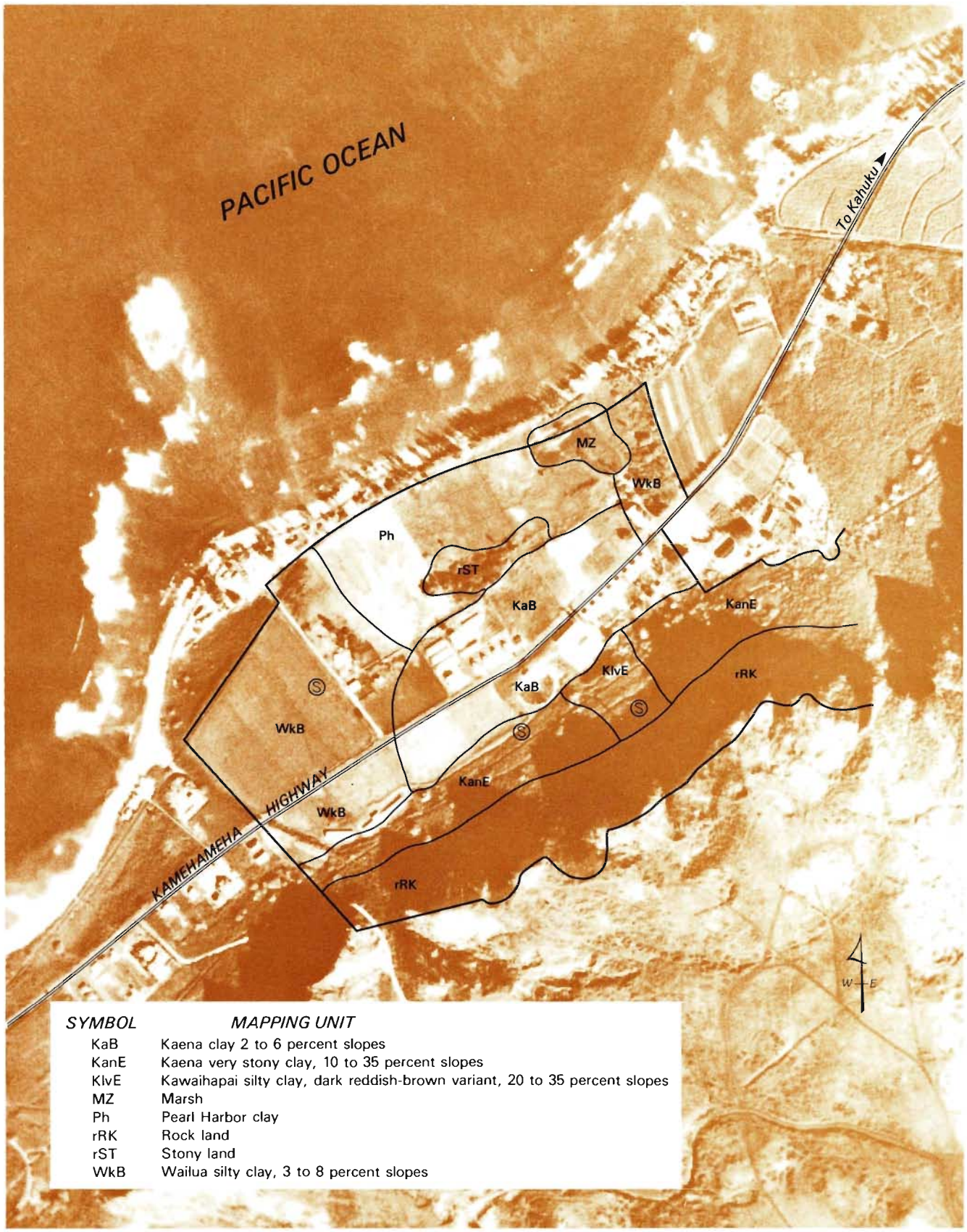


Fig. 3. Soil map of the Waialee Experiment Station, Waialee, Oahu. Approximate scale: 1:9000. For general location, see Sheet 37, Soil Survey by Foote et al. (1972), lat. 21°41′20″N; long. 158°01′45″W.

**Profile description of Kaena very stony clay:**
Island of Oahu, Waialee Experiment Station (Table 7).
Profile lies about 1000 feet southwest of the station headquarters along the farm road.

| | |
|---|---|
| A1 S71Ha-7-2-1 | 0 to 23 cm (0–9 inches), very dark brown (7.5YR 2/2) very stony clay; weak fine and medium subangular blocky structure; very firm when moist, very sticky and very plastic when wet; common roots; common very fine pores; common stones and pebbles; upper 1 inch has moderate very fine granular structure; gradual wavy boundary. |
| B21g S71Ha-7-2-2 | 23 to 76 cm (9–30 inches), dark brown (7.5YR 3/2) very stony clay; massive; firm when moist, very sticky and very plastic when wet; common roots; common very fine pores; common pebbles and stones; few fine faint dark gray mottles; few slickensides; gradual wavy boundary. |
| B22g S71Ha-7-2-3 | 76 to 127 cm (30–50 inches), dark brown (7.5YR 3/2) very stony clay; weak fine and medium subangular blocky structure to massive; firm when moist, very sticky and very plastic when wet; few roots; common very fine pores; common pebbles and stones; few fine faint dark gray and brown mottles; few slickensides. |

zon, moist values are 2 or 3 and dry values are 3 or 4. In the subsoil, values are 3 or 4 and chromas are 1 or 2, moist or dry. Capability classification VIs, nonirrigated.

***Kaena clay, 2 to 6 percent slopes* (KaB).**

This soil is similar to Kaena very stony clay, 10 to 35 percent slopes, except it is gently sloping and there are few or no stones on the surface.

The erosion hazard is slight. Workability is difficult because the soil is very sticky and very plastic when wet, and it has a narrow moisture range in which it can be satisfactorily cultivated. Capability classification IIIw, irrigated; IVw, nonirrigated.

KAWAIHAPAI VARIANT

This variant consists of well-drained soils on the Waialee Experiment Station. These soils developed in recent deposits weathered from basic igneous rocks. They are on steep talus slopes. Elevations range from 10 to 50 feet. The annual rainfall is 40 to 50 inches. The mean annual temperature is about 72°F. Kaena, Pearl Harbor, and Waialua series are associated with the Kawaihapai variant.

These soils are used for pasture. The natural vegetation consists of koa haole and guineagrass.

***Kawaihapai silty clay, dark reddish-brown variant, 20 to 35 percent slopes* (KlvE).**

This soil is on steep talus slopes.

In a representative profile, the surface layer is dark reddish-brown silty clay about 9 inches thick. The subsoil, about 31 inches thick, is dark reddish-brown silty clay with many stratified layers of sand-size weathered rock fragments that break down to silty clay texture.

Permeability is moderate and the erosion hazard is severe.

The A horizon ranges from 2 to 3 in value and from 3 to 4 in chroma when moist. The texture of the stratified layer of sand-size weathered rock fragments may have a silty clay loam texture.

This soil is used for pasture. Capability classification VIe.

**Profile description of Kawaihapai variant:**
Island of Oahu, Waialee Experiment Station.
The following profile description was taken along a roadcut about 350 feet southeast of the station headquarters.

| | |
|---|---|
| A1 | 0 to 23 cm (0–9 inches), dark reddish-brown (2.5YR 3/4) silty clay; weak fine and very fine subangular blocky structure; friable when moist, sticky and plastic when wet; many very fine pores; many sand-size weathered rock fragments; gradual smooth boundary. |
| B21 | 23 to 102 cm (9–40 inches), dark reddish-brown (2.5YR 3/4) silty clay; similar to above except there are many stratified layers of sand-size weathered rock fragments that break down to silty clay texture; few stones. |

**Table 7. Laboratory data of Kaena very stony clay**

Soil name: Kaena — Classification: Typic Pelluderts, very-fine, montmorillonitic, isohyperthermic
Soil no.: S71Ha-7-2-(1-3) — Location: Waialee Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-23 | A1 | 7.7 | 31.4 | 60.9 | 1.28 | | | 34.2 | 2.82 | | | 4.3 | 6.1 |
| 23-76 | B21g | 9.4 | 22.3 | 68.3 | 1.24 | | | 32.9 | 1.12 | | | 4.2 | 6.0 |
| 76-127 | B22g | 2.6 | 21.4 | 76.0 | 1.18 | | | 35.3 | 0.51 | | | 3.9 | 5.6 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-23 | 13.92 | 23.44 | 1.51 | 1.70 | 40.57 | | 42.1 | | < 0.1 | 96 | | 5.30 | 4.50 | -0.80 |
| 23-76 | 10.52 | 27.52 | 4.07 | 0.32 | 42.43 | | 45.6 | | | 93 | | 6.15 | 5.10 | -1.05 |
| 76-127 | 8.05 | 29.16 | 14.57 | 0.19 | 51.97 | | 43.2 | | | > 100 | | 6.90 | 6.00 | -0.90 |

MARSH

***Marsh* (MZ).**

Marsh consists of wet, periodically flooded areas covered dominantly with grasses, bullrush, or other herbaceous plants. It occurs in small bodies on low-lying areas along the coastal plains. The water that stands on this unit is either fresh or brackish, depending on the distance to the ocean. Small bodies of water are included in the mapping. Capability classification VIII.

PEARL HARBOR SERIES

The Pearl Harbor series consists of very poorly drained soils developed in alluvium over organic material. The soils occur on low-lying, nearly level coastal plains and have a high water table. Elevations range from near sea level to 5 feet. Mean annual rainfall is 18 to 40 inches. Mean annual soil temperature is about 74°F. The Pearl Harbor soils are geographically associated with the Hanalei, Kaloko, and Keaau soils.

Pearl Harbor soils are used for pasture and taro. Natural vegetation consists of paragrass and sedges.

***Pearl Harbor clay* (Ph).**

This soil is on smooth coastal plains. Slopes are 0 to 2 percent.

In a representative profile, the surface layer is very dark gray mottled clay about 12 inches thick. The subsoil is very dark gray and very dark grayish-brown mottled clay 1 to 3 feet thick. The substratum of muck or peat lies at depths of 20 to 50 inches. The brackish water table is at about the same depth. These soils are neutral in the surface layer and mildly to moderately alkaline in the subsoil.

Permeability is very slow. Runoff is very slow to ponded and erosion hazard is none to slight. Available water-holding capacity is about 2 inches per foot in the surface layer and subsoil. Roots may penetrate to 2 to 4 feet. Workability is very difficult because of wetness. This soil is subject to flooding. Capability classification IVw, irrigated and nonirrigated.

WAIALUA SERIES

This series consists of moderately well-drained soils on alluvial fans. These soils developed in alluvium weathered from basic igneous rock. They are nearly level to steep. Elevations range from 10 to 100 feet. The annual rainfall amounts to 25 to 50 inches; most of it occurs between November and April. The mean annual soil temperature is 73°F. Waialua soils are geographically associated with Honouliuli, Kaena, and Kawaihapai soils.

These soils are used for sugarcane, truck crops, orchards, and pasture. The natural vegetation is swollen fingergrass, koa haole, and uhaloa.

***Waialua silty clay, 3 to 8 percent slopes* (WkB).**

This soil occurs on smooth, gently sloping alluvial fans.

In a representative profile, the surface layer is dark reddish-brown silty clay about 12 inches thick. The subsoil, about 3 feet thick, is dark reddish-brown and reddish-brown silty clay that has subangular blocky structure. The substratum is reddish-brown, mottled silty clay.

---

**Profile description of Waialua silty clay:**

Island of Oahu, Waialee Experiment Station (Table 8).

Profile occurs on irrigated pasture north of Kamehameha Highway and approximately 1700 feet west of the headquarters building.

| | |
|---|---|
| Ap S71Ha-7-1-1 | 0 to 30 cm (0–12 inches), dark reddish-brown (5YR 3/3) silty clay; moderate fine and very fine subangular blocky structure; very firm when moist, very sticky and very plastic when wet; many roots; many pores; few white sand grains; firm in place; strong effervescence with $H_2O_2$; gradual smooth boundary. |
| B21 S71Ha-7-1-2 | 30 to 58 cm (12–23 inches), dark reddish-brown (5YR 3/4) silty clay; moderate very fine subangular blocky structure; friable when moist, very sticky and very plastic when wet; many roots; many very fine pores; variegated with red, brown, and black due to few weathered sand grains; moderate effervescence with $H_2O_2$; gradual smooth boundary. |
| B22 S71Ha-7-1-3 | 58 to 130 cm (23–51 inches), dark reddish-brown (5YR 3/3) silty clay; weak fine and medium subangular blocky structure; friable when moist, very sticky and very plastic when wet; many roots; many very fine pores; variegated with red, brown, and black due to common weathered sand grains; moderate effervescence with $H_2O_2$; gradual smooth boundary. |
| B23 S71Ha-7-1-4 | 130 to 155 cm (51–61 inches), dark reddish-brown (5YR 3/3) silty clay; weak fine and medium subangular blocky structure; friable when moist, sticky and plastic when wet; few roots; many pores; variegated with red, brown, and black due to many weathered sand grains; moderate effervescence with $H_2O_2$. |

---

**Table 8. Laboratory data of Waialua silty clay**

Soil name: Waialua — Classification: Vertic Haplustolls, very-fine, kaolinitic, isohyperthermic
Soil no.: S71Ha-7-1-(1-4) — Location: Waialee Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ----------pct---------- | |
| 0-30 | Ap | 10.0 | 38.9 | 51.1 | 1.28 | | | 27.5 | 4.08 | | | 8.2 | 11.7 |
| 30-58 | B21 | 11.3 | 38.4 | 50.3 | 1.27 | | | 28.5 | 1.20 | | | 7.6 | 10.9 |
| 58-130 | B22 | 13.7 | 35.5 | 50.8 | 1.29 | | | 31.8 | 0.70 | | | 7.8 | 11.2 |
| 130-155 | B23 | 12.7 | 36.0 | 51.3 | 1.44 | | | 34.1 | 0.41 | | | 8.2 | 11.7 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-30 | 25.80 | 7.07 | 1.16 | 1.92 | 35.95 | | 29.59 | | | > 100 | | 7.22 | 6.52 | -0.70 |
| 30-58 | 18.07 | 7.52 | 1.44 | 1.74 | 28.77 | | 26.50 | | | > 100 | | 7.75 | 6.60 | -1.15 |
| 58-130 | 16.08 | 8.86 | 1.60 | 0.95 | 27.49 | | 24.63 | | | > 100 | | 7.62 | 6.58 | -1.04 |
| 130-155 | 11.92 | 9.08 | 2.73 | 0.07 | 23.80 | | 22.96 | | | > 100 | | 7.60 | 6.40 | -1.20 |

The soil is neutral in the surface layer and slightly acid in the subsoil.

Permeability is moderate. Runoff is slow and the erosion hazard is slight. Available water-holding capacity is about 1.8 inches per foot in the subsoil. Roots can penetrate to 5 feet or more.

Fine black concretions may occur throughout the solum. Soil reaction varies from slightly acid to neutral. Highly weathered cobbles and gravel may occur in the profile. Plasticity of the clays vary from very sticky and very plastic in the lower elevations to sticky and plastic in the upper elevations. Hue in the solum ranges from 5YR to 10YR. Structure in the B horizon ranges from weak to moderate.

This soil is used for pasture. Capability classification IIe, irrigated; IIIc, nonirrigated.

ROCK LAND

***Rock land* (rRK).**

This land type consists of areas that have 25 to 90 percent exposed rock. Among the rocks are soils that are only a few inches deep. Slopes are mainly 40 to 70 percent. Stones are common, and there is a danger of stones rolling to areas below. Capability classification VIIs.

STONY LAND

***Stony land* (rST).**

This land type consists of a mass of boulders and stones that cover 15 to 90 percent of the surface area. Slopes range from 5 to 40 percent. The soil among the stones are dark reddish-brown silty clay loams and very dark brown clays. In most places there is enough soil among the stones to give plants a foothold. Capability classification VIs.

## Description of the Soils of the Waimanalo Experiment Station

Fig. 4 shows the soils of the Waimanalo Station.

WAIALUA VARIANT

This variant consists of moderately well-drained soils on alluvial fans. These soils developed in alluvium weathered from basic igneous rock. They are nearly level to steep. Elevations range from 10 to 100 feet. The annual rainfall amounts to 25 to 50 inches; most of it occurs between November and April. The mean annual soil temperature is 73°F. Waialua soils are geographically associated with Honouliuli, Kaena, and Kawaihapai soils.

These soils are used for sugarcane, truck crops, orchards, and pasture. The natural vegetation is swollen fingergrass, koa haole, and uhaloa.

***Waialua clay variant, 2 to 6 percent slopes* (WnB).**

This soil occurs on smooth gentle slopes.

The surface layer is dark brown clay about 15 inches thick. The subsoil is dark reddish-brown silty clay that has subangular blocky structure. There are many soft weathered pebbles in the subsoil.

Permeability is moderate. Runoff is slow and the erosion hazard is slight. The available water-holding capacity is about 1.8 inches per foot in the surface layer and 1.6 inches per foot in the subsoil. In places, roots penetrate to a depth of 5 feet or more.

