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CREATION OF FERTILE SOIL HORIZONS (ANTHROSOLS) IN THE PRE COLOMBIAN TIMES BY USING ORGANIC WASTES

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SUMMARY:
The process of formation and evolution of distinct anthropic horizons found widespread in Brazil will be reviewed and discussed focusing in the waste management. The Amazonian Dark Earths (*Terra Preta de Índio*), the shell mounds (*sambaquis*) and ditches from human earthworks (called *geoglifos*) are the archeological sites reviewed in this article. The main source of P and Ca in TPI sites is believed to be from the bones. Ashes are also a key source of nutrients in antropic soils and responsible to enhance the pH. Leaves are also a important source of nutrient. TPI owes its name to the dark color originated from a large stocks of carbon and it is believed that large part is preserved because a pyrogenic origin. The use of carbonized organic waste (charcoal) as soil conditioner is now being largely studied in the world, this technology is called biochar. The *sambaquis* are found mainly along the Brazilian coast with have a large amount of phosphorus and carbon. The *geoglifos* are constructed earthworks mainly circular or rectangular. Until now is intriguing the absence of dark horizons or clearly chemical signatures typical of anthropic modifications caused by waste accumulation in or near the geoglifos. Understanding the waste management used to create these fertile anthropic soils have possibility to provide new soil management practices for soil reclamation, sustainable production, and to enhance soil carbon storage and nutrient holding capacity therefore to use marginal soils.

Keywords: anthrosols, Terra Preta de Índio, Sambaquis, Geoglifos, Shell monds,

INTRODUCTION

Many civilization have lived in South America when the Europeans arrived in the century XV. Many of these civilizations have changed their landscapes and soils to live in marginal areas. They developed hydraulic soil management techniques to lived in periodically or permanent flooded environments or in very dry and poor soils areas. The ancient civilization that lived in Llanos de Moxo (Bolivia) faced shallow floodwater that covered the the most part of the land, they develop a system to constructed raised field above the level of seasonally flood to cultivate their crops. The Moche civilization development very refined system of channels and an irrigation management in the north cost of Peru, this civilization seems to be destroyed by a long term El Niño event with unpredictable catastrophically events of rain. The Incas that lived in the Andean mountains developed a sophisticated soil erosion control system with terraces (Andenes) which are still being used by farmers. The Aztecas developed techniques to created hundred hectares of anthropic soils horizons by using lake sediments (terric Anthrosols). In Brazil the anthropic soil horizons are only relatively recently being thoroughly investigated. To understand their formation and evolution is a rare opportunity not only to clarify cultural practices of prior civilizations but also to comprehend mechanisms of waste management to preserve carbon and to hold nutrients in the constantly leached soils of the tropics. The characteristics and challenges to understand the process of formation and evolution of distinct anthropic horizons found widespread in Brazil will be reviewed and discussed.

MATERIAL AND METHODS

The material and methods used in the experiments were detailed described in the publications listed in the reference section. The discussion summarize the main results of many experiments conducted by the authors et al. during the last decade.

RESULTS AND DISCUSSION

The Amazonian Dark Earths (*Terra Preta de Índio - TPI*), the anthropic shell mounds (*sambaquis*) and large ditches from human earthworks (called *geoglifos*) are the site reviewed in this article. TPI refers to expanses of anomalously dark, fertile soil horizons, created by per-Columbiam populations largely during the period from 500 to 2500 year B.P, they are found mainly in the Amazon Basin (Teixeira et al., 2010; Woods et al., 2009). TPI anthropic horizons exhibit high densities of ceramic sherds and greatly increased levels of total and available phosphorus and other minerals as P, Ca, Mg, Zn, Mn, Ba and Sr, when compared with surrounding soils in the upland. The main source of P and Ca is believed to be the bones, including fish bones (Table 1). Ashes are also a key source of nutrients in antropic soils horizons and responsible to enhance the pH. Leaves, peals and other vegetable residues are also a important source of nutrients. The palm leaves used in the roof the houses may be an important source of some micronutrients (Table 1). TPI owes its name to the dark color originated from a large stocks of carbon and it is believed that large part is preserved because a pyrogenic origin from incomplete combustion of organic materials, the use of carbonized organic waste (charcoal) as soil conditioner is now being largely studied in the world, this technology is called biochar. Figure 1 summarize the scheme of accumulation of nutrients in archeological sites by importation of food (vegetables and animal from hunting) in the village. The human manure could also have been used by improvement soil fertility (Birk et al., 2011; Taube et al., 2013). The *sambaquis* are found mainly along the Brazilian coast and are predominantly constituted of piled up mollusk shells and sediments in very complex stratigraphic configurations. Frequently they contain burial remains covered by dark soil and rare lithic artifacts. The *sambaquis* are believed to have been intentionally built by a population that inhabited the region for over 6000 years. Some studies are trying to understand the contributions from natural depositional processes and cultural deposition to their characteristics and results also indicated that those dark horizons have a large amount of phosphorus and carbon (Teixeira et al., 2014). The mechanism of stabilization of the carbon in the *sambaquis* is not clear, but probably is involved in the heating of organic material (pyrolysis) and large amounts of available calcium carbonate from the shells. The *geoglifos* are constructed earthworks of large and precise geometric forms, mainly circular or rectangular (Figure 2). They are characterized by excavated ditches and earthen banks, formed by deposition of the excavated soil frequently. They are connected by roads believed to have built by a large and sophisticated per-Columbian civilization in the Upper Amazon Basin. Until now the investigations carried out have not found typical antropic soil horizons related with the *geoglifos* or near them. What is intriguing in this case is the absence of dark horizons or clearly chemical signatures typical of anthropic modifications caused by waste accumulation in the archeological sites (Teixeira et al. 2014). To build ditches with a diameter larger than 300 meters with 10 meters wide and over four meters deep, surely a huge human work force was required and these people needed to be fed.

