

COMPARATIVE EFFECTS OF FOREST AND PASTURE ON SOME
PHYSICAL PROPERTIES OF LATOSOLIC SOILS

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ABSTRACT

A study was made to determine; some of the physical properties of two Hydrol Humic Latosol soils, the interrelationships of the physical properties measured, the relationships between land use and the variation in the physical ^{properties} measured, and the possible effects of these properties on the difference in productivity of stands of flooded-gum eucalyptus (E. saligna) on these soils.

Two soil types, Benokas and Pohakas were selected for the reason that both provided areas supporting a high and low productivity of stands of E. saligna and an adjacent pasture.

The results of this study show that a significant correlation exist between aggregate stability and organic matter in the forest plots. No significant correlation has been observed in the pasture plots. The lack of significance in the correlation coefficients in two of the forest and most of the pasture plots may be due to the high iron and aluminum oxides. In these soils, Benokas and Pohakas the iron and aluminum oxides probably play a greater role in stabilizing the aggregates formed than the cementation effects of organic matter.

Both the forest and pasture plots show a significant correlation (1% level) between organic matter and soil moisture content and between soil dry bulk density and soil moisture content.

A conclusion can be drawn from the foregoing interrelationships of some of the soil physical properties studied that in these soils the organic matter content ^{has} have a greater role in aggregation than in stabilizing the soil aggregates formed. This is indicated by the low absolute

value of the correlation coefficients between aggregate stability and organic matter but a high (significant) correlation coefficients between organic matter and soil moisture content. Also, the soils studied have a high percent aggregate stability and high organic matter content.

The results further show that there are no significant differences in the soil physical properties studied between the forest and pasture plots except in the percent aggregate stability. The high aggregate stability in the pasture is significant considering that it was on the land only eight years compared to twenty-eight years for the forest. The specific role played by the pasture in the formation of water-stable aggregates could not be determined in this study.

A conclusion can be drawn that, factors other than organic matter have a profound influence on aggregate stability. The higher per cent aggregate stability under the pasture is attributed to the effect of grass roots. Also, the high percent aggregate stability in the soils studied is attributed mainly to the high iron and aluminum oxides.

The results and observations show that putting the soils studied under pasture is better than putting it under forest. Aside from the greater beneficial effect of grasses on aggregate stability it is easier to establish on the land and also the benefits are derived much earlier than forest.

Although the high tree productivity plots have a higher aggregate stability and available moisture than the low tree productivity plots it is suspected that the cause for the low productivity in F # 2 is different from that in F # 4. The wetter condition of F # 2 as well as the drier condition of F # 4 may be unfavorable to the growth of trees. Furthermore, F # 4 has a red cap (6" red layer) and a shallow profile.

I. INTRODUCTION

The purpose of this research has been to determine;

- a) Some of the physical properties of two Hydral Hemic Latosol soils under forest and under pasture.
- ✓ b) The interrelationships between the physical properties measured.
- c) The relationships between land use and the variation in the physical properties measured.
- ✓ d) The possible effects of these properties on the difference in productivity of stands of flooded-gum eucalyptus (E. saligna) on these soils.

There is a general belief that soil management practices affect soil constitution. Wilson (37) reported that cropping system, tillage practice, and method of taking and handling samples before analysis all affect the size, distribution and stability of soil aggregates.

Different cover crops are known to have different effects on soil constitution. Winter cover crops increase the percentage of soil pores, total porosity and ease of penetration, Lutz et al (19). The number of water-stable aggregates are significantly increased by hairy vetch preceding cotton, Patrick (23) and Seale et al (6). Aggregation index is higher after bromegrass than after alfalfa, Barber (3).

Crop rotation has been demonstrated to improve soil constitution while continuous cropping has the opposite effect. Gramineous summer and winter green manures improved infiltration relative to fallow on soils of medium to fine textures, Williams and Donsen (36), Rye and Green-

land (22) stated that the physical properties of the soil surface horizon may be greatly improved by forest or grass fallow but it is rapidly reduced by cropping. The average state of aggregation of cultivated soils was 70% that of the uncultivated soils as determined by Bertramson and Rhodes (7) on a heavy soil in Eastern Nebraska.

Tillage practices have been found by many workers generally to cause continued decrease in soil aggregation, Baver (5), Beale et al (6) and Moldenhauer et al (21). Elder (13) had reported that after two years of perennial grass a single tillage operation on a single row-cropping season formed a compacted zone.

Baver (5) stated that lime has no direct effect on soil structure; manure has a favorable effect upon granulation and aeration but the effect is not permanent; little is known of the direct effect of fertilizer on soil structure except that large applications of sodium salts causes aggregate dispersion.

YANA and HPAH synthetic soil conditioners were found to be significant in increasing the mean-weight diameter and percent aggregation, Haise et al (16). Cut-back asphalt and asphalt-in-water emulsion films were found by Chapil (10) to be completely effective initially (two weeks to two months) against wind erosion.

Many mulching materials have been found to improve soil structure. Wheat straw formed more large aggregates than corn straw, Stauffer (31). Ground wheat straw and juniper wood significantly increased aggregation, Laws (18). Screnives (30) reported that soil detachment was effectively checked by two tons of oat straw mulch.

In cropping by ^{shifting} cultivation (patch agriculture), clearing and

burning of the forest expose the soil surface to sun and rain; deterioration of soil constitution is rapid until the crop forms cover. The effect is much pronounced when clearing savanna vegetation, Nye and Greenland (22).

Forest and pasture prevent or reduce floods by keeping watershed soils in a condition to absorb large quantities of water rapidly, Yamamoto and Duffy (41). They reported that the top foot of forest soils had more large pores and higher water-holding capacities than soils under cultivation, pasture or idle grassland. Yamamoto (39,40) found that forest soils maintained fairly uniform moisture content throughout the year. He also found that forest soils generally had lower bulk densities than other soils in Hawaii. Aggregates formed under rotation meadow and rotation with corn are less stable than aggregates under continuous blugrass, Wilson et al (37).

Soil erosion in general is affected by climate, topography, vegetation, soil and human activities. The interrelationships between these factors may be shown as; $E = f(C, T, V, S, H)$. The effect of soil factors on erosion is summarized by the relationship; $E = \frac{DK}{A^2 P}$ where K is the proportionality constant due to the other erosion factors, A is the infiltration capacity of the soil surface, F is the soil profile permeability, D is the index of dispersion and p is the size of the soil particles.

Elison (14) has shown that soils are not most easily transportable when completely dispersed- a limited amount of aggregation may increase their transportability and aggregation processes may increase detachability. Wittman and Masurek (38) found that as the diameter of

aggregates decreased their stability increased. Large soil particles underwent less transport by raindrop impact than small particles but smaller particles were compacted to seal the surface resulting in the formation of a film of water on the soil that absorbed much of the raindrop energy and reduced the amount of transport by splashing raindrops, Ekern (12).

The infiltration capacity of a given soil is affected by profile permeability, conditions of the soil surface and moisture content of the soil; an open permeable surface increase soil infiltration and decrease runoff while a compact surface causes low infiltration rates and high runoff. Infiltration rate of the rainfall on moist soil is considerably slower than on dry soils, Bayer (5). Discker (11) reported that if the soil is loose and granular there is little erosion at the beginning of a storm. But as rainfall intensity exceeds infiltration capacity, soil losses are high due to the absence of cementation on the granules. As particle size decreased infiltration rate decreased, Grant and Struob-tmeyer (16).

Textural class of soils is closely related to erodibility; clay soils are of high transportability and low detachability- sandy soils are often the opposite, Ellison (24).

The physical properties of soils as indicated by percolation rate, suspension percentage and dispersion ratio appear to give a good index of the relative erodibility of soils, Peole (24)

The foregoing interrelationships of management practices and physical properties of soils, and that between the physical properties of soils and soil erodibility may not hold true in the soils under

study. The Hydrol Humic Latosols are derived from volcanic ash. They are found in regions of high rainfall (100-500") and they have clays which are largely composed of iron and aluminum oxides. These soils dehydrate irreversibly, are high in organic matter throughout the solum and have very low base saturation. Their bulk densities are always less than 0.9 .

The Hydrol Humic Latosols have many peculiar properties, e.g. dehydrate irreversibly and have very high moisture contents. Yamamoto (40) found that 1 lb of Akaka soil, a Hydrol Humic Latosol, can hold 4 lbs of water. The high moisture content will cause the strength to decrease if subjected to repeated pressure (low remaining index, 0.40). Trouse and Lambert (33) reported that some Hydrol Humic Latosols of Hawaii will compact and puddle drastically with traffic, and the soil moisture is reduced as the bulk density increases. In other soils, the increase in bulk density lowered the porosity significantly but increased the water held at field capacity.

The only studies made on the physical properties of Hawaiian forest soils were undertaken by Yamamoto (1962, 1963). He reported that a number of soils under forest had better physical conditions than soils under pasture and cultivation. His study was based only on the surface soils (to the 12-inch depth).

II. MATERIALS AND METHODS

Soil profiles were sampled in triplicate in four 1/10 acre plots of E. saligna and again on adjacent pasture on the same soil type. The four E. saligna plots have been selected to approximate those studied by Pickford and Le Barren (25) and represent two soil types (Honokaa and Pohakaa) and two levels of tree productivity (high and low) on each soil type, as shown on figure 1. This arrangement allows the determination of differences between tree productivity in two categories (Honokaa and Pohakaa).

