Hawaii Tropical Fruit Growers
Back to Our Roots

Soil Culture and Soil Health in Hawaii

Bob Shaffer, agronomist
Soil Culture Consulting™
SOIL CULTURE

• Object is:
• Use cultural practices to elevate soil health, in preference to treatments, rescue of crops and environmental damage in the act of raising food
• Soil health preserves environmental health and function
• High quality food production and prevention of disease
Prevailing philosophy

“Specific pests, nutrient deficiencies and others are the cause of low productivity”

(Carroll et al. 1990)
Holistic philosophy

“Pests or nutrients only become limiting if conditions in the agroecosystem are not in equilibrium”

(Carroll et al. 1990)
Holistic philosophy

“Limiting factors only represent symptoms of a more systemic disease inherent to imbalances within the agroecosystem”

(Altieri et al. 1983; Altieri 1994; Altieri 1987; Altieri and Nicholls 2004)
An effective, simple and economical system for creating healthy soils comprised of three (3) groups cultural practices has become apparent.
3 groups of SOIL cultural practices

1. Organic matter management
   a)  Cover crops
   b)  Compost
   c)  Mulch

2. Mineral and nutrient management
   a)  Balance and Availability

3. Tillage management
   a)  Beneficial disturbance
Farm management systems designed to employ cultural practices which closely imitate nature and natural ecosystems
Developing a sustainable and preventative farming system

- Transition rather than instant change
- Integrate all cultural practices
- Focus on soil health
- Feed the soil (and the plant)
- Grow large volumes of plant biomass
- Diversity and Rotate
- Relentless learning
- Recognize opportunity in the
- Accepting change and practicing tolerance
Long term research

- 119 year long trial, A.C. Magruder, at Oklahoma State University
- 118 year long trial, Sanborn Field at the University of Missouri campus
- 170 year long trial, Rothamsted Experiment Station, England
Mid term research

• 30 year farming systems trials at Rodale Institute

• 28 year study or Swiss Research Institute of Organic Agriculture (DOK), comparison of organic, biodynamic and conventional

• 27 year Sustainable Agriculture Farming Systems (SAFS) project at UC Davis, CA on Russell Ranch studying organic, conventional and low input for crop rotations typical to Sacramento Valley

• Reganold 2001 published in Nature a 6 year study on apples showed comparable yield and many advantages to conventional and higher profit
Local current research

• Performance and Plant-Available Nitrogen (PAN) Contribution of Cover Crops in High Elevations in Hawaii
  Archana Pant, Theodore Radovich, Koon-Hi Wang, NV Hue

• Building the Future on a Foundation of Soil Health
  Susan Kubo, USDA NRCS Pacific Islands Area
Local current research

• Enhancing Phytonutrient Content, Yield and Quality of Vegetables with Compost Tea in the tropics

  Theodore Radovich, University of Hawaii, 2011

• Improving and extending the superhero status of the sunn hemp to other growers in need of help

  Dr. Cerruti Hooks, University of Maryland, 2009
Australia current research

- Soil health survey in Macadamia orchards in NSW
  Van-Zwieten, Kingston, Cox, Walker, Hotson, Morris

- Macadamia husk compost improves soil health in sub-tropical horticulture,
  Cox, Van-Zwieten, Ayres and Morris, 2001
SoilCare in Australia

Northern Rivers
Soil Health Card Video

WWW.SOILCARE.ORG
Compost, Manure and Synthetic Fertilizer Influences Crop Yields, Soil Properties, Nitrate Leaching and Crop Nutrient Content

Paul Hepperly, Don Lotter, Christine Ziegler Ulsh, Rita Seidel and Carolyn Reider
The Rodale Institute®, Kutztown, Pennsylvania e-mail: paul.hepperly@rodaleinst.org

Soil diversity
Species contained within *The Plant List* belong to 620 plant families and 16,167 plant genera.

*The Plant List* includes 1,040,426 scientific plant names of species rank.

Of these 298,900 are accepted species names

[www.theplantlist.org](http://www.theplantlist.org)
A Complex Food Web

**Generalists** e.g. earthworms*

* Earthworms are generalists that feed on many smaller soil organisms.

Figure 4
Potential threat of loss of biodiversity weighting (%)

65% Human intensive exploitation
63% Soil organic matter decline
60% Habitat disruption
60% Soil sealing
60% Soil pollution
59% Land use change
58% Soil compaction
56% Soil erosion
48% Habitat fragmentation
45% Climate change
38% Invasive species
35% GMO

The potential threat weighting given to a selection of possible threats to biodiversity
Soil Health
Soil health can be defined as the capacity of a soil to function within an agroecosystem to sustain biological productivity, maintain environmental health, and promote plant and animal health.
What is soil health?

