

# Developing a Simple Method to Estimate Clay Content for Tropical Soils that Resist Dispersion

Joshua Silva\*<sup>1</sup>, Jonathan Deenik<sup>1</sup>, Russell Yost<sup>1</sup>, Gregory Bruland<sup>2</sup>

<sup>1</sup>Department of Tropical Plant and Soil Sciences, University of Hawai'i at Mānoa; <sup>2</sup>Department of Biology and Natural Resources, Principia College



## Problem & Rationale

- Clay particles have high specific surface area (10-1200m<sup>2</sup>/g) and thus governs water retention (Banin & Amiel 1971), ion exchange capacity (Curtin & Rostad 1997), carbon stability (Wichern & Joergensen 2009), phosphorus sorption (Traikoonyingcharoen et al. 2005), and microbial activity (Muller & Hoper 2004).
- Accurate determination of clay content is an important component for predicting soil behavior.
- Clay does not exist as individual particles but as soil aggregates.
  - In high-activity clay soils, aggregate formation is a result of bonds between clay particles, polyvalent cations (Al<sup>3+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>), and organic matter.
  - In highly-weathered and volcanic soils, aggregation is primarily driven by the cementation of amorphous coatings consisting of organic matter and iron/aluminum oxides.
- Clay content is measured using the sedimentation method, which requires the complete dispersion of soil aggregates.
- Problem: Highly-weathered and volcanic soils high in iron, aluminum oxides or amorphous minerals resist dispersion via pipet method.**
- Clay particles remain as aggregates, and thus clay content is underestimated.
- Resulting clay content misrepresents and inaccurately predicts actual soil behaviors.
  - Example:** In high-activity clay soils, such as Pleasanton and Fargo series, low clay content is correlated to low 15 bar water contents and vice versa. These clay minerals are easily dispersed, and clay contents reflect true surface area controlling water retention (Table 1).
  - In oxide and amorphous mineral rich soils, such as Hali'i and Hilo series, high water contents compared to low clay contents indicate hidden sources of surface area within incompletely dispersed aggregates.

Table 1. Clay % vs. Water % for Four Different Soils

Series	Soil Order	Oxide, Amorphous Content	Clay %	15 Bar Water %
Pleasanton	Alfisol	Low oxide, amorphous	15.4	6.8
Fargo	Vertisol	Low oxide, amorphous	61.6	25.1
Hali'i	Oxisol	High oxide	12.2	20.2
Hilo	Andisol	High oxide, amorphous	14.7	134.2

NCSS 2012

## Objective & Hypothesis

**OBJECTIVE:** Determine if clay content measurements could be improved for highly-weathered and volcanic dispersion-resistant soils by:

- increasing chemical dispersant concentration
- increasing ultrasonication energy level.

### HYPOTHESES:

- Increasing chemical dispersant concentration will increase dispersion and thus clay content by overcoming the flocculating forces of polyvalent cations and oxide-cementing surfaces.
- Ultrasonication is more effective in dispersing soils higher in crystalline oxides than amorphous oxides due to higher surface areas associated with amorphous minerals that promote stronger organic matter-oxide cementation.

## Methods

### NRCS Standard Pipet Method (NRCS 2004)

- 30% Hydrogen Peroxide (37.5mL); Deionized Water Rinsing (750mL)
- Sodium Hexametaphosphate= Na-HMP (0.4408g/L)
- Horizontal Shaking (16 hours, 120 osc/min)

### Soils

- High-Activity:** Lualualei (*Smectitic, Gypsiteorrerts*)
- Oxide Rich:** Leilehua (*Ferruginous Kanhaplohumults*) Moloka'i (*Kaolinitic, Eutrotorrox*)  
Wahiawa (*Kaolinitic, Haplustox*) Pa'aloa (*Sesquic, Kandiodox*)  
Kapa'a (*Sesquic, Acrudox*) Hali'i (*Ferruginous, Acroperox*)
- Amorphous:** Hilo (*Ferrihydritic, Hydrudands*) Maile (*Ferrihydritic, Hydrudands*)

### Concentration Experiment

- Treatments: 0.4408g/L (standard), 0.8008g/L, 1.1606g/L
- Stock Solution pH = 9.69

### Ultrasonication Experiment

- Treatments: 0J/mL solution (standard shaking), 100J/mL, 200J/mL, 400J/mL, 1600J/mL
- 0.4408g/L of Na-HMP; pH buffered to 10 using 5M NaOH
- Soil: Water = 1:10
- Sonic Dismembrator Ultrasonic Processor (20kHz, 80% Amplitude, 4cm depth)
  - Power output calibrated according to Roscoe et al. (2000)
- Total Fe (crystalline) will be measured using Dithionite-Citrate Amorphous Fe using Hydroxylamine-Hydrochloride

## Results & Discussion

### Concentration Experiment:

- Increasing dispersant concentration up to ≈3 times the standard method had negligible effects on measured clay contents (Fig. 1).
- Dispersion-resistant Andisol (Hilo) and Oxisol (Hali'i) low clay contents did not reflect high water retention capacities (Table 1).