Each of the plots selected under E. saligna is located within two hundred yards of the forest boundary, and adjacent to pastured land on the same soil type. The plots selected under pasture are about two hundred yards from the forest edge. The two levels of XMM productivity were not duplicated under pasture because of the difficulty in determining grass productivity.

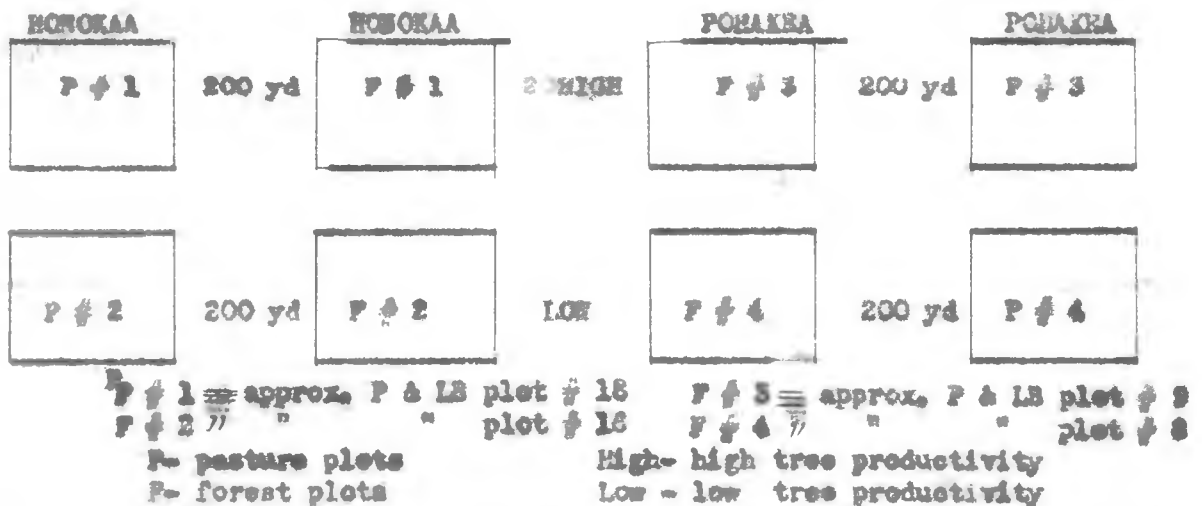


Fig. 1. Schematic diagram of the sampled forest and pasture plots.

Plot Description

F # 1

Series, type and phase --- Honokaa Silty Clay Loam
 Locality ----- Honokaa, P.H., Kaneo, Hawaii
 Productivity rating ----- High, 2.7 M bd ft /A/yr (Plot # 18, P & LB)
 Slope ----- 12%
 Soil ----- Intergrade (HHL-LBF), from ash
 Rainfall ----- 100"
 Vegetation ----- E. saligna (28 yrs old, 1965)

F # 2

Series, type and phase --- Honokaa Silty Clay Loam
 Locality ----- Approx. 1/2 mile from F #1
 Productivity rating ----- Low, 0.1 M bd ft /A/yr (Plot # 16, P & LB)
 Slope ----- 5%
 Soil ----- Intergrade (HHL-LBF), from ash
 Rainfall ----- 100-200"
 Vegetation ----- E. saligna (28 yrs old, 1965)

F # 3

Series, type and phase --- Pohakua Silty Clay Loam
 Locality ----- Hanalei P.H., Kalaheo, Hawaii
 Productivity rating ----- High, 3.2 M bd ft/A/yr (Plot # 9, P & LB)
 Slope ----- 10-15%
 Soil ----- Intergrade (HHL-LBF), from ash
 Rainfall ----- 100"
 Vegetation ----- E. saligna

P # 4

Series, type and phase --- Pohakoa Silty Clay Loam
Locality ----- Hanakua F.R., Pauilo Homestead, Hawaii
Productivity rating ----- Low, 0.5 M bd ft/A/yr (Plot # 8, P # 18)
Slope ----- 8%
Soil ----- Intergrade (HHL-LSP), from ash
Rainfall ----- 100"
Vegetation ----- E. saligna

The forest and pasture plots sampled are located on the Northern Slopes of Mt. Mauna Kea on the Island of Hawaii. Both the Hanakua and Pohakoa plots lie between the 2000' and 3000' contours as shown on the map of the growth study plots of Fickford and LeBarron (25).

P # 1

Series, type and phase --- Hanakua Silty Clay Loam
Locality ----- Hanakua F.R. , Maao, Hawaii
Slope -----
Soil ----- Intergrade (HHL-LSP), from ash
Rainfall ----- 100"
Vegetation -----

P # 1 is located in the old Ahualoa Homestead and probably cleared of native chia, kea and tree ferns many years ago. Mr. Penhallow in 1857 cleared the area which was then thick with guava trees that were as tall as 15 feet and ^a few big chia trees. The area was cleared by a deser[?], ^{ed} disc and harrowed twice. It was planted to pangola, white clover and

desmodium intortum . Fertilizer (11-14) was applied at the rate of 300 lbs per acre at the time of planting. The foregoing information was supplied by Mr. Sato, H. H. of USDA SOS Hawaii.

P # 2

Series, type and phase --- Honokaa Silty Clay Loam
Locality ----- Approx. 1/2 mile from P # 1
Slope -----
Soil ----- Intergrade (HHL-LBF), from ash
Rainfall ----- 100-200"
Vegetation -----

P # 2 is located in the same area as P # 1, approximately one-half way. Received the same treatment as P # 1.

P # 3

Series, type and phase --- Pohakaa Silty Clay Loam
Locality ----- Hamakua F.R., Kakaiahi, Hawaii
Slope -----
Soil ----- Intergrade (HHL-LBF), from ash
Rainfall ----- 100"
Vegetation -----

P # 4

Series, type and phase --- Pohakaa Silty Clay Loam
Locality ----- Hamakua F.R., Panulo, Hawaii
Slope -----
Rainfall ----- 100"
Vegetation -----

NOTE: See Appendix for profile description of the sampled plots.

Methods

Aggregate Stability

Aggregate stability values were obtained by the wet-sieving method as modified by Yoder (42). The water containers were filled with tap water just below the screen (just enough to release the air bubbles) of the topmost sieve when it is at the top-lead-center. 25g of soil sample that has been passed through a 3-mesh sieve (field moist condition) was dumped in one instant in the topmost sieve and wetted by capillary action. The sample was then wet-sieved for 30 minutes using a stroke of 2 inches and a frequency of 30 oscillations per minute. Aggregates retained on the 10, 20 and 40-mesh sieves were collected, oven-dried, weighed and calculated on an oven-dry basis as percent of total stable aggregates.

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Moisture Equivalent

20g of soil sample (field-moist through 3-mesh) was saturated overnight in a moisture box. It was allowed to drain for 30 minutes over a damp newspaper, then centrifuged for 30 minutes at 2440 rpm (equivalent to a force 1000 times that of gravity). It was then oven-dried and the moisture retained calculated. Richards and Weaver (26) concluded that on the average, the moisture equivalent have a fairly close relation to the moisture retained \bar{e} at the moisture tension of 345 cm. of water ($1/3$ atsp).

Soil Organic-matter Content

The organic matter content of the soil was determined by the

Walkley-Black method (34). Field-moist sample was oven-dried and ground to pass through a 60-mesh sieve (organic carbon is not destroyed by oven drying). Soil sample was digested using the heat of reaction between $K_2Cr_2O_7$ and H_2SO_4 . Percent organic matter equals 1.724 times the percent organic carbon (organic matter assumed to be 58% carbon). This method is satisfactory for soils known not to contain appreciable amounts of chlorides, nitrates and carbonates and was found to be in agreement with the results determined by dry combustion, Natabe, R. (private communication).

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Moisture Content at 4-bar

The moisture retained at 4-bar was obtained by using the pressure membrane apparatus following standard procedures, Richards (27). Only modification made in the procedure was the use of field-moist sample instead of the air-dry sample.

Available Moisture

The available moisture was obtained as the difference between the moisture retained at the moisture equivalent and at the tension of 4-bar. The moisture retained at 4-bar was used instead of the 15-bar because the soils studied are unlikely ever to dry below 4-bar in the natural state in which they occur in Hawaii.

Dry Bulk Density

The soil dry bulk densities of the pasture plots were determined by use of waxed clods while those of the forest plots were obtained by use of soil core samples. The dry bulk densities of one of the pasture

collected winter 1957

plots were determined using both waxed slides and soil core samples. The following results show that ~~both~~ the two methods are in close agreement:

| | | | | | |
|-----------------------|------|------|------|------|------|
| Waxed slide ----- | 0.48 | 0.29 | 0.25 | 0.26 | 0.23 |
| Soil core samples --- | 0.48 | 0.30 | 0.28 | 0.26 | 0.24 |

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III. RESULTS AND DISCUSSIONS

The Interrelationships of the Physical Properties Measured

Aggregate stability and organic matter- the forest plots (combined) show a significant correlation (at the 5% level) between aggregate stability and organic matter (Table 1). Two of the forest plots, F # 1 and F # 2 show a significant correlation at the 1% level but the other two, F # 3 and F # 4 does not show any significant correlation between aggregate stability and organic matter.

