USE OF 13C VARIATIONS AT NATURAL ABUNDANCE FOR STUDYING THE DOMESTIC SEWAGE SLUDGE IN A TROPICAL AGRICULTURAL SYSTEM PLANTED WITH CORN (*Zea mays*) IN JAGUARIUNA, SP, BRAZIL.

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Abstract
The aim of this study was to evaluate the soil organic carbon and nitrogen dynamics in fields treated with an annual application of sewage sludge in a tropical region. The sludge was produced at the Sewage Treatment Station in Franca, SP, Brazil. Five annual applications of sewage sludge (type Franca Sewage – FS) were made at rates equivalent in N content to one, two, four and eight time the recommended mineral N fertilization rate (90 kg N/ha), and a control treatment using the recommended rate of mineral fertilization. The agricultural field experiment was conducted since 1999 in Jaguariuna, Brazil. Organic C in bulk soil samples changed significantly since 1999. The present study utilized the natural abundance of 13C (delta C) to evaluate the effect of organic fertilizer application on changes in the organic C in the soil. Mass balance calculations showed that the proportion of organic C originating from sewage sludge increased significantly from a few percent up to 35% in the recent years.

Additional Keywords: Carbon, nitrogen stocks, biosolids, organic matter, $\delta^{13}C$,

Introduction

High demand for food and low supply of commercial fertilizers have raised their cost and created the need for alternative ways to improve soil fertility. Sewage sludge application to agricultural lands is one way to address such needs (Mbila *et al*, 2003). Residue management may have positive as well as negative influences on soil carbon (C) storage. Thus, some of these residues (manures, farming yard manure) are known to alter the soil organic matter composition and to act negatively on soil C stocks.

Very few studies are conducted under tropical conditions, where the turnover of soil organic matter is comparatively rapid (Ayanaba and Jenkinson 1990; Balesdent *et al*., 1987). In tropical and subtropical areas, where high temperature and humidity accentuate soil degradation a main agricultural research goal is the development of management systems that increase soil conservation and crop productivity. Knowledge of the main factors involved in soil organic matter increase is fundamental (Bayer *et al*., 2000).

Natural ^{13}C measurements can be used as an *in situ* tracer for turnover studies under field conditions (Cerri *et al*., 1985). In agroecosystems, C has at least two origins: the previous native vegetation, and the remains of the crop. Another source can represent the applications of sewage sludge to the soil. Changes in the ^{13}C values of soil organic C in these areas reflect soil organic matter turnover rate, and provide insight regarding the functional role of tropical ecosystems in the global C cycle (Bernoux *et al*. 1998). This study aimed at evaluating the long-term effect (5 years) on C and nitrogen (N) influenced by addition of domestic sewage sludge under field conditions in a tropical agriculture ecosystem.

Materials and Methods

Field sites

The experiment was conducted at an experimental field, located in Jaguariúna (SP), Brazil (22º 41' S, 47º W), at an altitude of 570 m. The mean annual temperature is 22°C and the annual precipitation is 1430 mm, with a dry season from April to September. The soils are medium-clayey texture, classified as Rhodic Ferrasol. The physical and chemical characteristics of the 0-20 cm layer, before the onset of the study, was as follows: pH H_20 = 5.8; OM%=2.55; P=3.5 mg dm^{-3}; K=1.51; Ca=27.5; Mg=8.5; Al=1; H=35; CEC=73.5 $mmol_c$ dm^{-3}; V%=50.8; and clay=450 g kg^{-1}. The study was carried out from 1999 to 2003. The cultural practices adopted were those traditionally used for culture maize (disc plough, followed by light disc harrowings), without irrigation. The stubble was removed from the plots before sludge application. Sewage sludge was obtained from treatment of domestic

sewage in Franca, SP, Brazil (Franca Sludge – FS). The sewage treatment process consists in an aerobic and anaerobic digestion.

Treatments and analysis
The different treatments consisted application of increasing doses of sewage sludge (type Franca Sewage – FS) equivalent in N content to one, two, four and eight times the recommended N fertilization (90 kgN ha^{-1}). One treatment with conventional recommended mineral fertilization was applied the control plot. The sludge was toss-distributed in the treatment plots and incorporated to a depth of 20 cm with a rotary harrow, three to four days before sowing. The experimental design was set up as 3 randomized blocks with three replicate plots for each treatment. Each plot measured 10 x 20 m, with 12 rows per plot. The plots were separated by hedgerows with at least 5 m on each side, planted with *Bracchiaria* grass kept at a short height.

Soil samples were collected at 0-10 cm depth for C and N analyses. One sample in each plot was collected, composed of twenty sub-samples. The above-ground biomass was removed (harvested) every year and not incorporated into the soil. The bulk density data were utilized to calculate organic matter stocks based on an equivalent soil mass (Angers *et al*., 1997).

