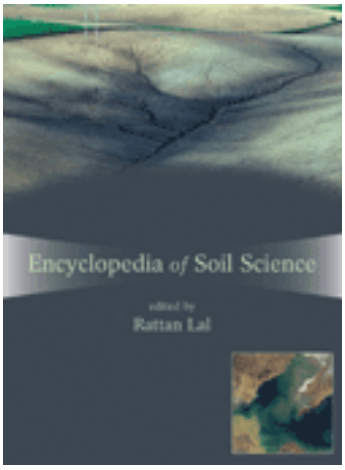

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Terra Preta de Indio

Johannes Lehmann [a]
[a] Department of Crop and Soil Sciences, Cornell University, Ithaca, New York, U.S.A.

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Terra Preta de Indio

Johannes Lehmann
Department of Crop and Soil Sciences, Cornell University, Ithaca, New York, U.S.A.

Abstract
Terra preta are fertile and carbon-rich soils found throughout Amazonia. These soils have been created by Amerindian populations before the arrival of Europeans. The key to their unique properties are the high charcoal (also called black carbon or biochar) contents that have great stability and ability to improve both chemical and biological properties of soils. Important lessons can be learned from terra preta about development of civilization in the Amazon, basic functioning of soils, carbon sequestration, and sustainable land use.

INTRODUCTION

Terra Preta de Indio soils, also called Amazonian Dark Earths,[1] are found throughout most of the Amazon Basin. Terra preta means "black earth" in Portuguese and their dark color makes them distinctly different from surrounding soils. The interest in terra preta arises from their unique properties, namely their high soil fertility and production potential as well as high carbon contents, which have implications both for the study of the development of civilization in the Amazon and for modern sustainable land use.[1] Terra preta soils were described in the scientific literature for the first time by Charles F. Hartt in 1874,[2] although in-depth scientific research documenting its unique properties started only in the middle of the twentieth century. This entry gives a brief overview of the properties, origin, and distribution of terra preta soils.

PROPERTIES OF TERRA PRETA DE INDIO

The dark color of terra preta results from large amounts of both organic matter and charcoal (also called "black carbon" in biogeochemical literature and "biochar" when linked to purposeful soil management).[3] The source of the charcoal can be linked to occupation by Amerindian populations, and the charcoal is therefore several hundred to a few thousand years old as seen from the C-14 dates obtained from charcoal fragments (Fig. 1). The high concentrations of charcoal in terra preta are also a testament to its high stability against mineralization. Indeed, the organic matter in terra preta is highly resistant against microbial decay and that recalcitrance barely changes over millennial time scales.[4]

Charcoal is the reason for the high cation exchange capacity of terra preta soils[5] with high concentrations of plant-available nutrients and often higher pH than surrounding soils[1] (Fig. 1). The elevated nutrient concentrations are also a result of burial activities, food preparation and waste (especially P- and Ca-rich fish waste), animal and possible human excrements, debris of housing materials such as straw or palm leaves, and various other activities (dyes, oils, fiber from palms and bark, etc.).[6] Characteristics are the often very high P and Ca contents in terra preta, but also Mg, Mn, Zn, and Cu and to a lesser extent N and K contents are typically elevated.[1]

The chemical properties and chiefly the high charcoal contents also change the environment for biological processes in terra preta. For example, the diversity of microbial populations commonly shows a greater species richness.[7] The mechanisms by which abundance and ecology of soil biota are affected are not sufficiently clear. It is plausible that better nutrient availability or higher pH values enhance activity and reproduction of microorganisms and alter species composition. Observations about the interactions between charcoal and microorganisms also suggest specific effects of charcoal on soil ecology.[8] In many instances, terra preta soils contain large amounts of pottery shards indicating past occupation that may also modify soil properties.

THE ORIGIN OF TERRA PRETA DE INDIO

The origin of terra preta has been subject of much debate.[9] While early reports speculate about volcanic ash deposits or sedimentation processes, it is by now accepted that terra preta soils were created by human activity,[10] and are therefore aptly called "Terra Preta de Indio"—black earth made by Amerindians. The main arguments for the human origin are the abundance of artifacts in combination with high charcoal and P contents in terra preta soils (Fig. 1) and similarity in mineralogy of clays between terra preta and the surrounding soils.[4] While some uncertainty will likely remain as to whether terra preta soils were created intentionally as part of soil management for agriculture or

