Mulch addition increase growth, yield, soil C and N in a managed full-sun coffee system in Hawaii

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Introduction

- Climate change is an enduring challenge for sustainability (Fig. 1).
- Increased use of trees in agriculture can remove excess CO_2 from the atmosphere, storing it in biomass and soil-C (Fig. 2).
- Studies with coffee shaded by an interspecific *Leucaena* hybrid (variety "KX2") demonstrate rapid potential for increasing soil C and N while balancing coffee yield and quality (Fig 3).
- One alternative for full-sun coffee is to grow trees separately and use as a source of mulch.

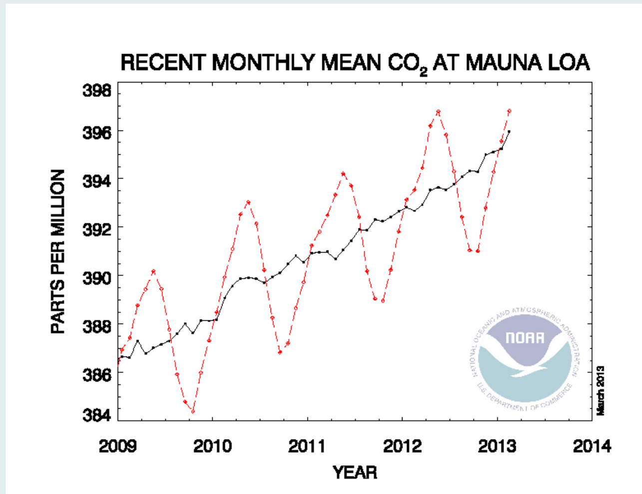


Fig. 1: CO_2 emission

Fig. 3: *Leucaena* variety KX2

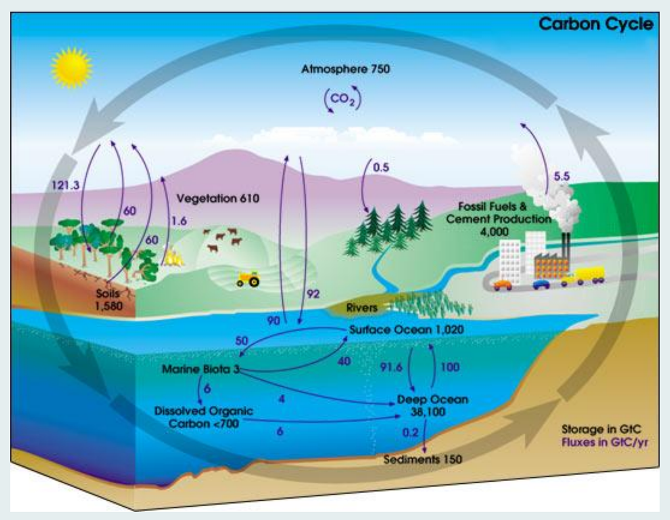
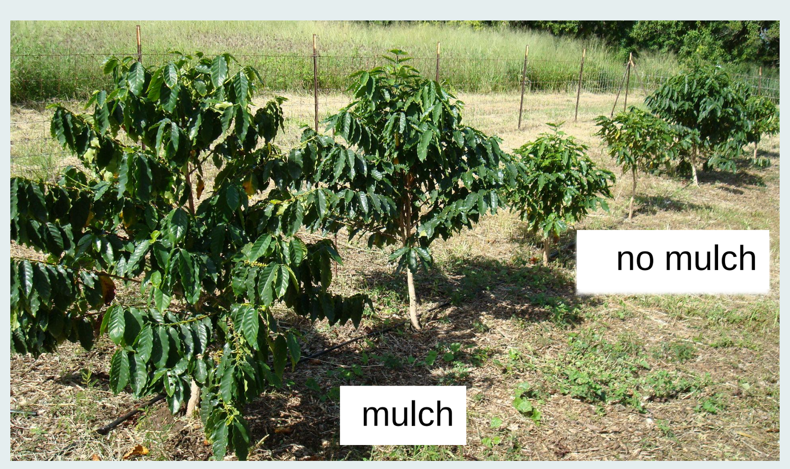


Fig. 2: C cycle

Objectives

- Evaluate the potential of chipped pruning residues of *Leucaena* variety KX2 as a mulch source for full-sun coffee production in a cut-and-carry system
- Investigate:

(1) mulch decomposition, N mineralization, and changes in major biochemical constituents over one year;
(2) changes in soil CO_2 efflux and total soil C and N after mulch additions over 3 years;
(3) coffee tree growth and yield in plots amended with mulch vs those where equivalent amounts of inorganic N were added.



