Soil Moisture Constants and Physical Properties of Selected Soils in Hawaii

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U S. FOREST SERVICE RESEARCH PAPER PSW-P2 1963

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The publishing unit will be identified by letters before the number, and the numbers will be consecutive in the order of publication dates. For example, this Station's first Research Paper in 1963 is designated U.S. Forest Service Research Paper PSW-P1.

Contents

The nature of soils influences and often determines the use of land. Information on the physical characteristics of soils is needed as a guide to managing land for water production and other uses. In 1961 a detailed study was made of the strength and soil moisture characteristics of 25 soil types in Hawaii.[1] Samples were obtained from the surface to the 12-inch depth at 34 sites on the islands of Hawaii, Kauai, and Oahu. These soils represent 10 great soil groups commonly found in the State of Hawaii.

Analyses were made of the differences in surface properties of fine-textured soils found under forest cover, in cultivated areas, in pastures, and in idle grassland. These studies provided data on soil texture, Atterberg limits, bulk density, organic matter content, specific gravity, pH, and soil moisture constants. This paper reports the results of these analyses.

Methods and Procedures

At each sampling site, we dug two to four pits, each about 2 feet deep. The exposed profile was described by- a soil scientist of the U.S. Soil Conservation Service. Bulk samples composited from three locations within a 21- by 36-foot plot were taken from the 0- to 3-, 3- to 6-, 6- to 9-, and 9- to 12-inch depths. Particle size distribution, Atterberg limits,[2] and specific gravity of soil particles were determined by following standard methods at the U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Miss. The pH of soils was determined by using a standard colorimetric kit.[3] Organic matter content of most soils was determined at the Mississippi Agricultural Experiment Station, Starkville, by using a modified Walkley rapid-dichromate method (Peech et al. 1947). Certain samples high in organic matter content were analyzed by the loss-on-ignition method (Association of Official Agricultural Chemists 1945).

Soil moisture retained at 15 atmospheres pressure (wilting point) was determined by the pressure-membrane method (Richards 1947). Undisturbed cores in triplicate were obtained to determine bulk density and soil moisture retained at 0 and 0.06 atmosphere tension using the method of Learner and Shaw (1941). Soil moisture retained at 60 centimeters water tension was taken as the upper limit of available soil moisture or field capacity.[4] Permanent wilting point was taken as the moisture retained at 15 atmospheres pressure. Available water capacity was calculated by subtracting the water held at 15 atmospheres pressure from the water retained at 60 centimeters tension.

Volume of large pores or readily drained pores was calculated by subtracting the total pore space occupied by water at 0.06 atmosphere tension from the total pore volume (Broadfoot and Burke 1958). The total pore volume was calculated from the average bulk density and average specific gravity of the soil particles.

We grouped the data representing known land use conditions into four categories: forest, pasture, cultivated area, and idle grassland (table 4, appendix).

The forest category consisted of soils supporting trees and associated vegetation. Soils in pastures were mainly under grasses, but some were under a mixed growth of grass, guava, ferns, and herbaceous cover. Eight of the cultivated soils were under sugar cane; one under pineapple; and

[1] A joint research project of the Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, and the U.S. Army Corps of Engineers, Waterways Experiment Station, in cooperation with the Hawaii Forestry Division and the Hawaiian Sugar Planters Association.

[2] Atterberg limits or consistency limits are the boundaries determined by moisture content (percent by weight) at which a soil may exist in different states: (a) Liquid limit--the boundary between liquid and plastic states; (b) plastic limit--the boundary between the plastic and semi-solid states; and (c) shrinkage limit--the boundary between semi-solid and solid states. Plasticity index is the numerical difference between the liquid limit and plastic limit.

[3] Truog soil reaction tester by Hellige, Inc.

[4] Data collected at the Vicksburg Research Center, Southern Forest Experiment Station, by Broadfoot and Burke (1958) indicated that the 60-centimeter determination closely approximated field capacity for all textural classes of soils in the United States.

one under a stand of papaya, grass, and guava. Idle grassland areas are those formerly cultivated or used as pasture several years ago but now idle and under grass cover.

Soil Properties

In spite of apparent textures, most soils of Hawaii fully dispersed are clay to colloidal in particle size (Hough and Byers 1937; Hough et al. 1941; Kelley et al. 1915; Tanada 1951; Richter 1931; Sherman 1955). They are aggregates of clay and colloidal particles and very difficult to disperse. Hough et al. (1941) concluded that conventional methods of analysis were useless, because the soils of Hawaii they studied consisted almost entirely of colloidal material. The hydrometer method is more reliable for dry area soils in which leaching is not a significant factor, according to Wadsworth (1936).