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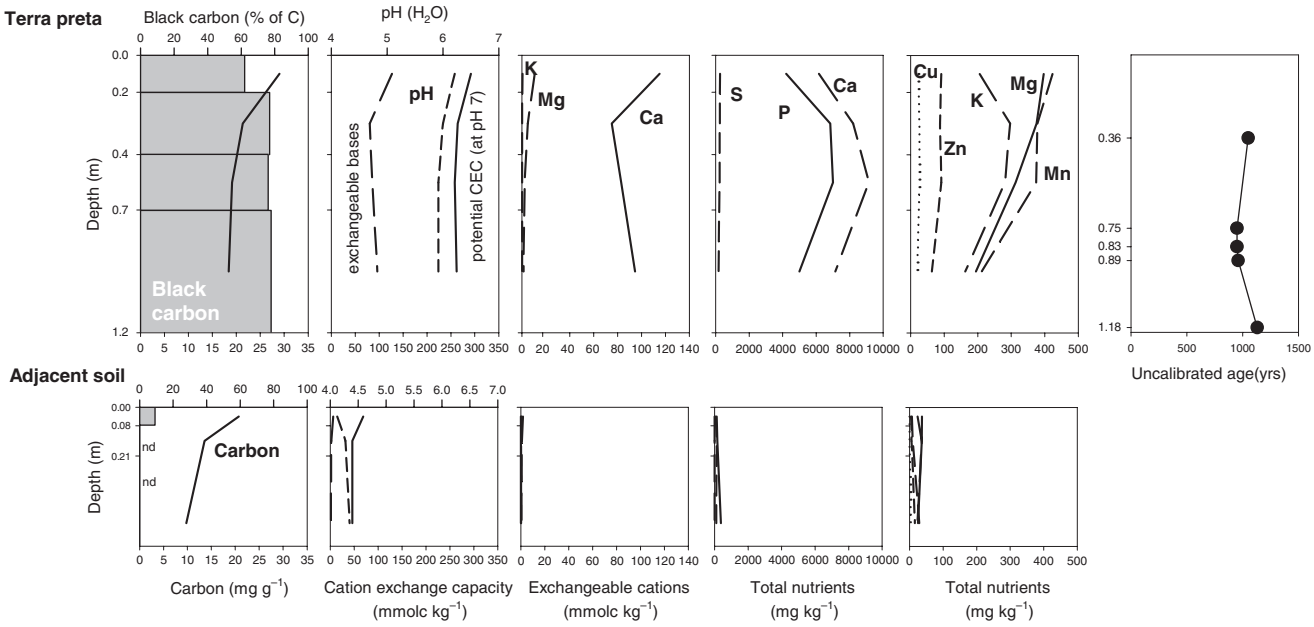

Fig. 1 Physical and chemical properties of a terra peta profile and the adjacent soil near Lago Grande, Manaus, Brazil (location and chemical analyses reported by Refs. 4 and 5; uncalibrated C-14 dates of charcoal from Ref. 6; nd: not determined).

they are a by-product of habitation, it is certain that their occurrence is inextricably linked to Amazonian civilizations before the arrival of the Europeans. Amazonia was densely populated around the year 1492, being home to sophisticated populations that lived in urban clusters.[11] Given that shifting cultivation is an unlikely land use system before steel axes made frequent slashing of trees possible,[12] a purposeful soil management is a more likely explanation for the high and sustained crop productivity needed to feed larger urban centers. Terra preta soils were created between 500 and 8000 years B.P.,[6] but not to any significant extent after the arrival of the first European explorers in 1541. They are therefore remnants of ancient civilizations in the Amazon Basin.

DISTRIBUTION OF TERRA PRETA DE INDIO

Terra preta soils are widely distributed in the Amazon Basin, but their occurrence is still poorly documented. It appears that terra preta soils are most widespread in the central Amazon between Manaus and Santarém (Fig. 2). At present, most terra preta sites have been mapped close to major streams that provide transportation by boat and food through fishing activities. Sites are located preferably on bluffs, which improves control over the surrounding area in case of warfare.[9] Some studies, however, find more than half the sites to be far from any major river.[10] As surveys extend further into remote areas and away from waterways, the present information may be refined.

Terra preta occur on all major soil types[13] indicating that physical and chemical attributes of the soil prior to occupation did not play a major role in their distribution. The enrichment with organic C and nutrients typically reaches much deeper in terra preta than in surrounding soils (Fig. 1). In an assessment of about 190 soils, 57% of the profiles had an A horizon that reached to a depth of between 0.2 and 0.6 m, which is significantly deeper than those of adjacent forest soils with about 0.1—0.15 m[13] depth. In some cases, the dark coloration reaches to depths of more than 2 m.

Some sites show vast expanse of several hundred hectares, such as the terra preta underlying the city of Santarem. But most documented sites are small with sizes of less than 2 ha.[13] The challenge in these assessments lies in the identification of what constitutes a terra preta, as the boundaries are still ill-defined and soil changes are often difficult to detect in the field without chemical analyses.

Another factor is that soil changes may occur gradually from terra preta to uninfluenced soils, and that such transitional soils may deserve their own category. These so-called "terra mulatta" (Portuguese for "brown earth") have been described as a distinct soil type[14] and often surround terra preta. The area of terra mulatta can be expansive and is estimated to exceed the area occupied by terra preta (Fig. 3).