The pasture plots (combined) does not show a significant correlation between aggregate stability and organic matter. Only one of the four plots (P # 1) show a significant correlation (at the 5% level) between aggregate stability and organic matter.

Patrik et al (35) reported a significant correlation between aggregate^{ion} and organic matter on a Commerce loam. The only group of soils in which a correlation has not been observed between aggregation and organic matter is the lateritic soils, Bayer (8). The lack of significance in the correlation coefficients between aggregate stability and organic matter in two of the forest plots and in the pasture plots may be due to the high iron and aluminum oxides. The clays in these soils are largely iron and aluminum oxides. Lutz (1936) reported a positive correlation between free iron oxide and ~~BRUNKE~~ aggregation in lateritic soils.

In these soils, Honokaa and Peohaka the iron and aluminum oxides probably play a greater role in stabilising the aggregates formed than the cementation effects of organic matter.

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Aggregate stability and the moisture retained at M.E. or 4-bar- the forest plots show a significant correlation (at the 5% level) between aggregate stability and the moisture retained at M.E. or 4-bar \bar{x} (Table 1). Some of the forest plots does not show a significant correlation between the moisture retained at M.E. or 4-bar and aggregate stability.

The pasture plots does not show a significant correlation between aggregate stability and the moisture retained at M.E. or 4-bar (Table 1).

The foregoing results show that the effect of soil moisture on aggregate stability is indirect. The biological regime of the soil and that of plants which have an important role in aggregation and in the formation of water-stable aggregates are largely influenced by the moisture regime of the soil.

Organic matter and soil moisture content- the forest plots show a significant correlation (at the 1% level) between organic matter and soil field moisture content or the moisture retained at M.E. or 4-bar (Table 1). All the forest plots show significance at the 1% level except F # 4 which show significance at the 5% level.

The pasture plots show significance at the 5% level between organic matter and soil field moisture content or the moisture retained at M.E. They show a significant correlation (at the 1% level) between organic matter and the moisture retained at 4-bar.

The lack of significance in some of the correlation coefficients in the pasture plots may be due to the small number of samples studied.

The significant correlation between organic matter and soil moisture content in both the forest and pasture plots is to be anticipated because organic matter plays a key role in soil aggregation. Also, organic matter has a greater capacity to hold moisture than the inorganic matter

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of soils except the amorphous portion.

Dry bulk density and soil moisture content- the forest plots show a significant correlation (at the 1% level) between soil bulk density and the soil moisture retained at M.E. or 4-bar and soil field moisture content (Table 1). Some of the forest plots does not show a significant correlation between dry bulk density and soil field moisture content or the moisture retained at M.E. or 4-bar. But the absolute value of the correlation coefficients are quite high. The lack of significance may be due to the small number of soil bulk densities obtained.

The pasture plots show a significant correlation (at the 1% level) between dry bulk density and soil field moisture content or the moisture retained at M.E. or 4-bar (Table 1). Some of the pasture plots lack significance in the correlation coefficients which may be due to the small number of soil bulk densities obtained.

The significant correlation between soil dry bulk density and soil moisture content in both the forest and pasture plots is to be anticipated. An increase in soil bulk density is accompanied by a reduction in soil porosity. The soil moisture content is directly related to soil porosity.

Dry bulk density and aggregate stability- the forest plots does not show a significant correlation between soil bulk density and aggregate stability (Table 1). Two of the forest plots, P # 1 and P # 4 show significance at the 1% level and P # 2 at 5% level.

The pasture plots does not show a significant correlation between soil bulk density and aggregate stability. Only one of the pasture plots, P # 4 show significance (at the 5% level).

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The foregoing interrelationships of the soil physical properties measured shows that the organic matter in the soils studied have a greater role in soil aggregation than in stabilizing the aggregates formed. This is indicated by the low absolute value of most of the correlation coefficients between aggregate stability and organic matter but a high (significant) absolute value of the correlation coefficients between organic matter and soil moisture content. Also, the soils studied have a high aggregate stability and high organic matter content. The capacity of a soil to hold moisture is largely influenced by soil porosity and soil porosity is in turn largely influenced by soil aggregation.

This is further indicated by the "Student's" t test between F_{High} vs. F_{Low} (Table 3) in which there is a significant difference in the mean aggregate stability, even though, the two levels of tree productivity plots have the same mean organic matter content.

The Relationship Between Land Use and the NEM Variation in Soil Physical Properties

Table 2 gives the analysis of variances which indicated the most significant sources of variation. This as a guide the "Student's" t test were made and are recorded in Table 3.

Aggregate stability- Only aggregate stability is significantly different between the two land uses studied (Table 3). The greater aggregate stability under the pasture with the two treatments having the same mean organic matter content suggest that, factors other than organic matter have a profound effect in the formation of water-stable aggregates. The specific role played by the pasture cover if determined is of prime im-

ortance considering that it was on the land only eight years compared to twenty-eight years for the forest.

Russell (28) stated that plant roots can bind soil particles together into strong and characteristic crumbs which is particularly marked with some grasses.

It is shown on Table 3 that F_{high} VS. P and F_{high} VS. F_{high} have no significant differences in their mean water-stable aggregates but F_{low} VS. P and F_{high} VS. F_{low} have significant differences in their mean aggregate stability. This could ^{be} attributed to ^{the} effects of roots on soil aggregation noting that, they have the same mean organic matter content. Root growth is related to vegetative growth.

Organic matter- the forest plots and pasture plots have the same mean organic matter contents. Forest soils typically have the bulk of their organic matter close to the surface for the litter falls on th^e surface, and most of the ephemeral~~tree~~ tree roots are concentrated near the surface while prairie soils have a considerable proportion of their organic matter in the deeper horizons, for many grasses produce a deep extensive root system which may add a greater weight of organic matter to the body of the soil than the leaves add to the surface, Russell (28). Analysis of the first 18 inches of all the forest and pasture plots did not any significant differences in all the physical properties measured. Some process probably translocated the organic matter throughout the soil profile.

Soil moisture content- the lack of significant differences between the forest and pasture plots in their soil field moisture contents, avail-

able moisture and the moisture retained at M.E. or 4-bar could be partly explained by their having the same mean organic matter content and mean dry bulk density. In general, these soils have high aggregate stability and high organic matter contents that, even if the pasture plots have a higher (significant) aggregate stability it does not mean much in their capacity to retain moisture.

Yamamoto (39) reported that the average field capacity of forest, pasture, idle K&M grassland and cultivated soils in Hawaii are about the same but the average available moisture is highest in forest and lowest in pasture. No direct comparison can be made here because in the present study the available moisture was assumed to be the difference between the moisture retained at moisture equivalent and 4-bar. The Hydrol Basic Lato-soils under their natural conditions rarely gets drier than 4-bar. But in the present study, the results (Table 3) show that no significant differences exist between the forest and pasture plots in their moisture retained at M.E. or 4-bar and in their soil field moisture contents.

The foregoing results show that only aggregate stability is significantly different between the forest and pasture plots. The desirable influence of pasture in the formation of water-stable aggregates have many practical significance:

Firstly, putting land under cultivation result to a gradual deterioration of soil structure. Therefore, the use of pasture in the rotation will help produce and maintain good structure. This is a decided advantage of pasture over the forest when we are to consider the length of time required to establish them on the land, and also, the length of time before their beneficial effects are derived. Russell (28)

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suggested 3 to 6 years of grass and 10 to 20 years of forest for a good cropping by shifting cultivation. In this study, the pasture was only eight years compared to twenty-eight years for the forest.

Secondly, pasture will be a better vegetative control for soil erosion than forest/ due to its greater beneficial effects on aggregate stability.

Thirdly, abundant nutrients in the soil and favorable air water relationships ensure good crop production. The air and water relationships in the soil are dependent upon structure. Also, it is generally recognized that soils which resist slaking by water are often ~~less~~ soils which are considered to be in a good state of tilth.

The Possible Effects of the Physical Properties Measured on the Difference of Stands of *E. Saligna*

F # 1 plus F # 3, the high tree productivity plots have a higher (significant) aggregate stability, higher (significant) available moisture and a lower (significant) soil field moisture content than the F # 2 plus F # 4, the low tree productivity plots.

Pickford and LeBaron (25) found that the best growth of *E. saligna* is at 3,150 ft elevations and 5 to 10% slopes and good growth between 1,800 ft and 6,600 ft contours. They reported that, soil depth and drainage are important factors in the growth of trees. They found a very poor growth of *E. saligna* on a Honokaa soil which they predicted to be a poorly drained phase. They reported that good drainage may result ^{from} steep slopes deep soil mantle, permeable underlying an or cinders or a combination of these, and poor drainage may result from level surfaces and shallow

pahoehoe bedrock.

The forest and pasture plots selected lie between the 2,000 ft and 3,000 ft contours, rolling and with slopes ranging from 5 to 10%.

Although the ~~low~~ F_{high} plots have a higher (significant) aggregate stability and available moisture than the F_{low} plots it is suspected that the causes for the low tree productivity in $F \# 2$ is different from that in $F \# 4$. This is apparent in Fig. ~~3 & 4~~^{2 & 3} in which $F \# 2$ show a consistently higher soil field moisture content and moisture retained at 4-bar than $F \# 1$ while $F \# 4$ show a consistently lower soil field moisture content and moisture retained at 4-bar than $F \# 3$.