The dominance of colloids strongly affects other soil properties. Fieldes (1955) has shown that dispersion is difficult when pumice soils have allophane. Packard (1957) found that the surface area method gave 9.6 percent more clay than the mechanical analysis of the same soils. Hough and Byers (1957) found that concretionary or aggregate material with a low degree of dispersion accounts for the high permeability and greater distribution of organic matter throughout the soil horizon. During our field investigations of soil strength and moisture characteristics, we found that soil structure was water stable and retains high permeability under wet conditions.

Texture and Structure

The majority of the soils sampled were fine-textured by mechanical analysis (figs. 1 and 2). The 0- to 6-inch layers of 7 out of 11 soils under forest cover were classified in the field as loamy type. Laboratory analysis indicates that three of these soils were of clay texture. Loamy soils are, in general, more favorable for forest growth than coarse sands or fine clays (Lutz and Chandler 1951). Of the 11 grass-covered soils classified in the field, 4 were clay in texture, 3 silty clay loam, and 4 silty clay.

Soil structure is greatly influenced by different land usage. Total pore volume and volume of large pores are highest in soils under forest (table 1 and fig. 3).

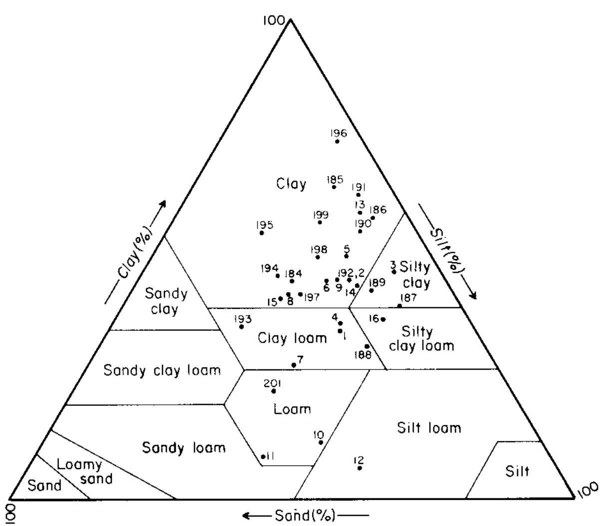

Figure 1.--Classification of soil texture of 34 soil sites studied, 0- to 6-inch depth.

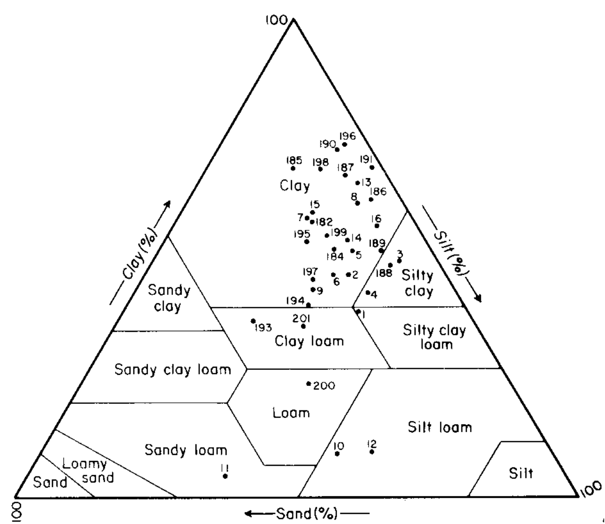

Figure 2.--Classification of soil texture of 34 soil sites studied, 6- to 12-inch depth.

Table 1. Porosity and soil moisture constants (percent by volume) of soils, 0- to 12-inch depth, under four different land uses

Land use	Total pore volume		Large pore volume		Field capacity		Wilting point		Available moisture	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Forest: 11 sites ------------	74	6	18	7	57	12	28	7	28	10
Pastureland: 6 sites ------------	71	11	14	6	56	8	38***	5	19*	4
Cultivated areas: 10 sites ------------	69	8	10**	4	58	9	35***	4	24	11
Idle grassland: 7 sites ------------	68	11	10**	6	58	13	32	5	26	12

** Significant at .10 level when compared to forest soils.*
*** Significant at .95 level when compared to forest soils.*
**** Significant at .01 level when compared to forest soils.*

Bulk Density

Low volume weight signifies relative porous soil condition and high values indicate greater compactness, lowered field capacity, and lower infiltration rates.

Except for some ash soils of Hawaii, analysis of the limited data indicates that bulk density tends to decrease with increased rainfall. Soils under low rainfall may have moderately low bulk density, but no soils under high rainfall have high density. Wadsworth (1936) also reported that soil bulk density decreased as rainfall increased.

