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Total Soil Quality Assesment under Eroded and Restored Conditions

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Abstract

This study used an integrated ecosystem approach to monitor total soil quality changes during the restoration of highly weathered tropical soils. To allow integrated assessment, the restoration techniques were based on quantifiable indicators of soil quality change; namely the chemical/ nutritional, physical, and biological attributes that are necessary for achieving the soil's productive and environmental functions. Our approach used greenhouse simulation in which corn was used as an "indicator" crop, water leachates were collected and analyzed weekly, and chemical analysis was conducted on the soils before and after every cropping cycle. Organic matter amendments and nitrogen supplements had more significant effects on crop responses and soil filtering capacity than did physical manipulation as reflected by soil bulk density.

Introduction

Soil resources are nonrenewable in the context of human life expectancy and the decline in the quality of soil resources usually lies at the core of land degradation and overall lack of sustainable land use and management. Soil degradation reduces the soil's ability to support and sustain vegetation and restricts the soil's ability to perform vital ecosystem functions as part of the earth's life support system. Table 1 shows the critical role played by different soil quality attributes for determining the soil's fitness and capacity for sustainable, productive and healthful use and ecosystem function.

Erosion is the primary human-induced soil degradation process globally, and especially in tropical environments. Its impacts on crop performance have been the subject of many investigations (e.g. Hurni, 1996 and El-Swaify 1999 and 2001). However, as shown in Table 1; supporting plant growth is but one of the vital functions played by soils in terrestrial ecosystems. It is important to recognize and quantify erosion impacts on other soil quality attributes so that our assessment of erosion hazards becomes comprehensive, and to guide soil restoration efforts toward optimum outcomes.

The objective of this study was to compare selected alternatives for restoring optimum quality to eroded tropical soils. Special emphasis was placed on soil nutrient enhancement, structural and porosity manipulation, and capacity for regulating water quality.

Materials and Methods

The soils -- We used eroded versions of Wahiawa silty clay, an Oxisol that has been well characterized in previous studies with only mild acidity due to high base saturation, and Leilehua clay an Utlisol with pronounced acidity in the B horizon. Soil samples were collected and analyzed for important chemical attributes, including acidity and electrical conductance.

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This report contains sample data for both soils. The liming curve for the latter soil is shown below. This Leilehua soil is classified as “very-fine, ferruginous, and isothermic Ustic Kanhaplohumults”

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Table 1. How Soil Attributes Influence Selected Terrestrial Ecosystem Functions

Soil Quality Attributes	Relevance to Soil Performance and Contribution to Ecosystem Function*							
	Produc tivity	**Product Quality**	**Degradation Resistance/ Resilience**	**Genetic pool**	**Biogeo-chemical function**	**Hydrologic partitioning**	**Buffering/filtering for regulating water and air quality**	**Sink/ sequestering medium**
Physical								
Soil depth and profile horizonation	**xxxx**	**xx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**
Water infiltration, storage, and availability	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**
Erodibility	**x**		**xxxx**	**xx**	**x**	**xxxx**	**xxxx**	**xxxx**
Structural integrity, porosity, compaction & bulk density	**xxxx**	**xx**	**xxxx**	**xx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**
Strength	**xxx**	**x**	**xx**	**xx**		**xx**	**xx**	**xxxx**
Surface sealing and crusting	**xxx**	**x**	**xxxx**	**xxx**	**xxx**	**xxxx**	**xxxx**	
Aeration	**xxx**	**xx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxx**
Chemical								
Nutrient storage & availability	**xxxx**	**xxxx**	**xxx**	**xxxx**	**xxxx**	**x**	**xxxx**	**xxxx**
Acidity and toxicity	**xxxx**	**xxxx**	**xxxx**	**xxx**	**xx**	**x**	**xx**	**xxxx**
Salinity/sodicity	**xxx**	**xx**	**xxx**	**xxx**	**xxx**	**xxx**	**xxxx**	**xxxx**
Mineralogy	**xx**	**x**	**xxx**	**xx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**
Redox status	**xx**	**x**	**xxx**	**xxxx**	**xxxx**	**xx**	**xxxx**	**xxxx**
Biological								
Diversity of soil communities	**xxx**	**x**	**xxx**	**xxxx**	**xxxx**		**xx**	**xxxx**
Microbial biomass	**xx**	**x**	**xx**	**xxxx**	**xxxx**		**xx**	**xxxx**
Organic carbon	**xxxx**	**xx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**	**xxxx**
Beneficial micro-organisms	**xxxx**	**xxxx**	**xx**	**xxxx**	**xx**			**xxxx**
Beneficial macro-organisms	**xx**	**xx**	**xx**	**xxxx**	**xx**			**xxxx**
Pathogens	**xxxx**		**xx**	**xxxx**	**xx**			