The possible causes for the lower tree productivity on $F \# 2$ (Honokaa) may be any or all of the following:

- a) $F \# 2$ have a lower aggregate stability and available moisture than $F \# 1$.
- b) $F \# 2$ have a higher moisture content at M.E. or 4-bar and higher soil field moisture content than $F \# 1$ (see Fig. 3 & 4). The soil field moisture content of $F \# 2$ ($\bar{x} = 206.8\%$) might be more than the favorable amount as to affect the growth of the trees. The mean soil field moisture content of $F \# 1$ is 178.3%.

The possible causes for the lower productivity of stands of *E. saligna* on $F \# 4$ (Pahoa) may be any or all of the following:

- a) $F \# 4$ have a lower aggregate stability than $F \# 3$.
- b) $F \# 4$ have a lower soil field moisture content ($\bar{x} = 144.5\%$) than $F \# 3$ ($\bar{x} = 177.6\%$). The soil field moisture content of $F \# 4$ might be that it is too low for favorable growth of trees.

Note that the high tree productivity plots, P # 1 and P # 3 have the same mean soil field moisture contents.

c) P # 4 has a ~~red~~ cap (6" red layer) and a very shallow profile. P # 3 has no red cap and has a deep profile.

Martin et al (20) found little evidence that aggregates have any direct influence on plant growth except as they modify the pore spaces in soils.

Table 1. Correlation coefficient, r values.

| Sampled Plots | A.S. VS. O.H. | A.S. VS. M.E. | A.S. VS. 4 H.C. | A.S. VS. B.D. | O.H. VS. M.E. | O.H. VS. 4 H.C. | G.H. VS. B.D. | M.E. VS. B.D. | 4 H.C. VS. B.D. | P VS. B.D. | P VS. O.H. |
|------------------|---------------------|---------------------|-----------------------|---------------------|---------------------|-----------------------|---------------------|---------------------|-----------------------|------------------|------------------|
| | Forest | 0.30* | 0.28* | 0.28* | 0.15 | 0.42* | 0.99** | 0.64** | 0.87** | 0.84** | 0.88** |
| F #1 | 0.67** | 0.62* | 0.74** | 0.96** | 0.82** | 0.90** | 0.95* | 0.97* | 0.85 | 0.97** | 0.95** |
| F #2 | 0.197** | 0.28 | 0.32 | 0.88* | 0.66** | 0.74** | 0.68 | 0.78 | 0.78 | 0.69 | 0.73** |
| F #3 | 0.18 | 0.07 | 0.08 | 0.62 | 0.65** | 0.64** | 0.77 | 0.82 | 0.79 | 0.94* | 0.72** |
| F #4 | 0.50 | 0.85** | 0.86** | 0.96** | 0.63** | 0.58* | 0.74 | 0.98** | 0.99** | 0.93* | 0.58* |
| Pasture | 0.03 | 0.02 | 0.08 | 0.22 | 0.47* | 0.50** | 0.30 | 0.90** | 0.93** | 0.87** | 0.45* |
| P #1 | 0.85* | 0.70 | 0.70 | 0.76 | 0.93** | 0.90** | 0.96** | 0.94** | 0.96** | 0.96** | 0.94** |
| P #2 | 0.30 | 0.28 | 0.21 | 0.27 | 0.28 | 0.84* | 0.55 | 0.80** | 0.87** | 0.68 | 0.95** |
| P #3 | 0.07 | 0.18 | 0.41 | 0.59 | 0.87** | 0.84** | 0.75* | 0.96** | 0.96** | 0.96** | 0.84** |
| P #4 | 0.16 | 0.56 | 0.56 | 0.83* | 0.46 | 0.42 | 0.26 | 0.70 | 0.70 | 0.74 | 0.42 |

*Significant at 5% level

**Significant at 1% level

4 H.C.-Moisture content at 4 bars

M.E.-Moisture equivalent

note D. of values say as for paper
1 layer (7 papers)
for illustration.

Table 2. Analysis of variance.

| Physical Property | Forest | | | | | | | Pasture | | | | | | |
|--------------------|-----------------------|-------|-------|-------|-------|--------|--------|-----------------------|-------|-----|-----|-----|-------|-----|
| | Sources of variations | | | | | | | Sources of variations | | | | | | |
| | Soils | Prod. | Prof. | Soils | Soils | Prod. | Soils | #8 | #16 | #8 | #9 | | | |
| | | | x | x | x | xProd. | VS. | VS. | VS. | VS. | | | | |
| | Soils | Prod. | Prof. | Prod. | Prof. | Prof. | xProf. | Prof. | Soils | #9 | #18 | #16 | Prod. | #18 |
| M.E. | | | | ** | | | | ** | ** | * | | ** | | |
| 4 M.C. | ** | | | ** | | | | | * | | | * | | |
| B.D. | | | | | | | | * | * | | | ** | Faco | |
| O.M. | | | | | | | * | | | | | | | |
| A.S. | | ** | | | | | | | | | | | | |
| A H ₂ O | | | | | | | | | | | | | * | |

*Significant at 5% level
 **Significant at 1% level
 A H₂O Available water

Table 3. Test between the means. Student's t-distribution.

| Property | Forest VS. Pasture (P) | F _{Low} VS. P | F VS. P _{Honokaa} | F _{Pohakea} VS. P | F _{High} VS. F _{Low} | F _{High} VS. P _{High} | F _{Low} VS. P _{Low} | F #1 VS. F #2 |
|--------------------|-------------------------------|---------------------------------|----------------------------------|----------------------------------|--|---|---|---------------------|
| A.S. | df=89 t=3.46 5% t=2.03* | df=58 t=-7.04 5% t=1.906* | | | df=63 t=4.29 P<0.1%* | df=43 t=1.25 5% t=2.06 | df=44 t=2.48 P<2.5%* | |
| O.M. | df=90 t=0.03 P>50% | | | | $\bar{x}_1=12.66$ $\bar{x}_2=12.68$ | df=44 t=-0.30 P>50% | df=44 t=0.44 P>50% | |
| M.E. | df=90 t=1.52 P>10% | | df=77 t=-2.99 P<0.5%* | | df=64 t=-1.82 5% t=1.86 | df=44 t=2.28 P<5%* | df=44 t=0.40 P>50% | |
| 4 M.C. | df=89 t=1.87 P>5% | | | df=58 t=-3.92 P<0.10%* | | df=44 t=2.32 P<5%* | df=43 t=0.71 P>50% | |
| B.D. | df=45 t=1.88 P>5% | | | | df=19 t=0.17 P=50% | | | |
| A H ₂ O | df=89 t=-0.31 P>50% | | | | df=63 t=5.84 5% t=1.96* | df=44 t=0.40 5% t=2.09 | df=43 t=-0.89 P>20% | |
| P _w | df=111 t=1.10 P>20% | | | | df=85 t'=2.14 5% t=2.01* | | df=41 t=3.90* P<1% | df=41 t=- P< |

*Significant
P_{High} - Pasture plots corresponding to F_{High} plots
P_{Low} - Pasture plots corresponding to F_{Low} plots

Honokaa_{High} VS. Honokaa_{Low} df=29
t=-3.49
P<0.5%*
Pohakea_{High} VS. Pohakea_{Low} df=32
t=1.98
P>5%