### Ultrasonication Experiment:

- Ultrasonication increased measured clay contents for all dispersion-resistant soils (Fig. 2).
  - Negligible increases for Lualualei soil (clay increased 70 to 72% for 0 to 400J/mL).
- Leilehua, Wahiawa, and Pa'aloa achieved complete dispersion at 100J/mL level (Fig. 2A,C,D).
  - Despite oxide mineralogy, measured high clay contents (>80% at 100J/mL).
  - Dispersion behavior of oxide soils similar to those found by de Sa et al. (2002).
  - Dispersion behavior may be due to crystallinity of oxides. Higher oxide crystallinity and lower surface area may result in fewer and weaker aggregate bonds, leading to easier dispersion.
- Hali'i, Kapa'a (Oxisols) and Hilo (Andisol) required 1600J/mL for maximum clay contents (Fig. 2E,F,G).
  - Maile completely dispersed at 400J/mL (Fig. 2H); Less-weathered Moloka'i soil was unexpectedly very dispersion resistant (Fig. 2B)
  - Dispersion resistant behaviors similar to those found by Hunter & Busacca (1989) and Roscoe et al. (2000).
  - Dispersion resistance may be due to high concentrations of amorphous oxide coatings that form stable aggregates (Prong et al. 2011; Uehara & Gilman 1981).
  - Amorphous oxides have high surface area (Wierzechos et al. 1992), which facilitate more oxide and organic matter bonding, resulting in stronger aggregation.
  - Drying of amorphous coatings may have caused clay particles to "irreversibly" cement, resulting in low clay contents at low energy levels for Hali'i, Kapa'a, and Moloka'i series (Nanzyo et al. 1993).
  - Maximum clay contents for Hilo and Maile soils still do not reflect high water retention capacity of Hydrudands when compared to high-activity clay soils.