* The relevance is judged on a relative scale with a minimum of 0 (left blank) and a maximum of xxxx

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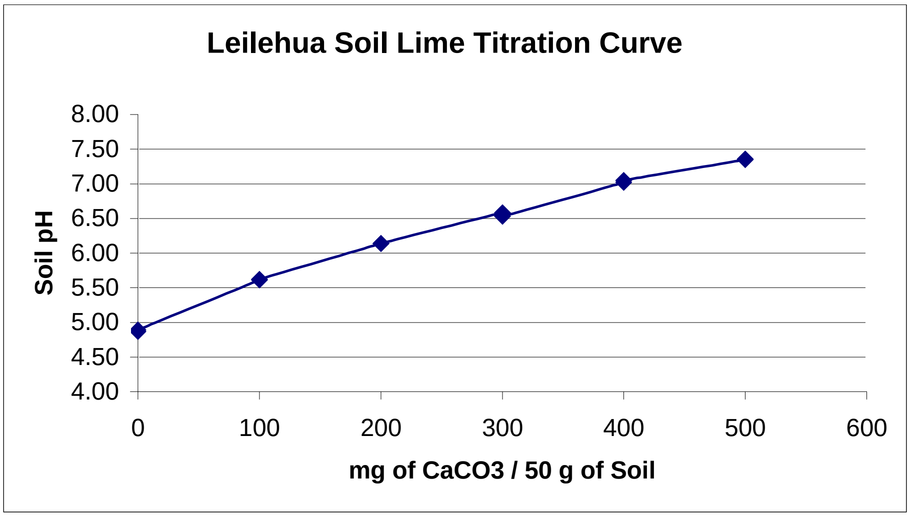


Soil rehabilitation treatments -- Soil quality indicators include the chemical (nutritional), physical, and biological attributes that are quantifiable as "sufficiencies" for achieving optimal functions of soil. Thus, we have selected the following variables to represent these attributes for simulation at the greenhouse scale alone and in selected combinations with 3 replications:

Soil bulk density (2 levels at 1.0 and 1.3 Mg/M^3),
Inorganic fertilization and liming (1 full sufficiency level, based on liming curve and earlier studies)
Organic residue/compost sources (redwood, peat moss, and poultry manure)
Organic residue/compost amounts (3 levels at 0, 10, and 25% by volume)

Total N and C contents, as well as the C/N ratios for the organic amendments are shown in the following table.

Sample ID	Label	N (%)	C (%)	Ratio(C/N)
1	Chicken Manure	2.99	35	12
2	Peat Moss	1.36	52	38
3	Redwood	0.75	52	69

Corn (Pioneer Hybrid # *1035*) was used as the "indicator crop" in all experiments. Several cropping cycles of 5 weeks were used to determine the residual benefits of applied treatments. Harvesting involved both shoots and roots of the plants. Leachates were collected from all pots in specially mounted sampling bags to determine how different treatments influenced percolating water quality. See the following photograph for the overall experimental setup.

Results

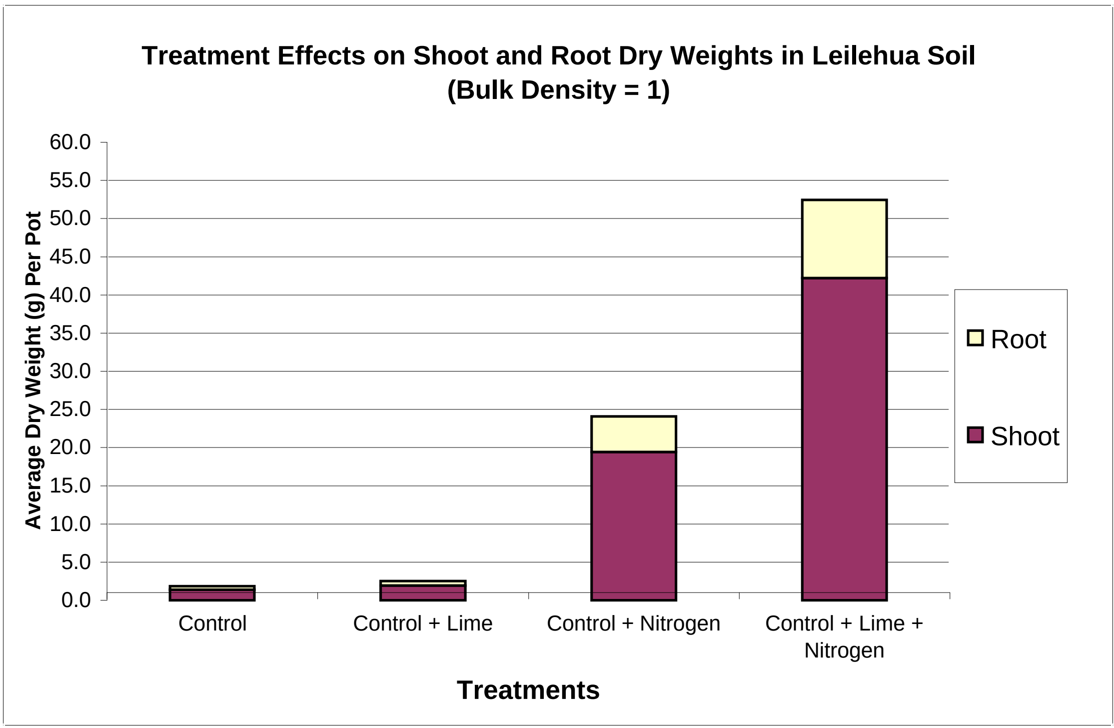
a. Productivity component of soil quality

