The papers published in this CD are of full responsability of their authors

ISSN 1982-3797

International Conference of Agricultural Engineering
XXXVII Brazilian Congress of Agricultural Engineering
International Livestock Environment Symposium - ILES VIII

August 31st to September 4th, 2008
Iguassu Falls City - Brazil

INTERNATIONAL CONFERENCE OF AGRICULTURAL ENGINEERING
CIGR 2008 / BRAZIL

CENTRAL THEME
Technology for All: Sharing the Knowledge for Development

Proceedings

Hosts

SBEA, ASABE, TECHNALLEN

Sponsors

CNPq, CONFEA CREA, ANDS, MASSEY FERGUSON, BANCO DO BRASIL, ÁGUA BOA, ITAIPU BINACIONAL, JOHN DEERE, CAPES, PG, unioeste, Seti, FUNDAÇÃO ARAUCÁRIA, British Embassy Brasilia, SCIENCE AND INNOVATION

Support

Funep, Universidade Estadual de Maringá, Unesp, Jaboticabal

PIXE ANALYSIS FOR NUTRIENT LOSSES EVALUATION FROM AGRICULTURAL SOIL DUE TO HEAVY MACHINERY PROCESSES

PAULO E. CRUVINEL[1]

[1] Researcher, Dr., Embrapa Agricultural Instrumentation /São Carlos – Brazil. e-mail: cruvinel@cnpdia.embrapa.br

Presented at

CIGR INTERNATIONAL CONFERENCE OF AGRICULTURAL ENGINEERING
XXXVII CONGRESSO BRASILEIRO DE ENGENHARIA AGRÍCOLA – CONBEA 2008
Brazil, August 31 to September 4, 2008

ABSTRACT: Heavy machinery process results in the loss of valuable soil and its nutrients that are necessary for crops to grow. Tillage erosion is mostly caused by the way a farmer tills the land. The kind of machinery a farmer uses, how often the farmer tills the fields, and how the farmer manages the agricultural fields during the planting periods affects how much soil may be lost. This work demonstrates the suitability of PIXE for evaluation of agricultural nutrient losses due to tillage erosion processes. A case study for a sugar-cane field is discussed, and losses in concentration of elements such as P (K_α=2.015keV), K (K_α=3.312keV), Ca (K_α=3.690keV), Fe (K_α=6.400keV), and Zn (K_α=8.631keV) were evaluated. The feasibility of this methodology for agricultural nutrient loss measurements for tillage erosion process is presented.
KEYWORDS: nutrient losses, soil erosion, PIXE

INTRODUCTION: One serious difficulty encountered in attempts to relate trace elements to plant response is the fact that their concentration in the agricultural soils varies in time and spatially. Furthermore when working with a large number of either soil or plant samples, the choice of the analytical technique to measure and identify trace-elements becomes to be another critical point, in terms of optimizing sample preparation, matrix corrections, requested time for each sample analysis, and non-destructive characteristics. In this context, the particle induced X-ray emission technique (PIXE) has been used successfully in agronomic applications (CRUVINEL & FLOCCHINI, 1993; CRUVINEL et al 1993; CRUVINEL et al 1996).

In the field of soil physics, a technique that permits a non-destructive, accurate and fast elemental analysis with a minimum of sample preparation effort is often desired. Although trace elements are minor components of the solid phase, they play an important role in soil fertility. The preservation of soil fertility and soil sustainability is a great challenge to grain and forage production. Up until the decade of the 70′s, the traditional system of intensive management (two harvests per year), using conventional clean tillage caused grave problems of soil degradation.

In Brazil, for instance, between 1970-83, the state of *Paraná* introduced minimum tillage and direct sowing in order to promote a good soil cover, improve the productivity of beans, and reduce soil erosion processes. It also introduced crop rotation systems of grasses with annual crops in order to renovate the prairies.

