Agroforestry systems to rehabilitate abandoned pastureland in the Brazilian Amazon

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Introduction

The 6.2 million hectare Amazon Basin is the world's largest remaining preserve of tropical rainforest and a large C pool. By 1988, however, development strategies aimed at settling the landless poor and integrating Amazonia into the Brazilian national economy had led to the deforestation of between 23 million (Skole and Tucker, 1993). Of the cleared areas, the dominant land use was, and continues to be, low productivity cattle pasture, over half of which is thought to be in some state of degradation (Serrão and Toledo, 1990). There are an estimated 20 to 35 million hectares of abandoned pastures in the Amazon Basin, and these abandoned lands may take 50 to 100 years to develop into mature secondary forest. Meanwhile, local farmers and new migrants to the Amazon continue to clear primary forest for transitory food, cash crop, and pasture systems, and eventually abandon the land as it loses productivity (Fernandes et al., 1997). Rehabilitating the productivity of these abandoned pasture lands has the potential to convert large areas from sources to sinks of C, while providing for the well-being of people in the region and preserving the world's largest undisturbed area of primary tropical rainforest.

Agroforestry systems are well suited to improve land productivity and conserve natural resources in the Amazon (Fernandes and Matos, 1995). To rehabilitate the productivity, C sequestration, and biodiversity of the huge expanses of low biomass, abandoned pastures in the Amazon, we have designed and are testing four agroforestry multistrata systems (sequences of crops, pastures and trees). The systems were designed on the basis of an intensive farmer survey and the results of two decades of soil/plant research in the Amazon. A key specification of the design was to optimize both biological productivity and economic returns, while minimizing nutrient losses through a combination of biological and modest chemical inputs.

Materials and Methods

Study Site

The proposed study site is located at the EMBRAPA-CPAA pasture research station, 54 km north of Manaus on the road BR 174 to Boa Vista at 02 31' 04 S", 60 01' 48" W, 60 m a.s.l. The site is characterized by rolling topography with plateaus and small valleys. The dominant vegetation at the site is moist, evergreen forest. The soil is a Xanthic Hapludox and the rainfall is c. 2,800 mm yr^{-1}. The degraded and abandoned pasture vegetation consists of 39 species representing 34 genera and 23 families. The most abundant tree species were *Laetia procera*, *Vismia amazonica*, *Vismia lateriflora*, and *Vismia cayennensis*. The most frequently encountered herbaceous species were the competitive forbs *Borreria verticillata* and *Rolandra fruticosa*. Many of the species and genera detected at this site have been reported in species inventories of abandoned pastures at other locations in the Amazon. Total aboveground biomass on the abandoned pastures corresponds to about 5% of the biomass reported for primary forests on Oxisols in the Amazon and less than half of that reported for other secondary forest regrowth of similar age. This is a reflection of moderate to

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high site disturbance intensity which hinders successional regrowth when the pastures were abandoned.

Multistrata System Design and Components

The specifications for designing the agroforestry prototype models were derived from extensive interviews with local farmers. We identified local agroforestry systems and the preferred food and fruit crops for home consumption and sale to local markets. Local researchers identified the key soil and crop production constraints. As most farmers used mixed, multistrata systems we derived the following design specifications for the prototype systems (1) multistrata systems involving annual and perennial food crops and fruit trees/shrubs adapted to local soil and climatic conditions; (2) modest nutrient inputs combined with N-fixing tree and herbaceous species and mulching to protect soil surface, provide cover for soil fauna, and improve soil structure; (3) food crops and some quick yielding fruit species provide income and food needs until tree crops start yielding; (3) fruit trees with multiple products; (4) N-fixing trees to provide green manure, mulch, and live fence posts; (5) as cattle are a priority of most local farmers, incorporate herbaceous pasture species at a later stage in the rotation; (6) incorporate trees for timber and building poles (to prevent their depletion from the surrounding forests). Not all of these specifications need appear in a single system but a mosaic of three to five systems containing these specifications in various combinations is likely to be both productive and resilient to biological, environmental and economic shocks.

Four agroforestry systems were developed as promising prototype systems for rehabilitation of degraded pastureland in the western Amazon. Two agrosilvicultural (trees and crops) and two agrosilvopastoral (trees, crops, and improved pasture) systems were established. The treatments imposed were designed to provide comparisons between a moderate and intensive land use within each of these agroforestry systems. Tree species combinations in each option were chosen on the basis of local farmer practices and for specific uses, e.g., as live fences (*Gliricidia sepium*), fruit (*Theobroma grandiflora*, *Inga edulis*, *Bactris gasipaes*, *Bertholettia excelsa*, *Malphigia emarginata*, and *Carica papaya*), firewood (*Inga edulis*) and timber (*Swietenia macrophylla* and *Schizolobium amazonicum*). Planting density and pattern for each tree species involved considerations of canopy architecture and whether competition among species was a desirable trait. Peach palm, for example, was planted at a high density because half of the plants are harvested every 12-14 months for heart-of-palm. Annual crops (*Oryza sativa, Manihot esculenta, Zea mays, Vigna unguiculata*) were planted during the initial periods of tree and pasture establishment, but were eventually phased out of the systems by tree shading or competition with grasses and forage legumes. Animal grazing of the grass-legume pastures in the agrosilvipastoral treatments began in 1996.