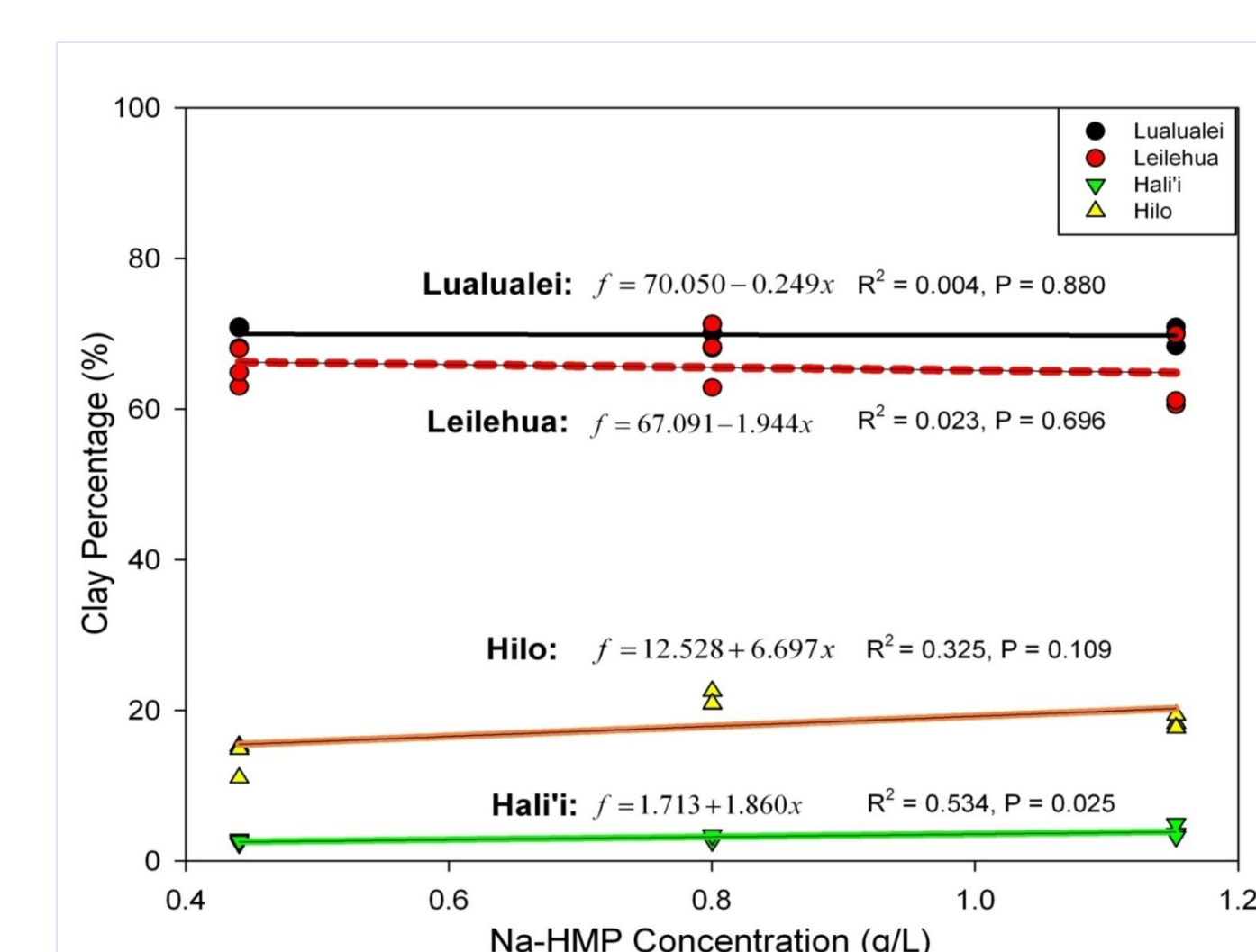
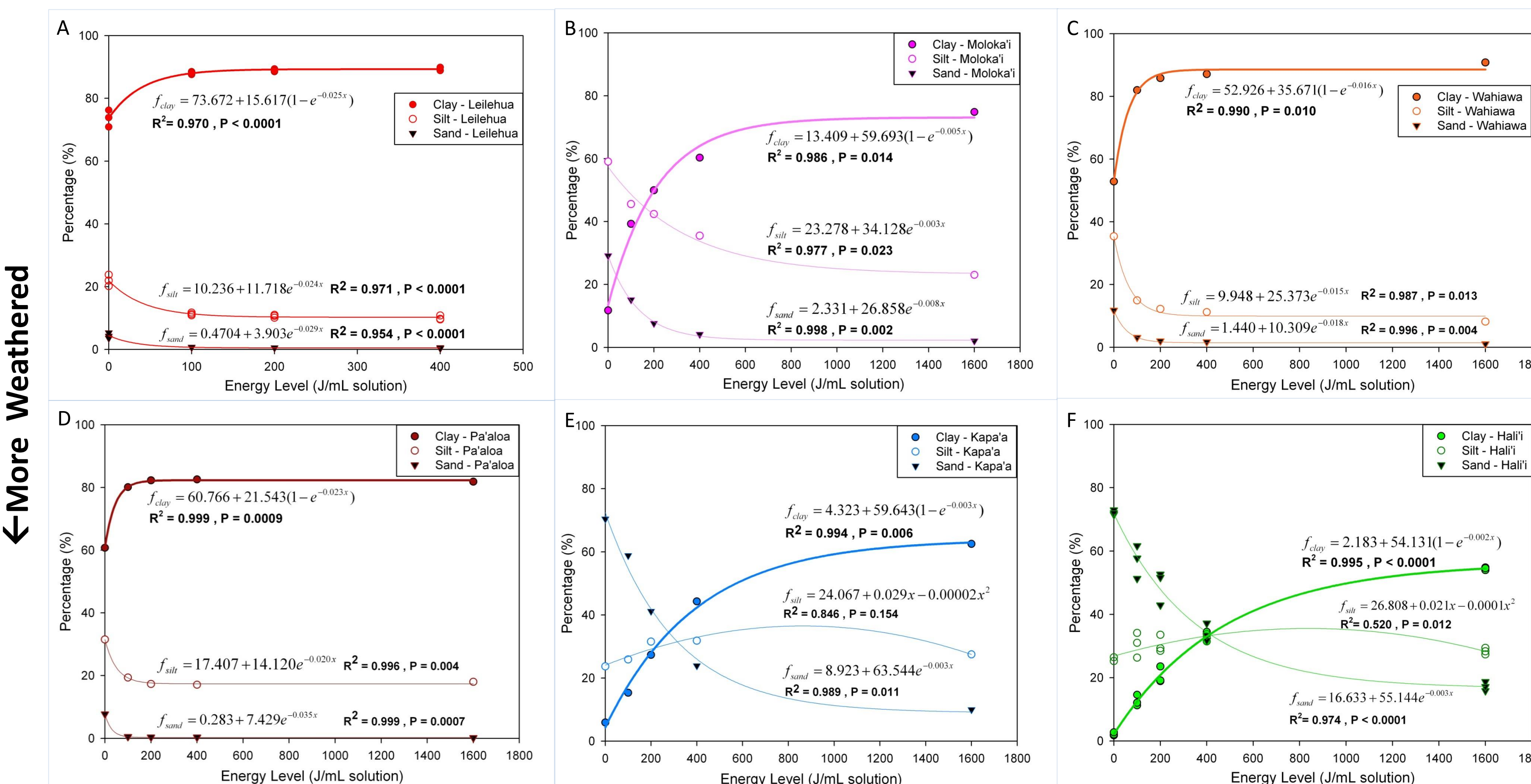


