Improved silvopastoral systems support early indicators of soil restoration in low-input agroecosystems of Nicaragua

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Introduction:

- Livestock production is the largest agricultural land use in Central America, supporting many smallholder farmers. Overgrazing and poor nutrient management have led to high levels of pasture degradation (Fig. 1) which impacts soil health and long-term productivity.
- Silvopastoral systems are promoted as promising strategies for restoring ecosystem services and production, but few studies have evaluated the impact of these systems under realistic, on-farm settings.

Figure 1. Degraded pasture dominated by naturalized *Hyparrhenia rufa* grass.

Objectives:

- Evaluate the early impacts of low-input, improved pasture establishment on soil health indicators, in actively grazed silvopastoral systems.
- Understand linkages between soil biological, chemical, and physical properties as restoration indicators.

Methods:

- In August 2013, paired pasture management treatments were established on nine farms with similar management histories and edaphic characteristics in the communities of Terrabona and San Dionisio, in the Matagalpa Dept. of Nicaragua (Fig. 2).
- On each farm, one plot was left as degraded pasture with naturalized grass species *Hyparrhenia rufa,* while the adjacent area was sown with the improved *Brachiaria brizantha cv. Marandu* species and planted with trees. Fertilizer inputs were not used and grazing intensity was managed by each farm's owner.

Figure 2a: study location

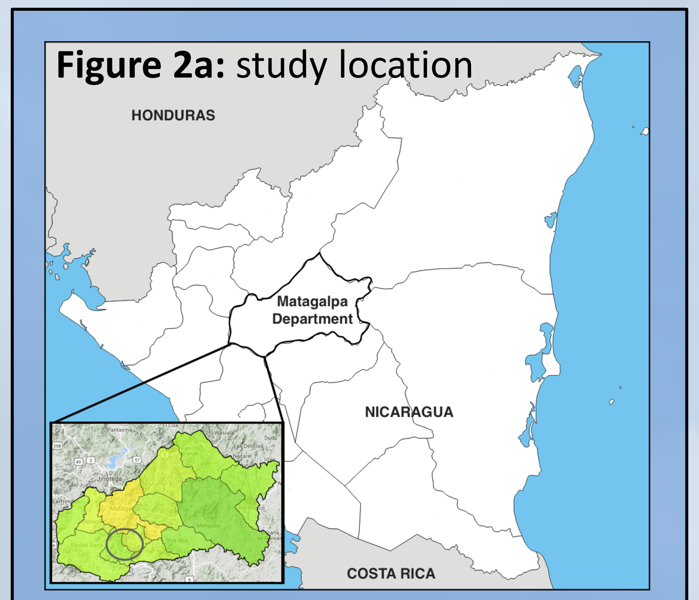
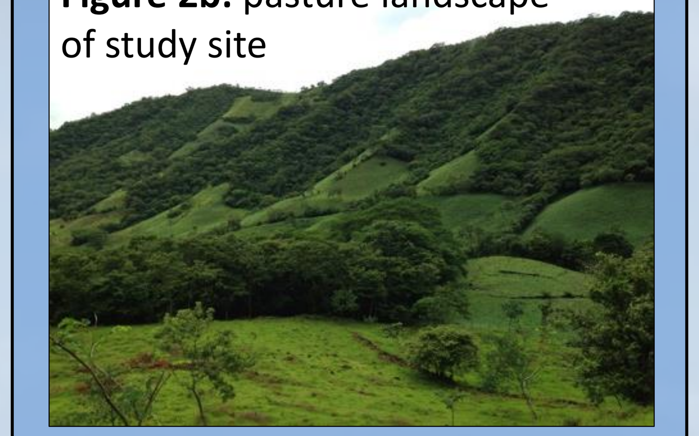


Figure 2b: pasture landscape of study site



In August 2015, pasture productivity and a suite of soil health indicators were measured (Figs. 3a-c):

1. Chemical characteristics: Total C & N, Permanganate oxidizable C, Available P, pH, CEC
2. Biological communities: soil macrofauna abundance and diversity.
3. Soil physical properties: aggregate stability, bulk density, penetration resistance, surface hydraulic conductivity, estimated plant available water holding capacity (PAW).
4. Standing biomass and composition of vegetation (weeds vs pasture grass).
5. Groundcover composition: % vegetation cover, exposed soil, rock, plant residue.