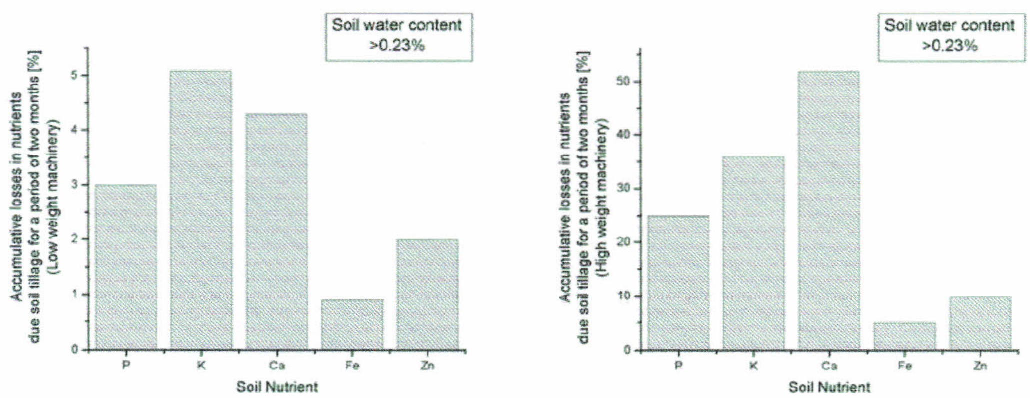
Over the last decade, systems of almost zero tillage have been widely adopted by large and small farmers. The change from conventional to conservation tillage has shown that erosive processes can be reversible if the farmers are willing to change their soil management system. Initial implementation of conservation tillage has two basic requisites: (a) loosening compacted layers in the subsoil, (b) correcting toxicity and low pH within at least the upper 20cm. These requirements are achieved by applying lime to the soil surface, followed by deep tillage or ripping passes below the compacted layer. When soil is tilled, roots and fungal hairs are broken and macro-aggregates break up. Micro-aggregates are not really affected by tillage in the short term. In the long term, however, once total material was obtained using X-ray fluorescence spectrometry. Results obtained for the reference material agree with those published by the National Bureau of Standards.

The resulting PIXE spectra were analyzed to provide the absolute concentration in (μg/g) of the measured nutrient, with particular attention in the concentration of the nutrients P (K_{α}=2.015keV), K (K_{α}=3.312keV), Ca (K_{α}=3.690keV), Fe (K_{α}=6.400keV), and Zn (K_{α}=8.631keV).

The Figure 1 show respectively the resultant analysis for a set of 240 samples, i.e., the summarized result for the quantitative losses in the nutrients P, K, Ca, Fe, and Zn as a function of the weight of the machinery used to plow the agricultural plot for sugar cane production.

TABLE 1. Resultant analysis for the reference material (CRM PACS-2) with attention to P(%), K(%), Ca(%), Fe(%), and Zn(μg/g).

Element	Mean	Std Dev	Mean (Certified)	Std Dev (Certified)
P	0.26 %	0.04 %	0.22 %	0.01 %
K	1.65 %	0.10 %	1.49 %	0.06 %
Ca	2.50 %	0.20 %	2.75 %	0.25 %
Fé	5.97 %	0.12 %	5.85 %	0.08 %
Zn	352	26	364	23



(a) (b)

FIGURE 1. Resultant analysis for losses in the nutrients P, K, Ca, Fe, and Zn based on PIXE measurements as a function of the: (a) high weight machinery used (b) low weight machinery used.

This analysis took into account the average values of the elemental concentration in the fine fractions of the collected soils. The fine fraction of the soil eroded was kept because the coarse fraction contributes very little to the maintenance of the agricultural characteristics. Validation was obtained considering an agricultural plot of one hectare prepared for sugar cane production. Nutrient losses were measured as a function of the weight of the machinery used during the tillage processes. Besides, results considering the class of data collected for an average values of soil water content higher than 0.23 % indicate a higher losses in nutrients for the period of study when using heavy machinery, i.e., in the order of 25 % for P, 36 % for K, 52 % for Ca, 5 % for Fe, and 10% for Zn. Results also show that erosion due to soil tillage, mainly in terms of nutrient loss, is dependent of the machinery weight, i.e., more relevant for the heavy machinery. Much of this losses takes place immediately after the soil is plowed and is directly related to the volume of soil disturbed and the roughness of the surface after organic matter contents decrease significantly, micro-aggregation also decreases because of natural degradation and a lack of new formation of micro-aggregates. Tillage also mixes crop residue and green manure with the soil, allowing better development of microbes in this material. The microbes release the short-lived compounds that glue particles together into aggregates. Once the plant remains have been decomposed, the supply of this glue stops and the macro-aggregates fall apart, especially at the surface of the soil where they are exposed to the impact of raindrops. This is the reason for the formation of crusts at the surface of tilled soils.

In soil that is not tilled, roots and fungal hairs stay intact and maintain the stability of soil structure. It is possible, however, to maintain good performance in a tilled soil by careful crop rotation, use of cover crops that add root biomass and residue, and add manure, other sources of organic matter, and fertilizers. Tillage leads to increased decomposition of organic matter; thus it is necessary to add more plant residue in such soil to maintain or increase organic matter content for good soil structure.

This work presents the suitability of PIXE analysis to evaluate agricultural nutrient losses due to tillage realized with heavy machinery.