Materials and Methods

Site - CTAHR Waimanalo Research Station, Honolulu, Hawaii.

- Eight open-grown coffee assigned to mulch or no-mulch treatments.
- *Leucaena*-KX2 grown in adjacent stand and pollarded at 1 m every year.
- Material chipped and added on an equal-area basis. Approx. 65 Mg ha^{-1} of mulch dry matter was added over a 3-year period, including ~27.5 Mg ha^{-1} of C and ~530 kg ha^{-1} of N.
- No-mulch plots fertilized with equivalent amounts of inorganic N for comparison.
- Microplot decay unit established in each plot with four 10-cm diameter cores.
- 50g fresh-weight of mulch placed inside each cylinder (Fig. 4).
- Mulch removed from at 3-mo intervals to estimate loss of mass, C, and N and changes in biochemical composition.

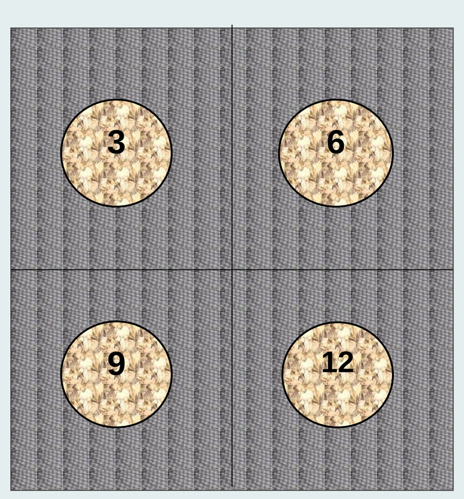


Fig. 4: Decay microplot

Materials and Methods (cont.)

- Biochemical composition determined using sequential fiber digestion analysis (Fig. 5).
- Soil samples and bulk density cores from 0-20 cm collected to monitor changes in soil C and N (Fig. 6).
- Soil-surface CO_2 efflux (µmol m^{-2} sec^{-1}) measured monthly in decay microplots using portable infrared gas analyzer attached to a soil respiration chamber (Fig. 7).
- Coffee leaf chlorophyll concentration (Fig. 8), main stem height and diameter, and components of fruit yield measured from 2006-2008.
- Annual green bean yield estimated for 2007 and 2008.

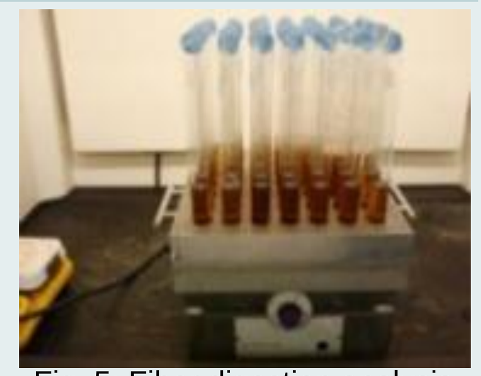


Fig. 5: Fiber digestion analysis

Fig. 6: Bulk density samples

Statistics:

- Mulch decomposition fitted to a negative exponential decay model: $L_t = L_0\, e^{-kt}$
- Repeated measures multivariate analysis of variance (MANOVA) used for comparison of changes in soil C and N.
- One-way ANOVA used to analyze coffee growth and green bean yield each year