Forest soils had the lowest average bulk density (table 2). Pasture and cultivated soils as expected had higher average bulk densities, although ungrazed grassland soils had the highest average value. Trouse and Humbert (1960) reported that some soils of Hawaii will compact and puddle

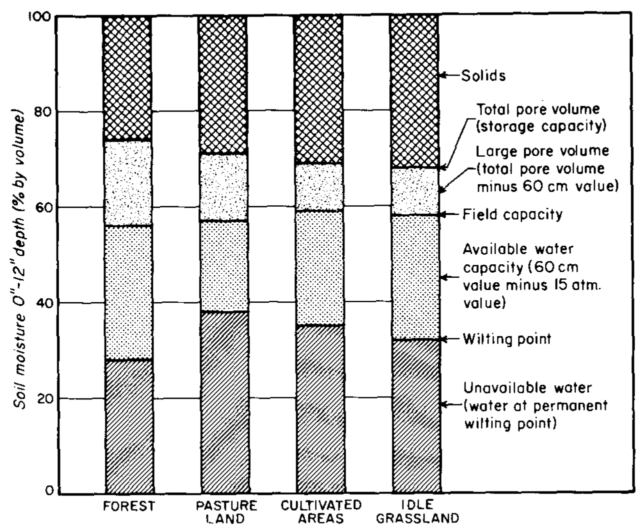

Figure 3.-Soil moisture constants (percent by volume, 0- to 12-inch depth) related to vegetative cover.

Table 2. Properties of soils under four different land uses, 9- to 12-inch depth

Land use	pH		Specific gravity		Organic matter		Bulk density	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
			Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Forest: 11 sites --------------	6.2	3.3	2.94	0.34	6.5	3.0	0.76	0.22
Pastureland: 6 sites---------------	5.9	0.4	2.75	0.18	8.7	8.7	0.81	0.34
Cultivated areas: 10 sites --------------	6.2	1.3	2.82	0.26	5.0	5.0	0.88	0.26
Idle grassland: 7 sites---------------	7.0	1.3	2.91	0.16	5.1	4.2	0.93	0.36

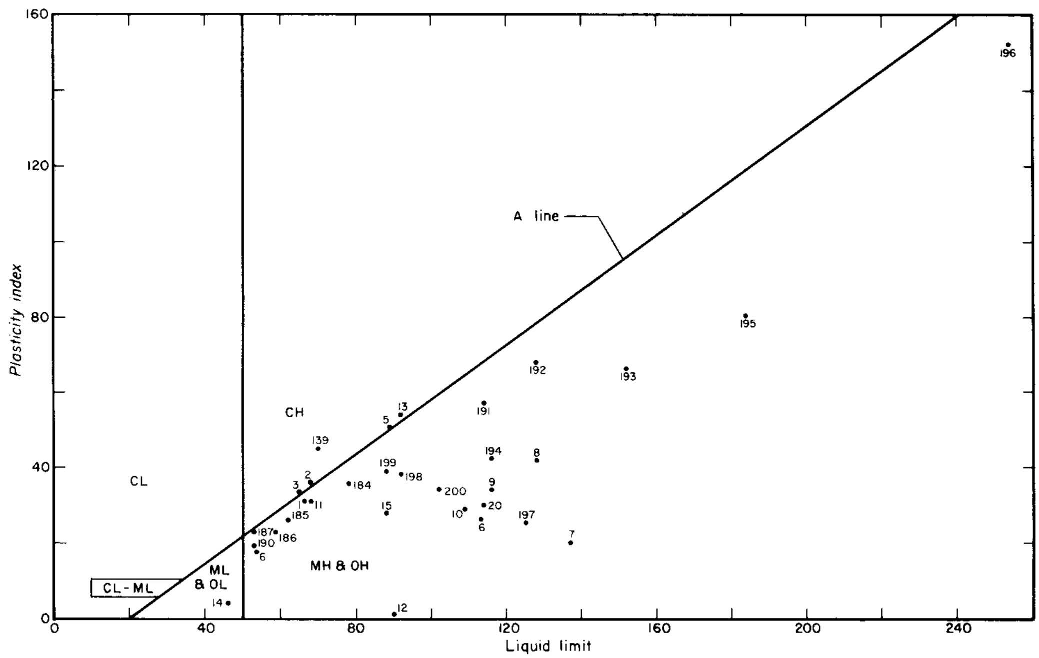

Figure 4.-Classification of surface (0-6 inches) soils by the Casagrande plasticity chart, showing that most points in the soils of Hawaii that were studied fell below the arbitrarily set "A" line, and beyond the 50 percent moisture content line.

drastically with traffic. The resulting increase in bulk density reduced soil moisture. The reduction of soil moisture with increase in bulk density was significant for the Hydrol Humic Latosols in which water is not held in the interstices of the soil particles. In other soils, the increase in bulk density significantly lowered porosity, but increased the water held at field capacity.

Soil Consistency

Ash-formed soils on the island of Hawaii have the highest plastic limits, the wet area soils of Kauai and Oahu have intermediate values, and the dry area soils on the three islands generally have lower values of plastic limit.

Soils should not be disturbed at or beyond their plastic limit because puddling occurs at these moisture contents. Plasticity is not as important in forest soils as in agricultural soils under intense cultivation. Nevertheless forest soils, if highly plastic, can be damaged by disturbance during wet periods. Soils disturbed at or beyond their liquid imit will behave as a liquid.[5] Data on soil consistency (table 3) can be used as a guide to tillage as well as to logging practices.