Natural ^{13}C abundance was determined after the conversion to total C to CO_2, by complete dry combustion at 1050°C in CE-CHN analyzer coupled to Thermoquest Delta Plus mass spectrometer at CENA, Piracicaba, Brazil. Results were expressed as $\delta^{13}C$ (‰), which is defined as the relative difference between the isotope ratios of the sample and a given standard: $\delta^{13}C = (^{13}R_{sample} - ^{13}R_{standard})/(^{13}R_{standard}) \times 1000$; where $^{13}R_{sample}$ and $^{13}R_{standard}$ are the $^{13}C/^{12}C$ isotope ratio for the sample and the standard, respectively. The international standard is PDB a carbonate from Pee Dee formation of South Carolina. C_3 plants show a $\delta^{13}C$ ranging from –32 to –22 (mean of -27‰) and C_4 plants have values of –16 to - 9‰ (mean of - 13‰) (Ballesdent and Mariotti., 1996).

Results and Discussion
Our results indicate positive effects of the application sewage sludge in soil. Higher organic C and N contents comparing with control can be attributed to sewage sludge associated with crop management system (Table 1). Total organic C concentrations in bulk soil samples from 0-10 cm of the profile responded significantly to 5 years of different treatments (Figure 1). The N values increased with time, however, the isotopic pattern do not allow us to quantify the sewage fraction in the soil. As shown in Table 1 the results indicated decreases in C and N in surface soil after application of sewage sludge with time. On the other hand, the contribution of C originated from sewage sludge increased over the investigated time period. Mass balance calculations showed that the proportion of organic C originating from sewage sludge increased significantly from a few percent up to 35% in the recent years (2003). This C fraction is not subjected to decomposition processes.

The organic matter in sewage is subject to an intensive microbial digestion during anaerobic and aerobic sewage treatment, leaving the sludge as a relatively recalcitrant residue. This explains the high stability of sewage sludge derived organic matter in the experiment (Gerzabek *et al*., 2001). Only few studies were accomplished considering this subject in combination with isotopic methods. Hence, a comparison with other published data is restricted. Because the present work can be considered as a pilot study in Brazil, future studies are necessary for a more comprehensive evaluation of the results found.

Conclusions
Organic C and N responded significantly to treatments. Mass balance calculations showed that the proportion of organic C originating from sewage sludge increased in several years. The natural abundance of $\delta^{13}C$ in bulk soil increased significantly in the continuous fallows. Our results suggest that sewage sludge acted as source for added organic C in tropical soils.

Acknowledgements
The authors wish to thank the Project Director “Uso de Biossolidos na Agricultura” Embrapa Meio Ambiente, Jaguariuna, Brazil for providing all the facilities to carry out the present study, and the “Biogequimica Ambiental” laboratory, CENA/USP/SP, Piracicaba, Brasil.

Table 1. Percent carbon and nitrogen, C/N ratios and $\delta^{13}C$ (‰) of 0-10 cm layer in several years (1999 to 2003). (F 8N) eight times the recommended N application treatment and control (C).

Year	Treatments	C	N	C/N	$\delta^{13}C$
		%			‰
1999	F 8N	2.99[a] (0.02)	0.25 (0.00)	11.87 (0.15)	-18.18 (0.12)
	C	1.38 (0.01)	0.09 (0.00)	15.70 (0.28)	-17.91 (0.06)
2002	F 8N	2.86 (0.05)	0.27 (0.01)	10.62 (0.16)	-19.02 (0.20)
	C	1.41 (0.09)	0.10 (0.01)	14.21 (0.11)	-17.00 (0.02)
2003	F 8N	2.24 (0.11)	0.20 (0.02)	11.10 (0.45)	-19.45(0.48)
	C	1.50 (0.23)	0.11 (0.02)	14.17 (0.06)	-17.76 (0.28)
Sewage sludge	-	29.54 (0.70)	3.87 (0.12)	7.65 (0.05)	-22.67 (0.11)

[a] Means originates from three samples and values in brackets are standard deviations (*n=3)*

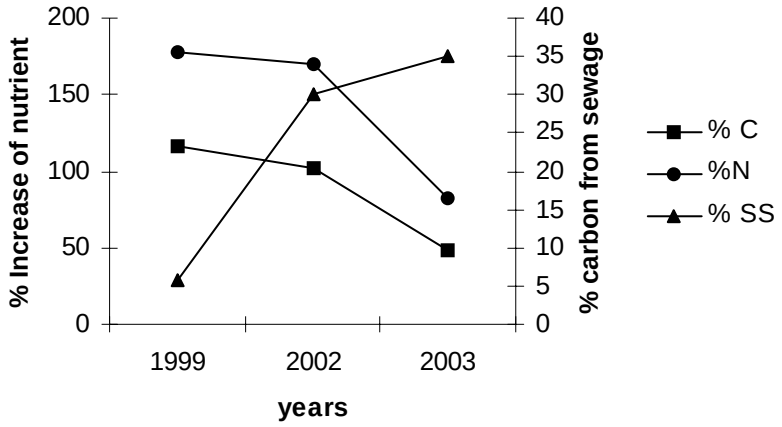

Figure 1. Percent increase of total C and N (%CT , %NT, respectively) and % contribution of sewage sludge to the Corg in several years (1999 to 2003) in depth 0-10cm (% CSS). (FS with the eight times the recommended N contents).

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