Opening the black box of Amazonian Dark Earths

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Introduction

Two years after Wim Sombroek, who can be considered the founder of research on Terra Preta (Amazonian Dark Earths, a fimic anthrosol), passed away, his legacy is still alive in Wageningen (The Netherlands), the city where he spent most of his career. Besides the legacy of Sombroek, anthrosols are common in many areas in the Netherlands and consequently much research has been done after these soils, in Wageningen.

Objective

We are starting a research program with Latin American research institutes that focuses on processes in space and time rather than on characteristics of Terra Preta. We will apply the concept of nutrient and carbon balances to the past as a framework for further investigation. The intended research aims at identifying and quantifying the carbon and nutrient fluxes as well as gaining insight in the subsurface processes that make these fertile soils so resistant against the harsh tropical conditions. Furthermore, we will use this approach to investigate the extent in which Terra Preta can contribute to an increased carrying capacity of various land use functions of the Amazon basin.

Methods

Nutrient balances describe the nutrient inputs and outputs of a certain unit of land over time. Nutrient balances are a useful tool for assessing the sustainability of an agro-ecosystem (e.g. Smaling et al., 1993). Classical nutrient balances are just the sum of the output and the inputs and do consider soil (and other) processes as a black box (figure 1). As our goal is not only to know what went in and out, but as well to understand what happened inside the black box, we concentrate processes at soil, field and village level (figure 2) .

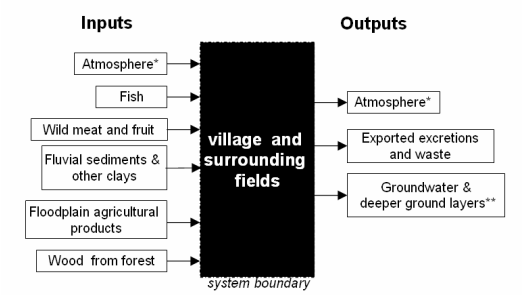

Figure 1: Classical conceptual nutrient balance model in which the processes that play in the village (including fields) are considered as a black box. All arrows represent flows of C, N & P except the flows to and from the atmosphere(*), and probably the flow to the groundwater (**) which mainly consist of C & N. Especially the flows of fluvial sediments and other clays (including ceramics) and wood import, which is later transformed to charcoal, are unique to the Terra Preta system.

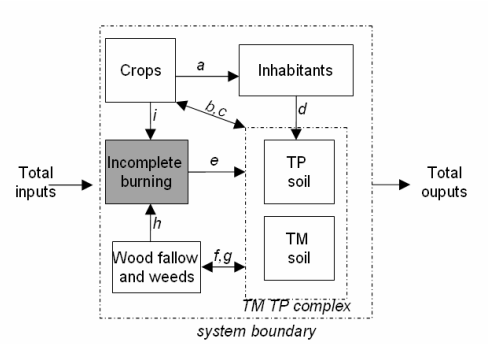

Figure 2: Conceptual model of internal flows that play a role within the village. All arrows represent flows of C, N and P and consist of a) harvested products b) uptake of nutrients by crops c) nutrients from crop residues d) household waste that is applied to the fields e) charcoal f) uptake of fallow vegetation and weeds g & h) nutrients from weed and fallow residues i) nutrients from crop residues. TP means Terra Preta and TM Terra Mulata (brownish soils similar to Terra Preta but without ceramics.)

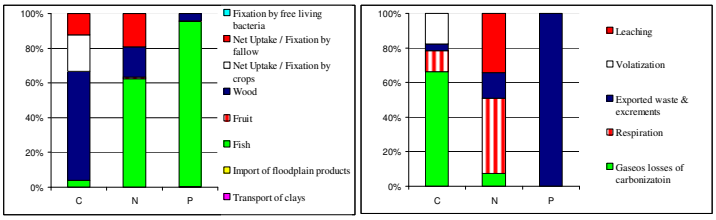

Figure 3 (left) & 4 (right) Initial estimates of distribution of C, N and P inputs (left) and outputs (right) of a Terra Preta System during build up phase with 2 ha of Terra Preta and no Terra Mulata with 100 inhabitants. Total estimated annual inputs amount 57 Metric tons (Mt) C, 0.7 Mt N and 0.1 Mt P Total estimated annual outputs amount 41 Metric tons (Mt) C, 0.7 Mt N and 46 kg P.

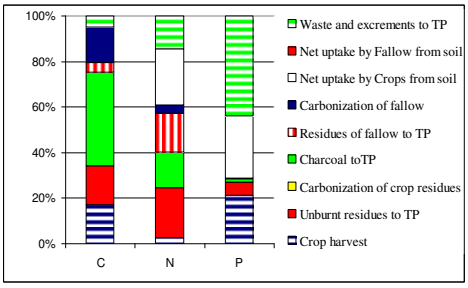

Figure 5 Initial estimates of aggregate distribution of internal flows of C, N and P in a Terra Preta system (see figure 2) with 2 ha of Terra Preta and no Terra Mulata with 100 inhabitants.

Initial Model Estimates & Road Ahead

Some initial estimates of C, N and P fluxes based on a large number of sources are presented in figure 3, 4 & 5. These initial model estimates show an annual accumulation per hectare of 8 Mg C 36 kg N and 50 kg P during the build-up phase of Terra Preta. Assuming linearity in accumulation over time, it would take about 33 years to reach the level of soil C of a typical Terra Preta (soils described by Glaser (1999) starting from the levels of a Ferrasol. 700 to reach the level of soil N and 300 years to reach the current level of soil P. Obviously, this static preliminary modelling cannot explain the formation of Terra Preta. Therefore, we will continue our modelling efforts to dynamically model nutrient and carbon fluxes in Terra Preta during its formation (built up) and under its current use.

Figure 5 provides some initial model estimates on the intra village fluxes. From this we can conclude that the model is especially sensitive to (unintentional) charcoal making activities and to the treatment of household waste and human excrements.

The flows shown do only partly explain why P-availability, pH and ECEC is that much elevated in Terra Preta even after so many years of abandonment. Soil chemistry studies are needed to gain insight the complex interplay between tropical clays, ceramics, charcoal and other organic inputs. Modelling of phosphorus dynamics together with laboratory experiments will provide new useful insight in these subsoil processes. There is a need to study soil biology as turnover of carbon and nutrients is driven by many biotic subsoil agents. Soil micro-organisms are present in much higher levels than in adjacent soils. Also the species composition of soil micro-organisms shows remarkable differences.

Little research has been undertaken on the sustainability of current Terra Preta use. Combinations of nutrient balances, socio-economic analyses and recent land use histories will yield important information on the sustainability of current agricultural practices.

Scaling

Little is known of the relative size of Terra Preta / Terra Mulata complexes in relation to the surrounding (selected cut) forest area. As this relation is a key indicator for sustainability of Terra Preta, we plan a study to enlighten the geographical distribution of Terra Preta by mapping new soils using indigenous knowledge and remote sensing techniques.

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