- Health as commonly understood
- Soil capacity to sustain quality crops
- Holistic biological, chemical, physical
- Life force in soil
- Living total soil biomass
  All soil animals and plant ROOTS
- Living soil micro-fauna biomass
  actinomycetes, bacteria, fungi, nematodes, protozoa
- Living soil macro-fauna biomass
  algae, insects, micro-arthropods, worms
By 1936 there was 41% of land in the U.S. had moderate soil erosion and 12% had severe soil erosion and 3% was essentially destroyed.

55% of the total land mass eroded by 1936

1936 USDA Year book of agriculture, Soils and Men
Healthy soil characteristics

• Erosion free, TILTH, pores, aggregation, crusts

• Soil life diverse, high populations, active
  Earthworms, 9 major soil surface dwelling animals, smell

• Reliably, ripens the highest quality crops

• Nutrient recycling obvious
  9 major animals present, residues from last crop decompose rapidly and fully

• SOM levels are 4 – 15 % + site specific, active inputs?
  0-7 inch depth, Walkley-Black method, Dichromate-sulfuric acid 90 minutes at 90°C, Spectrophotometer

• Minerals balanced

• Disease suppressive

• Crops show resistance-tolerance
  Pests present but damage is minimal
Soil microorganisms
A primary goal of the culture of soil is to elevate diversity population health of life in soil....including the roots
Four (4) groups of functional microorganisms in soil

Bacteria
Fungi
Nematode
Protozoa
Bacteria on fungal hyphae
Fungi feeding nematode
Bacteria feeding nematode
Bacteria 10,000 species
Fungi 500,000 species
Nematode 50,000 species
Protozoa 100,000 species

NRCS National Soil Tilth Lab
Protozoa (Amoeba)
7 essential functions provided by soil life
Living microbial biomass seven (7) functions in soil

- Organic matter decomposition
- Immobilize minerals from OM decomposition
- Recycling of immobilized minerals
- Plant growth promotion
- Disease prevention
- Aggregation
- Decomposition of toxins

Soil food web functions
Living microbial biomass seven (7) functions in soil

- Organic matter decomposition
Decomposition of organic matter and aggregation
Living microbial biomass
seven (7) functions in soil

• Aggregation
Glomalin, polysaccharides, humus
Living microbial biomass seven (7) functions in soil

- Decomposition of toxins
Lead ore crystal being decomposed by a fungi
Living microbial biomass
seven (7) functions in soil

• Disease prevention
Living microbial biomass provides plants

- Controlled release of **Nitrogen**
- Stress relief from salts and toxins
- Release of nutrients in available forms
- **Natural suppression against pests**
  - Antibiosis
  - Competition
  - Hyperparasitism
  - ANTAGONISM to PEST
  - Systemic acquired resistance (TOLERANCE – RESISTANCE – host)

- **Improved physico-chemical soil aspects**
  - Humus development is a microbe process
  - **Structure** development is a microbe process
Entomopathogenic nematode
Steinernema
The fruiting body of Lacrymaria sp. the carnivorous fungi Drechslerella anchonia which captures nematodes in rings which grow along its hyphae then penetrates the skin and consumes the nematode from the inside out the fruiting body of Hygrocybe punicea.
filamentous cyanobacteria
The best way to elevate the health and diversity life in soil is to provide air, water and FOOD
The best food for soil life is **CARBON** from diversified plant origin and quality.
4,400,000,000 tons of carbon (C) has been lost from farming soils

NRCS national soil tilth lab
3 essential groups of SOIL cultural practices

1. Organic matter management
   a) Compost
   b) Cover crops
   c) Mulch

2. Mineral and nutrient management
   a) Balance and Availability

3. Tillage management
   a) Beneficial disturbance
Definitions of compost

- **By process**  thermal compost or vermipost
- **By feedstock**  pumice or council greenwaste compost
- **By age,**  immature or mature compost
- **By biology,**  bacteria or fungi dominated compost
- **By QUALITY,**  stability, curing, amended
- **By Use,**  soil amendment
Definitions of compost

Aerobic microbial processes produces:

• Heat
• Water vapor
• Carbon dioxide
• HUMUS
Solar Powered Static Pile Aeration
Mackay Sub Surface Applicator
Cover Crops
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Primary effects
- If added to soil surface as mulch, protects soil surface from solar energy and rain drops
- Coarse organic matter particles loosen soil, provide macropores, channels, etc.
  - Enhanced microbial functions such as N fixation, decomposition, etc.
  - Production of humic substances