Experiment design and measurements

The four prototype systems and abandoned pasture control (treatments) were arranged in a randomized complete block design with three replications, blocked according to age of abandoned pasture. As the available P levels were <4 ppm at the start of the trial, all treatments received an initial application of 20-kg P/ha. One of the agrosilvipastoral systems also received two t/ha of lime (1 t $CaCO_3$ equivalent). In order to obtain representative economic measurements and account for increased variability among trees, each plot was 3000 m^2.

We measured all crop and fruit yields, soil and plant nutrients, labor, inputs, tree growth, biomass of prunings, weed dynamics, and soil macrofauna dynamics.

Results and Discussion

The systems are now 6-years-old and all the components have been installed. In the first two years, the high input agrosilvopastoral system produced 2.5 t ha^{-1} of maize and cowpea and 20 t ha^{-1} of cassava. The agosilvicultural systems produced 0.4t ha^{-1} of rice, 14t ha^{-1} of cassava and 20.12 t ha^{-1} of fruit (Theobroma grandiflorum, Malpighia, Eugenia, papaya, and passion fruit). The high market value of the fruits makes the latter system more attractive for farmers.

Weed management was crucial to ensuring successful establishment and growth of the crop and fruit species. On average plots contained 1.4 t ha^{-1} yr^{-1} of weeds containing 22 kg N, 2 kg P, 22 kg K, 8 kg Ca and 4 kg Mg ha^{-1}. Weed biomass was applied as mulch to fruit trees so that the nutrients released from the weeds would partially offset the cost of weeding. The diversity of plants appearing in the agroforestry plots was double that found in the abandoned pasture controls. We encountered 65 species distributed across 40 genera and 18 families.

The spatial arrangements in the agrosilvopastoral systems successfully inhibited the attack of *Hypsipylla grandella* on mahogany and resulted in clean stems of 6 m in three years before attacks were observed. The pole tree *Columbrina glandulosa* proved to be an excellent species for multistrata systems reaching 10 m in 3 years. All plant species responded positively to added nutrients. There was a dramatic shift in functional groups of soil macrofauna in the agroforestry systems compared to the abandoned pasture controls. Earthworm populations increased significantly in the system containing peach palms.

Measurements of total nutrient and carbon stocks, green house gas fluxes, macrofauna dynamics, and system productivity and profitability are in progress.

References

Ackerman, IL, McCallie, EL and Fernandes, ECM (1998) Inga and Insects: The potential for management in agroforestry. In: Pennington, TA and Fernandes, ECM (Eds) *The Utilization of the Genus Inga (Fabacae)*. The Royal Botanic Gardens, Kew and ICRAF, Nairobi.

Fernandes, ECM (1998) The effects of plant and soil management on nodulation and nitrogen-fixation in the genus Inga. In: Pennington, TA and Fernandes, ECM (Eds) *The Utilization of the Genus Inga (Fabacae)*. The Royal Botanic Gardens, Kew and ICRAF, Nairobi.

Fernandes, ECM, Biot, Y, Castilla, C, Canto, AC, Matos, JC, Garcia, S, Perin, R and Wandelli, E (1997) The impact of selective logging and forest conversion for subsistence agriculture and pastures terrestrial nutrient dynamics in the Amazon. *Ciencia e Cultura*. 49 (1): 34-47.

Serrao, EA and Toledo, JM (1990) The Search for sustainability in Amazonian pastures., (Ed) Anderson, AB. New York, Columbia University Press, pp. 195-214.

Skole, D. and C. Tucker (1993) "Tropical deforestation and habitat fragmentation in the Amazon: satellite data from 1978 to 1988." *Science* 260: 1905-1910.

Fernandes, ECM and Matos, JC (1995) Agroforestry strategies for alleviating soil chemical constraints to food and fiber production in the Brazilian Amazon. In: Seidl, P.R., Gottlieb, O.R. and Kaplan, M.A.C. (Eds.) Chemistry of the Amazon: Biodiversity, Natural Products, and Environmental Issues. American Chemical Society, Washington, DC. pp 34-50.