Fig. 7: Soil-surface CO_2 efflux measurement

Fig. 8 Chlorophyll content

Results

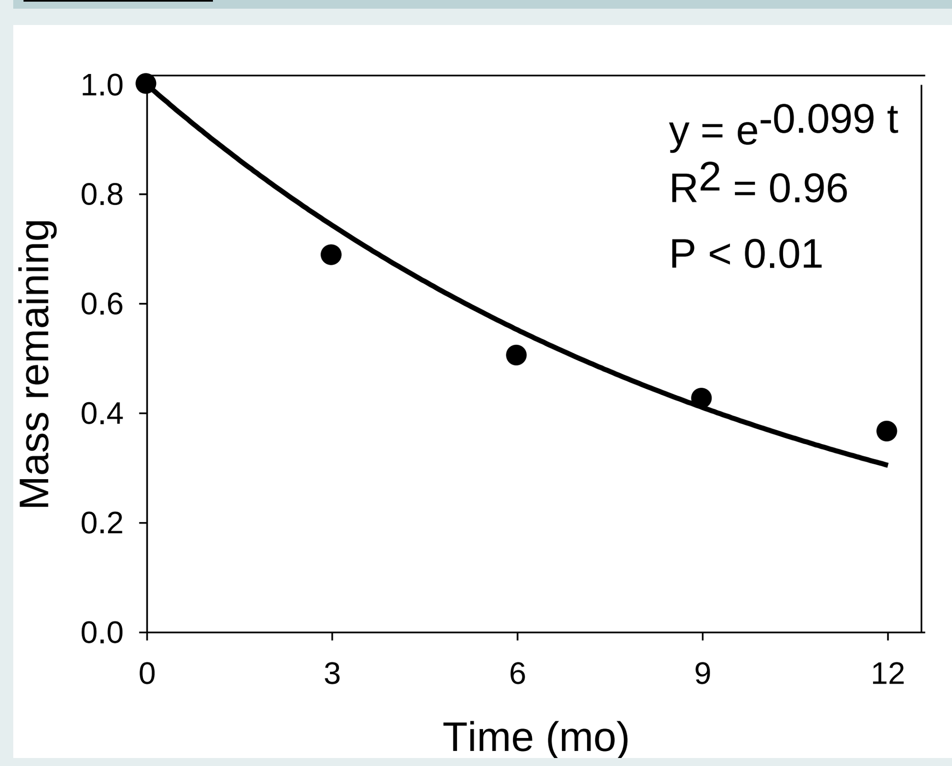


Fig 9: Mass remaining over time of decomposition

Mulch Decomposition

- Mass loss ~ 64% after1 year
- Net N loss began within first 3 months (Fig. 9).
- Significant loss of all biochemical components over 1 year (Fig. 10).