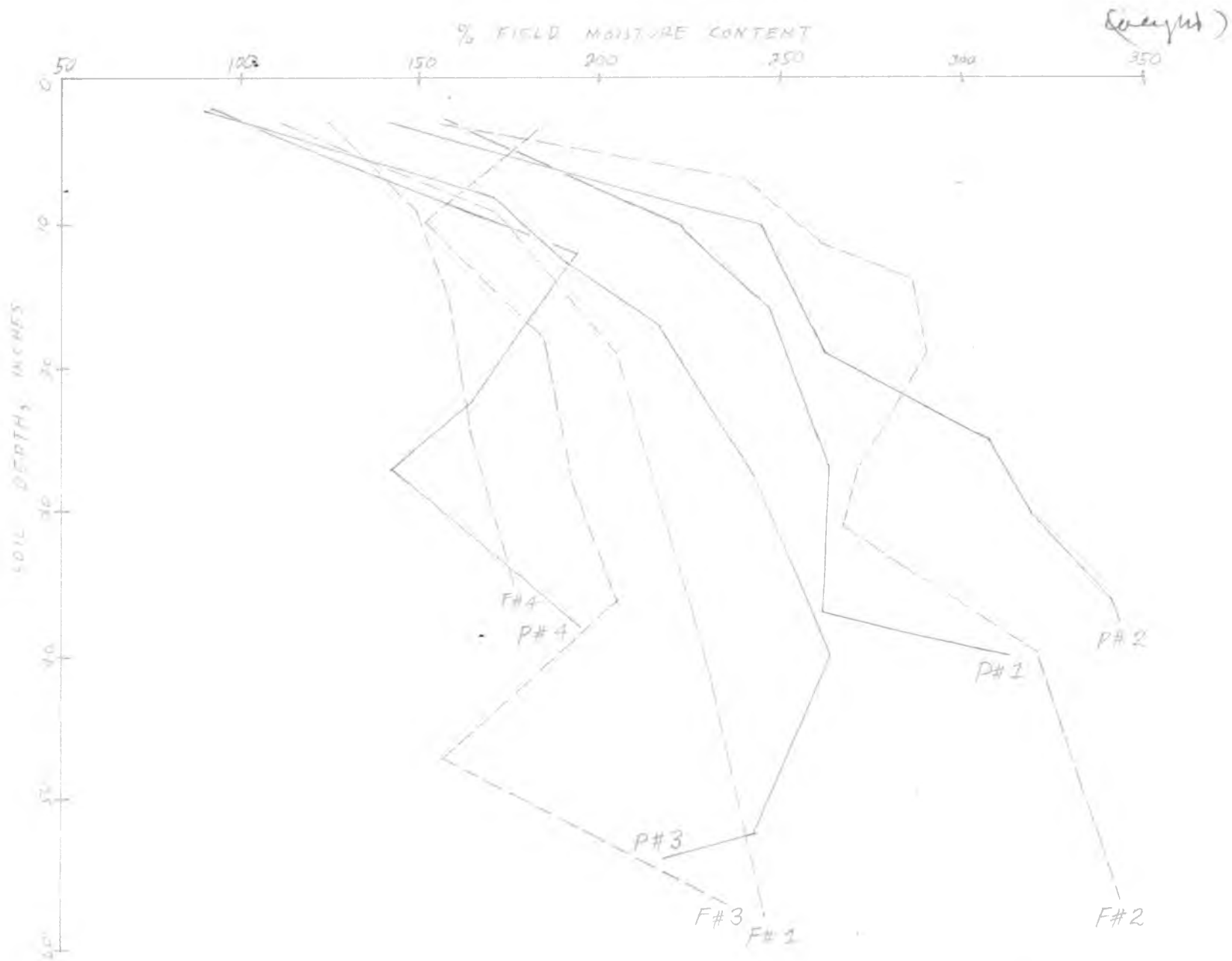


Fig. 2. Percent field moisture content of the forest and pasture plots ~~of~~ ~~XXXXXX~~ plotted against soil depth.

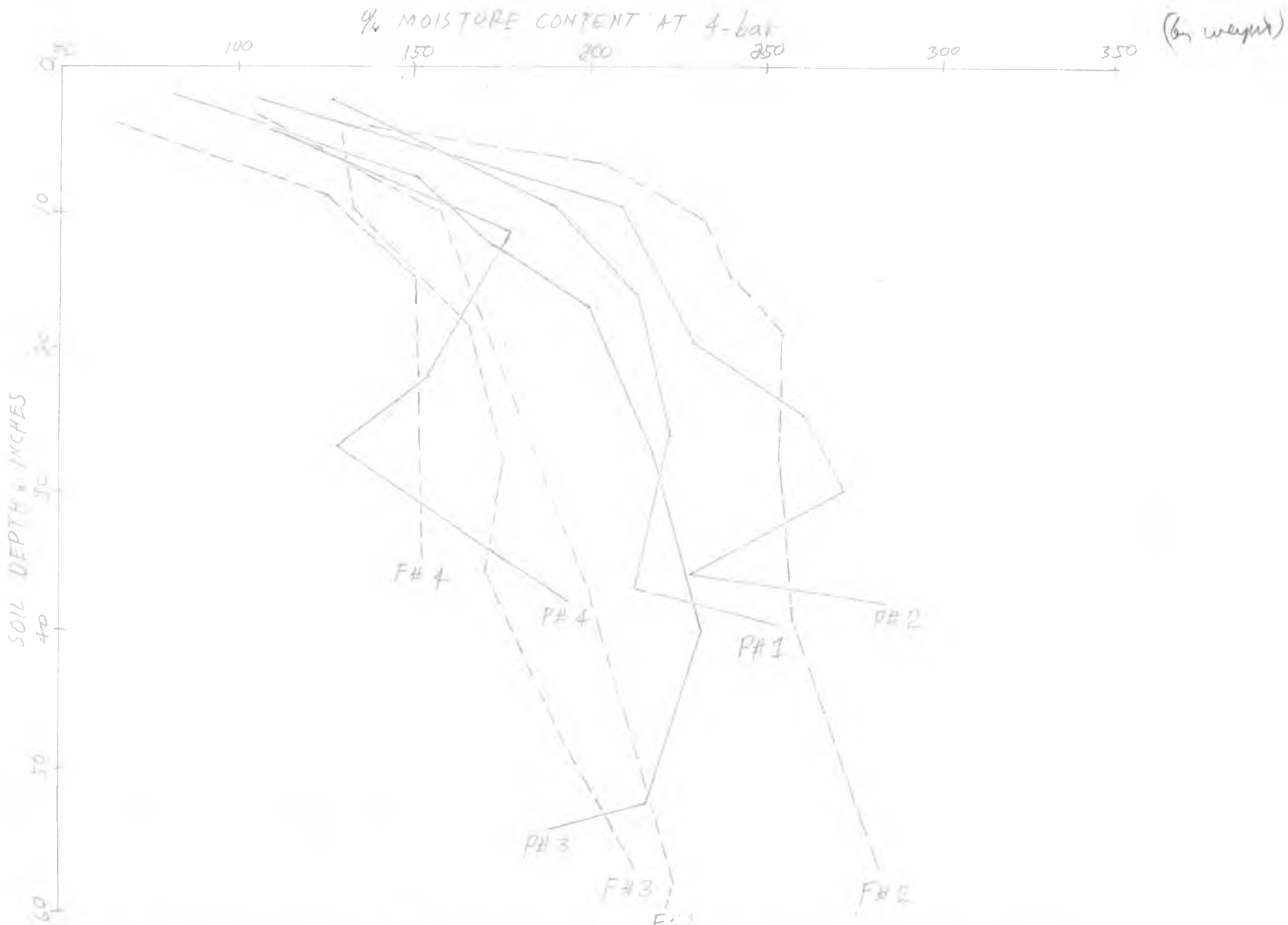


Fig. 3. Percent moisture content at 4-bar of the forest and pasture plots plotted against soil depth.

NOTE: The same pattern is observed with the graph of moisture equivalent.

IV. SUMMARY AND CONCLUSIONS

The results show that a significant correlation (at the 5% level) exist between aggregate stability and organic matter in the forest plots. ~~XXXXXXXXXX~~ No significant correlation has been observed in the pasture plots. The lack of significance in the correlation coefficients in two of the forest plots and most of the pasture plots may be due to the high iron and aluminum oxides. In these soils, Henokaa and Pohakea the iron and aluminum oxides probably play a greater role in stabilizing the aggregates formed than the cementation effects of organic matter.

A significant correlation (at the 5% level) between aggregate stability and the moisture retained at W_p , $W_{1/2}$ or 4-bar has been observed in the forest plots but not in the pasture plots and in some of the forest plots. Martin et al (20) found that the main role of soil aggregates is to modify the pore spaces in soils.

Both the forest and pasture plots show a significant correlation (at the 1% level) between organic matter and soil moisture content. This is to be anticipated because organic matter plays a key role in soil aggregation. Also, organic matter has a greater capacity to hold moisture than the inorganic matter in soils except, the amorphous portion. The χ lack of significance in the correlation coefficients in some of the pasture plots may be due to the small number of samples used.

The forest and pasture plots show significance at the 1% level between dry bulk density and soil moisture content- this is to be anticipated. An increase in soil bulk density is accompanied by a reduction in soil porosity and soil moisture content is directly related to

soil porosity.

A conclusion can be drawn from the foregoing interrelationships of the soil physical properties measured that the organic matter in the soils studied have a greater role in soil aggregation than in stabilizing the aggregates formed. This is indicated by the low absolute value of most of the correlation coefficients between aggregate stability and organic matter but a high (significant) correlation coefficients between organic matter and soil moisture content. Also, these soils have a high aggregate stability and high organic matter contents. This is further indicated by the "Student's" t test between F_{high} and F_{low} (Table 3) in which there is a significant difference in the mean aggregate stability, even though, the two levels of tree productivity plots have the same mean organic matter contents.

This study shows that no significant differences have been observed in the physical properties measured between forest and pasture except in the stability of aggregates. The pasture plots have a higher (significant) aggregate stability than the forest plots. This is significant considering that the pasture was on the land only eight years compared to twenty-eight years for the forest. The specific role played by the pasture in the formation of water-stable aggregates could not be determined in this study.

A conclusion can be drawn that, factors other than organic matter have a profound effect on aggregate stability. The higher (significant) aggregate stability under the pasture could be attributed to the effect of grass roots on soil aggregation. The pasture plots were observed to have abundant roots throughout the profile. Also, the high aggregate

stability in the soils studied is attributed mainly to the high iron and aluminum oxides.

The results and observations show that putting the soils studied under pasture is better than putting it under forest. Aside from the greater beneficial effects of grasses on aggregate stability it is easier to establish on the land and also the benefits are derived much earlier than forests.

The results further show that although the F_{high} plots have a higher (significant) aggregate stability and available moisture than the F_{low} plots it is suspected that the causes for low tree productivity in $F \# 2$ is different from that in $F \# 4$. This is apparent in Fig. 2 & 3 in which $F \# 2$ shows a consistently higher soil field moisture content and moisture retained at 4-bar than $F \# 1$ while $F \# 4$ show a consistently lower soil field moisture content and moisture retained at 4-bar than $F \# 3$.

The wetter condition of $F \# 2$ as well as the drier condition of $F \# 4$ may be unfavorable to the growth of the trees. Furthermore, $F \# 4$ has a red cap (6" red layer) and has a shallow profile.