The chemical properties of terra preta and terra mulatta are different. Typically, terra preta soils are darker than terra mulatta, even though organic C contents are often similar.[15] Terra mulatta have lower nutrient availability,

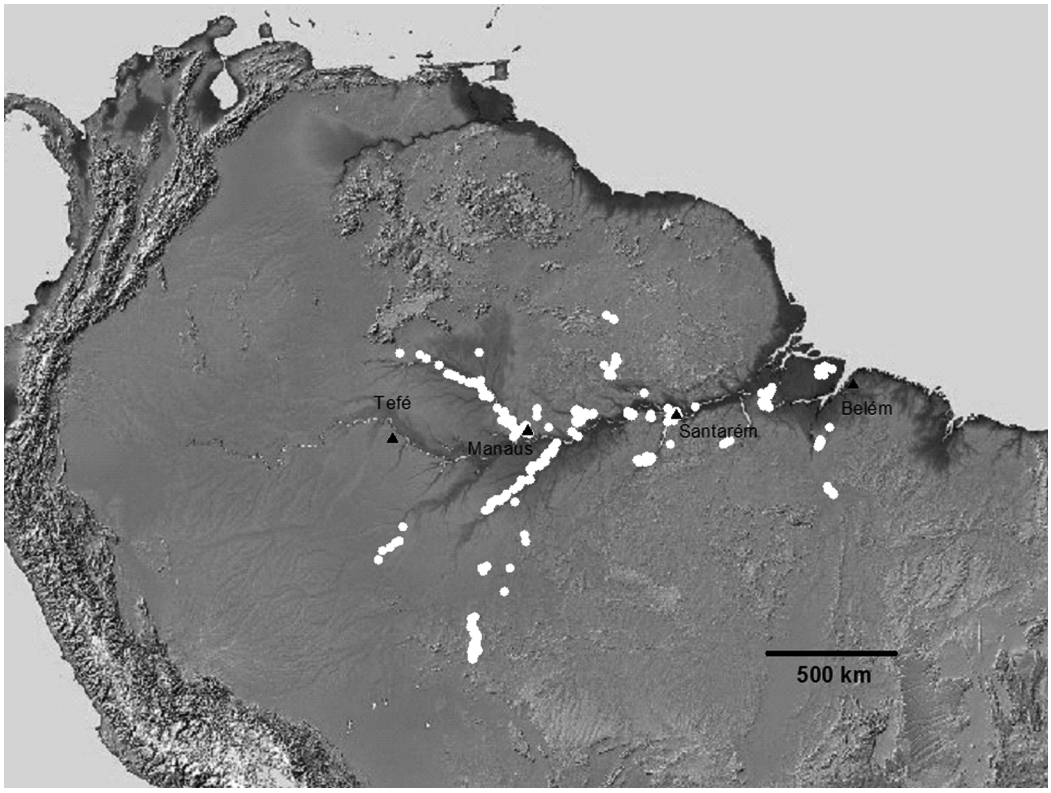

Fig. 2 Distribution of Terra Preta de Indio (white dots; from Refs. 1 and 13) and major cities (black triangles) in the Central and Eastern Amazon region (background map from NASA Images at www.nasaimages.org).

principally of P and Ca, than terra preta,[15] and do not contain artifacts such as pottery shards. Therefore, such terra mulatta are not middens but may actually constitute agricultural areas[15] that were generated through charring both during field establishment and on an annual basis using crop residues.

Terra preta and terra mulatta are archaeologically important testaments to the culture of ancient civilizations in the Amazon Basin. They provide information about the way Amerindian populations lived and utilized their environment, sustaining seemingly large and complex societies. Also the mere existence of C-rich and fertile Terra Preta de Indio several millennia after their creation demonstrates how soils function and suggests ways for improving soil sustainability today. Principally the discovery of the role of charcoal as a key ingredient in terra preta has led to the development of biochar soil management to improve soil fertility and mitigate global warming through long-term C sequestration.[16] Such modern biochar management affords the possibility of withdrawing carbon dioxide from the atmosphere while achieving sustainable soil improvement.

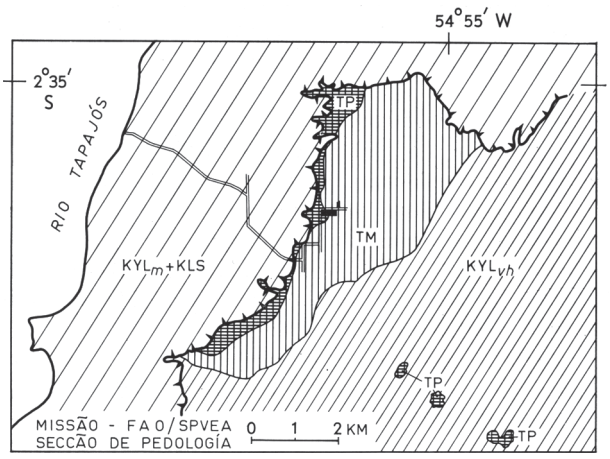

Fig. 3 Distribution of Terra Preta de Indio and terra mulatta at the Belterra Estate on the lower Tapajós River, near Santarém, Brazil. **Source:** From *Amazon Soils—A Reconnaissance of Soils of the Brazilian Amazon Region*, by Sombroek, W., in Agricultural Publications and Documentation: Wageningen, The Netherlands, 1966.[14]

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