The liquid limit and the plasticity index of the surface (0 to 6 inches) soils were plotted on the Casagrande plasticity chart[6] by extending the range of plasticity index and liquid limit. Most soils were in the MH class (fig. 4). "C" represents clay soils, "M" silty soils, and "O" organic soils. "L" represents liquid limits below 50, and "H" above 50. The "A" line represents the empirical boundary between the various plasticity groups. "MH", therefore, means that the soil material behaves as though it was predominantly silty with liquid limit above 50.

The Dark Magnesium Clay soil and one of the Alluvial soils have the lowest plastic limits at the 0- to 6-inch depth. These soils should not be dis-

[5]For trafficability, the liquid and plastic limits of the 6- to 12-inch layer are critical (Carlson and Horton 1957).

[6]U.S. Army Corps of Engineers Waterways Experiment Station. The unified soil classification system. Tech. Memo. 3-357, 30 pp., illus. 1953.

turbed when the moisture content exceeds their plastic limit (25 percent by dry weight). The highest plastic limit (117 percent) was found in the Latosolic Brown Forest soil. This soil would not be easily compacted except at very high moisture contents, above 117 percent moisture (by dry weight).

Organic Matter, pH, Specific Gravity

Pasture and forest soils had the highest average organic matter contents. The average pH for soils under all types of land use ranged from medium acid to neutral (table 2). The greater range in pH of forest soils indicates a greater range of rainfall and elevation between sampling sites. Kanehiro et al. (1951) reported that soils of the dry lowland areas tend to increase in acidity during hot summer months, but upland soils showed no increase in pH during summer months. There are no pronounced seasonal leaf falls, and the contribution of basic ions from leaves may not be significant.

The specific gravity of soil particles averaged 2.86, which is in contrast to the low bulk densities of some soils (table 2).

Table 3. Atterberg limits of selected soils in Hawaii

Great soil group	Site number	0- to 6-inch layer			6- to 12-inch layer		
		Liquid limit	Plastic limit	Plasticity index	Liquid limit	Plastic limit	Plasticity index
		Percent by dry weight			Percent by dry weight		
Alluvial	1	66	34	32	68	34	34
	4	94	45	49	85	41	44
	188	53	25	28	52	23	29
Dark Magnesium Clay	189	70	25	45	72	25	47
Gray Hydromorphic	5	89	38	51	96	39	57
	13	92	38	54	108	41	67
Humic Ferruginous Latosol	14	46	42	4	50	38	12
	186	59	36	23	62	38	24
	187	53	30	23	66	32	34
	198	92	54	38	110	57	53
	199	88	49	39	81	45	36
Humic Latosol	8	128	86	42	213	142	71
	9	116	82	34	143	112	31
	15	88	60	28	89	64	25
	16	54	36	18	55	32	23
	191	114	57	57	112	57	55
	192	129	61	68	104	55	49
	193	153	86	67	133	76	57
	194	116	73	43	101	65	36
	201	114	84	30	136	98	38
Hydrol Humic Latosol	6	113	87	26	144	109	35
	195	183	103	80	251	172	79
	196	254	102	152	328	193	135
	197	125	98	27	160	101	59
Latosolic Brown Forest	7	137	117	20	222	181	41
	12	90	89	1	110	101	9
	200	102	68	34	141	80	61
Low Humic Latosol	2	68	32	36	71	32	39
	3	65	32	33	66	33	33
	184	77	42	35	69	43	26
	185	62	35	27	64	38	26
	190	53	34	19	64	38	26
Reddish Brown	11	68	37	31	68	41	27
Reddish Prairie	10	109	80	29	130	118	12

Soil Moisture Constants and Land Use

Soil moisture constants, total pore volume, and aeration of soils were compared under the four categories: forest, pasture, cultivated area, and idle grassland (fig. 3 and table 1).

The data indicate that average total pore volume was highest under forest cover, but the difference with the other categories were not statistically significant (table 1) .

Infiltration rates were not measured, but forest soils probably have a greater infiltration capacity[7] as indicated by average higher total pore volume and large pore volume. By the same assumption pasture soils have a higher infiltration capacity than cultivated or idle land soils. These differences may indicate that some pastures are not heavily grazed. Also, inherent properties of the soil as well as land use influence infiltration capacity.

No significant difference in field capacity among the four categories of land use was found.

Average available moisture was highest in the forest soils and lowest in the pasture soils. The difference of 9 percent between the forest and pasture is significant at the 10 percent level. No significant differences in average available moisture existed between forest and cultivated soils or between forest and idle grassland soils.

The average volume of large pores was highest in the forested soils and lowest in the cultivated and idle grassland soils. The differences compared to forest soils are statistically significant.