**Profile description of Waialua clay variant (Table 9):**

The representative profile was taken at the Waimanalo Experiment Station about 450 feet southwest of the headquarters building.

| | |
|---|---|
| Ap1 S70Ha-7-1-1 | 0 to 18 cm (0–7 inches), dark brown (7.5YR 3/2) clay; weak very fine and fine granular structure; firm when moist, very sticky and very plastic when wet; many pores; few roots; strong effervescence with $H_2O_2$; clear wavy boundary. |
| Ap2 S70Ha-7-1-2 | 18 to 38 cm (7–15 inches), dark brown (7.5YR 3/2) clay; weak fine and medium subangular blocky structure; firm when moist, very sticky and very plastic when wet; many pores; few roots; strong effervescence with $H_2O_2$; clear smooth boundary. |
| B21 S70Ha-7-1-3 | 38 to 94 cm (15–37 inches), dark reddish-brown (5YR 3/3) silty clay; weak fine and medium subangular blocky structure; friable when moist, very sticky and very plastic when wet; many very fine pores; few roots; strong effervescence with $H_2O_2$; clear smooth boundary. |
| B22 S70Ha-7-1-4 | 94 to 127 cm (37–50 inches), dark reddish-brown (5YR 3/3) silty clay; weak fine and medium subangular blocky structure; friable when moist, sticky and plastic when wet; many very fine pores; few roots; many soft weathered pebbles; moderate effervescence with $H_2O_2$. |

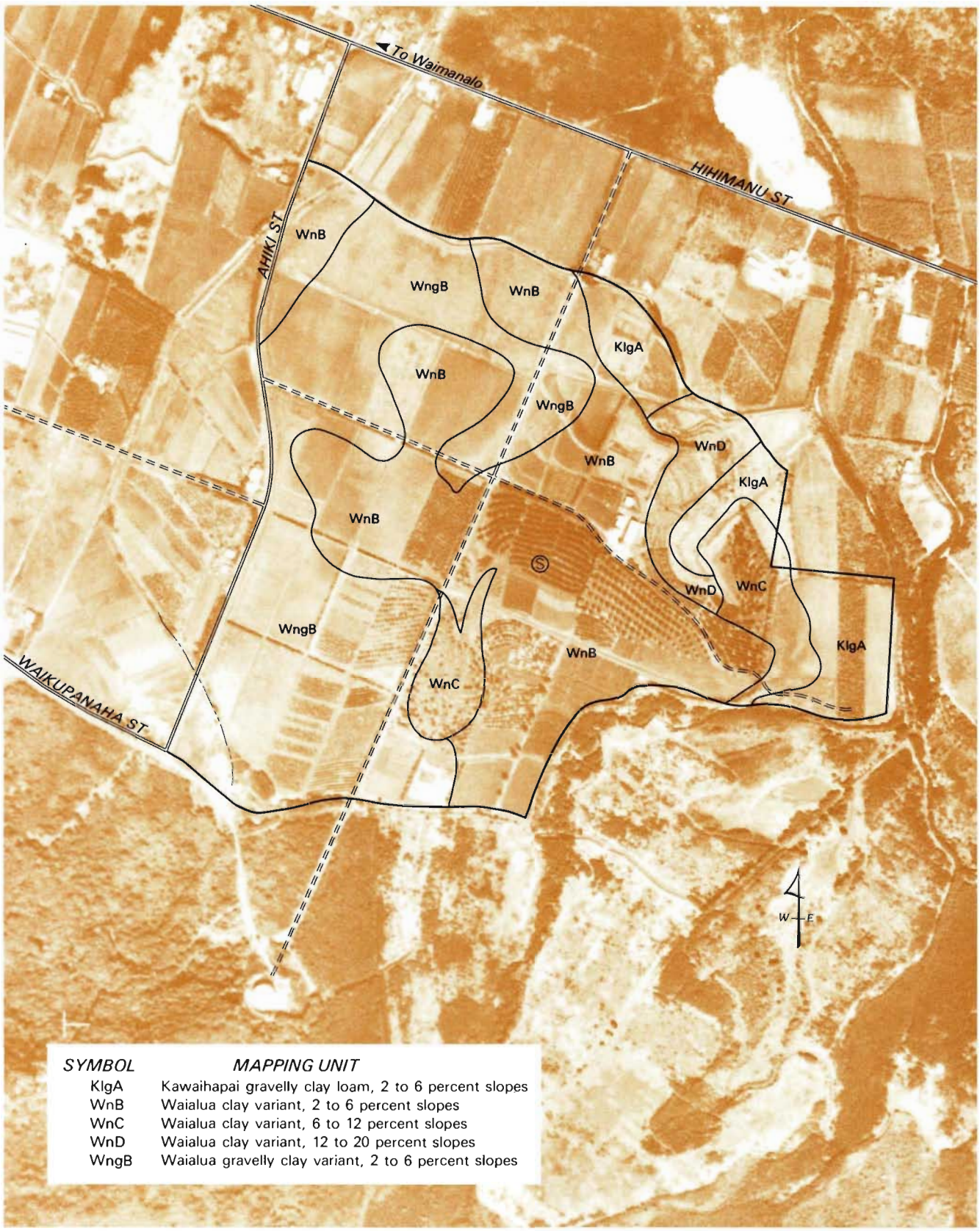


Fig. 4. Soil map of the Waimanalo Experiment Station, Waimanalo, Oahu. Approximate scale: 1:8000. For general location, see Sheet 66, Soil Survey by Foote et al. (1972), lat. 21°20′15″N; long. 157°43′30″W.

**Table 9. Laboratory data of Waialua clay variant**

Soil name: Waialua — Classification: Vertic Haplustolls, very-fine, kaolinitic, isohyperthermic
Soil no.: S70Ha-7-1-(1-4) — Location: Waimanalo Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-18 | Ap1 | 8.7 | 45.2 | 46.1 | 1.18 | | | 27.5 | 1.98 | | | 9.6 | 13.7 |
| 18-38 | Ap2 | 13.7 | 40.7 | 45.6 | 1.22 | | | 27.4 | 1.90 | | | 9.8 | 14.0 |
| 38-94 | B21 | 11.4 | 43.8 | 44.8 | 1.10 | | | 24.6 | 0.80 | | | 9.5 | 13.6 |
| 94-127 | B22 | 22.1 | 30.1 | 47.8 | 1.06 | | | 26.5 | 0.39 | | | 7.7 | 11.0 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | ----------meq/100 g soil---------- | | | --------pct-------- | | | | |
| 0-18 | 15.49 | 9.36 | 0.46 | 1.24 | 26.55 | | 33.34 | | | 80 | | 6.10 | 5.20 | -0.90 |
| 18-38 | 15.79 | 9.83 | 0.54 | 1.18 | 27.34 | | 33.74 | | | 81 | | 6.18 | 5.20 | -0.98 |
| 38-94 | 12.30 | 9.08 | 0.94 | 0.21 | 22.53 | | 28.86 | | | 78 | | 6.40 | 5.75 | -0.75 |
| 94-127 | 15.03 | 12.50 | 2.22 | 0.18 | 29.93 | | 36.74 | | | 81 | | 6.65 | 5.50 | -1.15 |

Depth to bedrock is more than 5 feet. The amount of soft weathered pebbles in the profile increases with depth. The soil is less friable and more sticky at the lower elevations of the station. This soil was formerly mapped as the Waimanalo series in the *Soil Survey of the Territory of Hawaii.* Capability classification IIe, irrigated; IIIc, nonirrigated.

***Waialua gravelly clay variant, 2 to 6 percent slopes* (WngB).**

This soil is similar to the Waialua clay variant, 2 to 6 percent slopes, except there is common weathered gravel in the surface layer and throughout the profile. The gravel has little or no effect on management for most crops. Capability classification IIe, irrigated; IIIc, nonirrigated.

***Waialua clay variant, 6 to 12 percent slopes* (WnC).**

This soil is similar to the Waialua clay variant, 2 to 6 percent slopes, except the slopes are moderate. In places the soil is slightly eroded and has little soft weathered gravel. The erosion hazard is moderate. Capability classification IIIe, irrigated and nonirrigated.

***Waialua clay variant, 12 to 20 percent slopes* (WnD).**

This soil is similar to the Waialua clay variant, 2 to 6 percent slopes, except the slopes are moderate. In places the soil is slightly eroded and has little soft weathered gravel. The erosion hazard is moderate to high. Capability classification IVe.

KAWAIHAPAI SERIES

This series consists of well-drained soils in drainageways and on alluvial fans on the coastal plains. These soils formed in alluvium derived from basic igneous rock in humid uplands. They are nearly level to moderately sloping. Elevation ranges from near sea level to 300 feet. The annual rainfall amounts to 30 to 50 inches. The mean annual soil temperature is about 73°F. Kawaihapai soils are geographically associated with Waialua, Lualualei, and Jaucas soils.

These soils are used for sugarcane, truck crops, and pasture. The natural vegetation consists of kiawe, koa haole, lantana, and bermudagrass.

***Kawaihapai gravelly clay loam, 2 to 6 percent slopes* (KlgA).**

This gently sloping soil occurs along the drainageways. Gravel and few cobbles occur on the surface and throughout the profile. Included in mapping were small areas where the texture is a clay and cracks 2 to 3 inches wide occur when dry.

In a representative profile, the surface layer is a dark brown clay loam. The subsoil is similar in color, is stratified, and has textures ranging from sandy loam to silty clay loam. The substratum is stony and gravelly. The soil is neutral in reaction throughout the profile.

Permeability is moderate. Runoff is slow, and the erosion hazard is slight. The available water-holding capacity is about 1.8 inches per foot in the surface layer and about 1.6 inches per foot in the subsoil. Roots penetrate to a depth of 5 feet or more. In places this soil is subject to flooding. Capability classification IIe, irrigated and nonirrigated. (The representative profile follows on page 34.)

**Profile description of Kawaihapai gravelly clay loam:**

Island of Oahu, Waimanalo Experiment Station (Table 10).

The site is in the lower field approximately 1250 feet southeast of the headquarters building.

| | |
|---|---|
| Ap1 S71Ha-7-3-1 | 0 to 18 cm (0–7 inches), very dark brown (7.5YR 2/2) gravelly clay loam; weak fine and medium subangular blocky structure; friable when moist, sticky and plastic when wet; few roots; common pores; many sand grains; common gravels; clear wavy boundary. |
| Ap2 S71Ha-7-3-2 | 18 to 33 cm (7–13 inches), very dark brown (7.5YR 2/2) clay loam; cloddy; slightly firm when moist, sticky and plastic when wet; few roots; few pores; many sand grains; common gravels; clear wavy boundary. |
| C1 S71Ha-7-3-3 | 33 to 48 cm (13–19 inches), very dark grayish-brown (10YR 3/2) loamy sand; single grain; very friable when moist, nonsticky and nonplastic when wet; many sand grains; many gravels; clear smooth boundary. |
| C2 S71Ha-7-3-4 | 48 to 61 cm (19–24 inches), very dark brown (10YR 2/2) sandy loam; weak very fine subangular blocky structure; friable when moist, sticky and plastic when wet; few roots; common fine and very fine pores; clear slightly wavy boundary; many sand grains; few gravels; clear smooth boundary. |
| C3 S71Ha-7-3-5 | 61 to 94 cm (24–37 inches), very dark grayish-brown loamy sand; single grain; loose when moist, slightly sticky and slightly plastic when wet; stratified layers of sand and gravel; few cobbles; clear wavy boundary. |
| C4 S71Ha-7-3-6 | 94 to 119 cm (37–47 inches), very dark brown silt loam; massive; very friable when moist, slightly sticky and slightly plastic when wet; common fine and very fine pores; many sand grains. |

**Table 10. Laboratory data of Kawaihapai gravelly clay loam**

Soil name: Kawaihapai — Classification: Cumulic Haplustolls, fine, mixed, isohyperthermic
Soil no.: S71Ha-7-3-(1-6) — Location: Waimanalo Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-18 | Ap1 | 33.1 | 33.3 | 33.6 | 1.34 | | | 24.8 | 1.09 | | | 3.8 | 5.4 |
| 18-33 | Ap2 | 38.8 | 36.1 | 25.1 | 1.33 | | | 22.9 | 0.93 | | | 4.1 | 5.9 |
| 33-48 | C1 | 66.9 | 6.8 | 26.3 | | | | 18.9 | 0.29 | | | 3.3 | 4.7 |
| 48-61 | C2 | | | | 1.21 | | | | 0.63 | | | 3.9 | 5.6 |
| 61-94 | C3 | | | | 1.14 | | | | 0.38 | | | 3.8 | 5.4 |
| 94-119 | C4 | | | | 1.08 | | | | 0.82 | | | 4.7 | 6.7 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | ---------pct--------- | | | | |
| 0-18 | 21.92 | 22.91 | 0.43 | 1.09 | 46.35 | | 41.1 | | | > 100 | | 6.70 | 5.32 | -1.38 |
| 18-33 | 22.55 | 22.60 | 0.52 | 1.07 | 46.74 | | 49.0 | | | 95 | | 6.65 | 5.35 | -1.30 |
| 33-48 | 18.67 | 20.73 | 0.70 | 0.43 | 40.53 | | 27.2 | | | > 100 | | 7.10 | 5.32 | -1.78 |
| 48-61 | 22.68 | 25.07 | 0.80 | 0.20 | 48.75 | | 48.1 | | | > 100 | | 6.70 | 5.40 | -1.30 |
| 61-94 | 19.08 | 21.75 | 0.80 | 0.09 | 41.72 | | 38.5 | | | > 100 | | 6.80 | 5.45 | -1.35 |
| 94-119 | 23.16 | 24.32 | 1.09 | 0.09 | 48.66 | | 47.6 | | | > 100 | | 7.15 | 5.55 | -1.60 |

# Island of Maui

## Description of the Soils of the Haleakala Experiment Station

Fig. 5 shows the soils of the Haleakala Station.

MAKAWAO SERIES

This series consists of well-drained soils on uplands on the Island of Maui. These soils developed from volcanic ash and from material weathered from basic igneous rock. They are gently sloping to moderately sloping. Elevations range from 1200 to 2500 feet. The annual rainfall amounts to 60 to 90 inches. The mean annual soil temperature is 69°F. Makawao soils are geographically associated with Haiku, Kailua, and Olinda soils.

These soils are used for pasture. Small acreages are used for pineapple, truck crops, and homesites. The natural vegetation consists of bermudagrass, eucalyptus, guava, hilograss, kaimiclover, and kikuyugrass.

***Makawao silty clay, 3 to 7 percent slopes* (201).**

This soil is on gentle slopes on intermediate uplands.

In a representative profile, the surface layer is a dark reddish-brown silty clay about 9 inches thick. The subsoil, about 30 inches thick, is a dark reddish-brown silty clay that has subangular blocky structure. The substratum is soft, weathered, basic igneous rock. The soil is strongly acid to medium acid in the surface layer and slightly acid in the subsoil.

---

**Profile description of Makawao silty clay:**

Island of Maui, Haleakala Experiment Station (Table 11).

| | |
|---|---|
| Ap1 S69Ha-4-2-1 | 0 to 15 cm (0–6 inches), dark reddish-brown (5YR 3/4) silty clay; strong medium and fine granular structure; firm, slightly sticky and plastic; many roots; many medium and fine pores; clear smooth boundary. |
| Ap2 S69Ha-4-2-2 | 15 to 33 cm (6–13 inches), dark reddish-brown (2.5YR 3/4) silty clay; moderate fine and very fine subangular blocky structure; friable, sticky and plastic; many roots; many very fine pores; abrupt wavy boundary. |
| B21t S69Ha-4-2-3 | 33 to 51 cm (13–20 inches), dark reddish-brown (2.5YR 3/4) silty clay; strong fine and very fine subangular blocky structure; friable, sticky, plastic, and weakly smeary; common roots; many very fine pores; thin patchy clay films on some ped faces; occasional krotovina, 5 cm (2 inches) in diameter; abrupt wavy boundary. |
| B22t S69Ha-4-2-4 | 51 to 112 cm (20–44 inches), dark brown (7.5YR 3/2) and dark reddish-brown (5YR 3/3); silty clay; strong medium and fine subangular blocky structure; friable, sticky, plastic, and weakly smeary; few roots; many fine and very fine pores; thick clay skins of dark red (2.5YR 3/6) on ped faces; about 10 percent gravels at the upper part and increase to 25 percent below 11 cm (4.4 inches). |

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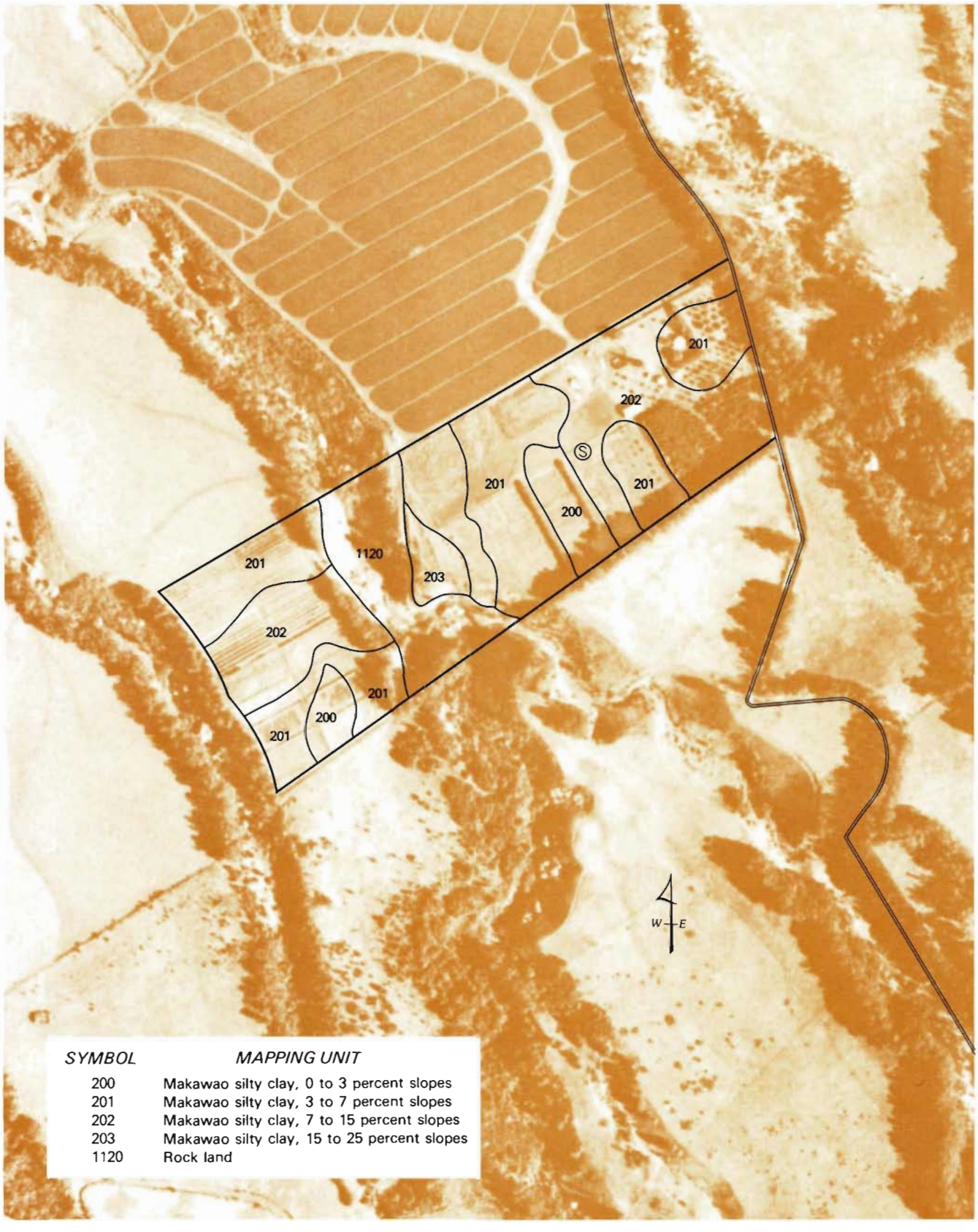


| SYMBOL | MAPPING UNIT |
|---|---|
| 200 | Makawao silty clay, 0 to 3 percent slopes |
| 201 | Makawao silty clay, 3 to 7 percent slopes |
| 202 | Makawao silty clay, 7 to 15 percent slopes |
| 203 | Makawao silty clay, 15 to 25 percent slopes |
| 1120 | Rock land |

Fig. 5. Soil map of the Haleakala Experiment Station, Makawao, Maui. Approximate scale: 1:5500. For general location, see Sheet 114, Soil Survey by Foote et al. (1972), lat. 20°50′42″N; long. 156°18′W.