Secondary effects
- Increased buffering capacity
- Increased water holding capacity
- Increased competition and antagonism against plant pests
- Increased ion adsorption capacity
- Darker soil color
- Production of burrows, macropores
- Increased aggregate stability, macro porosity
- Increased mineralization
- Production of polysaccharide and other nonhumic compounds
- Increased metal ion chelation
- Increased availability of N, P, S and micronutrients
- Increased availability of Fe, Mn, Cu, Zn
- Reduced toxicity of aluminum

Subsequent effects on soil
- Reduction of evaporative water losses
- Moderation of soil temperature extremes
- Greater absorption of solar energy
- More adsorption of organic compounds
- Inactivation of toxins, pesticides
- More retention of Ca, Mg, K, and micronutrients
- More stable soil pH
- Increased gas exchange
- Better aeration, oxygen supply to roots
- Increased water infiltration
- Less surface runoff water losses
- Increased water availability to plants

Environment effects
- Warmer soil at night, in winter
- Cooler soil in daytime, summer
- Warmer soil, on average
- Inactivation of toxins, pesticides

Green shows 7 functions

OM

Plants (and lichen, moss, algae, photosynthetic bacteria) are the primary producers of organic matter on land and in the sea and are the base of the food chain.
Cover crops are a high quality source of **organic matter** which provides energy for the soil organisms which provide perform seven (7) essential functions for the crop and soil that cannot be practically or economically provided otherwise.
Advantages of cover crops

• Prevention of soil erosion
• Diversity
• Soil health
• Nitrogen
• Beneficial habitat for life
• Field access
• Beauty
• Safety and comfortable work site
Benefits of cover crops

- Simple
  - Complex effects derived
  - Management increases benefits
  - Management and skill building
  - Increases benefits and decreases risk
  - Synergistic
Benefit of ground covers

- Inexpensive
  - Placement of carbon deep into soil
- Renewable
- Reliable
- Effective and simple
Barley and Oats: 60#/A; moderate rate of establishment; needs water; not great weed competition; good mulch source

Examples of barley-vetch mix: right is clean part of field; lower left has weeds; both pictures from March 2007; lower right shows mowed field planted with mangos in August 2007
Hunter turnip *Sinapis alba* L.

Graza radish *Sinapis alba* L.

Diakon
Biological fumigation

Winfred turnip
Brassica

Biological fumigation
Daikon radish on compacted high clay soil
Insectary Plants, Intercropping and Biological Control

By William Quarles and Joel Grossman

Diverse crop plantings can lead to fewer pests, more beneficial insects, and fewer pesticide applications. This article discusses increased diversity through field insectary plantings and strip intercropping. An earlier Practitioner article called “IPM and Farmscaping” (IPMP 13(10):1-12) reviewed the use of boundary plantings. “Agroforestry and IPM” (IPMP 14(4):1-12) discussed the interplanting of crops and trees.

Large monocultures may cause many of the problems associated with conventional agriculture. Extensive unbroken acreage of the same crop, such as corn or cotton, encourages arthropod pests (insects and mites) that specialize in these crops (Root 1973; Elton 1958; Andow 1991a). Because pests often expand more rapidly than beneficial populations in these situations, broad-spectrum pesticides are applied. These pesticides then cause problems such as target pest resistance, pest resurgence, and secondary pest outbreaks that are all too familiar (see Quarles 1999; DeBach and Rosen 1991).

If it is true that monocultures encourage pests, then fewer pests should be seen when there is an increase in crop diversity (Andow 1991a; Pimentel 1961; Elton 1958). Generally, diversity does lead to lower pest densities. When the published literature was reviewed in 1991, about 52% of pest insects and mites studied had lower population densities in diverse plantings than in monocultures, while only 15% had higher densities. In 20% of the cases effects were variable [sometimes lower, sometimes higher], and in 12% of the cases, there was no effect. Most of the studies conducted in this review were on various kinds of intercropping (Andow 1991a).