The average wilting point was lowest for soils under forest, higher for idle grassland and cultivated land, and highest under pastures. The difference in wilting point of 10 percent moisture (by volume) between forest and pasture and a difference of 7 percent moisture (by volume) between forest and cultivated soils were highly significant at the 1 percent level (table 1).

Individual differences in total pore space, available water, unavailable water, large pores, and wilting point are shown in figure 3 and table 5 (appendix).

Total pore volume is generally lower for Low Humic Latosols and Alluvial soils and highest in Hydrol Humic Latosols. Available moisture capacity is higher under Hydrol Humic Latosols and some Latosolic Brown Forest soils. The volume of large pores is lower for Hydrol Humic Latosols, Alluvial, Gray Hydromorphic, and Dark Magnesium Clay soils. Eleven soils had a wilting point of greater than 30 percent moisture (by volume) of which 7 were under forest cover, 1 under cultivation and 3 in idle grassland. Soils with higher wilting points (40 percent by volume) are the Gray Hydromorphics and some of the Humic Latosols.

[7]The maximum rate at which water can enter the soil surface (Lassen et al. 1952).

Summary

- Most surface soils in Hawaii are fine textured and composed of aggregates of clay and colloidal particles. Data show that forest soils have structures which favor infiltration and percolation of water.
- Forest soils were found to have the lowest average bulk density; pasture and cultivated soils, as expected, have higher bulk densities. Except for some of the ash soils of Hawaii, bulk density tended to decrease as rainfall increased.
- Soils studied on the island of Hawaii have the highest plastic limits, the wet area soils of Kauai and Oahu have intermediate values, and the dry area soils on the three islands have lower values of plastic limit. The majority of the soils have liquid limits above 50 and therefore should behave like a silty soil or clay soil relatively high in organic matter.
- Pasture and forest soils have the highest average organic matter content.
- The specific gravity of soil particles of all soils sampled averaged 2.86.
- Average total pore volume is highest under forest cover, although the difference from other categories was not statistically significant.
- The average volume of large pores is highest in the forest soils and lowest in the cultivated and idle grassland soils.
- Average field capacity is about the same under each of the four land use categories.
- Average available moisture is highest in the forest soils and lowest in the pasture soils.
- The average wilting point of the soil is lowest under forest and highest under pasture.