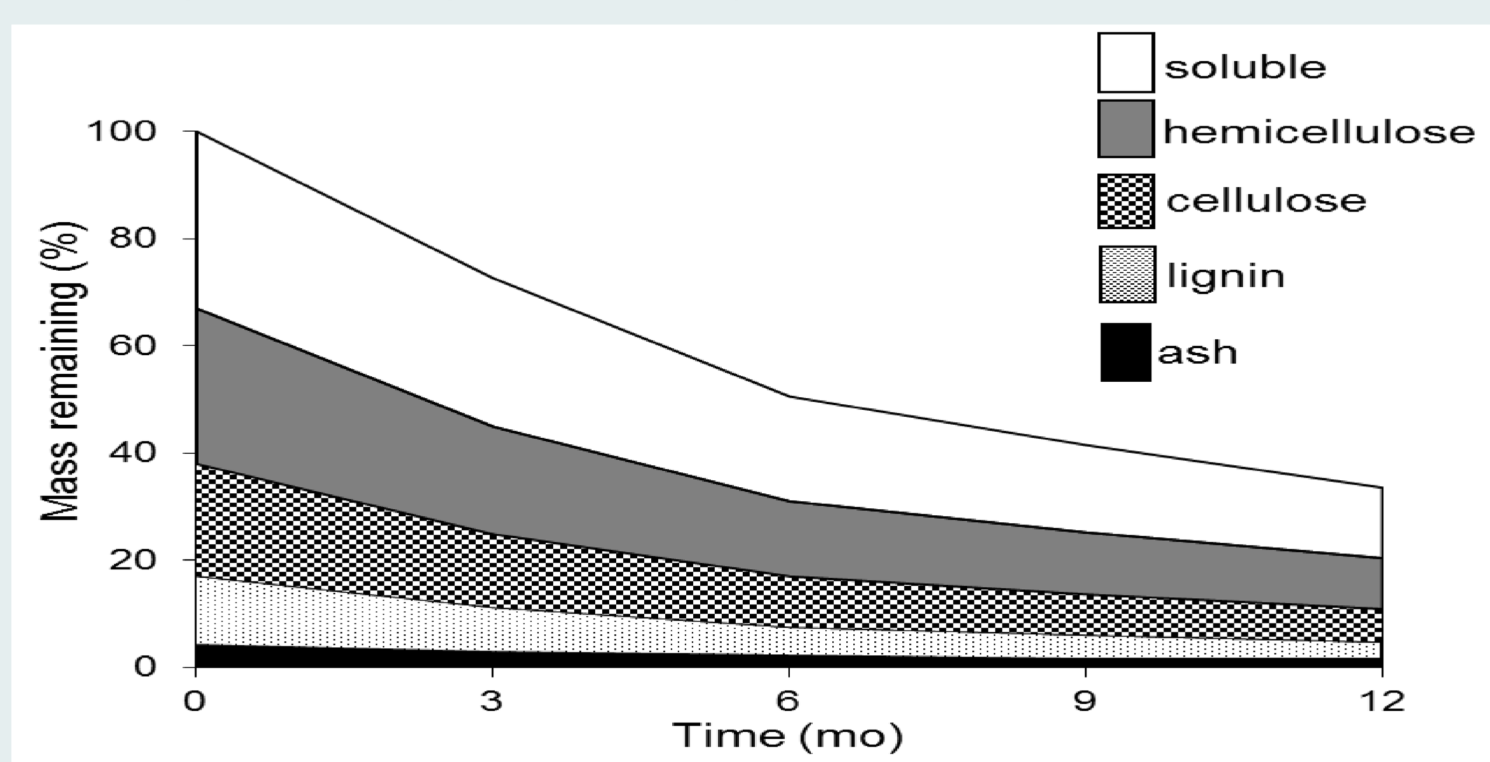


Fig. 10: Mass loss from mulch biochemical components

Results (cont.)

Soil C and N

Table 1: Changes in soil C, N & CO_2 efflux due to mulch

Year	No Mulch	Mulch
	Carbon (Mg ha^{-1})	
2006	45.60	45.60
2008	38.80	48.50†
Change	-6.80*	2.90
	Nitrogen (Mg ha^{-1})	
2006	2.50	2.50
2008	2.40	3.92†
Change	-0.10	1.42*
	CO_2 efflux (µ mol m^{-2} sec^{-1})	
2006	3.82	3.90
2008	3.30	4.65†
Change	-0.53	0.75*

*significant change between 2006 and 2008
† significant difference between mulch and no-mulch.

- Mulch increased soil C, N and CO_2 efflux (Table 1).
- Decrease in bulk density over time masked changes in soil C concentration in mulch-addition plots.

Coffee Growth and Yield

Table 2: Growth and yield characteristics

Growth and yield characteristics	2007		2008	
	no mulch	mulch	no mulch	mulch
Main stem D (mm)	17.3 b	29.6 a	29.7 b	40.5 a
Plant H (cm)	108.0 b	166.5 a	147.8 b	205.0 a
Chl content (SPAD)	60.8 a	64.0 a	60.2 b	68.6 a
Yield (g) / tree	250.3 b	407.3 a	344.8 b	855.3 a
Fruit / node	8.1 b	15.6 a	9.0 b	19.4 a
Nodes / lateral	11.5 b	18.6 a	14.5 b	25.3 a
Laterals / stem	18.2 b	28.4 a	22.2 b	31.4 a
100 green beans (g)	16.1 a	17.9 a	16.6 b	18.8 a

- Mulch increased growth and yield components of coffee in both years (Table 2).
- Leaf chlorophyll content significantly greater in 2008

Conclusions

- *Leucaena* mulch added to full-sun coffee improved soil C and N, sequestering ~17% of added mulch
- Mulch benefited coffee growth and yield beyond comparable inorganic N fertilization
- Thus, a cut-and-carry system for soil C sequestration and crop growth improvement is a viable alternative to overhead shade for capturing benefits of trees in coffee and likely other perennial cropping systems in the tropics.

Related studies

- Youkhana, A., Idol, T., 2009. Tree pruning mulch increases soil C and N in a shaded coffee agroecosystem in Hawaii. Soil Biology & Biochemistry 41(12), 2527-2534.
- Youkhana, A., Idol, T. 2011. Addition of *Leucaena*-KX2 mulch in a shaded coffee agroforestry system increases both stable and labile soil C fractions. Soil Biology & Biochemistry 43: 961-966.
- Youkhana, **A.** and Idol, T. (2010): Growth, yield and value of a managed coffee agroecosystem in Hawaii. Pacific Agriculture and Natural Resources, 2: 12-19.
- Youkhana, A. and Idol, T. (2011): Addition of *Leucaena*-KX2 mulch in a shaded coffee agroforestry system increases both stable and labile soil C fractions. Soil Biology and Biochemistry 43: 961-966.