Figure 3a: bulk density

Figure 3b: macrofauna identification

Figure 3c: biomass production & groundcover composition

Results and Discussion:

- Total standing biomass was 2.4 times greater in improved vs. naturalized pastures (Fig. 4.)
- Improved pastures had significantly higher levels of pasture grass contributing to total standing biomass.

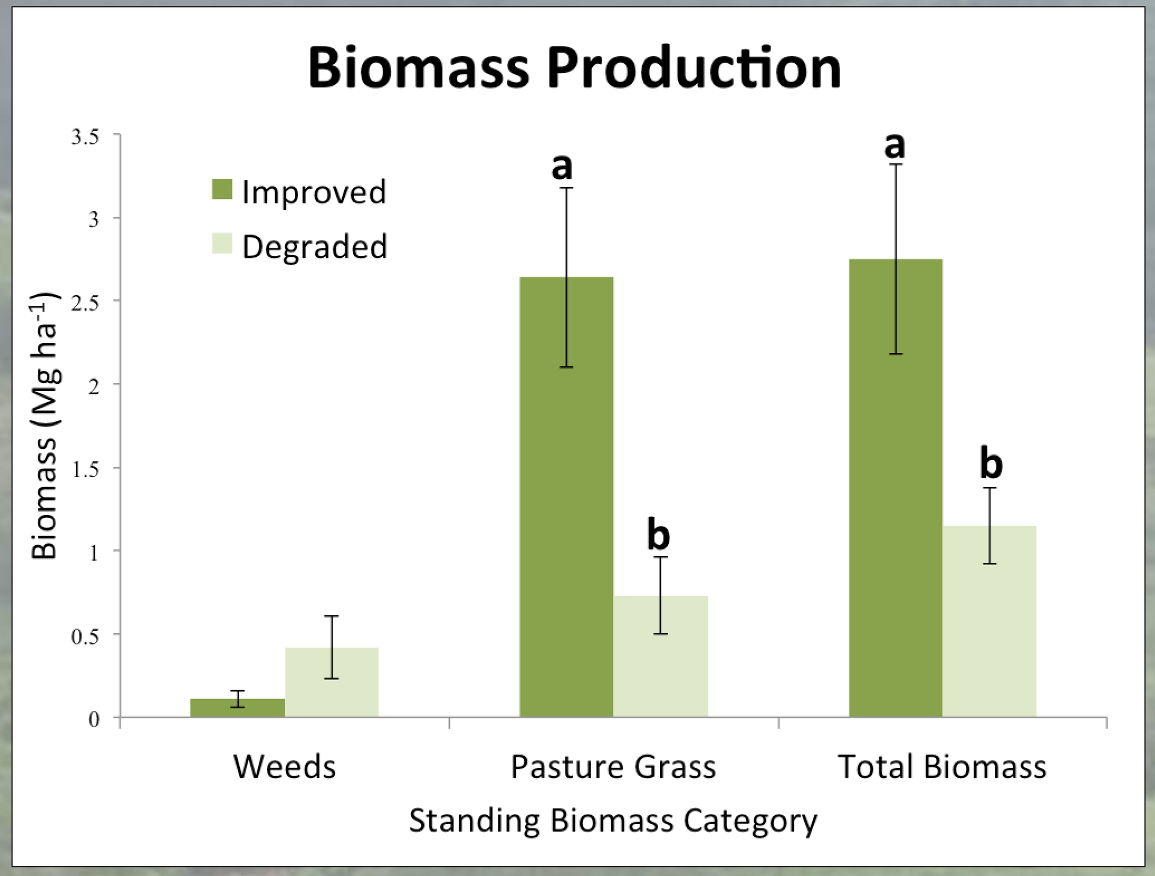


Figure 4. Composition of standing biomass in improved and degraded pastures. Treatments with different letters indicate significant differences (P < 0.05). Error bars represent the standard error of the mean.

- Improved pastures significantly increased earthworm abundance compared to naturalized pastures (Fig. 5).

