

## The Terras Pretas de Índios investigation by Raman spectroscopy and a sustainable agriculture

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### Introduction

The Terras Pretas de Índios da Amazonia (TPI's or Indian Black Earths) are extremely fertile soils found in northern Brazil in contrast with surrounding soils. The origin may be anthropogenic, probably from the Pre-Colombian civilizations.

The presence of charcoal in this material is very expressive (containing 70 times more black carbon than the adjacent soils [1]) and the Raman spectroscopy is a widely used technique to characterize carbonaceous materials, from the more organized structures (graphene, nanotubes) to the most random (amorphous carbon, a mixture of carbon atoms with sp, sp<sup>2</sup> and sp<sup>3</sup> hybridization). Thus, we used Raman spectroscopy to classify the forms of carbon found in three samples of TPI's.

The origin of our TPI's can be found in the Table 1.

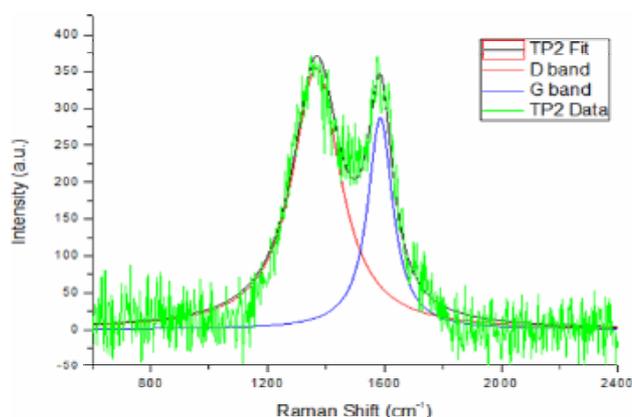
**Table 1.** Origin of TPI's

Soil sample	Origin*
TP1	Serra Baixa (costa do Açutuba), Iranduba
TP2	Balbina, Presidente Figueiredo
TP3	Costa do Laranjal, Maracapurú

\* Regions near Manaus (AM)

### Results and Discussions

The disorder-induced mode (D band  $\approx 1350 \text{ cm}^{-1}$ ) and the tangential stretching mode ( $\approx 1580 \text{ cm}^{-1}$ ) are present in the spectra obtained with a 632.8 nm laser. The peaks are very broad and it is characteristic of amorphous carbon materials. The frequencies of these bands vary with the amount of sp<sup>2</sup> and sp<sup>3</sup> hybridizations, the presence of polycyclic and distorted chains [2].



**Figure 1.** Typical spectrum of a TPI sample. Our spectra were obtained with a 632.8nm laser.

Our results indicate that the TPI's are in different stage of amorphization, and it is possible to distinguish three different phases for the three TPI samples we have analyzed. These phases seem to be related with each kind of TPI is the most productive.

### Conclusions

Raman spectra show different phases for different TPIs, being able to distinguish them. The variety of structures of carbon present in the TPIs, in addition to field observations and the analysis made conventionally seems to indicate the relative productivity of the TPIs. To identify the structural disposition of carbon in TPIs it is important to give a direction in the attempts of producing synthetic Terra Preta, and might be fundamental to the development of sustainable practices in agriculture.

### Acknowledgements

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<sup>1</sup> Glaser, B. 2007. *Phil. Trans. R. Soc. B* 362, 187-196.

<sup>2</sup> Ferrari, A. C.; Robertson, J. 2000. *Phys. Rev. B* 61, 20.