

# Tree pruning residues increase soil carbon and nitrogen in shade and full-sun coffee agroecosystems in Hawaii

Adel Youkhana

Travis Idol

Department of Natural Resources and Environmental Management,  
College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii 96822  
Corresponding Author: 808-956-2620 adel@hawaii.edu



Shade Coffee



Leucaena KX2 regrowth

## Abstract

Agroforestry can increase carbon sequestration through the accumulation of woody biomass and higher inputs of organic material to the soil. Our objective was to study tree mulch decay and effects on soil C and N in a shaded and open-grown coffee agroecosystem in Hawaii. We measured decomposition, nitrogen mineralization, and changes in soil carbon and nitrogen over 2 years after additions of chipped tree pruning residues added to coffee plots in full sun or shaded with the leucaena hybrid KX2. Mass loss of mulch was 80% in the shade system and 64% in the full-sun system. Both followed first-order decay dynamics. Net N mineralization was positive throughout the entire period. There was significant loss of all major biochemical components during the mulch decomposition process in both systems. Soil C and N increased significantly due to mulch additions in shade system by 11.5 and 2.12 Mg ha<sup>-1</sup>, respectively. In the full-sun field, there was a significant loss of soil C due to declines in soil bulk density. Carbon sequestration in coffee-leucaena systems is a promising incentive for introducing best management agroforestry practices and contributing to the development of sustainable land-use systems in Hawaii.

## Introduction

Climate change is one of the greatest challenges now facing humanity and will likely remain so for generations to come (Fig. 1).

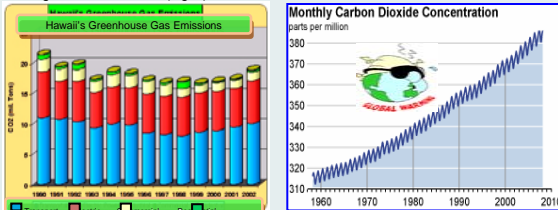


Fig 1. Carbon dioxide emission in Hawaii and atmospheric CO<sub>2</sub> concentrations.

There is an increasing need to design strategies that will both curtail emissions and remove excess CO<sub>2</sub> from the atmosphere that altered the nature carbon cycle (Fig 2).

- Agroforestry systems can play a major role in the sequestration of carbon because of their higher input of organic material to the soil (Olebermann et al. 2006).
- One way to ease CO<sub>2</sub> accumulation in the atmosphere is by removing it from the air and storing it on land in the form of biomass and soil-carbon reservoirs (Pfaff et al 2000).

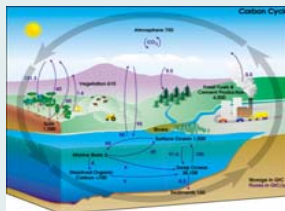


Fig 2. Carbon cycle.

Decomposition of litter is a key process in organic matter and nutrient cycling (Peng 2002).

## Objectives

- Determine decomposition, N mineralization rates, and changes in soil C and N from additions of chipped tree pruning residues (mulch) of a fast-growing *Leucaena* hybrid added to shade and full sun coffee agroecosystems in Hawaii.



Leucaena leucocephala KX2

## Materials and Methods

Site: CTAHR Waimanalo Research Station, Honolulu, Hawaii.

- In shade field: 16 separate plots were established, each containing 6 trees of *Leucaena* hybrid KX2 and 2 coffee (*Coffea arabica* var. 'Kona typica') plants planted on 2 x 2 m spacing.
- In full-sun field: 8 plots of the same size, with 2 coffee seedlings only.
- On Sept 2005 all leucaena trees were pollarded at 1 m above ground level.
- The harvested biomass was chipped in a mechanical tree chipper and distributed uniformly back to the plots as a green manure (Fig 3).
- On Sept 2006 all trees in the shade plots were pollarded as before. The chipped mulch was distributed uniformly back to the mulch-addition plots.
- In the full-sun coffee field, similar quantities of chipped tree mulch taken from border trees were added to the mulch-addition plots.
- Tree pollarding and mulch addition were repeated one year later in 2007. Annual dry mass, C, and N additions averaged 16, 7, and 0.13 Mg ha<sup>-1</sup>, respectively.



Fig 3. Pollarding, Chipping & Mulching.

- A 50 x 50 cm microplot decay unit was established in each plot with 4 cores.
- 50g of mulch was placed inside each cylinder (Fig 4).