Traditional farmers in other countries have long intercropped beans, corn, squash and other subsistence crops to make maximum use of their land (Francis 1986; Funes et al. 2002). There are several different ways to intercrop, and these are discussed in Box A. Published studies on intercropping since 1991 confirm the trend of lower pest densities in intercrops versus monocultures. For instance, in the 38 studies of intercropping and pest abundance cited in CAB Abstracts between 2000 and 2002, about 86% (25) showed lower pest densities with intercropping. Of these, 24% (9) intercropped a veg-

White flowering alyssum, *Lobularia maritima*, has been planted on the edge of this commercial lettuce field. Alyssum has abundant pollen and nectar to help feed beneficial insects that provide biological control.
Benefits of cover crops

• Effective
  • Prevents movement of soil
  • Elevates level of soil health
  • Develops Humus
  • Increases water infiltration, storage
  • Simple and inexpensive!
Rye grass. Oregon annual seeded at 30#/acre; Grows best in winter with cooler and wetter weather Good weed competition Good fibrous roots for erosion control

Left: Rye grass after 8 weeks in winter; inset above shows soil surface after heavy rain with soil retention by fibrous rye roots after mowing, rototilling, and overseeding with buckwheat (10 day old seedlings)
Buckwheat: 40#/acre; fast germination and canopy closure; excellent insectiary; fast to flower (30 days); good in summer or winter; will reseed; easy to kill with mowing only.
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Mulch

- Elevates level of soil health
- Food and habitat
- Prevent soil erosion and surface crusts
- Reflects light, cools soil surface
- Prevents soil compaction
- Tillage reduced
- Genes activated in crops growing with mulch

Soil organisms creating suppressive soil, resistant crops
Soil loss is principally due to water and wind erosion, both heightened by practices that reduce surface cover.
Soil SURFACE biology
9 soil surface dwelling animals

- Wood louse
- Orbatid mite
- Termite
- Springtail
- Fly larva
- Beetle larva
- Millipede
- Enchytraeid worm
- Earthworm
Amynthas corticis,  
A. diffringens,  A. gracilis  
(Kinberg,1867) (Megascolecidae)  
Black wriggler, Snake worm, Crazy worm, Alabama jumper or Georgia jumper 

- **Peregrine earthworm** (transported world wide by farmers)  
  first described in Oahu, Kinberg, 1867  
  misidentified as *A. hawayanus or Pheretima hawayana*  
  Mr. Domingo Cravalho, Jr. Invertebrate, Aquatic Biota specialist, U/H (1/14/04)  
  origin in Southern Asia, described as common Darjeeling in the Himalayas  
  common in Oceania including Polynesia, Micronesia, Japan, Australia, China  
  dark chocolate brown with green iridescence  
  4 ½ to 6 ½ length with 3-6 mm width  
  behavior when perturbed is vigorous lashing and rapid snaking escape  

- **Epigeic species earthworm** (soil surface litter dwellers)  
  Amynthas has capacity to exist on high C:N ratio organic matter  
  Amynthas tolerates heat, drought, sandy soil or clay soil  
  Amynthas highly mobile, wanders at night, transportation exceeds Lumbricids  

- **Parthogentic earthworm** (virgin birth)  
  reproduces without a mate  
  produces cocoons containing one (1) or two (2) eggs  
  multiplies rapidly throughout year producing up 360 juvenile worm per year
Direct Chipping
Herbicide

Mulched with woodchips
“tomatoes cultivated in vetch mulch have reduced disease”

disease tolerance of mulched tomatoes is linked to increased expression of specific genes and accumulation of their products”
Soil Minerals
Nutrient Quantity or Nutrient Access?
Figure 2.2.1—The relative availability (the wider the band, the more available the nutrient) of the various mineral nutrients is different for mineral-based and organic-based soils. Maximum nutrient availability for mineral soils is pH 6.5, compared to 5.5 for organic soils (Kuhns 1985).
A New Understanding to Maintain Soil Fertility in the Tropics

Dr. Roland Bunch
Association of Consultants for a Sustainable Ecological and People-Centered Agriculture (COSECHA)
http://ppathw3.cals.cornell.edu/mba_project/moist/Rolandpd

The Management of Soils (Spanish)

Dr. Ana Primavesi
Soil life and chemical fertilizers
Nutrient Quantity or Nutrient Access?

• The Concept

Emphasis on access of roots to nutrients
Emphasis on nutrient balance
Nutrient Quantity or Nutrient Access?

“crop growth above a certain extreme concentration of nutrients depends, rather, on the constant access of plant roots to nutrients even when these nutrients are in low concentrations” R. Bunch

“all we discovered in our 12 year odyssey is something we should have known all along. For tropical agriculture to be sustainable and highly productive it must imitate the highly productive tropical forest” R. Bunch
Tillage
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20 years of similar tillage intensity and C inputs but contrasting types of organic inputs
Overgrazing: another source of disturbance
PROPERLY STOCKED

ROTATIONALLY GRAZED
(4 inch cover)

RESTED PASTURE

OVER-STOCKED
OVER-GRAZED
PASTURE
Continuous

Good Rotational

Excellent Rotational

Infiltration

Runoff
Hawaii Tropical Fruit Growers
Back to Our Roots

Thanks

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