CONCLUSIONS

The results from different archeological sites in Brazil indicate that waste management was used to improve soils in the pre-Columbiam times. The chemical

markers found in antropic soils are not only a consequence of kitchen middens but a more complex management involving carbonization. To understand so complexes processes and systemic and modeling approached will be necessary. Therefore, it is still a large open field for multidisciplinary research and many lessons are waiting to be learned about landscapes and soil waste management and mechanisms to preserve the carbon and hold the nutrients in the tropical environmental. Understanding the waste management used to create these fertile anthropic soils horizons may provide a possibility to innovative soil management practices for soil reclamation, sustainable production, and to enhance soil carbon storage and nutrient holding capacity therefore to use marginal soils.

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Table 1. Botanical and animal wastes - sources of the main chemical nutrients added in archeological sites in the Amazon

Waste source	pH	P	K	Ca	MG	FE	MN	ZN	C
		---------- g kg^{-1} ----------				-------- mg kg^{-1} ----------			%
Charcoal	7.15	0.61	1.24	3.7	0.73	172	35.5	10.8	40 - 70
Ashes	12.0	6.85	54.5	80.2	20.2	2833	1012	485	1-2
Bones	-	125	1.05	230	9.2	2440	163	83	tr
Palm leaves+	-	1.28	23.07	4.23	1.16	16	47	16	-

P- Phosporus, Ca- Calcium; Mg- Magnesium; K- Potassium;Sr – Strontium, Mn – Magnesium, Zn -Zinc + Data from leaves of Elaeis oleifeira (Caiuaé)

Figure 1 – Scheme of creation of fertile soil in the Amazon (Courtesy - William Woods)

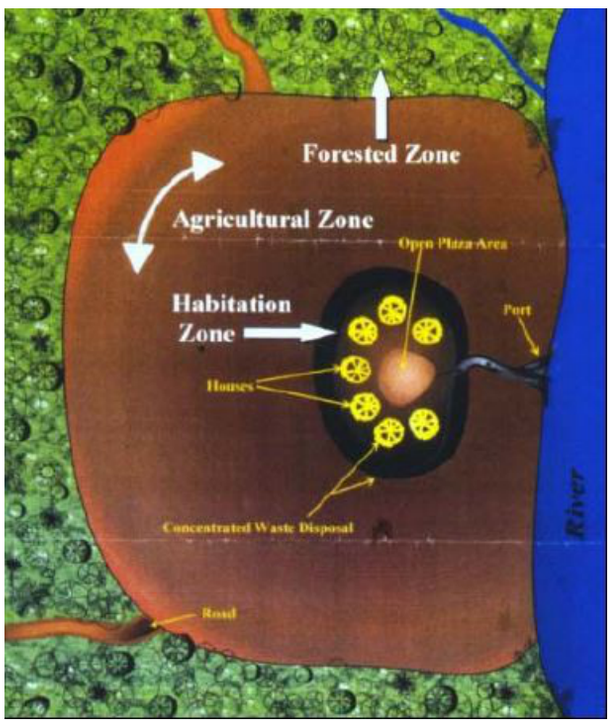

Figure 2 – Aerial photograph of the JK geoglyphs (courtesy – Denise Schaan)