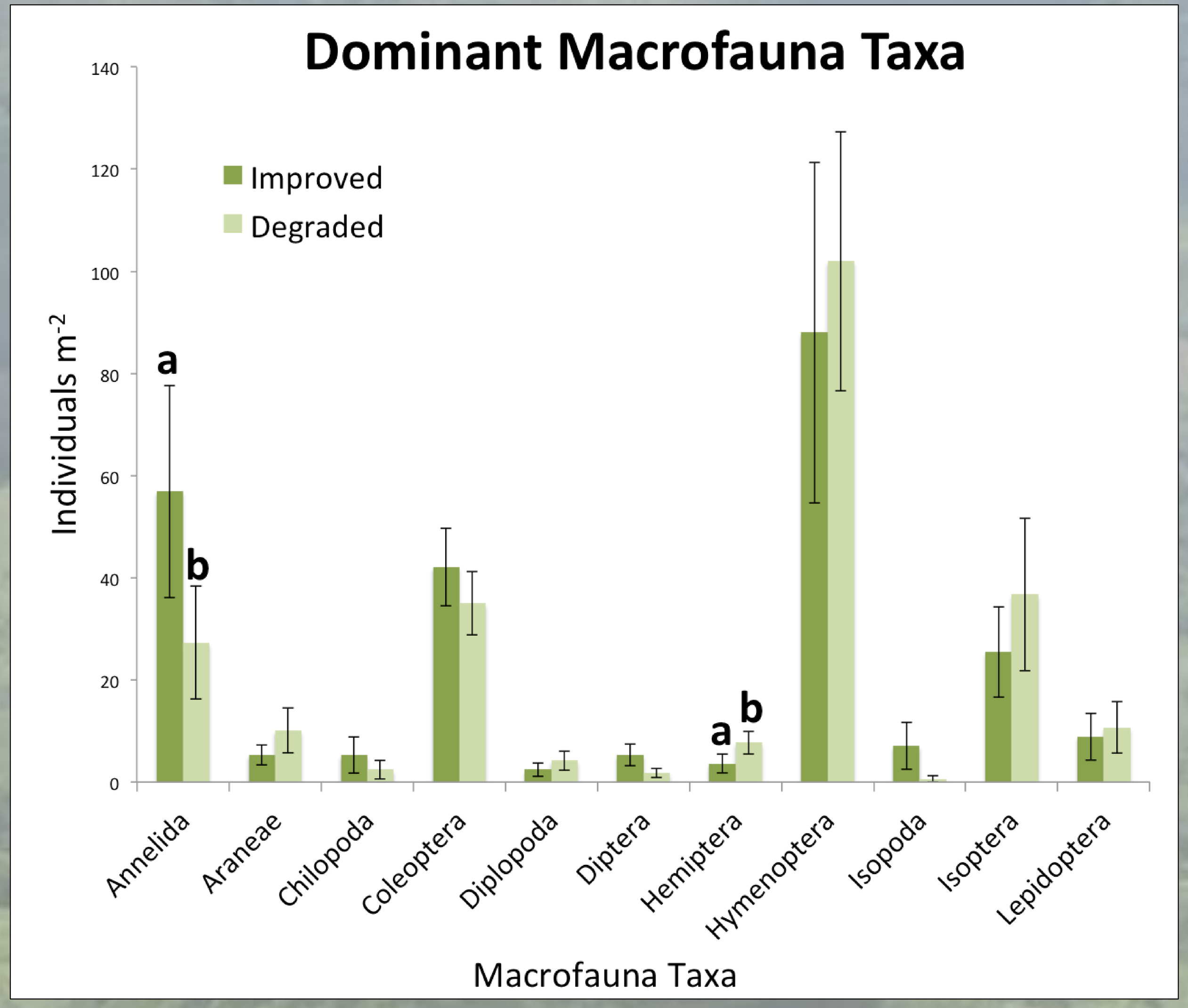


Figure 5. Mean abundance of dominant soil macrofauna taxa in improved and naturalized pastures. Treatments with different letters indicate significant differences (P < 0.05). Error bars represent the standard error of the mean.

- POXC was 13% higher in improved pastures (Table 1).
- Improved pastures had significantly higher estimated PAW than naturalized pastures.

Table 1.
Mean of soil physical, chemical, and water retention variables in degraded and improved pasture treatments. Values in parentheses represent the standard error of the mean.