**Table 11. Laboratory data of Makawao silty clay**

Soil name: Makawao — Classification: Humoxic Tropohumults, clayey, oxidic, isothermic
Soil no.: S69Ha-4-2-(1-4) — Location: Haleakala Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ----------pct---------- | |
| 0-15 | Ap1 | 4.3 | 63.7 | 32.0 | 1.39 | | | 17.5 | 2.88 | 0.30 | 10 | 24.7 | 35.3 |
| 15-33 | Ap2 | 4.3 | 64.3 | 31.4 | 1.41 | | | 19.7 | 2.15 | 0.22 | 10 | 23.3 | 33.3 |
| 33-51 | B21t | 3.8 | 43.1 | 53.1 | 1.01 | | | 25.1 | 2.08 | 0.19 | 11 | 27.0 | 38.6 |
| 51-112 | B22t | 18.2 | 43.1 | 38.7 | 1.00 | | | | 2.51 | 0.17 | 15 | 13.7 | 19.6 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | ---------pct--------- | | | | |
| 0-15 | 2.54 | 0.29 | 0.06 | 0.14 | 3.03 | 24.9 | 17.19 | 27.9 | 0.35 | 18 | 11 | 4.25 | 4.03 | -0.22 |
| 15-33 | 0.41 | 0.05 | 0.05 | 0.08 | 0.59 | 25.9 | 15.50 | 26.5 | 0.75 | 4 | 2 | 4.19 | 3.99 | -0.20 |
| 33-51 | 0.28 | 0.03 | 0.12 | 0.05 | 0.48 | 36.0 | 21.89 | 36.5 | 0.84 | 2 | 1 | 4.03 | 3.84 | -0.19 |
| 51-112 | 0.48 | 0.06 | 0.07 | 0.04 | 0.65 | 33.7 | 30.37 | 34.4 | 0.34 | 2 | 2 | 4.71 | 4.26 | -0.45 |

Permeability is moderately rapid. Runoff is slow, and the erosion hazard is slight. In places roots penetrate to a depth of 5 feet or more.

Smeariness ranges from weak at the lower elevations to moderate at the higher elevations. The A horizon ranges from 4 to 5 in value when dry, and from 2 to 3 in chroma when moist and 4 to 6 when dry. The Bt horizon ranges from 5YR to 2.5YR in hue, from 3 to 4 in value when moist and 4 to 5 when dry, and from 3 to 4 in chroma when moist and 3 to 5 when dry. The texture is silty clay or clay. Capability classification IIe, nonirrigated.

***Makawao silty clay, 7 to 15 percent slopes* (202).**

This soil is similar to Makawao silty clay, 3 to 7 percent slopes, except that it is moderately sloping to strongly sloping. Runoff is slow to medium, and the erosion hazard is slight to moderate. Capability classification IIIe, nonirrigated.

***Makawao silty clay, 0 to 3 percent slopes* (200).**

This soil is similar to Makawao silty clay, 3 to 7 percent slopes, except that it is nearly level. Runoff is slow and the erosion hazard is slight. Capability classification I, nonirrigated.

***Makawao silty clay, 15 to 25 percent slopes* (203).**

This soil is similar to Makawao silty clay, 3 to 7 percent slopes, except that it is strongly sloping. Runoff is medium and erosion hazard is moderate to severe. Capability classification IVe.

## Description of the Soils of the Kula Experiment Station

Fig. 6 shows the soils of the Kula Station.

KULA SERIES

This series consists of well-drained soils on uplands on the Island of Maui. These soils developed from volcanic ash. They are gently sloping to steep. Elevations range from 2000 to 3500 feet. The annual rainfall amounts to 25 to 40 inches. The mean annual soil temperature is 66°F. Kula soils are geographically associated with the Kaipoipoi, Kamaole, and Pane soils.

These soils are used for pasture, truck crops, orchard crops, and wildlife habitat. The natural vegetation consists of bermudagrass, black wattle, Natal redtop, oi, rattailgrass, and yellow foxtail.

***Kula loam, 2 to 6 percent slopes* (104).**

This soil is on intermediate uplands.

In a representative profile, the surface layer is dark reddish-brown loam about 8 inches thick. The subsoil, about 46 inches thick, is dark reddish-brown loam, silt loam, and silty clay loam that has subangular blocky structure. The substratum is slightly weathered basic igneous rock. The soil is slightly acid in the surface layer and slightly acid to neutral in the subsoil.

**Profile description of Kula loam:**

Island of Maui, Kula Experiment Station (Table 12).

| | |
|---|---|
| A1 S69Ha-4-1-1 | 0 to 18 cm (0–7 inches), dark reddish-brown (5YR 3/2) loam; weak very fine, granular structure; friable, nonsticky, and slightly plastic; many roots; roots matted on upper inch; many fine and very fine pores; gradual smooth boundary. |
| B1 S69Ha-4-1-2 | 18 to 48 cm (7–19 inches), dark reddish-brown (5YR 3/2) loam; weak medium and fine subangular blocky structure; friable, nonsticky, and slightly plastic; many roots; many fine and very fine pores; clear smooth boundary. |
| B21 S69Ha-4-1-3 | 48 to 76 cm (19–30 inches), dark reddish-brown (5YR 3/2) silt loam; moderate medium and fine subangular blocky structure; friable, slightly sticky, and slightly plastic; many roots; many fine, very fine, medium pores; abrupt wavy boundary. |
| IIB22 S69Ha-4-1-4 | 76 to 132 cm (30–52 inches), dark reddish-brown (5YR 3/3) silt loam; strong medium and fine angular and subangular blocky structure; firm, slightly sticky, and slightly plastic; few roots; many very fine pores; shiny coatings on ped faces. |
| IIIC S69Ha-4-1-5 | 132 cm (52 inches), many rock fragments with soil material from above filling the interstices. |


| SYMBOL | MAPPING UNIT |
|---|---|
| 100 | Kula loam, 0 to 2 percent slopes, terraced |
| 101 | Kula loam, 12 to 20 percent slopes |
| 102 | Kula gravelly loam, 12 to 20 percent slopes |
| 103 | Kula loam, 20 to 35 percent slopes |
| 104 | Kula loam, 2 to 6 percent slopes |
| 105 | Kula loam, 6 to 12 percent slopes |

Fig. 6. Soil map of the Kula Experiment Station, Kula, Maui. Approximate scale: 1:4500. For general location, see Sheet 116, Soil Survey by Foote el al. (1972), lat. 20°45′45″N; long. 156°19′30″W.

**Table 12. Laboratory data of Kula loam**

Soil name: Kula — Classification: Typic Eutrandepts, medial, isothermic
Soil no.: S69Ha-4-1-(1-4) — Location: Kula Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-18 | A1 | | | | 0.79 | | | | 8.65 | 0.65 | 13 | 9.1 | 13.0 |
| 18-48 | B1 | | | | 0.54 | | | 34.1 | 8.73 | 0.56 | 16 | 9.9 | 14.2 |
| 48-76 | B21 | | | | 0.54 | | | 36.6 | 5.16 | 0.42 | 12 | 7.6 | 10.9 |
| 76-132 | IIB22 | | | | 0.81 | | | 30.9 | 2.92 | 0.23 | 13 | 8.2 | 11.7 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-18 | 38.02 | 6.82 | 0.24 | 1.27 | 46.35 | | 62.67 | | | 74 | | 6.11 | 5.58 | -0.53 |
| 18-48 | 51.32 | 6.56 | 0.65 | 0.10 | 58.63 | | 69.90 | | | 84 | | 7.14 | 6.22 | -0.92 |
| 48-76 | 59.12 | 7.09 | 0.43 | 0.10 | 66.74 | | 71.19 | | | 94 | | 7.63 | 6.51 | -1.12 |
| 76-132 | 38.72 | 8.84 | 0.79 | 0.11 | 48.46 | | 57.97 | | | 84 | | 7.64 | 6.59 | -1.05 |

Permeability is moderately rapid. Runoff is medium, and the erosion hazard is moderate. The available water capacity is about 1.8 inches per foot of soil. In places roots penetrate to rock.

The depth to slightly weathered andesite and basalt ranges from 24 to 60 inches. In some places rock outcrop occupies 0.1 to 3 percent of the surface. The A horizon ranges from 5YR to 10YR in hue, from 2 to 3 in value when moist and 3 to 4 when dry, and from 2 to 3 in chroma when moist and 2 to 4 when dry. The B horizon ranges from 5YR to 10YR in hue, from 3 to 4 in value when moist or dry, and from 2 to 4 in chroma when moist. The B horizon ranges from loam to silty clay loam in texture. The IIB horizon has strong to moderate subangular blocky structure. Capability classification IIe, irrigated or nonirrigated.

***Kula loam, 12 to 20 percent slopes*** **(101).**

This soil has a profile similar to Kula loam, 2 to 6 percent slopes, except that it is steeper. The surface horizon is about 4 inches thick. Depth to bedrock is 25 to 36 inches. Although it is nonstony on the surface, there are about 25 percent stones by volume in the profile. Capability classification IVe, irrigated or nonirrigated.

***Kula loam, 6 to 12 percent slopes*** **(105).**

This soil has a profile like that of Kula loam, 2 to 6 percent slopes, except that it is steeper. Capability classification IIIe, irrigated or nonirrigated.

***Kula gravelly loam, 12 to 20 percent slopes*** **(102).**

This soil has a profile like that of Kula loam, 2 to 6 percent slopes, except that it is steep and gravelly. The solum has 25 to 40 percent stones. Depth to bedrock ranges from 10 to 24 inches. Capability classification IVe, irrigated or nonirrigated.

***Kula loam, 20 to 35 percent slopes*** **(103).**

This soil has a profile like that of Kula loam, 2 to 6 percent slopes, except that it is steep and depth to bedrock is about 24 to 36 inches. There are about 25 percent by volume of stones in the solum. Runoff is medium, and the erosion hazard is moderate. Capability classification VIe, nonirrigated.

***Kula loam, 0 to 2 percent slopes, terraced*** **(100).**

This soil has a mixture of surface and subsoil in the topsoil. Soils are more than 3 feet deep and nonstony. Stones have been removed from 1 foot to over 6 feet deep. This soil is used for truck crop production. Capability classification I, irrigated; IIe, nonirrigated.

# Island of Hawaii

## Description of the Soils of the Lalamilo Experiment Station

Fig. 7 shows the soils of the Lalamilo Station.

WAIMEA SERIES

The Waimea series consists of well-drained loam to silt loam soils developed in volcanic ash underlain by weathered andesite and basalt. These soils occur on nearly level to steep leeward slopes. Mean annual rainfall is 30 to 45 inches. Mean annual soil temperature is about 60°F. Waimea soils are geographically associated with Kikoni, Palapalai, Waikaloa, and Puu Pa soils.

The Waimea soils are used primarily for truck crops and pasture.

***Waimea silt loam, 0 to 3 percent slopes* (16A).**

This soil occupies the nearly level areas on the Waimea Plain.

In a representative profile, the surface layer is very dark brown to dark brown, very fine sandy loam to loam about 7 inches thick. The subsoil is dark brown silt loam. The substratum is unconforming bedrock which generally occurs between 30 to 60 inches.

These soils are neutral to mildly alkaline in the surface layers and mildly alkaline in the subsoil.

Permeability is moderately rapid, runoff is slow to medium, and erosion hazard is moderate. Roots penetrate to 3 feet or more.

**Profile description of Waimea silt loam:**

Island of Hawaii, Lalamilo Experiment Station (Table 13).

| | |
|---|---|
| Ap S69Ha-1-1-1 | 0 to 18 cm (0–7 inches), very dark grayish-brown (10YR 3/2) silt loam; moderate fine granular structure; friable, slightly sticky, slightly plastic; few roots; many fine pores; cobbles occupy 1 to 2 percent of the surface; abrupt smooth boundary. (7 to 9 inches thick) |
| B1 S69Ha-1-1-2 | 18 to 25 cm (7–10 inches), dark yellowish-brown (10YR 3/4) very fine sandy loam; weak fine subangular blocky structure; friable, nonsticky, slightly plastic; few roots; many fine and very fine pores; clear smooth boundary. (2 to 3 inches thick) |
| B21 S69Ha-1-1-3 | 25 to 51 cm (10–20 inches), dark yellowish-brown (10YR 3/4) very fine sandy loam; weak medium and coarse subangular blocky structure; friable, slightly sticky, slightly plastic; few roots; many fine and very fine pores; clear smooth boundary. (8 to 10 inches thick) |
| B22 S69Ha-1-1-4 | 51 to 81 cm (20–32 inches), dark brown (7.5YR 3/2) loam; weak medium and coarse subangular blocky structure; friable, slightly sticky, slightly plastic; few roots; many very fine and fine pores; 5 to 10 percent a'a fragments about 5 inches in diameter; abrupt wavy boundary. (10 to 13 inches thick) |
| C1 | 81 cm (32 inches), fragmental a'a lava |

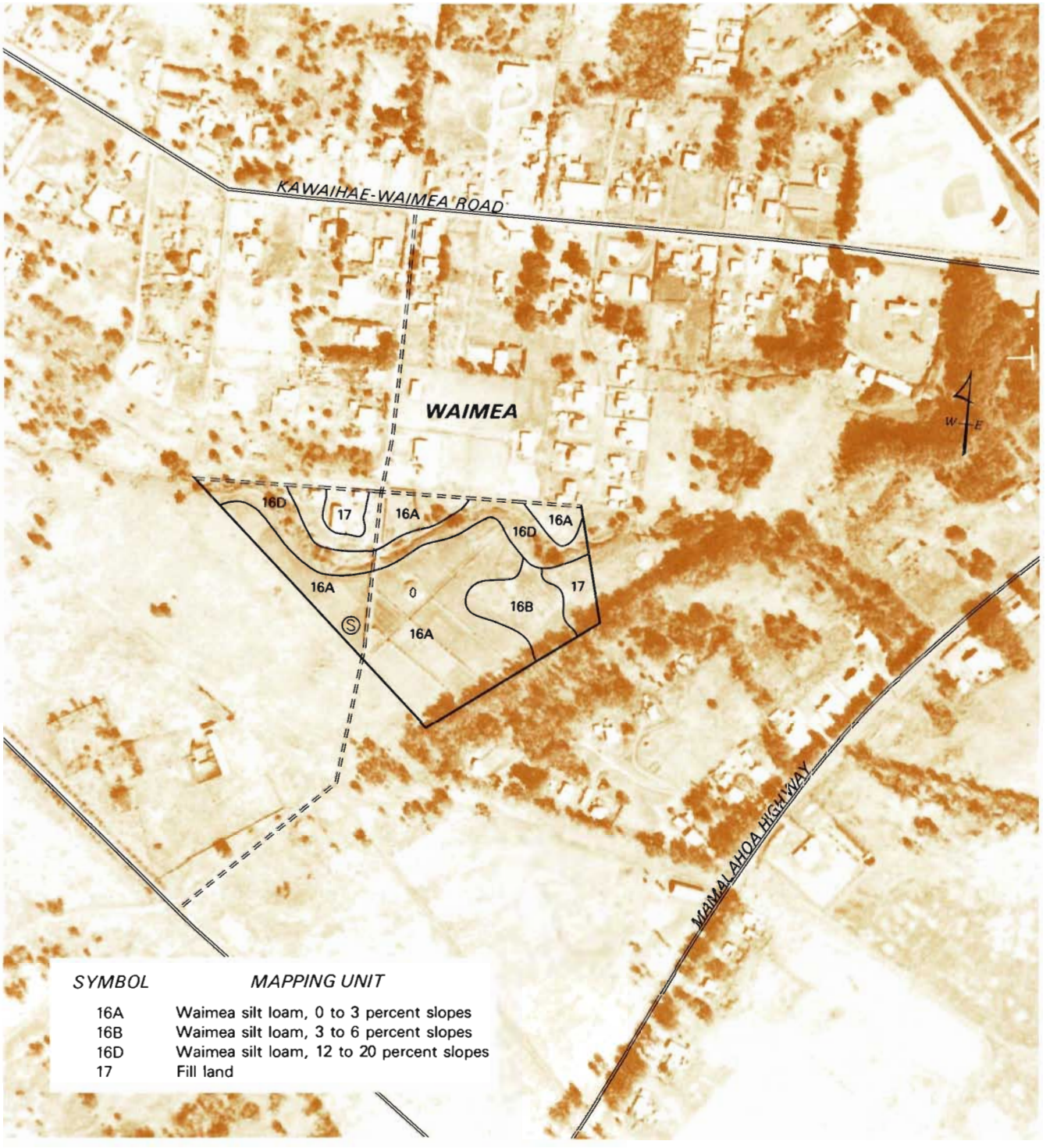


Fig. 7. Soil map of the Lalamilo Experiment Station, Waimea, Hawaii. Approximate scale: 1:6000. For general location, see Sheet 19, Soil Survey by Sato et al. (1973), lat. 20°, 01′30″N; long. 155°41′W.

**Table 13. Laboratory data of Waimea silt loam**

Soil name: Waimea — Classification: Typic Eutrandepts, medial, isothermic
Soil no.: S69Ha-1-1-(1-4) — Location: Lalamilo Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-18 | Ap | | | | | | | | 8.23 | 0.63 | 13 | 6.9 | 9.9 |
| 18-25 | B1 | | | | 0.66 | | | | 4.99 | 0.33 | 15 | 9.1 | 13.0 |
| 25-51 | B21 | | | | 0.84 | | | | 2.59 | 0.19 | 14 | 9.3 | 13.3 |
| 51-81 | B22 | | | | 0.77 | | | | 1.23 | 0.09 | 14 | 6.0 | 8.6 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-18 | 20.34 | 8.37 | 0.39 | 5.66 | 34.76 | | 58.60 | | | 59 | | 5.40 | 4.67 | -0.73 |
| 18-25 | 26.53 | 10.90 | 1.04 | 4.78 | 43.25 | | 62.41 | | | 69 | | 6.08 | 5.22 | -0.86 |
| 25-51 | 25.31 | 9.91 | 3.32 | 1.71 | 40.25 | | 59.61 | | | 68 | | 6.15 | 5.27 | -0.88 |
| 51-81 | 22.15 | 8.01 | 2.70 | 0.55 | 33.41 | | 49.87 | | | 67 | | 6.23 | 5.32 | -0.91 |

The solum ranges in hue from 5YR to 10YR, in value and in chroma 2 to 4 moist and 3 or 4 dry.

The B horizon ranges in textures from silt loam to loam. The B horizon is structureless, massive, or weak-structured. Cobbles occupy about 1 to 2 percent of the surface. Capability classification IIe, nonirrigated and irrigated.

***Waimea silt loam, 3 to 6 percent slopes* (16B).**

This soil is similar to Waimea silt loam, 0 to 3 percent slopes, except that slopes are gentle and gravel occupies about 5 to 10 percent of the surface. Runoff is slow to medium and erosion hazard is moderate. Capability classification IIe, nonirrigated and irrigated.

***Waimea silt loam, 12 to 20 percent slopes* (16D).**

This soil is similar to Waimea silt loam, 0 to 3 percent slopes, except that it is moderately steep. Runoff is rapid and erosion hazard is high. Capability classification IVe, nonirrigated.

FILL LAND

***Fill land* (17).**

Mixture of cinders, stone fragments, and ash soil material.

This area was part of an old Marine Corps camp. This area may have been used as a dumping ground and then smoothed over with a mixture of cinders, rock, and ashy soil material. The amount of these materials vary. Depth to the original soil material also varies.

## Description of the Soils of the Pukalani Experiment Station

Fig. 8 shows the soils of the Pukalani Station.

WAIMEA SERIES

The Waimea series consists of well-drained loam to silt loam soils developed in volcanic ash underlain by weathered andesite and basalt. These soils occur on nearly level to steep leeward slopes. Mean annual rainfall is 30 to 45 inches. Mean annual soil temperature is about 60°F. Waimea soils are geographically associated with the Kikoni, Palapalai, Waikaloa, and Puu Pa soils.