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Appendix

Table 4. Description of soils and sampling sites, by land use

Site number	Great soil group	Soil type field classification[1]	Texture (Lab. classification)[1] 0 to 6 inches	Texture (Lab. classification)[1] 6 to 12 inches	Slope	Elevation	Position	Annual rainfall	Location	Vegetation
					Percent	Feet		Inches		
				FOREST						
11	Reddish Brown	Waikaloa sicl	l	sl	8	2,650	Upland upper slope	15	Keamoku, Hawaii	Eucalypts
12	Latosolic Brown Forest	Hanaipoe sil	sil	sil	8	4,750	Upland upper slope	20	Waikii, Hawaii	Eucalypts
14	Humic Ferruginous	Mahana vfsl	c	c	13	2,250	Upland upper slope	40	Kokee, Kauai	Rice grass, pukiawe, silk-oak
15	Humic Latosol	Paaiki sicl	c	c	28	3,600	Upland lower slope	100	Kokee, Kauai	Koa, Monterey cypress, Moreton-Bay-chestnut
16	Humic Ferruginous Latosol	Paaiki sicl	sicl	c	3	2,940	Upland ridge	75	Kaweki, Kauai	Yellow foxtail, eucalypts
184	Low Humic Latosol	Wahiawa sic	c	c	2	840	Upland upper flat	40	Wahiawa, Oahu	Eucalypts
187	Humic Ferruginous Latosol	Leilehua sic	sic	c	43	1,240	Upland upper slope	75	Helemano, Oahu	False staghorn fern, 'ohi'a-lehua
192	Humic Latosol	Iolekaa sic	c	c	27	1,150	Upland upper slope	150	Nuuanu, Oahu	Bamboo
193	Humic Latosol	Iolekaa sic	cl	cl	18	1,100	Upland upper slope	150	Nuuanu, Oahu	Robusta eucalyptus
194	Humic Latosol	Kahanik1 sicl	c	c	18	1,280	Upland upper slope	100	Tantalus, Oahu	Australian redcedar
196	Hydrol Humic Latosol	Akaka sicl	c	c	18	1,800	Upland slope	250	Honomu, Hawaii	Robusta eucalyptus
				PASTURE						
4	Alluvial	Hanalei c	cl	sic	0	20	Bottom land flat	50	Olomana, Oahu	Panicum grass
7	Latosolic Brown Forest	Maile sil	cl	c	17	3,400	Upland upper slope	75	Umikoa, Hawaii	Dallis, panicum, rattail grass
8	Humic Latosol	Niupea sicl	c	c	15	2,300	Upland lower slope	100	Kukaiau, Hawaii	Hilo, kikuyu, molasses grass
9	Humic Latosol	Kukaiau sicl	c	c	10	1,700	Upland slope	75	Honokaa, Hawaii	Panicum, hilo grass
190	Low Humic Latosol	Alaeloa sic	c	c	15	200	Upland lower slope	40	Waimanalo, Oahu	Guava, molasses grass, kikuyu grass
199	Humic Ferruginous Latosol	Puhi sicl	c	c	3	250	Upland flat	75	Waialua, Kauai	Yellow foxtail, glenwood, honohono grass
				CULTIVATED AREAS						
1	Alluvial	Haleiwa sic	cl	cl	4	20	Bottom land depression	30	Waialua, Oahu	Sugar cane
2	Low Humic Latosol	Waialua c	sic	sic	4	30	Bottom land upper slope	30	Waialua, Oahu	Sugar cane
3	Low Humic Latosol	Waialua c	sic	sic	4	30	Bottom land upper slope	30	Waialua, Oahu	Sugar cane
6	Hydrol Humic Latosol	Hilo sicl	c	c	3	350	Upland lower slope	150	Wainaku, Hawaii	Sugar cane
13	Gray Hydromorphic	Nohili c	c	c	2	15	Bottom land flat	20	Kekaha, Kauai	Sugar cane
185	Low Humic Latosol	Wahiawa sic	c	c	2	840	Upland flat	40	Wahiawa, Oahu	Pineapple
191	Humic Latosol	Iolekaa sic	c	c	12	200	Terrace slope	75	Kaneohe, Oahu	Panana, panicum grass
197	Hydrol Humic Latosol	Hilo sicl	c	c	5	300	Upland lower slope	140	Honomu, Hawaii	Sugar cane
200	Latosolic Brown Forest	Waihaka vfsl	l	l	8	3,250	Upland upper slope	75	Pahala, Hawaii	Sugar cane
201	Humic Latosol	Niupea sicl	l	cl	15	2,300	Upland upper slope	100	Kukaiau, Hawaii	Sugar cane
				IDLE GRASSLAND						
5	Gray Hydromorphic	Laie c	c	c	0	70	Bottom land flat	40	Waimanalo, Oahu	Panicum grass
10	Reddish Prairie	Puukapu sil	l	sil	3	2,850	Upland flat	36	Kamuela, Hawaii	Bermuda, honono grass
186	Humic Ferruginous Latosol	Manana sic	c	c	4	1,280	Upland ridge	75	Helemano, Oahu	Dallis, rice, broomsedge, carpet grass
188	Alluvial	Waianae	cl	sic	0	30	Bottom land flat	20	Lualualei, Oahu	Swollen fingergrass, plush grass, buffel grass
189	Dark Magnesium Clay	Lualualei c	sic	c	0	40	Terrace flat	20	Lualualei, Oahu	Swollen fingergrass, plush grass, buffel grass, klu
195	Hydrol Humic Latosol	Akaka sicl	c	c	12	1,750	Upland lower slope	250	Honomu, Hawaii	Rice, hilo grass, sugar cane
198	Humic Ferruginous Latosol	Kapaa sicl	c	c	5	550	Upland ridge	80	Waialua, Kauai	Yellow foxtail, glenwood grass

[1] l: loam; sl: sandy loam; sil: silt loam, c: clay; sic: silty clay; sicl: silty clay loam; cl: clay loam; vf: very fine.