Soil Variables†	Improved	Degraded	P-value‡
Chemical			
pH	6.4 *(0.1)*	6.4 *(0.1)*	ns
Total C (g/kg^{-1})	24.4 *(1.7)*	22.1 *(2.5)*	ns
Total N (g/kg^{-1})	2.8 (0.2)	2.3 (0.2)	ns
POXC (g/kg^{-1})	0.8 *(0.1)*	0.7 *(0.1)*	0.033
Available P (mg/kg)	6.2 *(1.6)*	5.3 *(1.2)*	ns
CEC (MEQ/100g)	41.7 *(2.7)*	40.4 *(2.9)*	ns
Physical			
MWD (um)	4014.8 *(301.7)*	4107.4 *(376.0)*	ns
BD 0-10 cm (g cm^{-3})	1.1 *(0.0)*	1.1 *(0.0)*	ns
BD 10-20 cm (g cm^{-3})	1.1 *(0.0)*	1.0 *(0.0)*	ns
PR Avg 0-20 cm (mPa)	232.6 *(12.1)*	229.1 *(11.2)*	ns
Water Retention			
Estimated PAW (%)	12.3 *(0.4)*	11.1 *(0.7)*	0.048
SHC (mm/sec)	0.004 *(0.0)*	0.005 *(0.0)*	ns

†POXC, permanganate oxidizable carbon; CEC, cation exchange capacity; MWD, mean weight diameter; BD, bulk density; PR, penetration resistance; PAW, plant available water; SHC, surface hydraulic conductivity.

- Earthworms, POXC & were positively correlated to aggregate stability and estimated PAW (Fig. 6).
- Such linkages illustrate the contribution of earthworms and Labile C in generating incipient improvements to soil structure and water retention. Earthworms and POXC were positively correlated to % vegetation cover suggesting that maintaining vegetation cover supports improvements to these key variables and vice versa.

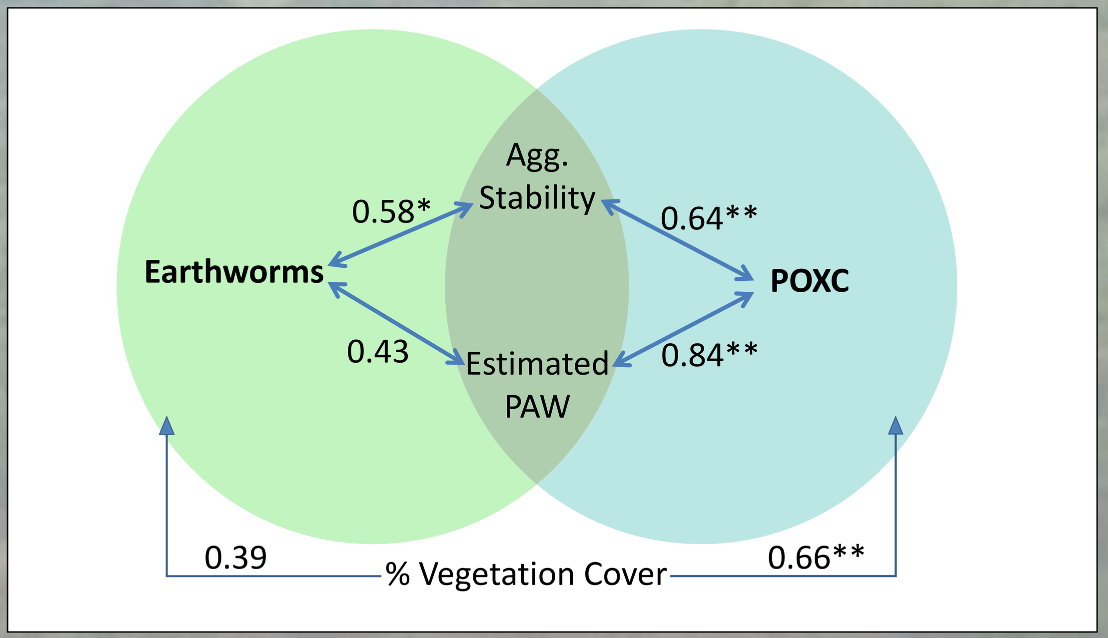


Figure 6. Pearson's positive correlations between predominant and significantly different variables. * Significant at P < 0.05; ** Significant at P < 0.01.

Conclusions:

- Low-input improved pastures have the potential to make at least short-term progress in reversing soil degradation as evidenced by improvements to primary production, earthworms, and POXC.
- Earthworms and POXC appear to be both sensitive indicators of early restoration efforts and useful variables for restoration monitoring, especially given their roles in subsequent improvements to soil structure and water retention dynamics.
- Further study of the effect of continued grazing in low-input improved pastures on soil health, and evaluations of the effects of fertilization and appropriate stocking rates, can help formulate management recommendations that combine feasibility for low-input, smallholder settings, while effectively meeting restoration goals.

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