The Waimea soils are used primarily for truck crops and pasture.

***Waimea loam, 0 to 3 percent slopes, isomesic variant* (16A).**

This soil occupies the nearly level areas on the Waimea Plains. They are similar to the Waimea series except that the mean annual soil temperature is less than 59°F.

In a representative profile, the surface layer is very dark brown to dark brown, very fine sandy loam to loam about 7 inches thick. The subsoil is dark brown silt loam. The substratum is unconforming bedrock, which generally occurs between 30 to 60 inches. These soils are neutral to mildly alkaline in the surface layers and mildly alkaline in the subsoil.

Permeability is moderately rapid, runoff is slow to medium, and erosion hazard is moderate. Roots may penetrate to 3 feet or more.

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**Profile description of Waimea loam, isomesic variant:**
Island of Hawaii, Pukalani Experiment Station (Table 14).

| | |
|---|---|
| Ap S69Ha-1-3-1 | 0 to 18 cm (0–7 inches), dark brown (10YR 3/3) loam; weak fine granular structure; friable, nonsticky, slightly plastic; many roots; roots matted upper 2 inches; many fine and very fine pores; thin black broken horizon at bottom; abrupt smooth boundary. (6 to 7 inches thick) |
| B21 S69Ha-1-3-2 | 18 to 36 cm (7–14 inches), dark reddish-brown (5YR 3/3) very fine sandy loam; weak medium and coarse subangular blocky structure; many roots; many fine pores; very friable, nonsticky, nonplastic; gradual smooth boundary. (10 to 11 inches thick) |
| B22 S69Ha-1-3-3 | 36 to 61 cm (14–24 inches), dark brown (7.5YR 3/3) very fine sandy loam; weak medium and coarse subangular blocky structure; many roots; many fine pores; very friable, nonsticky, nonplastic; clear smooth boundary. (10 to 11 inches thick) |

*—Continued*

**Profile description:** *Continued.*

| | |
|---|---|
| B23 S69Ha-1-3-4 | 61 to 99 cm (24–39 inches), dark brown (7.5YR 4/4) very fine sandy loam; weak medium and coarse subangular blocky structure; many very fine roots; many fine pores; very friable, nonsticky, nonplastic; clear smooth boundary. (14 to 16 inches thick) |
| B24 S69Ha-1-3-5 | 99 to 132 cm (39–52 inches), dark reddish-brown (5YR 3/3) very fine sandy loam, with pockets of firm (5YR 3/2) very fine sandy loam; weak medium and coarse subangular blocky structure; many roots; many fine pores; very friable, nonsticky, nonplastic. (11 to 13 inches thick) |
| C S69Ha-1-3-6 | 132 to 152 cm (52–60 inches), dark brown (7.5YR 3/2) compacted ash layers breaking to loamy sand; extremely hard, nonsticky, nonplastic; roots matted on surface of horizon. |

The solum ranges in hue from 5YR to 10YR; value and chroma are 2 to 4 moist and 3 to 4 dry. Values and chromas of 4 are higher than typical.

The B horizon ranges in textures from a loam to a very fine sandy loam. The B horizon is structureless, massive, or weak-structured. Capability classification IIe, nonirrigated and irrigated.

***Waimea loam, 3 to 6 percent slopes, isomesic variant* (16B).**

This soil is similar to Waimea loam, 0 to 3 percent slopes, except that slopes are gentle. Runoff is slow and erosion hazard is moderate. Capability classification IIe, nonirrigated and irrigated.

***Waimea loam, 6 to 12 percent slopes, isomesic variant* (16C).**

This soil is similar to Waimea loam, 0 to 3 percent slopes, except slopes are moderate. Runoff is medium and erosion hazard is moderate. Capability classification IIIe, nonirrigated and irrigated.

KIKONI SERIES

The Kikoni series consists of well-drained, very fine sandy loam soils developed in volcanic ash underlain by unconforming fragmental a'a or pahoehoe lava bedrock. These soils occur on nearly level to gently sloping intermediate leeward mountain slopes. Mean annual rainfall ranges from 35 to 70 inches. Mean annual soil temperature is about 65°F. Kikoni soils are geographically associated with Hanipoe, Maile, Punohu, and Waimea soils.

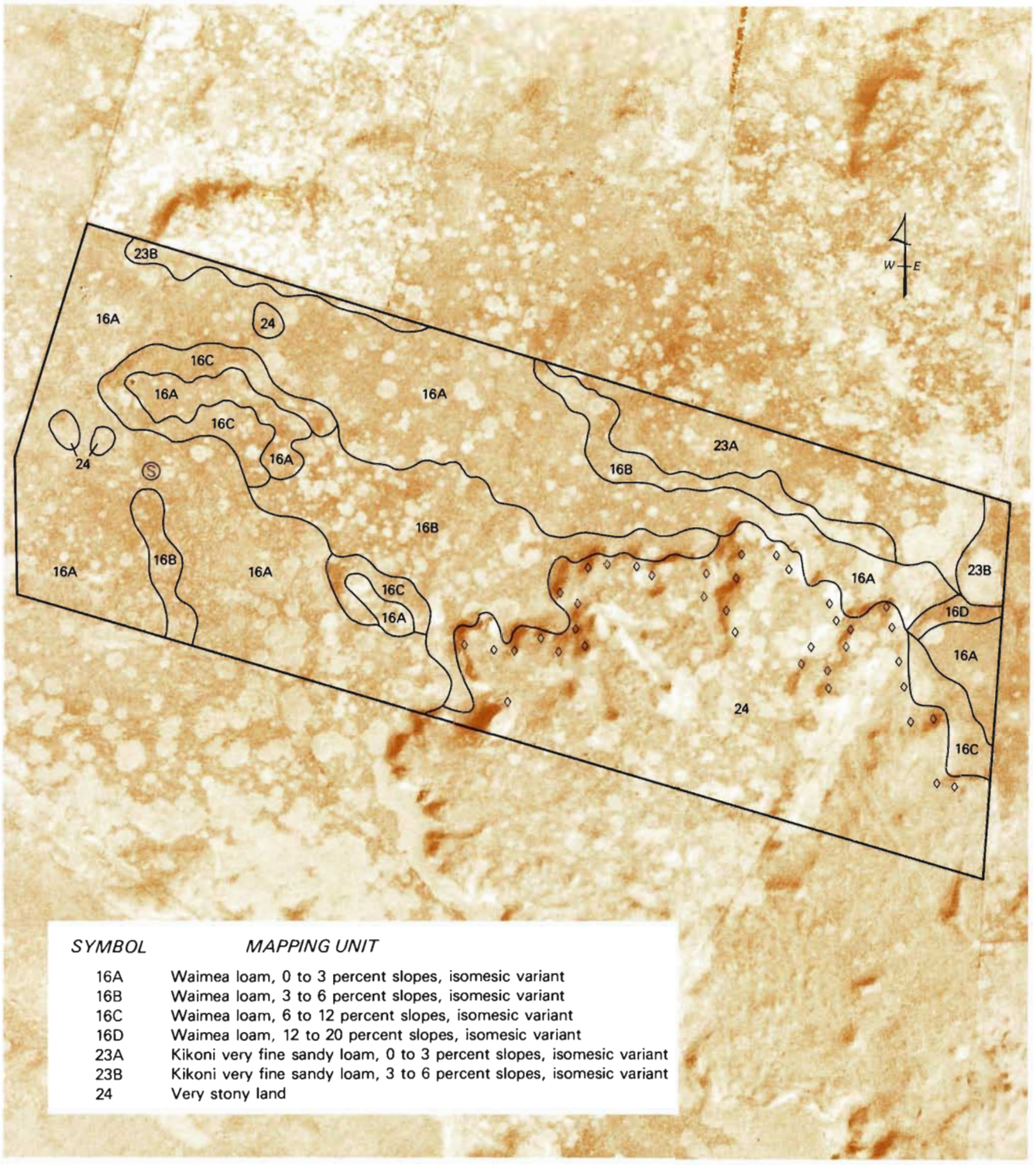
The Kikoni soils are used primarily for pasture with a few acres in truck crops.

***Kikoni very fine sandy loam, 0 to 3 percent slopes, isomesic variant* (23A).**

This soil occupies the nearly level areas on the Waimea Plains. It is similar to the Kikoni series except that the mean annual air temperature is less than 59°F.

In a representative profile, the surface layer is very dark brown, very sandy loam about 6 inches thick. The subsoil is dark brown to dark reddish-brown, very fine sandy loam to silt loam. The substratum is unconforming bedrock, which generally occurs between 4 to 18 feet. These soils are neutral in the surface layer and neutral to mildly alkaline in the subsoil.

Permeability is moderately rapid, runoff is slow, and erosion hazard is moderate. Roots may penetrate to 4 feet or more.




| SYMBOL | MAPPING UNIT |
|---|---|
| 16A | Waimea loam, 0 to 3 percent slopes, isomesic variant |
| 16B | Waimea loam, 3 to 6 percent slopes, isomesic variant |
| 16C | Waimea loam, 6 to 12 percent slopes, isomesic variant |
| 16D | Waimea loam, 12 to 20 percent slopes, isomesic variant |
| 23A | Kikoni very fine sandy loam, 0 to 3 percent slopes, isomesic variant |
| 23B | Kikoni very fine sandy loam, 3 to 6 percent slopes, isomesic variant |
| 24 | Very stony land |

Fig. 8. Soil map of the Pukalani Experiment Station, Waimea, Hawaii. Approximate scale: 1:9000. For general location, see Sheet 25, Soil Survey by Sato et al. (1973), lat. 19°59′N; long. 155°36′30″W.

**Table 14. Laboratory data of Waimea loam, isomesic variant**

Soil name: Waimea — Classification: Typic Eutrandepts, medial, isomesic
Soil no.: S69Ha-1-3-(1-6) — Location: Pukalani Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ----------pct---------- | |
| 0-18 | Ap | | | | 0.69 | | | 33.6 | 9.81 | 0.88 | 11 | 5.1 | 7.3 |
| 18-36 | B21 | | | | 0.72 | | | 24.2 | 5.78 | 0.48 | 12 | 5.7 | 8.1 |
| 36-61 | B22 | | | | 0.60 | | | 33.8 | 5.36 | 0.56 | 10 | 6.6 | 9.4 |
| 61-99 | B23 | | | | 0.81 | | | 22.4 | 2.45 | 0.22 | 11 | 5.8 | 8.3 |
| 99-132 | B24 | | | | 0.66 | | | 23.9 | 2.48 | 0.18 | 14 | 7.3 | 10.4 |
| 132-152 | C | | | | 1.09 | | | 20.0 | 1.03 | 0.09 | 11 | 5.8 | 8.3 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-18 | 26.44 | 6.53 | 0.26 | 4.22 | 37.45 | | 51.99 | | | 72 | | 6.04 | 5.19 | -0.85 |
| 18-36 | 37.44 | 3.93 | 0.42 | 6.18 | 47.97 | | 48.86 | | | 98 | | 7.06 | 6.26 | -0.80 |
| 36-61 | 56.96 | 6.04 | 0.38 | 5.77 | 69.15 | | 68.34 | | | > 100 | | 7.32 | 6.35 | -0.97 |
| 61-99 | 39.77 | 4.99 | 0.35 | 2.58 | 47.69 | | 46.60 | | | > 100 | | 7.48 | 6.58 | -0.90 |
| 99-132 | 47.93 | 8.64 | 0.62 | 3.31 | 60.50 | | 56.52 | | | > 100 | | 7.70 | 6.71 | -0.99 |
| 132-152 | 27.23 | 9.47 | 0.75 | 4.14 | 41.59 | | 35.98 | | | > 100 | | 7.83 | 7.01 | -0.82 |

**Profile description of Kikoni very fine sandy loam, isomesic variant:**
Island of Hawaii, Pukalani Experiment Station (Table 15).

| | |
|---|---|
| A1<br>S69Ha-<br>1-9-1 | 0 to 13 cm (0–5 inches), black (10YR 2/1) very fine sandy loam, very dark brown (10YR 2/2) dry; moderate fine and very fine granular structure; soft, friable, nonsticky, and nonplastic; many roots (roots matted top 2 inches); many very fine and fine pores; abrupt smooth boundary. (5 to 6 inches thick) |
| B21<br>S69Ha-<br>1-9-2 | 13 to 33 cm (5–13 inches), dark brown (7.5YR 3/2) very fine sandy loam, brown (7.5YR 4/4) dry; massive; soft, very friable, nonsticky, and nonplastic; many roots; many very fine and fine pores; gradual smooth boundary. (8 to 11 inches thick) |
| B22<br>S69Ha-<br>1-9-3 | 33 to 84 cm (13–33 inches), brown (7.5YR 4/2) very fine sandy loam, strong brown (7.5YR 5/6) dry; massive; soft, very friable, nonsticky, and nonplastic; many roots; many very fine and fine pores; abrupt smooth boundary. (20 to 23 inches thick) |
| IIC<br>S69Ha-<br>1-9-4 | 84 to 104 cm (33–41 inches), dark brown (7.5YR 3/2), dark brown (7.5YR 4/2) dry; firm in place weathered tuff; many roots; many fine and very fine pores; white material in root channels, possibly root hairs; abrupt smooth boundary. (7 to 8 inches thick) |
| IIIB21b<br>S69Ha-<br>1-9-5 | 104 to 122 cm (41–48 inches), dark brown (7.5YR 3/2) silt loam, brown (7.5YR 4/4) dry; moderate and strong fine and very fine subangular blocky structure; friable, slightly sticky, and slightly plastic; common firm fragments of tuff and fine peds; abrupt wavy boundary. (6 to 12 inches thick) |
| IVC<br>S69Ha-<br>1-9-6 | 122 to 127 cm (48–50 inches), mostly fragmental a'a lava with soft material from above filling the interstices. |

The solum ranges in hue from 5YR to 10YR. Value and chroma of the B horizon range from 2 to 4 when moist. The B horizon ranges in texture from a very fine sandy loam to a silt loam. Consistence of the lower B horizon may be weakly smeary toward the wetter limits of the series. Capability classification IIe, nonirrigated and irrigated.

***Kikoni very fine sandy loam, 3 to 6 percent slopes, isomesic variant* (23B).**

This soil is similar to Kikoni very fine sandy loam, 0 to 3 percent slopes, except that slopes are gentle. Runoff is slow and erosion hazard is moderate. Capability classification IIe, nonirrigated and irrigated.

VERY STONY LAND

***Very stony land* (24).**

This miscellaneous land type consists of very shallow soils with a high proportion of a'a lava outcrops. The surface is a mass of a'a lava outcrops between which the soil material occurs as fillings to depths of 5 to 20 inches. A'a lava outcrops occupy 30 to 50 percent of the surface. Below the 20-inch depth, the profile consists mostly of unweathered a'a lava. Vegetation varies from a sparse cover in dry areas to a dense vegetation of ohia and tree fern in high rainfall areas. Elevation ranges from near sea level to 13,000 feet. Annual rainfall ranges from 10 to over 150 inches. Water erosion hazard is slight. Alternative land use is wildlife. Capability classification VIIs.

## Description of the Soils of the Mealani Experiment Station

Fig. 9 shows the soils of the Mealani Station.

MAILE SERIES

The Maile series consists of well-drained silty clay loam soils developed in volcanic ash underlain by unconforming bedrock. These soils occur on nearly level to steep intermediate windward mountain slopes. Mean annual rainfall ranges from 60 to 90 inches. Mean annual soil temperature is about 58°F. Maile soils are geographically associated with Puu Oo, Honokaa, Kahua, Kehena, Palapalai, Piihonua, and Umikoa soils.

The Maile soils are used primarily for pasture.

**Table 15. Laboratory data of Kikoni very fine sandy loam, isomesic variant**

Soil name: Kikoni — Classification: Typic Eutrandepts, medial, isomesic
Soil no.: S69Ha-1-9-(1-5) — Location: Pukalani Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-13 | A1 | | | | 0.62 | | | | 12.50 | 0.97 | 13 | 4.8 | 6.9 |
| 13-33 | B21 | | | | 0.65 | | | | 6.78 | 0.68 | 10 | 6.9 | 9.9 |
| 33-84 | B22 | | | | 0.65 | | | | 4.52 | 0.33 | 14 | 9.2 | 13.2 |
| 84-104 | IIC | | | | 1.21 | | | | 0.66 | 0.08 | 8 | 6.4 | 9.2 |
| 104-122 | IIIB21b | | | | 1.00 | | | | 0.86 | 0.09 | 10 | 5.3 | 7.6 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-13 | 36.74 | 8.80 | 0.37 | 6.94 | 52.85 | | 65.08 | | | 81 | | 5.72 | 5.20 | -0.52 |
| 13-33 | 41.40 | 7.37 | 0.41 | 7.90 | 57.08 | | 66.89 | | | 85 | | 6.55 | 5.75 | -0.80 |
| 33-84 | 50.21 | 5.59 | 0.91 | 6.48 | 63.19 | | 61.66 | | | > 100 | | 7.80 | 6.50 | -1.30 |
| 84-104 | 24.03 | 4.83 | 0.75 | 3.19 | 32.80 | | 27.78 | | | > 100 | | 7.80 | 6.90 | -0.90 |
| 104-122 | 27.60 | 8.96 | 2.19 | 3.24 | 41.99 | | 40.29 | | | > 100 | | 8.00 | 6.80 | -1.20 |

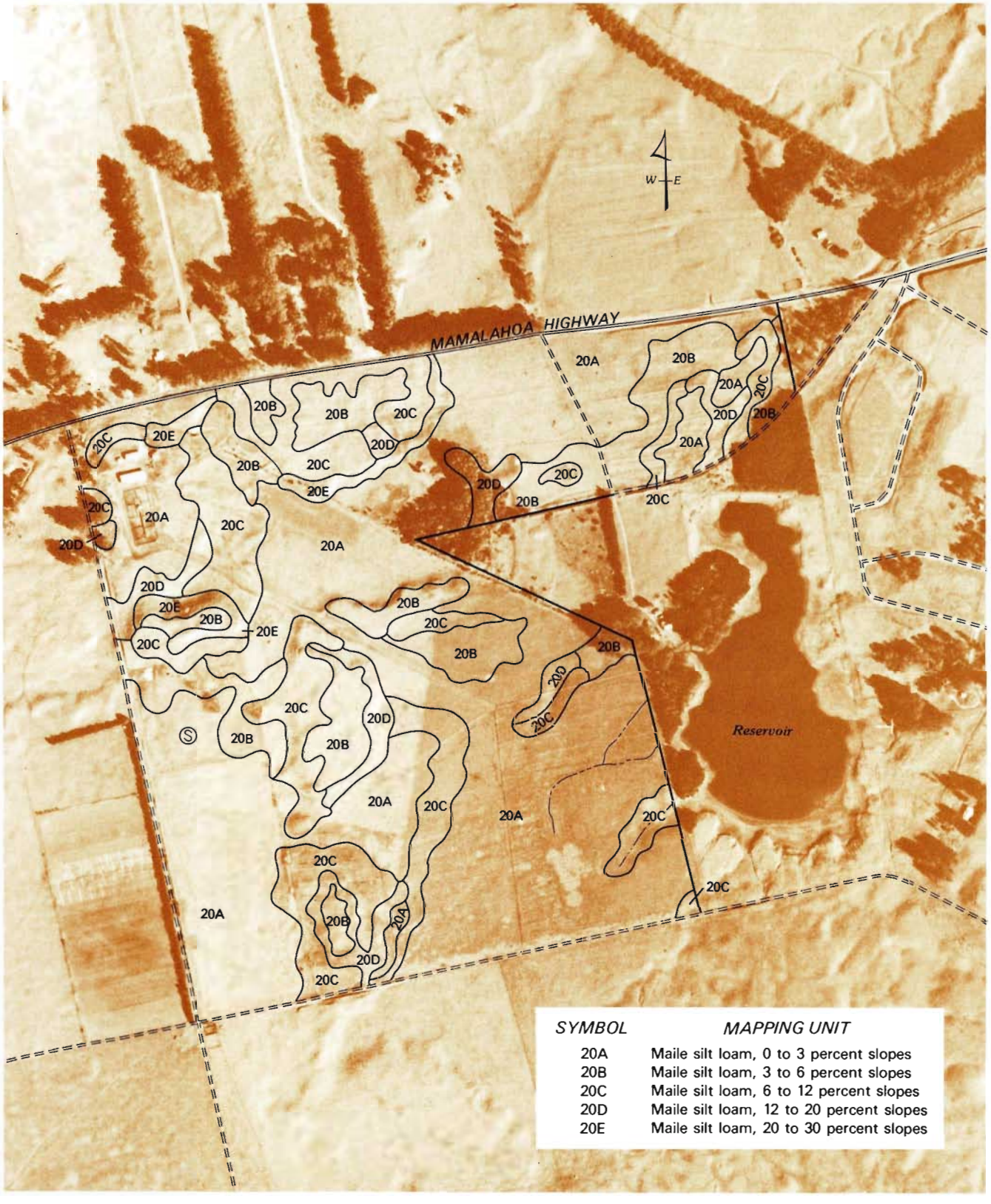



Fig. 9. Soil map of the Mealani Experiment Station, Waimea, Hawaii. Approximate scale: 1:9000. For general location, see Sheet 16, Soil Survey by Sato et al. (1973), lat. 20°02′30″N; long. 155°36′30″W.