MATERIALS AND METHODS: In terms of the study area a farm was selected in the Center-South Region of Brazil, which has expressive mechanization for sugar-cane production. The Center-South Region in Brazil is now responsible for more than 80% of the Brazilian output, and the crop begins in May and ends in December. The 2003/2004 total sugar crop in Brazil will reach 317 million tons, which take near 40% of the available sugar cane (the rest goes for alcohol - as fuel for the automotive fleet - and other by-products). From the 317 million tons, 6% is refined sugar, and the rest is white unrefined sugar and raw sugar (CARVALHO, 2004). Regarding this total in production, approximately 20% are harvested by mechanical procedures.

To evaluate the total of the nutrients losses due to tillage, the relative erosion carried by the machinery was measured for the period of time related to land preparation, and two classes of data were prepared as a function of the different machinery weight in two ranges of soil water content, which was measured daily by means of classical procedures. Therefore, the soil eroded was collected daily during a period of two month from the pneumatic tires of the tractors by periodic washing.

The elemental analysis was carried out based on the application of the particle induced X-ray emission (PIXE) technique (JOHANSSON et al 1970; CAMPBELL, 1988). Then, the soil samples collected from the pneumatic tires were analyzed using an incident 2.4MeV proton beam (15nA and charge of 8 μC), i.e., with the PIXE station installed at the Physics Institute of the University of São Paulo (SP), Brazil. The detectors used to obtain a suitably high sensitivity for each element is two Si(Li) from Kevex, model 3000 (resolution of 175eV in 5.9keV). The method used for soil sample preparation was based on the collection of soil onto filter media in the form of a uniform layer of particulate matter (Cruvinel et al, 1999). Also, all soil samples were prepared as a powder before sample preparation to allow both the penetration of the 2.4MeV proton bean and to decrease the effects of X-ray attenuation by the aggregates of the eroded soil. Nucleopore filter with a thickness of approximately 10^{-2}mm was used to hold the crushed soil as a thin layer for analysis Thus, intermediate thickness samples, whose masses per area unit were smaller than 1μg/cm^2 were analyzed. The instruments used for signal processing were a standard electronic pulse handling system from EG&G ORTEC. Data were accumulated into a PC-compatible computer and the AXIL code was used for spectra analysis (NULLENS, 1984).

The absolute accuracy of the analysis system was established through the use of gravimetric thin film standards. Therefore, in order to have accurate measurements for the soil samples analysis a standard reference material from National Bureau of Standards was used. This reference material, i.e., CRM PACS-2, is a sediment standard and it is intended primarily to calibrate and to use in the analysis of sediments, soils, or materials of a similar matrix (National Bureau of Standards 1984).

RESULTS AND DISCUSSION: Table 1 shows concentrations in (μg/g) of elements P, K, Ca, Fe, and Zn. in the reference material. The certified concentration of the elements in that standard reference plowing, which is also function of the machinery employed. Any reduction of soil disturbance can be expected to reduce such losses.

CONCLUSION: Along with the quantitative measurements of soil nutrient losses by tillage in agricultural fields the presented methodology can be used as an optimization tool for selection of adequate machinery.
Therefore, the results of the study conducted indicate the potential to extend the methodology for large areas, since it can provide the multi-nutrient quantification and its losses due to tillage by heavy machinery. Furthermore, such result can be used to give feedback of the choice of the mechanization process to reduce not only environmental impacts but also the fertilization cost.

.

ACKNOWLEDGMENT: The work reported in this paper was supported in part by Grants provided by CNPq, and the Brazilian Enterprise for Agricultural Research. The author also thanks Prof. Dr. Paulo Artaxo from the Physics Department of University of São Paulo, Brazil.

REFERENCES:

CAMPBELL J. L. Nucl. Instr. and Meth. Phys. Res. B 1988 **31:**518-521.

CARVALHO P., O Sulço, 2004, Ano 108, **18:**10-13.

CRUVINEL P. E., CRESTANA S., ARTAXO P., MARTINS J.V., and ARMELIN M. J., Nucl. Instr. and Meth. Phys. Res. B 1996 **75:**415- 419.

CRUVINEL P. E., FLOCCHINI R. G. Nucl. Instr. and Meth. Phys. Res. B 1993 **75:**415- 419.

CRUVINEL P. E., FLOCCHINI R. G., CRESTANA S., MORALES J. R., MIRANDA J., KUSKO B. H., and NIELSEN D. R. Soil Sci.1993 **155 (2):** 100-104.

CRUVINEL P. E., FLOCCHINI R.G., ARTAXO P., CRESTANA S., HERRMANN JR P.S. Nucl. Instr. and Meth. Phys. Res. B 1999 **150:** 478-483.

JOHANSSON T. B., ARSELSSON R., JOHANSSON S. A. E. Nucl. Instr. and Meth. Phys. Res. 1970, **84:**141-145.

NULLENS H., ESPEN P. VAN Pro-Axil User's Manual Canberra: Elektronic, Vienna 1984.