Table 5. Properties of selected soils in Hawaii, by great soil group

Soil type[1]	Site no.	Soil layer (inches)	Total pore space percent by volume	Large pores, 0 atm. minus .06 atm.	Soil moisture in percent by volume: 0 atm.	.06 atm.	3 atm.	15 atm.	Available moisture .06-15 atm.	Bulk density g/cc	Specific gravity g/cc	Organic matter by weight percent	pH	Mechanical analyses by weight percent: Sand	Silt	Clay
ALLUVIAL																
Haleiwa sic	1	0- 6	61.0	4.6	60.9	56.3	41.0	34.1	22.2	1.14	2.92	2.0	8.0	24	41	35
		6-12	61.2	5.5	62.2	56.7	42.2	35.8	20.9	1.14	2.94	2.0	8.0	20	41	39
Hanalei c	4	0- 6	61.0	5.7	61.5	55.8	45.0	37.6	18.2	1.06	2.72	5.8	7.0	23	40	37
		6-12	57.3	2.7	56.3	53.6	48.0	40.0	13.6	1.20	2.81	2.0	6.5	16	41	43
Waianae c	188	0- 6	58.5	15.4	61.0	45.6	33.6	23.4	22.2	1.22	2.94	2.2	8.0	21	47	32
		6-12	52.7	9.4	55.1	45.7	35.5	27.1	18.6	1.42	3.00	1.2	8.0	9	42	49
DARK MAGNESIUM CLAY																
Lualualei c	189	0- 6	65.3	8.1	54.3	46.2	38.0	26.2	20.0	1.04	3.00	1.1	8.0	14	42	44
		6-12	58.7	4.8	62.7	57.9	45.1	30.4	27.5	1.24	3.00	1.0	8.0	9	39	52
GRAY HYDROMORPHIC																
Laie c	5	0- 6	61.6	7.0	64.5	57.5	45.9	36.2	21.3	1.12	2.92	3.9	8.0	15	34	51
		6-12	59.0	2.9	63.2	60.3	52.4	40.4	19.9	1.17	2.85	2.8	8.0	14	34	52
Nohili c	13	0- 6	67.6	12.4	65.3	52.9	39.4	32.0	20.9	.92	2.84	2.4	8.0	8	32	60
		6-12	63.4	4.6	63.9	59.3	54.5	38.0	21.3	1.00	2.73	2.2	8.0	6	28	66
HUMIC FERRUGINOUS LATOSOL																
Kapaa sicl	198	0- 6	70.1	15.2	68.2	53.0	42.6	32.3	20.7	.91	3.04	15.0	5.5	20	29	51
		6-12	74.0	9.6	69.0	59.4	53.4	39.0	20.4	.80	3.08	9.2	5.0	11	20	69
Leilehua sic	187	0- 6	67.5	17.7	67.9	50.2	33.8	24.1	26.1	1.10	3.38	4.8	5.0	11	49	40
		6-12	68.2	17.3	65.6	48.3	38.6	31.4	16.9	1.09	3.43	3.6	4.5	7	25	68
Mahana vfsl	14	0- 6	77.6	15.1	68.6	53.5	20.7	17.0	36.5	.78	3.48	11.5	5.5	16	39	45
		6-12	75.4	11.4	69.2	57.8	28.0	24.5	33.3	.87	3.54	7.7	5.0	14	32	54
Manana sic	186	0- 6	62.8	13.6	62.2	48.6	42.6	34.6	14.0	1.15	3.09	3.6	7.0	6	35	59
		6-12	60.8	12.0	60.0	48.0	42.4	38.2	9.8	1.20	3.06	3.0	5.0	5	32	63
Puhi sicl	199	0- 6	67.5	13.8	65.4	51.6	40.7	31.8	19.8	.96	2.95	6.3	6.0	16	26	58
		6-12	66.9	17.9	62.4	44.5	35.6	32.4	12.1	1.01	3.05	4.1	5.0	17	28	55
HUMIC LATOSOL																
Iolekaa sic	191	0- 6	68.8	11.4	69.1	57.7	47.3	38.4	19.3	.89	2.85	4.7	4.5	6	30	64
		6-12	65.4	5.6	67.0	61.4	54.2	49.2	12.2	.98	2.83	1.9	4.5	2	29	69
Iolekaa sic	192	0- 6	74.7	20.0	75.9	55.9	46.1	30.5	25.4	.68	2.69	5.2	7.0	17	37	46
		6-12	71.3	24.3	74.8	50.5	41.9	32.8	17.7	.81	2.82	3.8	6.0	18	24	58
Iolekaa sic	193	0- 6	76.1	9.2	68.5	59.3	52.0	37.6	21.7	.64	2.68	6.8	7.5	41	23	36
		6-12	73.8	10.6	74.6	64.0	50.3	39.3	24.7	.73	2.79	3.5	5.5	39	24	37
Kahaniki sicl	194	0- 6	75.9	15.9	75.5	59.6	45.8	33.9	25.7	.68	2.82	6.8	6.5	29	24	47
		6-12	71.1	9.5	69.2	59.7	48.2	39.0	20.7	.86	2.98	5.8	6.0	28	32	40
Kukaiau sicl	9	0- 6	72.4	17.0	74.9	57.9	46.7	39.0	18.9	.71	2.57	6.1	6.0	19	35	46
		6-12	80.4	13.8	82.6	68.8	52.7	43.0	25.8	.53	2.70	5.9	5.5	25	31	44