*Retention
in effects*

APPENDIX

Profile Description of Sampled FlotsF # 1

- A₁ 0-6" Dark brown (7.5 YR 3/2) when moist; silty clay loam; strong fine to very fine subangular blocky structure; very hard, friable, slightly sticky, plastic and weakly smeary; abundant roots; clear smooth boundary. 6 inches thick.
- B₁ 6-13" Dark brown (7.5 YR 3/4) when moist; silty clay loam; moderate medium subangular blocky structure; very hard, friable, slightly sticky, plastic and weakly smeary; many fine and medium pores; thin continuous oxide coatings on peds and in pores; clear smooth boundary. 7 inches thick.
- B₂₁ 13-26" Dark brown (10 YR 3/3) when moist; silty clay loam; strong medium to fine subangular blocky structure; very hard, friable, sticky, plastic and moderately smeary; plentiful roots; many fine to medium pores; thin continuous oxide coatings on peds and in pores; clear smooth boundary. 12 inches thick.
- B₂₂ 26-54" Dark brown (10 YR 3/3, 5 YR 3/4) when moist; silty clay loam; strong medium to fine subangular blocky structure; very hard, friable, plastic and smeary; few cobble size basalt fragments; plentiful roots; many fine and medium pores; clear smooth boundary. 28 inches thick.
- B₂₃ 54-65" Dark yellowish brown (10 YR 3/4) when moist; silty clay

loam; strong medium angular blocky structure; very hard, friable, sticky, plastic and smeary; plentiful up to 1/2" in diameter roots; many fine and medium pores; thick continuous oxide coatings (10 YR 6/6) on pedis and in pores; 9 inches thick.

NOTE: 26-54", the 5 YR 3/4 makes up to 40% of the horizon. It is not banded-random arrangement.

54-55", this horizon consists of 50% cobble size basalt fragments.

7 + 2

- O₂** 3"-0 Dark reddish brown (5 YR 3/2) when moist; muck; moderate fine to very fine granular structure; friable, slightly sticky, slightly plastic and weakly smeary; matted roots; abrupt smooth boundary, 3 inches thick.
- A₁** 0-5" Dark brown (10 YR 5/3) when moist; silty clay loam; moderate to fine subangular blocky structure; hard, friable, sticky, plastic and weakly smeary; abundant roots; many fine pores- thin continuous gelatinous glass; clear smooth boundary, 5 inches thick.
- B₁** 5-9" Dark brown (7.5 YR 3/4) when moist; silty clay loam; strong medium to fine subangular blocky structure; very hard, friable, sticky, plastic and smeary; abundant roots; many fine pores- thick continuous gelatinous coatings; clear smooth boundary, 4 inches thick.
- B₂₁** 9-13" Dark brown (7.5 YR 3/4) when moist; silty clay loam; medium to fine subangular blocky structure; very hard,

- friable, sticky, plastic and smeary; abundant roots; many fine pores- thick continuous oxide coatings; clear smooth boundary. 4 inches thick.
- B₂₂ 13-15" Dark brown (7.5 YR 3/3) when moist; silty clay loam; strong medium to fine subangular blocky structure; very hard, friable, sticky, plastic and smeary; few roots; many fine pores- thick continuous oxide coatings; clear smooth boundary. 2 inches thick.
- B₂₃ 15-23" Yellowish red (5 YR 4/6) when moist; silty clay; strong medium to fine subangular blocky structure; very hard, friable, sticky, plastic and very smeary; few roots; many fine pores- thick continuous oxide coatings and common marble size cinder fragments; clear smooth boundary; 6 inches thick.
- B₂₄ 23-30" Dark yellow brown (10 YR 3/4) when moist; silty clay; strong medium to fine subangular blocky structure; very hard, friable, sticky, plastic and very smeary; few roots; many fine pores- thick continuous oxide coatings; abrupt boundary. 7 inches thick.
- B₂₅ 30-33" Consolidated ash layer that is discontinuous- has thick continuous oxide coatings on upper surface and in cracks; abrupt boundary. 2 inches thick.
- B₂₆ 32-40" Dark yellowish brown (10YR 3/4, 7.5 YR 3/4) when moist; silty clay loam; strong medium to fine subangular blocky structure; very hard, sticky, plastic and very smeary; few roots; thick continuous oxide coatings; many fine pores and

common marble size cinder fragments; clear smooth boundary. 17 inches thick.

B₂₇ 49-68" Dark brown (7.5 YR 3/4) when moist; silty clay loam; moderate medium to fine angular blocky structure; very hard, friable, sticky, plastic and very smeary; no roots; many fine pore-thick continuous oxide coatings. 16 inches thick.

F 3

O₂ 2-0" Dark brown (5 YR 3/2) when moist; muck and peat/massive structure; soft, friable, non-sticky, non-plastic and non-smeary; abundant roots; partially decomposed roots and litter; abrupt smooth boundary. 2 inches thick.

A₁ 0-6" Dark brown (7.5 YR 3/2) when moist; silty clay loam; strong fine to very fine granular structure; hard, friable, slightly sticky, plastic and non-smeary; abundant roots; a lot of white mycelia in this horizon; clear smooth boundary. 6 inches thick.

B₁ 6-14" Dark brown (7.5 YR 3/2) when moist; strong to very fine subangular blocky structure; very hard, friable, sticky, very plastic and moderately smeary; abundant roots; thick continuous coatings; many fine pores; clear smooth boundary. 8 inches thick.

B₂₁ 14-22" Dark reddish brown (5 YR 3/4) when moist; very hard, friable, sticky, plastic and moderately smeary; abundant roots; many fine pores; thick continuous oxide coatings; clear smooth boundary. 8 inches thick.

- B₂₂ 22-23" Very dark brown (10 YR 2/2) when moist; silty clay loam; strong medium to fine subangular blocky structure; very hard, sticky, very plastic and moderately smeary; abundant roots; many fine pores- thick continuous oxide coatings; abrupt boundary. 13 inches thick.
- B₂₃ 35-37" Consolidated ash layer, discontinuous in places- thick oxide coatings on top and in cracks. abrupt boundary. 2 inches thick.
- B₂₄ 37-57" Very dark brown (10 YR 2/2) when moist; silty clay loam; strong medium prismatic structure; very hard, firm, sticky, very ~~plastic~~ plastic and moderately smeary; abundant roots; many fine pores; thick oxide coatings- common compact ash nodules; clear smooth boundary. 20 inches.
- B₂₅ 57-62" Dark reddish brown (5 YR 3/4) when moist; silty clay loam; strong fine to medium prismatic structure; very hard, firm, sticky, very plastic and moderately smeary; plentiful roots; many fine pores- thick continuous oxide coatings. 5 inches thick.

F 4

- O₁ 1-0" Rile grass: ~~mat~~ matting. Abundant roots.
- A₁ 0-5" Dark ~~reddish~~ brown (8YR 3/4) when moist; silty clay loam; strong fine to very fine granular to subangular blocky structure; hard, friable, slightly sticky, plastic and non-smeary; abundant roots; a great deal of white mycelia; clear smooth boundary. 6 inches thick

- B₁ 6-12" Dark brown (7.5 YR 3/4) when moist; silty clay loam; weak coarse subangular blocky structure; very hard, friable, sticky, plastic and weakly smeary; abundant roots; many fine pores, many worm casts, thin patchy oxide coatings; clear smooth boundary. 6 inches thick.
- B₂₁ 12-19" Dark yellowish brown (10 YR 3/4) when moist; silty clay loam; moderate fine to medium subangular blocky structure; very hard, friable, sticky, plastic and weakly smeary; few gravel; abundant roots; many fine pores; thick nearly continuous oxide coatings; clear wavy boundary. 7 inches thick.
- B₂₂ 19-23" Dark brown (7.5 YR 3/4) when moist; silty clay loam; moderate to medium subangular blocky structure; very hard, friable, sticky, plastic and moderately smeary; 15% basaltic fragments; plentiful roots; many fine pores; thick nearly continuous oxide coatings; clear wavy boundary. 9 inches thick.
- B₂₃ 28-45" Dark brown (10 YR 3/3) when moist; silty clay loam; weak medium subangular blocky structure; very hard, friable, sticky, plastic and moderately smeary; 40-50% basalt fragments; plentiful roots; many fine pores, few patchy oxide coatings- common consolidated ash nodules up to golf ball size. 18 inches thick.

Note: Roots stop at about 80 inches depth. Water seeped into pit beginning at about 48 inches depth.

12-19" horizon has pockets of strong fine angular blocky structure.

There are near rock fragments, these pockets have firm consistence.

P & 1

- O₁ 2-0" Rotted kikuyu roots.
- A₁ 0-1" Root filled, numerous black aggregates.
- A₂ 1-3" Dark brown (7.5 YR 3/3) when moist; silty clay loam; strong very fine subangular blocky structure; friable, non-sticky, plastic and non-smeary; abundant coarse roots; clear smooth boundary; 3 inches thick.
- B₁ 6-15" Dark brown (7.5 YR 3/4) when moist; silty clay loam; strong very fine subangular blocky structure; friable, sticky, plastic and slightly smeary; abundant coarse roots; continuous oxide coatings; clear smooth boundary. 9 inches thick.
- B₂₁ 15-18" Dark brown (7.5 YR 4/3) when moist; silty clay loam; weak very fine subangular blocky structure; friable, sticky, plastic and smeary; abundant coarse roots; clear smooth boundary. 3 inches thick.
- B₂₂ 18-35" Dark brown (10 YR 3/3) when moist; silty clay loam; strong medium subangular blocky structure; friable, sticky, plastic and smeary; abundant coarse roots, abrupt boundary, 18 inches thick.
- B₂₃ 36-40" Consolidated red ash layer; firm, sticky, plastic and smeary; abundant coarse roots; abrupt boundary. 4 inches thick.
- B₂₄ 40-60" Dark yellowish brown (10 YR 3/4) when moist; silty clay loam; strong medium angular blocky structure; friable,

slightly sticky, plastic and smeary; abundant coarse roots; continuous oxide coatings; clear smooth boundary, 20 inches thick.