The following table shows how the organic amendments affected corn yield at harvest in the Oxisol. The residual benefits of these amendments were determined on additional cropping cycles without additional amendments.

Total Dry Weight per Pot (g) in Wahiawa Soil (Oxisol)

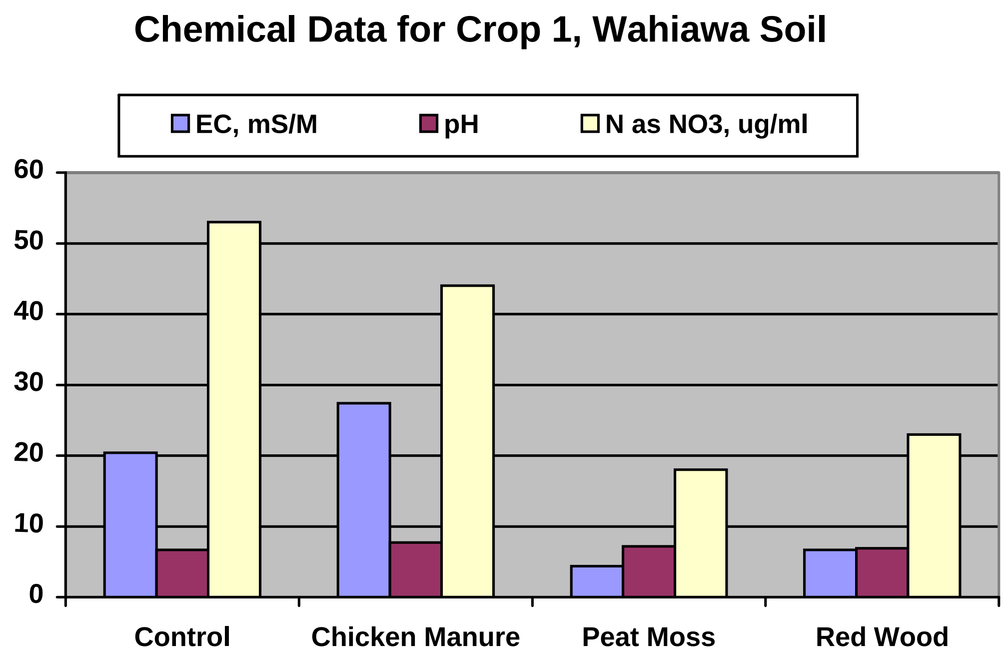
Treatment	Exp # 1 (Amendments Applied)	Exp # 2 (Residual of Exp 1)	Exp # 3 (Residual of Exp 2)
Control	93	72	100
Chicken Manure	250	191	168
Peat Moss	235	207	170
Red Wood	226	210	175

Our early trials showed that bulk density levels did not affect crop performance; this is explained by the high structural quality of well-weathered tropical soils. The next figure shows crop response to liming and restorative fertilization in the Ultisol, combined for all organic amendments.



b. Environmental/water quality component

The chemical composition of leachates from the growing pots indicates the soil's ability to intercept water quality contaminants, and how that ability is influenced by different amendments, The following diagram shows such data for the first cropping cycle on the Oxisol.



Discussion and conclusions

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Restoring optimum quality to highly eroded soils should encompass not only its ability to to support crop growth, but also to act as an environmental buffer. Organic amendments are necessary for both of these roles to take place as they influence the dynamics of the root zone in such a way as to reduce the mobility of such ground water contaminants as NO_{3-}.

Conducting soil remediation research at the field scale is both expensive and time consuming. Greenhouse simulation as described in this paper allows a realistic evaluation of alternative soil rehabilitation strategies.

Literature cited

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