Niupea sicl	8	0- 6	79.0	27.3	87.8	60.5	42.4	32.8	27.7	.55	2.62	6.8	6.0	29	28	43
		6-12	81.4	13.7	82.7	69.0	69.2	54.1	14.9	.49	2.63	6.3	6.0	8	30	62
Niupea sicl	201	0- 6	73.1	20.8	73.1	50.3	40.0	30.5	19.8	.72	2.68	17.1	5.5	42	35	23
		6-12	78.2	14.9	82.2	67.3	39.6	30.0	37.3	.57	2.62	19.7	5.5	31	33	36
Paaiki sicl	15	0- 6	74.9	21.6	67.7	46.1	29.3	26.6	19.5	.70	2.79	5.9	6.0	31	27	42
		6-12	75.1	20.0	70.4	50.4	37.1	32.8	17.6	.72	2.89	6.6	5.0	17	23	60
Paaiki sicl	16	0- 6	69.8	22.0	67.1	45.1	28.6	21.2	23.9	1.02	3.38	6.8	6.0	15	47	38
		6-12	70.6	17.2	66.2	49.0	30.3	23.5	25.5	.98	3.33	3.8	5.5	7	36	57
HYDROL HUMIC LATOSOL																
Akaka sicl	195	0- 6	86.1	8.2	87.8	79.6	44.3	27.5	52.1	.39	2.80	5.3	5.5	27	17	56
		6-12	86.1	4.6	98.9	94.3	67.2	46.1	48.2	.38	2.74	6.3	6.0	21	25	54
Akaka sicl	196	0- 6	86.0	7.2	88.5	81.3	64.7	32.6	48.7	.37	2.64	10.0	6.0	4	21	74
		6-12	89.5	5.0	95.3	90.3	69.0	43.1	47.2	.30	2.85	6.2	5.0	4	22	74
Hilo sicl	6	0- 6	86.4	8.2	87.8	79.6	44.3	27.5	52.1	.39	2.86	5.5	5.5	21	33	46
		6-12	79.4	8.2	82.8	74.6	58.0	37.9	36.7	.59	2.87	5.4	5.5	20	33	47
Hilo sicl	197	0- 6	78.8	11.2	81.0	69.8	50.6	34.9	34.9	.58	2.74	5.7	5.5	27	30	43
		6-12	82.7	10.0	82.4	72.4	54.9	32.3	40.1	.48	2.77	6.4	5.0	24	30	46
LATOSOLIC BROWN FOREST																
Hanaipoe sil	12	0- 6	79.0	12.5	75.9	63.4	27.1	20.6	42.8	.54	2.57	16.1	7.0	35	58	7
		6-12	80.4	8.3	78.8	70.5	35.0	28.6	41.9	.54	2.75	7.7	8.0	32	58	10
Maile sil	7	0- 6	83.4	21.0	80.1	59.1	34.9	29.2	29.9	.43	2.59	27.3	6.0	36	36	28
		6-12	86.0	16.7	83.4	66.7	56.3	50.8	15.9	.35	2.50	27.0	6.0	18	23	59
Waihaka vfsl	200	0- 6	74.3	15.4	73.6	58.2	37.9	22.7	35.5	.70	2.72	6.8	6.5	43	38	19
		6-12	80.4	12.3	91.3	79.0	47.6	28.9	50.1	.53	2.70	7.5	6.5	36	40	24
LOW HUMIC LATOSOL																
Alaeloa sic	190	0- 6	60.3	17.1	60.8	43.7	33.4	28.7	15.0	1.18	2.97	4.3	6.0	10	34	56
		6-12	58.2	11.3	57.9	46.6	40.3	35.1	11.5	1.23	2.94	3.0	5.0	6	21	73
Wahiawa sic	184	0- 6	65.0	21.0	64.4	43.4	36.1	29.2	14.2	.96	2.74	4.2	7.0	27	27	46
		6-12	64.0	16.7	64.8	48.1	33.8	29.1	19.0	1.00	2.78	2.5	6.0	17	31	52
Wahiawa sic	185	0- 6	60.1	19.4	63.5	44.1	33.7	30.4	13.7	1.13	2.83	1.6	4.5	10	25	65
		6-12	59.2	13.4	59.4	46.0	38.4	33.2	12.8	1.16	2.84	1.7	5.0	16	16	68
Waialua c	2	0- 6	61.4	8.7	56.9	48.2	40.5	32.7	15.5	1.12	2.90	1.6	7.5	17	37	46
		6-12	57.9	3.0	55.6	52.6	44.5	36.9	15.7	1.23	2.92	1.9	7.0	17	36	47
Waialua c	3	0- 6	63.5	17.1	61.1	44.0	33.9	29.2	14.8	1.05	2.88	2.4	7.0	8	44	48
		6-12	60.0	8.9	58.8	49.9	42.5	34.6	15.3	1.16	2.90	2.3	7.0	7	43	50
REDDISH BROWN																
Waikaloa sicl	11	0- 6	72.5	7.6	59.4	51.8	27.5	21.0	30.8	.72	2.62	8.0	7.0	51	40	9
		6-12	73.0	11.3	73.3	62.0	29.1	24.3	37.7	.74	2.74	6.1	8.0	60	35	5
REDDISH PRAIRIE																
Puukapu sil	10	0- 6	78.6	21.8	76.9	55.1	35.8	25.8	29.3	.55	2.57	17.5	8.0	39	49	12
		6-12	93.3	12.2	81.2	69.0	38.5	33.3	35.7	.45	2.70	13.6	8.0	38	52	10

[1] l: loam; sl: sandy loam; sil: silt loam; c: clay; sic: silty clay; sicl: silty clay loam; cl: clay loam; vf: very fine.