Note: No layer of 50% basalt found, many large earthworms.

P 2

- A₁ 0-7" Brown to dark brown (10 YR 4/3) when moist; silty clay loam; medium very fine subangular blocky structure; friable, non-sticky, plastic and slightly smeary; abundant fine roots; clear smooth boundary, 7 inches thick.
- B₁ 7-14" Dark brown (7.5 YR 4/4) when moist; silty clay loam; very weak to weak very fine subangular blocky structure; friable, non-sticky, plastic and slightly smeary; abundant fine roots; clear smooth boundary, 7 inches thick.
- B₂₁ 14-24" Dark brown (10 YR 3/5) when moist; silty clay loam; strong medium to fine subangular blocky structure; friable, sticky, plastic and smeary; abundant fine roots; rock fragments; clear smooth boundary, 10 inches thick.
- B₂₂ 24-25" Dark reddish brown (5 YR 3/3) when moist; silty clay loam; very weak to weak very fine subangular blocky structure; friable, very sticky, very plastic and non-smeary; abundant fine roots; clear smooth boundary, 2 inches thick.
- B₂₃ 26-35" Dark yellowish brown (10 YR 5/4) when moist; silty clay loam; strong medium subangular blocky structure; friable, sticky, plastic and slightly smeary; abundant fine roots; continuous oxide coatings; clear smooth boundary, 9 inches

- " thick.
- B₂₄ 35-38" Dark reddish brown (2.5 YR 3/4) when moist; consolidated ash; abundant fine roots; abrupt boundary. 3 inches thick.
- B₂₆ 38-50" Dark brown (7.5 YR 3/4) when moist; silty clay loam; strong medium subangular blocky structure; friable, sticky, plastic ~~plastic~~ and very smeary; abundant fine roots; continuous oxide coatings; clear smooth boundary. 22 inches thick.

Note: Matted roots at immediate surface. Many earthworms in the surface layers. Old root channels from 7 inches down the profile forming open channels up to 1-inch in diameter.

P 3

- O₁ 2-0" Matted roots of kilaya.
- A₁ 0-4" Dark brown (10 YR 3/5) when moist; silty clay loam; strong very fine subangular blocky structure; firm, sticky, plastic and slightly smeary; abundant roots; clear smooth boundary. 4 inches thick.
- B₁ 4-12" Dark brown (7.5 YR 3/3) when moist; silty clay loam; very weak to weak very fine granular structure; friable, sticky, plastic and smeary; abundant roots; clear smooth boundary. 8 inches thick.
- B₂₁ 12-13" Dark brown (10 YR 3/3) when moist; silty clay loam; strong fine subangular blocky structure; friable, sticky, plastic and smeary; abundant roots; clear smooth boundary. 3 inches thick. (discontinuous zone).
- B₂₂ 15-22" Dark brown (7.5 YR 3/3) when moist; silty clay loam; very

- weak to weak very fine granular structure; friable, slightly sticky, plastic and non-smearly; abundant roots; clear smooth boundary. 7 inches.
- B₂₃ 22-32" Dark yellowish brown (10 YR 3/4) when moist; silty clay loam; strong fine subangular blocky structure; friable, sticky, plastic and slightly smearly; abundant roots; oval black pebbles, decomposed roots; clear smooth boundary. 10 inches thick.
- B₂₄ 32-36" Dark brown (7.5 YR 3/4) when moist; silty clay loam; very weak to weak very fine granular structure; some rock fragments; abundant roots; 4 inches thick.
- B₂₅ 36-47" Very dark brown (10 YR 2/2) when moist; silty clay loam; strong medium angular blocky structure; friable, sticky, plastic and slightly smearly; abundant roots; abrupt boundary. 9 inches thick.
- B₂₆ 47-58" Dark yellowish brown (10YR 3/4) when moist; silty clay loam; strong medium structure; friable, sticky, plastic and smearly; abundant roots; clear smooth boundary. 9 inches thick.
- B₂₇ 58-65" Dark reddish brown (5 YR 3/4) when moist; silty clay loam; weak to moderate very fine structure; friable, slightly sticky, plastic and non-smearly; abundant roots; oxide coatings. 9 inches thick.

Note: Numerous red tree root cavities up to 3 inches in diameter, open, from 7 inches down the profile.

P 4

- A₁** 0-4" Dark reddish brown (5 YR 3/4) when moist; silty clay loam; strong very fine granular to subangular blocky structure; friable, sticky, plastic and non-smeary; abundant roots; clear smooth boundary. 4 inches thick.
- B₁** 4-18" Brown to dark brown (7.5 YR 4/4) when moist; silty clay loam; very weak to weak subangular blocky structure; friable, sticky, plastic and non-smeary; few roots; clear smooth boundary. 14 inches thick.
- B_{2A}** 18-26" Dark brown (7.5 YR 3/4) when moist; silty clay loam; moderate very fine subangular blocky structure; firm, sticky, plastic and μ slightly smeary; 50% oval pebbles; abundant roots; clear smooth boundary. 7 inches thick.
- B_{2B}** 26-28" Dark yellowish brown (10 YR 3/4) when moist; silty clay loam; strong fine to very fine subangular blocky structure; friable, sticky, plastic and smeary; abundant roots; clear smooth boundary. 3 inches thick.
- B_{2C}** 28-30" Red, rock with consolidated ash fragments. Clear smooth boundary. 2 inches thick.
- B₂₄** 30-48" Very dark grayish brown (10 YR 3/2) when moist; silty clay loam; strong fine angular blocky structure; friable, sticky, plastic and smeary; abundant roots; few fragments; clear smooth boundary. 18 inches thick.
- B_{2B}** 48-48" Consolidated ash, red; abundant roots; clear smooth boundary. 2 inches thick.
- B_{2B}** 48-50" Very dark grayish brown (10 YR 3/2) when moist; silty clay loam; moderate very fine subangular blocky structure;

abundant roots; clear smooth boundary. 2 inches thick.
B₂₇ 60-60" Dark reddish brown (6 YR 3/4) when moist; silty clay
loam; weak ~~to~~ very fine subangular blocky structure;
abundant roots; 10 inches thick.

defuse

units?

42

No > 40 mesh

Table 1.

Positive experimental data.

| Soils & horizons | (Pw) % wt. | M.E. | + M.C. | ΔH_2O | B.D. g/cc | O.M. % wt | A.S. % | 10 > 20 | PA 710 mesh |
|------------------|------------|--------|--------|---------------|-----------|-----------|--------|---------|-------------|
| Pohakea #8 | | | | | | | | | |
| 0-4 in | 91.16 | 71.27 | 81.06 | 8.56 | 0.51 | 19.07 | 52.76 | | |
| 4-18 | 173.78 | 181.14 | 179.71 | 1.93 | 0.33 | 16.19 | 48.81 | | |
| 18-25 | 165.76 | 161.07 | 154.24 | 6.83 | 0.45 | 9.90 | 71.59 | | |
| 25-30 | 145.31 | 138.16 | 129.38 | 15.91 | 0.54 | 7.34 | 29.08 | | |
| 30-46 | 195.02 | 193.26 | 189.52 | 2.74 | 0.42 | 5.81 | 72.28 | | |
| Pohakea #9 | | | | | | | | | |
| 0-4 | 90.12 | 72.08 | 81.30 | 10.88 | 0.57 | 19.96 | 55.86 | | PA |
| 4-12 | 176.00 | 164.25 | 151.68 | 13.27 | 0.37 | 16.88 | 76.62 | | |
| 12-15 | 172.76 | 158.45 | 176.59 | 12.34 | 0.38 | 13.20 | 72.86 | | |
| 15-22 | 215.55 | 209.84 | 200.11 | 9.05 | 0.39 | 10.34 | 71.71 | | |
| 22-32 | 241.45 | 233.53 | 217.50 | 16.5 | 0.30 | 10.28 | 75.90 | | |
| 32-36 | | | | | | | | | |
| 36-47 | 264.08 | 245.43 | 212.19 | 12.94 | 0.30 | 7.53 | 53.11 | | |
| 47-50 | | | | | | | | | |
| 50-54 | 242.64 | 240.96 | 217.92 | 22.84 | 0.30 | 7.70 | 80.35 | | |
| 54+ | 217.34 | 214.98 | 190.42 | 24.56 | 0.37 | 7.19 | 84.28 | | |
| Honokaa #16 | | | | | | | | | |
| 0-7 | 141.31 | 142.28 | 116.10 | 26.08 | 0.48 | 19.40 | 65.73 | | 02 |
| 7-14 | 245.14 | 233.76 | 210.17 | 23.59 | 0.39 | 12.29 | 36.65 | | |
| 14-24 | 263.14 | 258.80 | 229.87 | 22.93 | 0.25 | 14.33 | 69.81 | | |
| 24-26 | 308.16 | 285.26 | 261.66 | 23.60 | 0.36 | 14.27 | 74.56 | | |
| 26-35 | 319.32 | 301.93 | 273.22 | 28.21 | 0.23 | 12.24 | 76.88 | | |
| 35-38 | 341.20 | 256.14 | 229.38 | 56.76 | 0.38 | 10.77 | 99.82 | | |
| 38+ | 343.22 | 315.30 | 284.86 | 30.44 | 0.21 | 10.62 | 78.72 | | |
| Honokaa #18 | | | | | | | | | |
| 1-6 | 157.00 | 155.92 | 177.04 | 26.28 | 0.47 | 19.74 | 65.35 | | 01 |
| 6-15 | 221.14 | 227.30 | 191.16 | 31.16 | 0.37 | 16.14 | 82.66 | | |
| 15-18 | 247.16 | 226.70 | 214.36 | 12.34 | 0.36 | 14.00 | 81.81 | | |
| 18-36 | 262.86 | 249.34 | 223.23 | 26.11 | 0.31 | 10.64 | 76.20 | | |
| 36-39 | 261.46 | 251.59 | 214.50 | 37.09 | 0.31 | 9.17 | 78.44 | | |
| 39+ | 313.33 | 296.04 | 253.70 | 42.34 | 0.29 | 7.17 | 79.67 | | |