***Maile silt loam, 0 to 3 percent slopes* (20A).**

This soil occupies the nearly level areas on intermediate windward mountain slopes.

In a representative profile, the upper surface layer is dark reddish-brown silt loam to cindery sandy loam about 4 inches thick and dark reddish-brown silty clay loam in the lower part of the surface about 10 inches thick. The subsoil is dark brown to dark yellowish-brown silty clay loam. The substratum is unconforming bedrock, which generally occurs below 60 inches. These soils are medium to slightly acid in the surface layer and slightly acid to neutral in the subsoil.

Permeability is moderately rapid, runoff is slow, and erosion hazard is slight. Roots may penetrate to more than 60 inches.

**Profile description of Maile silt loam:**

Island of Hawaii, Mealani Experiment Station (Table 16).

| | |
|---|---|
| Ap S69Ha-1-2-1 | 0 to 18 cm (0–7 inches), very dark brown (10YR 2/2) silt loam; moderate fine and very fine granular structure; very friable, slightly sticky, slightly plastic; few roots; abrupt smooth boundary. (7 to 10 inches thick) |
| B21 S69Ha-1-2-2 | 18 to 43 cm (7–17 inches), dark brown (7.5YR 3/2) silty clay loam; moderate medium and fine subangular blocky structure; friable, slightly sticky, plastic; weakly smeary; many roots; many very fine pores; many gelatinous coatings; clear smooth boundary. (7 to 10 inches thick) |
| B22 S69Ha-1-2-3 | 43 to 61 cm (17–24 inches), dark reddish-brown (5YR 3/4) silty clay loam; moderate medium and fine subangular blocky structure; friable, slightly sticky, plastic, moderately smeary; many roots; many very fine pores; many gelatinous coatings; abrupt smooth boundary. (5 to 8 inches thick) |
| B23 S69Ha-1-2-4 | 61 to 79 cm (24–31 inches), dark brown (10YR 3/3) silty clay loam with 1-inch thick ashy bands, dark yellowish-brown (10YR 4/4) moderate fine and very fine subangular blocky structure; friable, slightly sticky, plastic, smeary; many roots; many very fine pores; many gelatinous coatings; abrupt smooth boundary. (6 to 7 inches thick) |
| B24 S69Ha-1-2-5 | 79 to 99 cm (31–39 inches), dark yellowish-brown (10YR 3/4) silty clay loam, with 1-inch thick ashy bands (10YR 4/4); moderate medium and fine subangular blocky structure; friable, sticky, plastic, smeary; many roots; many fine pores; many gelatinous coatings; few fine iron-like concretions; abrupt smooth boundary. (8 to 10 inches thick) |
| B25 S69Ha-1-2-6 | 99 to 132 cm (39–52 inches), dark brown (7.5YR 3/2) silty clay loam; strong fine and very fine angular and subangular blocky structure; friable, sticky, plastic, smeary; common roots; many fine and very fine pores; many thick gelatinous coatings. |

The solum ranges in hue from 5YR to 10YR; value and chroma range from 2 to 4 moist. Structure of the A1 horizon ranges from moderate to strong. Structure of the B horizon ranges from weak to moderate subangular blocky. The B horizon dehydrates irreversibly and forms dark brown or black very hard sand and silt-size particles. Thin bands of volcanic ash are throughout the sola; they are extremely variable in both number and position within the sola. Capability classification IIc, nonirrigated.

***Maile silt loam, 3 to 6 percent slopes* (20B).**

This soil is similar to Maile silt loam, 0 to 3 percent slopes, except that it is gently sloping. Capability classification IIc, nonirrigated.

***Maile silt loam, 6 to 12 percent slopes* (20C).**

This soil is similar to Maile silt loam, 0 to 3 percent slopes, except that it is strongly sloping. Runoff is medium and erosion hazard is moderate. Capability classification IIIe, nonirrigated.

***Maile silt loam, 12 to 20 percent slopes* (20D).**

This soil is similar to Maile silt loam, 0 to 3 percent slopes, except that it is moderately steep. Runoff is rapid and erosion hazard is high. Capability classification IVe, nonirrigated.

***Maile silt loam, 20 to 30 percent slopes* (20E).**

This soil is similar to Maile silt loam, 0 to 3 percent slopes, except that it is steep. Runoff is rapid and erosion hazard is high. Capability classification VIe, nonirrigated.

**Table 16. Laboratory data of Maile silt loam**

Soil name: Maile — Classification: Hydric Dystrandepts, thixotropic, isomesic
Soil no.: S69Ha-1-2-(1-6) — Location: Mealani Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-18 | Ap | | | | 0.49 | | | | 14.27 | 1.23 | 12 | 11.8 | 16.9 |
| 18-43 | B21 | | | | 0.36 | | | | 9.77 | 0.83 | 12 | 11.6 | 16.6 |
| 43-61 | B22 | | | | 0.33 | | | | 6.94 | 0.59 | 12 | 12.5 | 17.9 |
| 61-79 | B23 | | | | 0.36 | | | | 6.54 | 0.46 | 14 | 11.5 | 16.4 |
| 79-99 | B24 | | | | 0.51 | | | | 5.58 | 0.40 | 14 | 14.8 | 21.2 |
| 99-132 | B25 | | | | 0.34 | | | | 6.62 | 0.39 | 17 | 10.1 | 14.4 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | ---------pct--------- | | | | |
| 0-18 | 22.94 | 3.68 | 0.15 | 0.60 | 27.37 | | 72.29 | | | 38 | | 5.54 | 5.10 | -0.44 |
| 18-43 | 17.44 | 2.86 | 0.17 | 0.73 | 21.20 | | 67.76 | | | 31 | | 6.32 | 5.44 | -0.88 |
| 43-61 | 13.14 | 2.17 | 0.23 | 0.54 | 16.08 | | 65.01 | | | 25 | | 6.43 | 5.80 | -0.63 |
| 61-79 | 10.75 | 1.76 | 0.28 | 0.72 | 13.51 | | 65.30 | | | 21 | | 6.46 | 5.94 | -0.52 |
| 79-99 | 13.71 | 1.84 | 0.22 | 0.62 | 16.39 | | 60.73 | | | 27 | | 6.58 | 5.98 | -0.60 |
| 99-132 | 18.94 | 2.18 | 0.21 | 0.10 | 21.43 | | 81.32 | | | 26 | | 6.56 | 6.08 | -0.48 |

## Description of the Soils of the Hamakua Experiment Station

Fig. 10 shows the soils of the Hamakua Station.

MAILE SERIES

The Maile series consists of well-drained silty clay loam soils developed in volcanic ash underlain by unconforming bedrock. These soils occur on gently sloping to steep intermediate windward mountain slopes. Mean annual rainfall ranges from 60 to 90 inches. Mean annual soil temperature is about 58°F. Maile soils are geographically associated with Puu Oo, Honokaa, Kahua, Kehena, Palapalai, Piihonua, and Umikoa soils.

The Maile soils are used primarily for pasture.

*Maile silty clay loam, 6 to 12 percent slopes* (20C).

This soil occupies the moderately sloping side slopes on intermediate windward mountain slopes.

In a representative profile, the upper surface layer is dark reddish-brown silt loam to cindery sandy loam about 4 inches thick and dark reddish-brown silty clay loam in the lower part of the surface about 10 inches thick. The subsoil is dark brown to dark yellowish-brown silty clay loam. The substratum is unconforming bedrock, which generally occurs below 60 inches. These soils are medium to slightly acid in the surface layer and slightly acid to neutral in the subsoil.

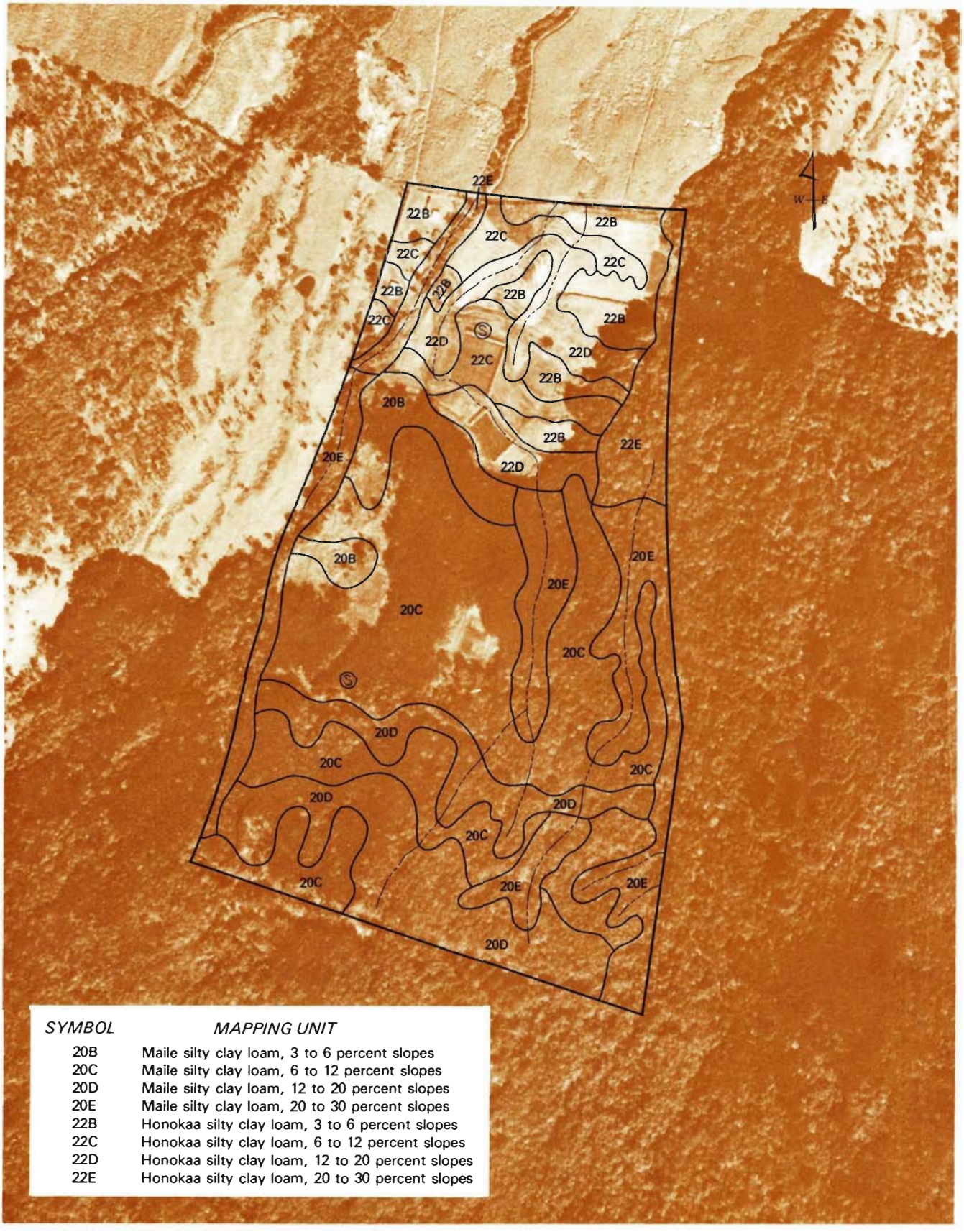
Permeability is moderately rapid, runoff is medium, and erosion hazard is moderate. Roots may penetrate to more than 60 inches.

**Profile description of Maile silty clay loam:**

Island of Hawaii, Hamakua Experiment Station (Table 17).

The surface has been scraped by bulldozers when the area was cleared.

| | |
|---|---|
| A1 S69Ha-1-7-1 | 0 to 10 cm (0–4 inches), dark reddish-brown (5YR 3/2) silty clay loam; strong fine and very fine subangular blocky structure; hard, friable, sticky, plastic; common roots; common pores; abrupt smooth boundary. (3 to 4 inches thick) |
| B21 S69Ha-1-7-2 | 10 to 33 cm (4–13 inches), dark reddish-brown (5YR 3/4) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, plastic, weakly smeary; gelatin-like coatings on ped; common roots; many fine and very fine pores; clear smooth boundary. (8 to 9 inches thick) |
| B22 S69Ha-1-7-3 | 33 to 48 cm (13–19 inches), dark reddish-brown (5YR 3/3) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, slightly plastic, weakly smeary; gelatin-like coatings on peds; abrupt smooth boundary. (5 to 6 inches thick) |
| IIB23 S69Ha-1-7-4 | 48 to 61 cm (19–24 inches), dark brown (7.5YR 3/2) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, plastic, moderately smeary; thick gelatinous coatings on ped faces; abrupt smooth boundary. (4 to 5 inches thick) |
| IIB24 S69Ha-1-7-5 | 61 to 79 cm (24–31 inches), reddish-brown (5YR 4/4) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, plastic, moderately smeary; thick gelatinous coatings on ped faces; common roots; many fine and very fine pores; abrupt smooth boundary. (6 to 7 inches thick) |
| IIB25 S69Ha-1-7-6 | 79 to 107 cm (31–42 inches), dark brown (10YR 3/3) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, plastic, moderately smeary; sticky gelatinous coatings on ped faces; few roots; many fine and very fine pores; abrupt smooth boundary. (10 to 11 inches thick) |
| IIB26 S69Ha-1-7-7 | 107 to 130 cm (42–51 inches), dark brown (10YR 3/3) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, plastic, moderately smeary; thick gelatinous coatings on ped faces; 2-inch discontinuous tuff band overlying the horizon; few roots; many fine and very fine pores; abrupt smooth boundary. (9 to 10 inches thick) |
| IIB27 S69Ha-1-7-8 | 130 to 150 cm (51–59 inches), variegated colors of yellowish-red (5YR 4/6) and dark reddish-brown (5YR 3/4) silty clay loam; moderate fine and very fine subangular blocky structure; friable, slightly sticky, plastic, strongly smeary; thick gelatinous coatings on ped faces; few roots; many fine and very fine pores. |




| SYMBOL | MAPPING UNIT |
|---|---|
| 20B | Maile silty clay loam, 3 to 6 percent slopes |
| 20C | Maile silty clay loam, 6 to 12 percent slopes |
| 20D | Maile silty clay loam, 12 to 20 percent slopes |
| 20E | Maile silty clay loam, 20 to 30 percent slopes |
| 22B | Honokaa silty clay loam, 3 to 6 percent slopes |
| 22C | Honokaa silty clay loam, 6 to 12 percent slopes |
| 22D | Honokaa silty clay loam, 12 to 20 percent slopes |
| 22E | Honokaa silty clay loam, 20 to 30 percent slopes |

Fig. 10. Soil map of the Hamakua Experiment Station, Honokaa, Hawaii. Approximate scale: 1:9000. For general location, see Sheet 21, Soil Survey by Sato et al. (1973), lat. 20°00′30″N; long. 155°23′30″W.

**Table 17. Laboratory data of Maile silty clay loam**

Soil name: Maile — Classification: Hydric Dystrandepts, thixotropic, isomesic
Soil no.: S69Ha-1-7-(1-8) — Location: Hamakua Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ----------pct---------- | |
| 0-10 | A1 | | | | 0.51 | | | | 13.97 | | | 14.1 | 20.2 |
| 10-33 | B21 | | | | 0.38 | | | | 11.99 | | | 11.7 | 16.7 |
| 33-48 | B22 | | | | 0.34 | | | | 10.19 | | | 11.8 | 16.9 |
| 48-61 | IIB23 | | | | 0.33 | | | | 9.39 | | | 10.5 | 15.0 |
| 61-79 | IIB24 | | | | 0.31 | | | | 7.16 | | | 12.9 | 18.4 |
| 79-107 | IIB25 | | | | 0.32 | | | | 7.09 | | | 10.3 | 14.7 |
| 107-130 | IIB26 | | | | 0.30 | | | | 6.23 | | | 9.5 | 13.6 |
| 130-150 | IIB27 | | | | 0.30 | | | | 6.52 | | | 11.5 | 16.4 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-10 | 1.83 | 0.47 | 0.15 | 0.18 | 2.63 | | 68.04 | | | 4 | | 4.54 | 4.30 | -0.24 |
| 10-33 | 0.58 | 0.15 | 0.15 | 0.07 | 0.95 | | 72.25 | | | 1 | | 5.00 | 4.74 | -0.26 |
| 33-48 | 0.32 | 0.10 | 0.11 | 0.07 | 0.60 | | 66.41 | | | 1 | | 5.41 | 5.21 | -0.20 |
| 48-61 | 0.14 | 0.07 | 0.07 | 0.05 | 0.33 | | 70.89 | | | < 1 | | 5.47 | 5.35 | -0.12 |
| 61-79 | 0.09 | 0.07 | 0.10 | 0.04 | 0.30 | | 62.32 | | | < 1 | | 5.05 | 5.31 | 0.26 |
| 79-107 | 0.07 | 0.04 | 0.08 | 0.07 | 0.26 | | 68.48 | | | < 1 | | 4.95 | 5.29 | 0.34 |
| 107-130 | 0.08 | 0.04 | 0.08 | 0.04 | 0.24 | | 70.24 | | | < 1 | | 4.84 | 5.32 | 0.48 |
| 130-150 | 0.11 | 0.08 | 0.08 | 0.03 | 0.30 | | 62.22 | | | < 1 | | 4.75 | 5.29 | 0.54 |

The solum ranges in hue from 5YR to 10YR, in value and in chroma from 2 to 4 moist. Structure of the A1 horizon ranges from moderate to strong. Structure of the B horizons ranges from weak to moderate subangular blocky. The B horizons dehydrate irreversibly and form dark brown or black very hard sand and silt-size particles. Thin bands of volcanic ash are throughout the sola; they are extremely variable in both number and position within the sola. Capability classification IIIe, nonirrigated.