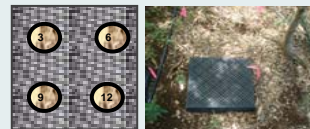


Fig 4. Decay microplot. Numbers indicate incubation time (mo).

- Biochemical composition was determined using a modified sequential fiber digestion analysis (Fig 5).
- Soil samples and bulk density cores from 0-20 cm were collected randomly within the plots at approx. 6-month intervals from May 2006 until May 2008 to monitor changes in soil C and N concentration.

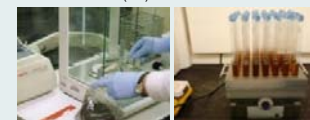


Fig 5. Digestion of mulch for determination of biochemical composition

## Statistics:

- Mulch decomposition rates were fitted to a negative exponential decay model:  $L_t = L_0 e^{-kt}$
- $L_t$  is the proportion of litter mass at time  $t$ ,  $L_0$  is the proportion of litter mass at time zero,  $k$  is decomposition rate over the measured time interval.
- Repeated measures multivariate analysis of variance (MANOVA), was used for comparison of changes in soil C and N.



Full-sun coffee with mulch



Full-sun coffee without mulch

## Results and Discussion

- Mass remaining under shaded coffee system was less than full-sun (Fig. 6).
- Both systems showed first-order decay dynamics.

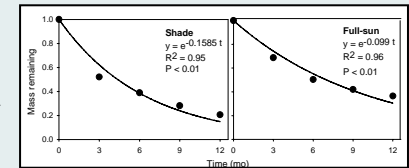


Fig 6: Mass remaining over time of decomposition

- N mineralization occurred throughout the decomposition process (Fig. 7). Thus, leucaena mulch acts as an effective slow-release fertilizer with no significant immobilization period.

- There was significant loss of all major biochemical components during the mulch decomposition process (Fig. 7). There was no preferential loss of easily degraded components or build-up of lignin or cellulose.

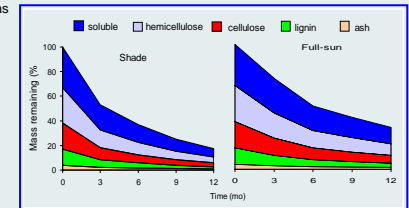


Fig 7: Mass components (%) remaining over time

- In the shade coffee system, mulch additions from 2006-2008 significantly increased soil C and N. This represents ~40% of the C added as mulch
- In the full-sun field, mulch additions negated a significant loss of soil C due to declines in soil bulk density.

- In the leucaena stand, mulch can provide an important source of organic C and N to coffee agroecosystems.
- It can help sequester C lost as plant biomass during shade tree management. The additional C sequestered in both systems was ~40% of the amount applied as mulch.

Table 12: Changes in Soil C and N

Year	Full-sun		Shade	
	Soil Carbon (Mg ha <sup>-1</sup> )		Soil Nitrogen (Mg ha <sup>-1</sup> )	
	No Mulch	Mulch	No Mulch	Mulch
2006	45.6	45.6	57.4	57.4
2008	33.8	46.7	51.7	68.9 †
Change	-11.8	1.1	-5.7*	11.5*
Soil Nitrogen (Mg ha <sup>-1</sup> )				
2006	2.5	2.5	2.6	2.6
2008	2.4	3.92	3.04	4.72 †
Change	-0.1	1.42	0.4	2.12 *

\* significant change in soil C or N between 2006 and 2008.

† significant difference between mulch and no-mulch treatments.



## Conclusions

- Application of leucaena KX2 pollarding materials as mulch decays rapidly, mineralizes N continuously, and increases soil C and N.
- Using *Leucaena* KX2 as a shade tree is a promise option for increasing carbon sequestration and productivity of coffee agroforestry systems in Hawaii.



## Selected references

- Coppens, F., Garnier, P., Findeling, A., Merckx, R., and Recous, S. 2007. Decomposition of mulched versus incorporated crop residues: Modeling with PASTIS clarifies interactions between residue quality and location. *Soil Biology and biochemistry* 39(9): 2339-2350.
- Olebermann M., Voroney R. P., Kass D.C.L. and Schlonvoigt A.M. (2006) Soil carbon and nitrogen dynamics using stable isotopes in 19- and 10-year-old tropical agroforestry systems. *Geoderma*, 130: 356-367.