Table 5. Forest experimental data.

| soils & harvests | Pw | M.E. | 4 M.C. | ΔH_2O | B.D | O.M | A.S. |
|--------------------|--------|--------|--------|---------------|------|-------|-------|
| Pohakoa # 5 | | | | | | | |
| 4-1-1 | 181.28 | 148.72 | 143.11 | 12.15 | 0.51 | 18.69 | 86.87 |
| 1-2 | 181.28 | 148.72 | 143.11 | 12.15 | 0.31 | 19.65 | 87.80 |
| 1-3 | 181.28 | 148.72 | 143.11 | 12.15 | 0.26 | 19.33 | 18.93 |
| 1-4 | 181.28 | 148.72 | 143.11 | 12.15 | 0.35 | 19.28 | 87.28 |
| 1-5 | 181.28 | 148.72 | 143.11 | 12.15 | 0.29 | 19.67 | 16.80 |
| 4-2-1 | | | | | | | |
| 2-2 | 153.11 | 155.6 | 152.19 | 35.79 | | 17.31 | 76.77 |
| 2-3 | 153.11 | 155.6 | 152.19 | 35.79 | | 8.14 | 70.65 |
| 2-4 | 153.11 | 155.6 | 152.19 | 35.79 | | 9.79 | 62.40 |
| 2-5 | 153.11 | 155.6 | 152.19 | 35.79 | | | |
| 4-3-1 | | | | | | | |
| 3-2 | 173.17 | 175.15 | 154.12 | 31.07 | | 10.67 | 32.75 |
| 3-3 | 173.17 | 175.15 | 154.12 | 31.07 | | 9.14 | 57.08 |
| 3-4 | 173.17 | 175.15 | 154.12 | 31.07 | | | |
| 3-5 | 173.17 | 175.15 | 154.12 | 31.07 | | | |
| Pohakoa # 3 | | | | | | | |
| 3-1-1 | 181.28 | 148.72 | 143.11 | 12.15 | 0.54 | 18.00 | 86.49 |
| 1-2 | 181.28 | 148.72 | 143.11 | 12.15 | 0.36 | 18.58 | 87.19 |
| 1-3 | 181.28 | 148.72 | 143.11 | 12.15 | 0.38 | 18.10 | 89.14 |
| 1-4 | 181.28 | 148.72 | 143.11 | 12.15 | 0.34 | 18.21 | 70.94 |
| 1-5 | 181.28 | 148.72 | 143.11 | 12.15 | 0.30 | 18.33 | |
| 1-6 | 181.28 | 148.72 | 143.11 | 12.15 | | 9.31 | 55.77 |
| 1-7 | 181.28 | 148.72 | 143.11 | 12.15 | | 9.46 | 54.75 |
| 3-2-1 | | | | | | | |
| 2-2 | 161.27 | 157.94 | 167.62 | 18.66 | | 14.45 | 89.36 |
| 2-3 | 161.27 | 157.94 | 167.62 | 18.66 | | 12.74 | 69.66 |
| 2-4 | 161.27 | 157.94 | 167.62 | 18.66 | | 11.22 | 16.71 |
| 2-5 | 161.27 | 157.94 | 167.62 | 18.66 | | 8.28 | 78.70 |
| 2-6 | 161.27 | 157.94 | 167.62 | 18.66 | | | |
| 3-3-1 | | | | | | | |
| 3-2 | 173.17 | 175.15 | 154.12 | 31.07 | | 10.78 | 88.15 |
| 3-3 | 173.17 | 175.15 | 154.12 | 31.07 | | 13.17 | 83.09 |
| 3-4 | 173.17 | 175.15 | 154.12 | 31.07 | | 12.07 | 89.08 |
| 3-5 | 173.17 | 175.15 | 154.12 | 31.07 | | 13.41 | 69.84 |
| 3-6 | 173.17 | 175.15 | 154.12 | 31.07 | | 9.41 | 78.76 |
| 3-7 | 173.17 | 175.15 | 154.12 | 31.07 | | 9.52 | 81.31 |

Table 5. continuation.

| soils & horizon | Pw | M.E. | A.M.C. | ΔH ₂ O | B.D. | O.M. | A.S. |
|--------------------|--------|--------|--------|-------------------|------|-------|-------|
| Honokaa #16 | | | | | | | |
| 2-1-1 | 311.64 | 26.99 | 23.03 | 16.90 | 0.46 | 16.81 | 46.57 |
| 1-2 | 275.51 | 27.52 | 21.17 | 30.57 | 0.25 | 14.72 | 67.43 |
| 1-3 | 267.32 | 28.44 | 24.05 | 21.74 | 0.25 | 13.17 | 71.27 |
| 1-4 | 271.25 | 28.76 | 23.57 | 24.50 | 0.25 | 12.45 | 71.71 |
| 1-5 | 271.25 | 28.57 | 23.57 | 42.11 | 0.27 | 11.29 | 66.22 |
| 1-6 | 280.14 | 28.32 | 23.26 | 24.04 | 0.25 | 10.15 | 68.85 |
| 1-7 | 271.64 | 28.26 | | | | 9.86 | 58.62 |
| 1-8 | 273.51 | 28.80 | 255.68 | 47.18 | | 8.53 | 50.74 |
| 1-9 | 244.26 | 36.60 | 23.03 | 50.58 | | 8.09 | 64.30 |
| 2-2-1 | 147.89 | 141.90 | 112.44 | 22.44 | | 18.15 | 62.04 |
| 2-2 | 225.10 | 210.05 | 190.22 | 23.43 | | 9.55 | 71.05 |
| 2-3 | 241.07 | 225.58 | 212.07 | 16.00 | | 12.57 | 78.56 |
| 2-4 | 272.81 | 250.20 | 232.13 | 27.56 | | 11.10 | 63.40 |
| 2-5 | 272.81 | 272.37 | 219.38 | 42.99 | | 10.28 | 65.88 |
| 2-3-1 | 135.41 | 116.53 | 104.82 | 29.45 | | 19.89 | 70.08 |
| 3-2 | 181.20 | 137.52 | 180.08 | 16.85 | | 17.48 | 52.91 |
| 3-3 | 272.81 | 272.51 | 231.86 | 36.65 | | 15.14 | 63.77 |
| 3-4 | 296.66 | 250.15 | 247.12 | 41.00 | | 14.05 | 62.86 |
| 3-5 | 296.66 | 275.01 | 257.28 | 15.73 | | 12.70 | 23.94 |
| Honokaa #18 | | | | | | | |
| 1-1-1 | 111.35 | 110.28 | 104.74 | 5.54 | 0.52 | 19.50 | 70.41 |
| 1-2 | 151.00 | 151.18 | 143.00 | 13.14 | 0.36 | 14.65 | 77.49 |
| 1-3 | 211.52 | 200.01 | 142.59 | 65.42 | 0.32 | 12.03 | 71.94 |
| 1-4 | 252.95 | 252.47 | 231.54 | 20.93 | 0.38 | 10.08 | 68.01 |
| 1-5 | 272.22 | 251.00 | 224.66 | 26.31 | 0.29 | 8.46 | 79.85 |
| 1-2-1 | 105.02 | 106.74 | 99.00 | 11.53 | | 23.93 | 41.41 |
| 2-2 | 145.60 | 151.34 | 153.26 | 16.08 | | 17.41 | 71.99 |
| 2-3 | 212.31 | 202.96 | 188.03 | 14.73 | | 14.45 | 65.86 |
| 2-4 | 211.31 | 207.05 | 183.32 | 23.93 | | 10.08 | 62.58 |
| 1-3-1 | 116.57 | 115.59 | 105.65 | 109.91 | | 19.89 | 96.44 |
| 3-2 | 164.57 | 157.70 | 149.48 | 8.22 | | 16.02 | 55.19 |
| 3-3 | 216.25 | 198.48 | 153.10 | 15.38 | | 13.98 | 65.10 |
| 3-4 | 276.06 | 222.05 | 197.98 | 24.10 | | 10.15 | 68.32 |

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