***Maile silty clay loam, 3 to 6 percent slopes* (20B).**

This soil is similar to Maile silty clay loam, 6 to 12 percent slopes, except that it is gently sloping. Runoff is slow and erosion hazard is slight. Capability classification IIc, nonirrigated.

***Maile silty clay loam, 12 to 20 percent slopes* (20D).**

This soil is similar to Maile silty clay loam, 6 to 12 percent slopes, except that it is moderately steep. Runoff is rapid and erosion hazard is high. Capability classification IVe, nonirrigated.

***Maile silty clay loam, 20 to 30 percent slopes* (20E).**

This soil is similar to Maile silty clay loam, 6 to 12 percent slopes, except that it is steeper. Runoff is rapid and erosion hazard is high. Capability classification VIe, nonirrigated.

HONOKAA SERIES

The Honokaa series consists of well-drained silty clay loam soils developed in volcanic ash underlain by unconforming bedrock. The soils occur on nearly level to steep rolling windward mountain slopes, dissected by many gulches. Mean annual rainfall is 100 to 150 inches. Mean annual soil temperature is about 66°F. Honokaa soils are geographically associated with Kahua, Kukaiau, Maile, Ookala, and Kaiwiki.

The Honokaa soils are used primarily for pasture and sugarcane.

***Honokaa silty clay loam, 6 to 12 percent slopes* (22C).**

This soil occupies the moderate side slopes between gulches.

In a representative profile, the surface layer is dark brown silty clay loam about 6 inches thick. The subsoil is dark brown to very dark grayish-brown silty clay loam. The substratum is unconforming bedrock, which generally occurs below 40 inches. These soils are medium acid in the surface layer and slightly to medium acid in the subsoil.

Permeability is rapid, runoff is medium, and erosion hazard is moderate. Roots may penetrate to more than 60 inches.

---

**Profile description of Hamakua silty clay loam:**

Island of Hawaii, Hamakua Experiment Station (Table 18).

| | |
|---|---|
| Ap<br>S69Ha-<br>1-8-1 | 0 to 25 cm (0–10 inches), dark brown (10YR 3/3) silty clay loam; weak fine and very fine subangular blocky structure; hard, friable, sticky, plastic; many roots; many pores; mixing from B horizon; abrupt smooth boundary. (9 to 10 inches thick) |
| B21<br>S69Ha-<br>1-8-2 | 25 to 46 cm (10–18 inches), dark brown (7.5YR 4/4) silty clay loam; moderate fine and very fine subangular blocky structure; friable, slightly sticky, plastic, weakly smeary; gelatin-like coatings on ped faces; common roots; many fine and very fine pores; 1/4-inch krotovina in horizon; abrupt smooth boundary. (7 to 8 inches thick) |
| B22<br>S69Ha-<br>1-8-3 | 46 to 86 cm (18–34 inches), dark brown (7.5YR 3/2) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, plastic, weakly smeary; gelatinous coatings on ped faces; few roots; many fine and very fine pores; clear smooth boundary. (15 to 17 inches thick) |
| B23<br>S69Ha-<br>1-8-4 | 86 to 96 cm (34–38 inches), dark brown (7.5YR 4/4) silty clay loam; moderate fine and very fine subangular blocky structure; friable, sticky, plastic, weakly smeary; gelatinous coatings on ped faces; few roots; many fine and very fine pores; clear smooth boundary. (3 to 4 inches thick) |

*—Continued*

**Profile description:** *Continued.*

| | |
|---|---|
| B24<br>S69Ha-<br>1-8-5 | 96 to 127 cm (38-50 inches), dark brown (10YR 3/3) silty clay loam; strong fine and very fine subangular blocky structure; friable, sticky, plastic, weakly smeary; gelatinous coatings on ped faces; few roots; many fine and very fine pores; abrupt smooth boundary. (11 to 12 inches thick) |
| IIC<br>S69Ha-<br>1-8-6 | 127 to 135 cm (50-53 inches), dark red (2.5YR 3/6) weakly cemented volcanic ash; massive; hard, very firm, nonsticky, nonplastic, moderately smeary; few roots; many very fine, fine and common medium coarse pores; patchy red coatings of gelatin-like material; abrupt smooth boundary. (3 to 4 inches thick) |
| IIIB21b<br>S69Ha-<br>1-8-7 | 135 to 150 cm (53-59 inches), dark brown (10YR 4/3) silty clay loam; strong fine and very fine subangular blocky; friable, sticky, plastic, moderately smeary; gelatinous coatings on ped faces; few roots; many fine and very fine pores; few fragments of highly weathered tuff. |

Hue of the solum ranges from 5YR to 10YR. Value of the B horizons ranges from 3 to 5, and chroma ranges from 2 to 4. The upper B horizon has weak to moderate subangular blocky structure. In the natural state, these soils are always moist. The B2 horizons dehydrate irreversibly into black, sharp angular, very hard, fine pebble-size aggregates. Capability classification IIIc, nonirrigated and irrigated.

***Honokaa silty clay loam, 0 to 3 percent slopes* (22A).**

This soil is similar to Honokaa silty clay loam, 6 to 12 percent slopes, except that it is nearly level. Runoff is slow and erosion hazard is slight. Capability classification IIs, nonirrigated.

***Honokaa silty clay loam, 3 to 6 percent slopes* (22B).**

This soil is similar to Honokaa silty clay loam, 6 to 12 percent slopes, except that slopes are gentle. Runoff is slow and erosion hazard is slight. Capability classification IIs, nonirrigated.

***Honokaa silty clay loam, 12 to 20 percent slopes* (22D).**

This soil is similar to Honokaa silty clay loam, 6 to 12 percent slopes, except that it is moderately steep. Runoff is medium and erosion hazard is moderate. Capability classification IVe, nonirrigated.

***Honokaa silty clay loam, 20 to 30 percent slopes* (22E).**

This soil is similar to Honokaa silty clay loam, 6 to 12 percent slopes, except that it is steeper. Runoff is medium and erosion hazard is severe. Capability classification VIe, nonirrigated.

## Description of the Soils of the Kona Experiment Station

Fig. 11 shows the soils of the Kona Station.

HONUAULU SERIES

The Honuaulu series consists of well-drained silty clay loam soils developed in volcanic ash underlain by a'a lava. These soils occur on nearly level to steep low leeward slopes. Mean annual rainfall is 60 to 80 inches, most of which falls in summer. Mean annual soil temperature is about 66°F. Honuaulu soils are geographically associated with the Kainaliu and the Kealakekua soils.

The Honuaulu soils are used primarily for pasture and for growing coffee; a small acreage is used for growing macadamia nuts and truck crops.

***Honuaulu very stony silty clay loam, 3 to 6 percent slopes* (18B).**

This soil occupies the ridges in the uplands.

In a representative profile, the surface layer is very dark brown stony silty clay loam about 9 inches thick. The subsoil is dark brown silty clay loam with 10 to 60 percent pebble- to cobble-size fragments of basalt. The substratum is fragmental a'a lava, which generally occurs between 20 and 70 inches. These soils are strongly acid in the surface layer and strongly to medium acid in the subsoil.

Permeability is rapid, runoff is slow, and erosion hazard is slight. Roots may penetrate to 20 to 40 inches.

**Table 18. Laboratory data of Honokaa silty clay loam**

Soil name: Honokaa — Classification: Typic Hydrandepts, thixotropic, isothermic
Soil no.: S69Ha-1-8-(1-7) — Location: Hamakua Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-25 | Ap | | | | 0.42 | | | | 11.51 | | | 12.2 | 17.4 |
| 25-46 | B21 | | | | 0.32 | | | | 9.68 | | | 12.9 | 18.4 |
| 46-86 | B22 | | | | 0.31 | | | | 8.27 | | | 9.9 | 14.2 |
| 86-96 | B23 | | | | 0.29 | | | | 6.83 | | | 12.3 | 17.6 |
| 96-127 | B24 | | | | 0.36 | | | | 6.63 | | | 10.2 | 14.6 |
| 127-135 | IIC | | | | 0.48 | | | | 4.67 | | | 12.3 | 17.6 |
| 135-150 | IIIB21b | | | | 0.23 | | | | 5.93 | | | 12.7 | 18.2 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-25 | 3.57 | 0.20 | 0.09 | 0.10 | 3.96 | | 60.19 | | | 7 | | 5.14 | 4.73 | -0.41 |
| 25-46 | 1.63 | 0.16 | 0.09 | 0.05 | 1.93 | | 63.21 | | | 3 | | 5.68 | 5.28 | -0.40 |
| 46-86 | 0.12 | 0.05 | 0.17 | 0.04 | 0.38 | | 68.84 | | | < 1 | | 4.82 | 5.35 | 0.53 |
| 86-96 | 0.14 | 0.06 | 0.10 | 0.06 | 0.36 | | 65.25 | | | < 1 | | 5.13 | 5.51 | 0.38 |
| 96-127 | 0.08 | 0.06 | 0.07 | 0.06 | 0.27 | | 71.46 | | | < 1 | | 5.02 | 5.40 | 0.38 |
| 127-135 | 0.18 | 0.05 | 0.09 | 0.05 | 0.37 | | 61.75 | | | < 1 | | 5.17 | 5.56 | 0.39 |
| 135-150 | 0.17 | 0.07 | 0.08 | 0.06 | 0.38 | | 65.46 | | | < 1 | | 5.11 | 5.40 | 0.29 |


Fig. 11. Soil map of the Kona Experiment Station, Kainaliu, Hawaii. Approximate scale: 1:6000. For general location, see Sheet 111, Soil Survey by Sato et al. (1973), lat. 19°32′N; long. 155°55′30″W.

**Table 19. Laboratory data of Honuaulu very stony silty clay loam**

Soil name: Honuaulu — Classification: Hydric Dystrandepts, thixotropic over fragmental, isothermic
Soil no.: S69Ha-1-6-(1-3) — Location: Kona Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ----------pct---------- | |
| 0-20 | Ap | | | | 0.72 | | | | 9.72 | | | 10.3 | 14.7 |
| 20-36 | B21 | | | | 0.39 | | | | 5.87 | | | 12.6 | 18.0 |
| 36-61 | B22 | | | | 0.39 | | | | 4.81 | | | 12.5 | 17.9 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | ---------pct--------- | | | | |
| 0-20 | 13.40 | 2.93 | 0.15 | 0.39 | 16.87 | | 54.92 | | | 31 | | 5.05 | 4.72 | -0.33 |
| 20-36 | 12.00 | 4.10 | 0.22 | 0.49 | 16.81 | | 56.42 | | | 30 | | 5.67 | 5.42 | -0.25 |
| 36-61 | 12.20 | 3.82 | 0.21 | 0.43 | 16.66 | | 48.37 | | | 34 | | 5.95 | 5.64 | -0.31 |

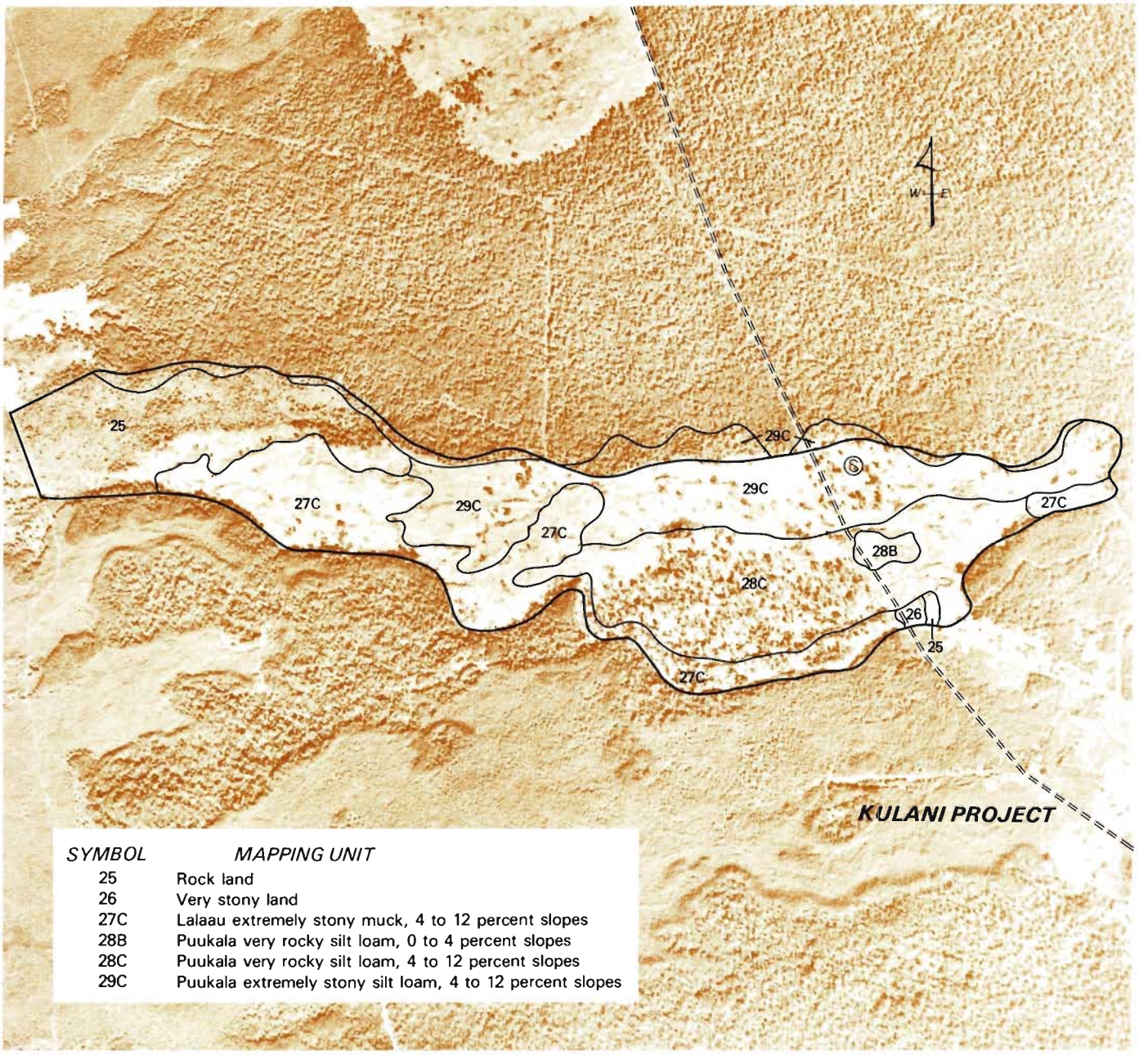



Fig. 12. Soil map of the Kulani Experiment Station, Kulani, Hawaii. Approximate scale: 1:20000. For general location, see Sheet 107, Soil Survey by Sato et al. (1973), lat. 19°33′45″N; long. 155°19′30″W.

**Profile description of Puukala extremely stony silt loam:**
Island of Hawaii, Kulani Experiment Station (Table 20).

| | |
|---|---|
| A11 S70Ha-1-1-1 | 0 to 15 cm (0–6 inches), dark brown (7.5YR 3/2) silt loam; moderate fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic, and weakly smeary; abundant roots; many thin gelatin-like coatings on peds; very porous; 10 to 20 percent stones; abrupt wavy boundary. (4 to 10 inches thick) |
| C1 S70Ha-1-1-2 | 15 to 30 cm (6–12 inches), dark reddish-brown (5YR 3/3); bulk of the horizon is soft weathered cinders mixed with volcanic ash that breaks down to a loam texture; massive; loose, slightly sticky, nonplastic, moderately smeary; thick gelatin-like coatings; common roots; many very fine pores; 10 percent stones with pockets of dark reddish-brown (2.5YR 3/4) silt loam; moderate fine and medium subangular blocky; friable, slightly sticky, slightly plastic, and strongly smeary; thick gelatin-like coatings on ped faces; abundant roots; many very fine pores; abrupt wavy boundary. (5 to 10 inches thick) |
| IIR | 30 cm (12 inches), pahoehoe lava; roots may be matted over pahoehoe lava or may penetrate through cracks in the pahoehoe lava. |

Three to 15 percent of the surface area is covered by loose stones. This soil is typically about 15 inches but is shallower near the outcrops. Stones may occupy 10 to 50 percent of the soil mass. Included are lesser or steeper sloping areas. Major agricultural land uses are pasture, woodland, and wildlife. Capability classification VIIs.

***Puukala very rocky silt loam, 0 to 4 percent slopes* (28B).**

Pahoehoe rock outcrops occupy about 10 to 25 percent of the surface area. This soil is typically about 10 to 20 inches but is shallower near the outcrops. Stones may occupy 10 to 50 percent of the soil mass. Major alternative agricultural land uses are orchards and vineyards, pasture, woodland, and wildlife. Capability classification IV.

***Puukala very rocky silt loam, 4 to 12 percent slopes* (28C).**

Pahoehoe rock outcrops occupy about 10 to 25 percent of the surface area. This soil is typically about 10 to 20 inches but is shallower near outcrops. Stones may occupy 10 to 50 percent of the soil mass. Included are lesser or steeper sloping areas. Major alternative agricultural land uses are pasture, woodland, and wildlife. Capability classification VIs.

ROCK LAND

***Rock land* (25).**

This miscellaneous land type consists of pahoehoe lava with pockets in some places with very shallow soil (6 to 8 inches). In some areas, the soil extends deeper into the cracks and crevices of the lava. Vegetation is confined mainly to the soil-covered areas and in fractures and crevices of the pahoehoe lava. Major agricultural land use is pasture. Capability classification VIIs.

VERY STONY LAND

***Very stony land* (26).**

This miscellaneous land type consists of very shallow soils with a high proportion of a'a lava outcrops. The surface is a mass of a'a lava outcrops between which the soil material occurs as fillings to depths of 5 to 20 inches. A'a lava outcrops occupy 30 to 50 percent of the surface. Below this depth, the profile consists mostly of unweathered a'a lava. Major alternative agricultural land uses are pasture and wildlife. Capability classification VIIs.

LALAAU SERIES

The Lalaau series consists of well-drained, thin, extremely stony mucky soils over recent a'a lava. These soils are gently sloping to moderately steep. They receive from 90 to more than 150 inches of rainfall annually. Their mean annual soil temperature is between 56° and 59°F. These soils and the Puukala and Kahaluu soils are in the same general area.

Lalaau soils are used for woodland, wildlife habitat, and watershed. The natural vegetation consists of ohia, tree fern, amaumau fern, uluhe fern, and pukeawe.

***Lalaau extremely stony muck, 4 to 12 percent slopes* (27C).**

In a representative profile, the surface layer is very dark brown extremely stony muck about 3 inches thick. It is underlain by fragmental a'a lava. The surface layer is very strongly acid. Depth to the a'a lava ranges from 5 to 10 inches. Included are small areas of exposed a'a lava. Also included are steeper areas usually along contacts between lava flows. Lesser sloping areas are included, which are not practical to delineate. Major alternative agricultural land uses are pasture, woodland, and wildlife. Capability classification VIs.