Figure 1. Clay contents of four tropical soils with increasing Na-HMP concentrations

### Oxides



### Amorphous

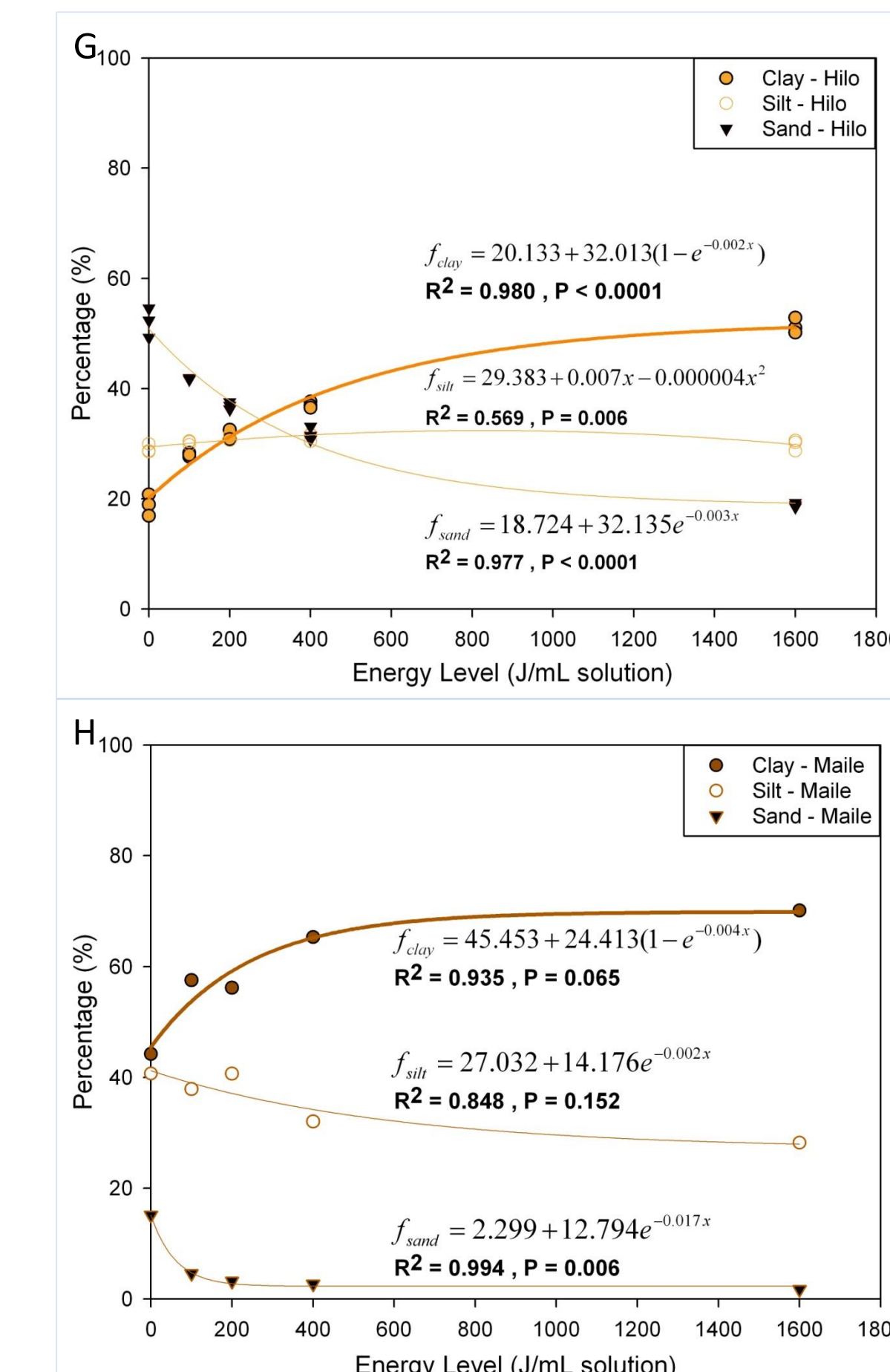


Figure 2. Particle size distributions at different ultrasonication energy levels for the A) Leilehua, B) Moloka'i, C) Wahiawa, D) Pa'aloa, E) Kapa'a, F) Hali'i, G) Hilo, H) Maile series

## Implications & Future Research

- Only ultrasonication was a suitable alternative for increasing clay content measurements for problematic tropical soils.
- Two distinct soil dispersion behaviors; maximum clay content near 100J/mL or 1600J/mL..
- Research In Progress:**
  - Scanning electron microscopy will be used to assess possible damage to particle surfaces.
  - Describing dispersion-resistance by iron and aluminum fractions using dithionite-citrate, hydroxylamine hydrochloride, and pyrophosphate methods
  - Analyze the role of organic matter in Hydrudand microstructure and water retention capacities
  - Evaluate the use Visible Near-Infrared Spectroscopy to predict clay content of tropical soils

## References

Banin, A. and A. Amiel. (1971). A Correlative Study of the Chemical and Physical Properties of a Group of Natural Soils of Israel. *Geoderma*, 3, 185-198.

Curtin, D. and P.W. Rostad. (1997). Cation exchange and buffer potential of Saskatchewan soils estimated from texture, organic matter and pH. *Can. J. Soil Sci.*, 77, 621-626.

de Sa, M.A.C., Lima, M.L., de Medis, R.C. (2002). Level of ultrasonic energy in the study of aggregate stability stable Latosol (Oxisol) under different uses. *Pesquisa Agropecuaria Brasileira*, 37(11), 1649-1655.

Hunter, C.R. and A.J. Busacca. (1989). Dispersion of Three Andic Soils by Ultrasonic Vibration. *Soil Science Society of America Journal*, 53, 1299-1302.

Muller, T. and H. Hoper. (2004). Soil organic matter turnover as a function of the soil clay content: consequences for model applications. *Soil Biology & Biochemistry*, 36, 877-888.

Nanzyo, M., Shoji, S., Dalgren, R. (1993). Physical Characteristics of Volcanic Ash Soils. In Shoji, S., Nanzyo, M., and Dalgren, R. *Volcanic Ash Soils: Genesis, Properties and Utilization*. Amsterdam: Elsevier, pp. 189-207.

Natural Resources Conservation Service, USDA. (2004). Soil Physical and Fabric-Related Analyses. In *Soil Survey Laboratory Methods Manual: Soil Survey Investigations Report No. 42 Version 4.0*. Retrieved from [http://ftp://fc.sc.gov.usda.gov/NSSC/Lab\\_Methods\\_Manual/S08R42\\_2004\\_view.pdf](http://ftp://fc.sc.gov.usda.gov/NSSC/Lab_Methods_Manual/S08R42_2004_view.pdf)

National Cooperative Soil Survey. (2012). *National Cooperative Soil Characterization Database [Data Sets]*. Retrieved from <http://ncsslab.usda.gov>

Prong, G.J., Hester, K., and I. Kogel-Knabner. (2011). Iron Oxides as Major Available Interface Component in Loamy Arable Topsoils. *Soil Sci. Soc. Am. J.*, 75, 2158-2168.

Traikoonyingcharoen, P., Kheueeromene, I., Sudthiprakarn, A., and R.J. Gilkes. (2005). Phosphate Sorption by Thai Red Oxisols and Red Ultisols. *Soil Science*, 170(9), 716-725.

Uehara, G. and G. Gilman. (1981). *The Mineralogy, Chemistry, and Physics of Tropical Soils with Variable Charge Clays*. Boulder, CO: Westview Press.

Wichern, F. and R.G. Joergensen. (2009). Soil Microbial Properties Along a Precipitation Transect in Southern Africa. *And Land Research and Management*, 23, 115-126.

Wierzechos, J., Acasco, C., and M.T. Garcia-Gonzalez. (1992). Changes in microstructure of soils following extraction of organically bonded metals and organic matter. *Journal of Soil Science*, 43, 495-504.

## Acknowledgements

Thank you very much to my advisors, professors, and the Natural Resources Conservation Service for guidance throughout this project and experiment. Thank you to Dr. Goro Uehara for his guidance and advice to have fun. This project was made possible by funding provided by the NRCS and the University of Hawai'i Graduate Student Organization.