**Table 20. Laboratory data of Puukala extremely stony silt loam**

Soil name: Puukala — Classification: Hydric Lithic Dystrandepts, thixotropic, isomesic
Soil no.: S70Ha-1-1-(1-2) — Location: Kulani Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-15 | A11 | | | | 0.51 | | | | 15.71 | | | 4.6 | 6.6 |
| 15-30 | C1 | | | | 0.24 | | | | 8.95 | | | 4.5 | 6.4 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-15 | 5.36 | 1.32 | 0.63 | 0.17 | 7.48 | | 48.08 | | | 16 | | 4.30 | 4.25 | -0.05 |
| 15-30 | 3.71 | 0.73 | 0.28 | 0.18 | 4.90 | | 47.03 | | | 10 | | 5.50 | 4.95 | -0.55 |

**Profile description of Lalaau extremely stony muck (Sato et al., 1973):**

Island of Hawaii, Kulani Experiment Station.

| | |
|---|---|
| 02 | 8 to 0 cm (3–0 inches), very dark brown (10YR 2/2) extremely stony muck; weak, very fine, granular structure; friable, slightly sticky, slightly plastic, and strongly smeary; many roots; many fine pores; very strongly acid; a'a lava makes up about 25 to 50 percent of the horizon by volume; abrupt wavy boundary. (2 to 8 inches thick) |
| IIC | 0 to 25 cm (0–10 inches), fragmental a'a lava; small amount of material from above in spaces between a'a lava fragments. |

## Description of the Soils of the Volcano Experiment Station

Fig. 13 shows the soils of the Volcano Station.

PUAULU SERIES

The Puaulu series consists of well-drained silty clay loam soils developed in geologically recent volcanic ash. These soils occur on nearly level to undulating mountain slopes. Mean annual rainfall is 90 to 120 inches. Mean annual soil temperature is about 58°F. Puaulu soils are geographically associated with Akaka, Heake, Manu, and Puhimau soils.

The Puaulu soils are used for grazing and truck crops. Most of these soils occur in rainforest.

***Puaulu silt loam, 0 to 3 percent slopes* (10A).**

This soil occupies the nearly level ridges in the upland.

In a representative profile, the surface layer is dark reddish-brown silt loam about 7 inches thick underlain by stratified bands or layers of volcanic ash and fine cinder. These soils are very strongly acid to neutral.

Permeability is rapid, runoff is slow, and erosion hazard is slight. Roots may penetrate to more than 60 inches.

**Profile description of Puaulu silt loam:**

Island of Hawaii, Volcano Experiment Station (Table 21).

| | |
|---|---|
| Ap S69Ha-1-4-1 | 0 to 23 cm (0–9 inches), very dark brown (10YR 2/2) silt loam; moderate medium and fine subangular blocky structure; friable, slightly sticky, plastic, weakly smeary; few roots; many very fine pores; abrupt smooth boundary. (9 to 11 inches thick) |
| B21 S69Ha-1-4-2 | 23 to 41 cm (9–16 inches), dark brown (7.5YR 3/2) silty clay loam; moderate medium and coarse subangular blocky structure; friable, slightly sticky, plastic, smeary; few roots; many very fine pores; abrupt wavy boundary. (2 to 8 inches thick) |
| C1 S69Ha-1-4-3 | 41 to 64 cm (16–25 inches), dark reddish-brown (5YR 3/4) tuff layer with very fine black and red mottles; thin layer of reddish bands with fine grain texture; thick gelatinous coatings; abrupt wavy boundary. (7 to 11 inches thick) |
| IIB2 S69Ha-1-4-4 | 64 to 91 cm (25–36 inches), dark brown (7.5YR 3/2) silty clay loam; moderate medium and fine subangular blocky structure; friable, slightly sticky, plastic, strongly smeary; few roots; many fine and very fine pores; thick gelatinous coatings; the upper 2 inches has a band of dark yellowish brown (10YR 3/4) silt loam; moderate medium subangular blocky structure; friable, slightly sticky, plastic, smeary; few roots; many fine and very fine pores; abrupt smooth boundary; 5 to 10 percent rock fragments about 1/2-inch in diameter. (10 to 12 inches thick) |
| IIC1 S69Ha-1-4-5 | 91 to 145 cm (36–57 inches), banded layer of ash and cinder dark red (10R 3/5), dark brown (7.5YR 4/4), yellowish-red (5YR 4/6) cinder bands are gritty; ash bands silty clay loam; moderate medium and fine subangular blocky structure; friable, slightly sticky, plastic, strongly smeary; few roots; many very fine pores; basalt fragment is less than 10 percent |

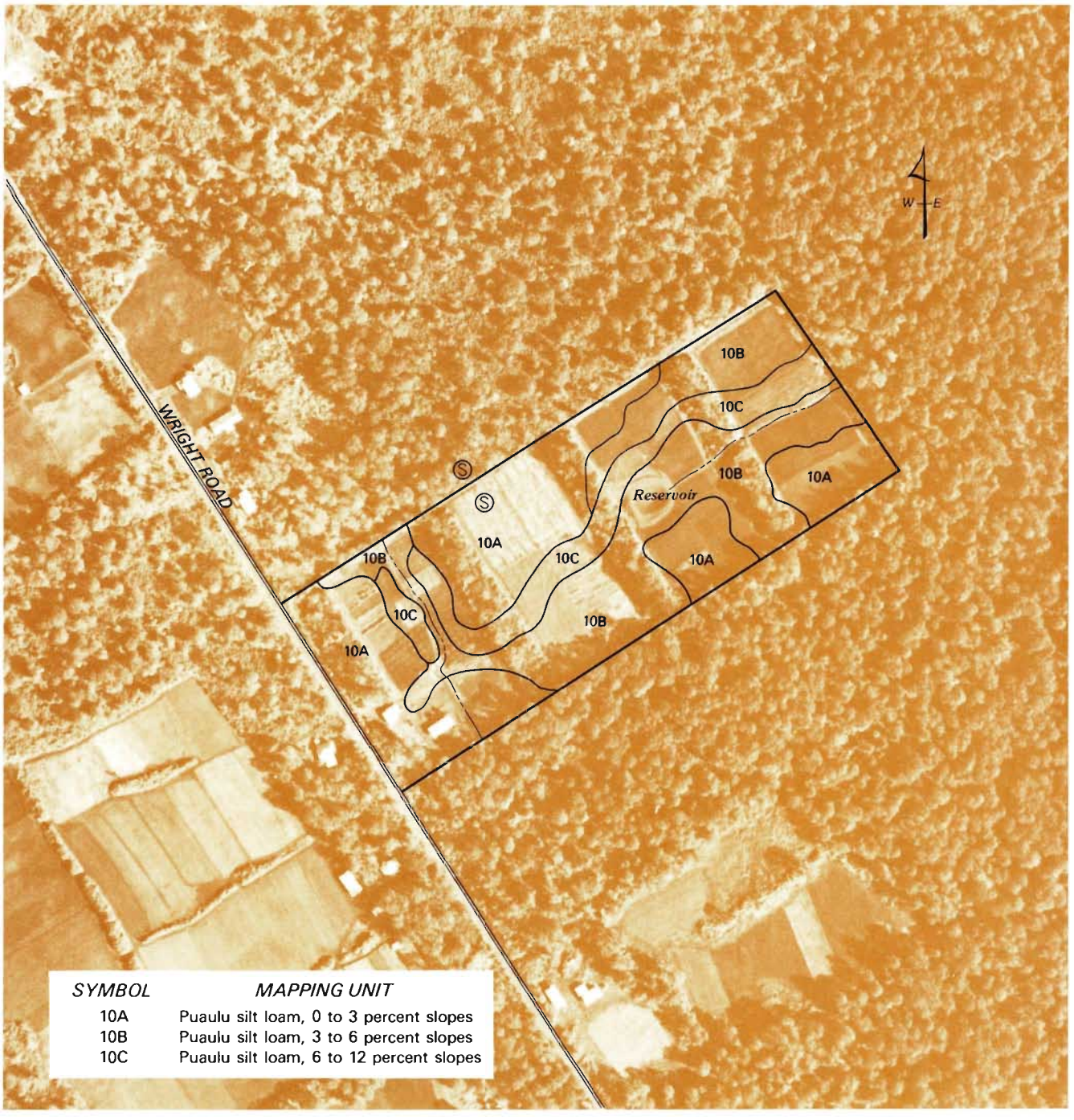



Fig. 13. Soil map of the Volcano Experiment Station, Volcano, Hawaii. Approximate scale: 1:6000. For general location, see Sheet 126, Soil Survey by Sato et al. (1973), lat. 19°28′45″N; long. 155°15′50″W.

**Table 21. Laboratory data of Puaulu silt loam**

Soil name: Puaulu — Classification: Typic Hydrandepts, medial over thixotropic, isomesic
Soil no.: S69Ha-1-4-(1-5) — Location: Volcano Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 0-23 | Ap | | | | 0.63 | | | | 5.84 | | | 4.0 | 5.7 |
| 23-41 | B21 | | | | 0.31 | | | | 8.36 | | | 7.2 | 10.3 |
| 41-64 | C1 | | | | 0.68 | | | | 4.03 | | | 7.2 | 10.3 |
| 64-91 | IIB2 | | | | 0.27 | | | | 4.54 | | | 7.4 | 10.6 |
| 91-145 | IIC1 | | | | 0.40 | | | | 3.70 | | | 5.3 | 7.6 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 0-23 | 16.39 | 2.61 | 0.28 | 0.42 | 19.70 | | 36.67 | | | 54 | | 5.98 | 5.26 | -0.62 |
| 23-41 | 16.87 | 2.85 | 0.38 | 0.25 | 20.35 | | 54.70 | | | 37 | | 5.92 | 5.39 | -0.53 |
| 41-64 | 7.09 | 2.70 | 0.20 | 0.16 | 10.15 | | 44.69 | | | 23 | | 6.15 | 5.54 | -0.61 |
| 64-91 | 7.10 | 3.11 | 0.30 | 0.28 | 10.79 | | 45.92 | | | 24 | | 6.24 | 5.76 | -0.48 |
| 91-145 | 5.66 | 3.21 | 0.22 | 0.17 | 9.26 | | 45.17 | | | 20 | | 6.41 | 5.86 | -0.55 |

These soils are developed on geologically recent volcanic ash and are extremely variable in color, texture, and development.

Subsurface horizons with textures finer than silt loam dehydrate irreversibly into black and dark brown, sharp angular, very hard gravel-size aggregates. Capability classification IIs, nonirrigated.

***Puaulu silt loam, 3 to 6 percent slopes* (10B).**

This soil is similar to Puaulu silt loam, 0 to 3 percent slopes, except slopes are gentle. Runoff is slow and erosion hazard is slight. Capability classification IIs, nonirrigated.

***Puaulu silt loam, 6 to 12 percent slopes* (10C).**

This soil is similar to Puaulu silt loam, 0 to 3 percent slopes, except slopes are moderate. Runoff is medium and erosion hazard is moderate. Capability classification IIIe, nonirrigated.

***Puaulu muck, 0 to 3 percent slopes.***

**Profile description of Puaulu muck:**

Taken in rain forest adjoining the Volcano Experiment Station (Table 22).

| | |
|---|---|
| O2 S69Ha-1-5-1 | 8 to 0 cm (3–0 inches), dark reddish-brown (5YR 2/2) muck; weak very fine and fine granular structure; friable, slightly sticky, slightly plastic, smeary; abundant roots, matted; many fine pores; abrupt boundary. (2 to 4 inches thick) |
| A1 S69Ha-1-5-2 | 0 to 13 cm (0–5 inches), dark reddish-brown (5YR 2/2) loam; moderate fine and medium subangular blocky structure; firm; nonsticky, slightly plastic; few roots; many fine pores; 2 percent cinders; clear smooth boundary. (5 to 7 inches thick) |
| IIB1 S69Ha-1-5-3 | 13 to 38 cm (5–15 inches), dark reddish-brown (5YR 2/2), dusky-red (2.5YR 3/2), dark brown (10YR 4/3) bands of volcanic ash silty clay loam to silt loam; moderate fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic, smeary; common roots; many fine and very fine pores; 1-inch band of pumice; thick gelatinous coatings; clear smooth boundary. (9 to 11 inches thick) |
| IIB2 S69Ha-1-5-4 | 38 to 74 cm (15–29 inches), dark brown (7.5YR 3/2), dark reddish-brown (5YR 3/2), dark red (2.5YR 3/6) silty clay loam to silt loam, bands of volcanic ash; moderate fine and medium subangular blocky structure; friable, slightly sticky, plastic, smeary; many roots; many fine and very fine pores; thick gelatinous coatings; abrupt smooth boundary. (14 to 16 inches thick) |
| IIC1 S69Ha-1-5-5 | 74 to 104 cm (29–41 inches), dark red (2.5YR 3/6) coarse silty clay loam; moderate very fine subangular blocky structures; friable, sticky, plastic, smeary; few roots; many fine pores; thick gelatinous coatings; 1 to 2 percent 1/2-inch basalt rock fragments; clear smooth boundary. (12 to 15 inches thick) |
| IIIC2 S69Ha-1-5-6 | 104 to 140 cm (41–55 inches), compacted ash layer, variegated colors of dark red (2.5YR 3/6) and dark red (10R 3/6) coarse silty clay loam; massive; friable, slightly sticky, slightly plastic, weakly smeary; few roots; many fine pores; 4 to 5 percent 1-inch basalt rock fragments; thick gelatinous coating; ash band of brown (10YR 4/3) silt loam; moderate fine subangular blocky structure lower 3 inches. |

## Description of the Soils of the Malama-Ki Experiment Station

Fig. 14 shows the soils of the Malama-Ki Station.

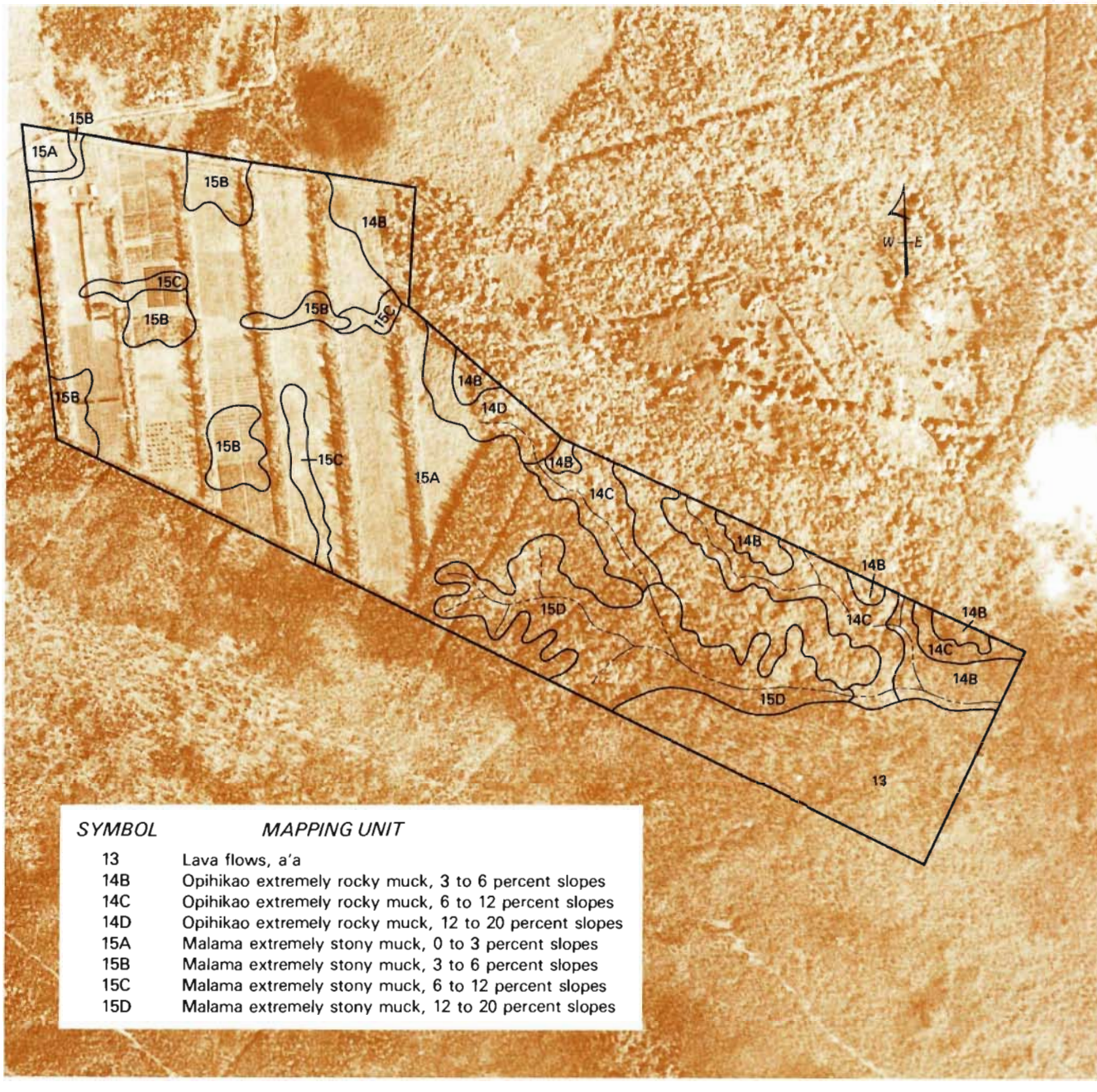
The soils of the Malama-Ki and Waiakea Stations are unique because they are actually lava lands rather than soils with conventional A, B, and C horizons. Previously classified as Lithosols under the 1938 soil classification system, these soils have only a thin organic surface underlain by either a'a or pahoehoe lava. No profiles were collected at either the Malama-Ki or the Waiakea Stations because of the difficulty in selecting what would be con-

**Table 22. Laboratory data of Puaulu muck**

Soil name: Puaulu — Classification: Typic Hydrandepts, medial over thixotropic, isomesic
Soil no.: S69Ha-1-5-(1-6) — Location: Volcano Experiment Station

| Depth | Horizon | Particle size analysis | | | Bulk density | Water content | | | Organic C | Total N | C/N | Extractable iron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | .1-bar | .3-bar | 15-bar | | | | Fe | $Fe_2O_3$ |
| ---cm--- | | ----------pct < 2 mm---------- | | | ---g/cc--- | ----------pct---------- | | | ---pct--- | ---pct--- | | ---------pct--------- | |
| 8-0 | O2 | | | | 0.26 | | | | 12.10 | | | 1.8 | 2.6 |
| 0-13 | A1 | | | | 0.99 | | | | 1.78 | | | 1.3 | 1.9 |
| 13-38 | IIB1 | | | | 0.37 | | | | 5.20 | | | 3.6 | 5.1 |
| 38-74 | IIIB2 | | | | 0.38 | | | | 5.58 | | | 5.5 | 7.9 |
| 74-104 | IIC1 | | | | 0.43 | | | | 5.81 | | | 7.5 | 10.7 |
| 104-140 | IIIC2 | | | | 0.65 | | | | 3.59 | | | 7.7 | 11.0 |

| Depth | Extractable bases | | | | | Extractable acidity | Cation-exchange capacity | | Extractable Al | Base saturation | | pH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Mg | Na | K | Sum | | $NH_4OAc$ | Sum | | $NH_4OAc$ | Sum | $H_2O$ | KCl | Difference |
| ---cm--- | ----------meq/100 g soil---------- | | | | | | | | | --------pct-------- | | | | |
| 8-0 | 13.19 | 9.49 | 0.54 | 0.60 | 23.82 | | 38.32 | | | 62 | | 4.67 | 4.28 | -0.39 |
| 0-13 | 2.61 | 1.52 | 0.24 | 0.08 | 4.45 | | 9.27 | | | 48 | | 5.78 | 4.95 | -0.83 |
| 13-38 | 11.28 | 5.37 | 0.31 | 0.12 | 17.08 | | 31.03 | | | 55 | | 5.81 | 5.12 | -0.69 |
| 38-74 | 11.58 | 5.49 | 0.28 | 0.07 | 17.42 | | 43.80 | | | 40 | | 5.81 | 5.32 | -0.49 |
| 74-104 | 10.20 | 4.37 | 0.25 | 0.05 | 14.87 | | 52.97 | | | 28 | | 5.84 | 5.33 | -0.51 |
| 104-140 | 5.72 | 1.95 | 0.25 | 0.04 | 7.96 | | 44.34 | | | 18 | | 5.80 | 5.36 | -0.44 |




| SYMBOL | MAPPING UNIT |
|---|---|
| 13 | Lava flows, a'a |
| 14B | Opihikao extremely rocky muck, 3 to 6 percent slopes |
| 14C | Opihikao extremely rocky muck, 6 to 12 percent slopes |
| 14D | Opihikao extremely rocky muck, 12 to 20 percent slopes |
| 15A | Malama extremely stony muck, 0 to 3 percent slopes |
| 15B | Malama extremely stony muck, 3 to 6 percent slopes |
| 15C | Malama extremely stony muck, 6 to 12 percent slopes |
| 15D | Malama extremely stony muck, 12 to 20 percent slopes |

Fig. 14. Soil map of the Malama-Ki Experiment Station, Malama-Ki, Hawaii. Approximate scale: 1:2000. For general location, see Sheet 129, Soil Survey by Sato et al. (1973), lat. 19°27′40″N; long. 154°53′W.

Remarks: Soil samples were not collected at this station; refer to official soil series description. There is little or no organic matter on the surface of the Malama soils.

sidered to be representative profiles. Accordingly, no chemical data are reported for these soils on these two stations. The morphological, chemical, and physical data of several profiles, however, may be found in the dissertation prepared by Yaibuathes (1969) and in the thesis by Periaswamy (1973).

Despite their unusual characteristics, these soils nevertheless have significant agricultural potential for the production of papaya, macadamia, forage and vegetable crops, and pasture (Periaswamy, 1973).

OPIHIKAO SERIES

The Opihikao series consists of well-drained muck soils developed in organic matter and volcanic ash underlain by pahoehoe lava. These soils occur on nearly level to strongly sloping uplands. Mean annual rainfall is 60 to 90 inches. Mean annual soil temperature is about 72°F. Opihikao soils are geographically associated with the Kaimu, Keaukaha, Keei, Kiloa, Kona, Malama, Puna, and Punaluu series.

Opihikao soils are used primarily for forest or pasture.

***Opihikao extremely rocky muck, 3 to 6 percent slopes* (14B).**

This soil occupies the gently sloping uplands.

In a representative profile, the surface layer is a very dark brown extremely rocky muck about 3 inches thick, underlain by pahoehoe lava. Volcanic ash occurs in rock interstices in some areas.

Permeability is very slow over pahoehoe lava, runoff is rapid, and erosion hazard is slight. Roots may penetrate deep where the pahoehoe is fractured.

Hue of the organic horizon ranges from 7.5YR to 10YR. Capability classification VIs, nonirrigated.

***Opihikao extremely rocky muck, 6 to 12 percent slopes* (14C).**

This soil is similar to Opihikao extremely rocky muck, 3 to 6 percent slopes, except that it is steeper.

***Opihikao extremely rocky muck, 12 to 20 percent slopes* (14D).**

This soil is similar to Opihikao extremely rocky muck, 3 to 6 percent slopes, except that it is steeper.

MALAMA SERIES

The Malama series consists of well-drained muck soils developed in organic matter and volcanic ash underlain by fragmental a'a lava. The soils occur on nearly level to strongly sloping uplands. The annual rainfall is 60 to 90 inches. Mean annual soil temperature is about 72°F. Malama soils are geographically associated with the Kaimu, Keaukaha, Keei, Kiloa, Kona, Puna, Opihikao, and Punaluu series.

Malama soils are used for forest, pasture, macadamia, papaya, citrus or guava.

***Malama extremely stony muck, 0 to 3 percent slopes* (15A).**

This soil occupies the nearly level uplands.

In a representative profile, the surface layer is a very dark brown extremely stony muck about 3 inches thick, underlain by a'a lava. Volcanic ash may filter through fragments of a'a lavas.

Permeability is very rapid, runoff is slow, and erosion hazard is slight. Roots penetrate deep into the fragmental a'a lava.

A description of a representative profile was not taken due to the oxidation of the organic surface horizon and downward movement of the "fines" that occur after land preparation.

Hue of the organic surface horizon ranges from 7.5YR to 10YR. Capability classification VIs, nonirrigated.

***Malama extremely stony muck, 3 to 6 percent slopes* (15B).**

This soil is similar to Malama extremely stony muck, 0 to 3 percent slopes, except that it is deeper.

***Malama extremely stony muck, 6 to 12 percent slopes* (15C).**

This soil is similar to Malama extremely stony muck, 0 to 3 percent slopes, except that it is steeper.

***Malama extremely stony muck, 12 to 20 percent slopes* (15D).**

This soil is similar to Malama extremely stony muck, 0 to 3 percent slopes, except that it is steeper.

LAVA FLOWS, A'A

***Lava flows, a'a* (13).**

This miscellaneous land type consists of geologically young lava flows of the a'a type, some of which have been laid down in historical times. There is practically no soil covering. They are essentially bare of vegetation except for mosses, lichen, ferns, and a few small ohia trees. Elevation range from near sea level to 13,000 feet. They receive 10 to 250 inches of rainfall annually. These flows are associated with the pahoehoe lava flows and many other soils.

The surface of this lava is rough and broken. They are a mass of clinkery, hard, glassy, sharp pieces of lava piled in tumbled heaps and filled with cracks and crevices.

These areas are idle. Capability classification VIIIs.

## Description of the Soils of the Waiakea Experiment Station

Fig. 15 shows the soils of the Waiakea Station.

As explained under the section of the Malama-Ki Station, no profiles were collected at the Waiakea Experi-

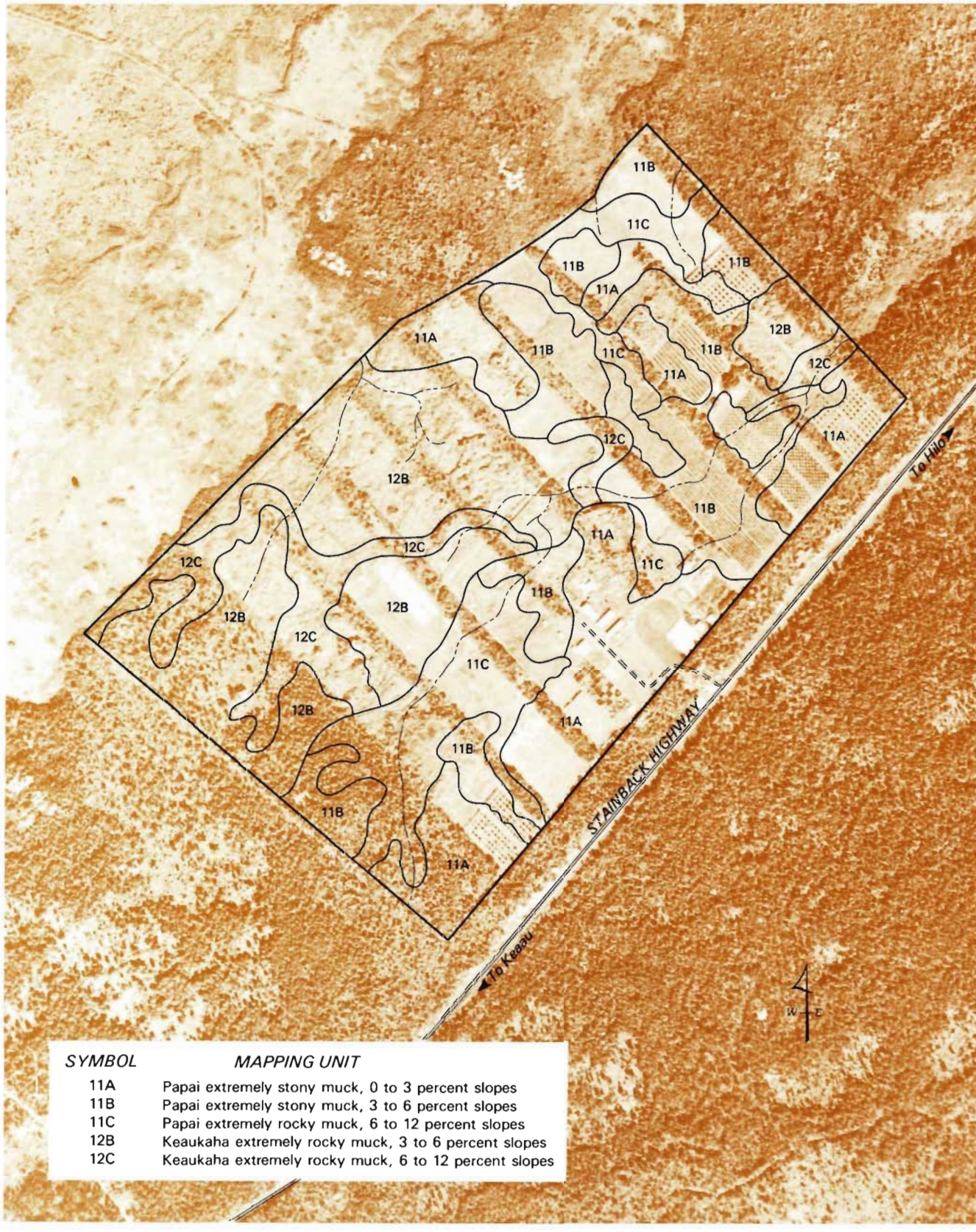



Fig. 15. Soil map of the Waiakea Experiment Station, Waiakea, Hawaii. Approximate scale: 1:9000. For general location, see Sheet 92, Soil Survey by Sato et al. (1973), lat. 19°39′N; long. 155°05′W.

Remarks: Soil samples were not collected at this station; refer to official soil series description. There is little or no organic matter on the surface of these soils.

ment Station because of the difficulty in selecting what would be considered to be representative profiles. No chemical data are also reported. The properties of several profiles, however, are reported by Yaibuathes (1969) and Periaswamy (1973).

PAPAI SERIES

The Papai series consists of well-drained muck soils developed in organic matter and volcanic ash underlain by a'a lava. These soils occur on nearly level to strongly sloping uplands. Mean annual rainfall is 90 to more than 150 inches. Mean annual soil temperature is about 72°F. Papai soils are geographically associated with the Keaukaha, Keei, Kiloa, Malama, and Opihikao series.

Papai soils are used primarily for forest. A small acreage is used for pasture, macadamia, papaya, and citrus.

***Papai extremely stony muck, 0 to 3 percent slopes*** **(11A).**

This soil occupies the nearly level uplands.

In a representative profile, the surface layer is a very dark brown extremely stony muck about 8 inches thick, underlain by a'a lava.

Permeability is very rapid, runoff is slow, and erosion hazard is slight. Roots may penetrate deep into the fragmental a'a lava.

Hue of the organic surface horizon ranges from 7.5YR to 10YR. Capability classification VIs, nonirrigated.

***Papai extremely stony muck, 3 to 6 percent slopes*** **(11B).**

This soil is similar to Papai extremely stony muck, 0 to 3 percent slopes, except that it is steeper.

***Papai extremely stony muck, 6 to 12 percent slopes*** **(11C).**

This soil is similar to Papai extremely stony muck, 0 to 3 percent slopes, except that it is steeper.

KEAUKAHA SERIES

The Keaukaha series consists of well-drained muck soils developed in organic matter and volcanic ash underlain by pahoehoe lava. These soils occur on nearly level to strongly sloping uplands. Mean annual rainfall is 90 to more than 150 inches. Mean annual soil temperature is about 72°F. Keaukaha soils are geographically associated with the Kiloa, Malama, Olaa, Panaewa, and Papai series.

Keaukaha soils are used primarily for forest and pasture.

***Keaukaha extremely rocky muck, 3 to 6 percent slopes*** **(12B).**

This soil occupies the gently sloping uplands.

In a representative profile, the surface layer is very dark brown extremely rocky muck about 8 inches thick, underlain by pahoehoe lava.

Permeability is very slow over pahoehoe lava, runoff is rapid, and erosion hazard is slight. Roots may penetrate deep into cracks and crevices.

Hue of the organic surface horizon ranges from 7.5YR to 10YR. Capability classification VIs, nonirrigated.

***Keaukaha extremely rocky muck, 6 to 12 percent slopes*** **(12C).**

This soil is similar to Keaukaha extremely rocky muck, 3 to 6 percent slopes, except that it is steeper.

# Literature Cited


Cline, M. G. 1955. Soil survey of the Territory of Hawaii. Series 1939, No. 25. USDA in cooperation with Univ. Hawaii Agr. Exp. Sta. U.S. Govt. Printing Office, Wash. D.C.

Foote, D. E., E. L. Hill, S. Nakamura, and F. E. Stephens. 1972. Soil survey of the islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii. SCS, USDA, in cooperation with Univ. Hawaii Agr. Exp. Sta. U.S. Govt Printing Office, Wash. D.C.

Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Periaswamy, S. P. 1973. Agricultural potential of forested lava lands (Tropofolists). M.S. thesis, Univ. Hawaii, Honolulu.

Sato, H. H., W. Ikeda, R. Paeth, R. Smythe, and M. Takehiro, Jr. 1973. Soil survey of the island of Hawaii, State of Hawaii. SCS, USDA, in cooperation with Univ. Hawaii Agr. Exp. Sta. U.S. Govt. Printing Office, Wash. D.C.

Soil Survey Staff. 1951. Soil survey manual. USDA Agr. Handbook No. 18. SCS, USDA, Wash. D.C.

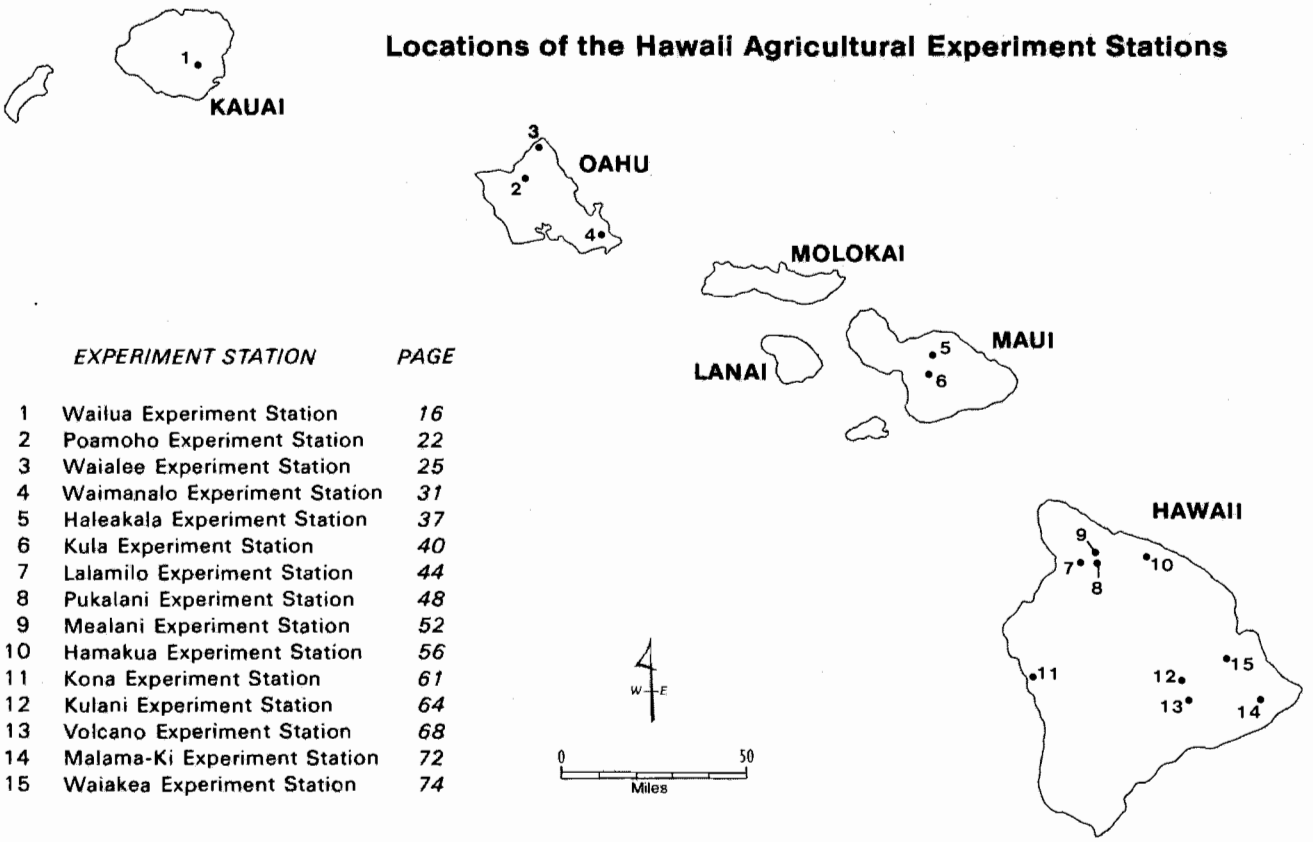
Soil Survey Staff. 1961. Land-capability classification. USDA Agr. Handbook No. 210. SCS, USDA, Wash. D.C.

Soil Survey Staff. 1972. Soil survey laboratory methods and procedures for collecting soil samples. Soil Survey Investigations Report No. 1. SCS, USDA, Wash. D.C.

Soil Survey Staff. 1975. Soil taxonomy. SCS, USDA Agr. Handbook No. 436. U.S. Govt. Printing Office, Wash. D.C.

Yaibuathes, N. 1971. An investigation of tropical Histosols in Hawaii. Ph.D. dissertation, Univ. Hawaii, Honolulu.

## Locations of the Hawaii Agricultural Experiment Stations

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## MAP LEGEND

- Sample sight
- Swampy land
- Stony spot
- Quarry
- Depression
- Poor motor road
- Good motor road
- Station boundary
- Soil boundary
- Intermittent stream or Stream bed

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NOTE: As part of a structural reorganization, the Hawaii Agricultural Experiment Station and the Hawaii Cooperative Extension Service have been merged administratively under the name HAWAII INSTITUTE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES, College of Tropical Agriculture and Human Resources, University of Hawaii.

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