Introduction

Understanding nitrogen transformation in soil is complicated by the complexity of individual and interconnected processes within the soil media. Utilizing non-invasive sensing techniques maintains a near-native state of an observed system such as soil nitrogen transformations. Coupling visualization techniques to quantitative measurements can provide an insightful and intuitive technique to understand complex processes. N-sight is the name of a system under development that uses novel optical sensors to non-invasively quantify soil analytes relevant to nitrogen transformations and then convert data to visual images.

The basis of N-sight is a sensor foil made with analyte-specific indicator dyes embedded in a thin, polymer-based support material (Gansert and Blossfeld, 2008). The fluorescence signals from the indicator dye and reference material are read with optics at high resolution in space and time. Being true sensors and read remotely by optics, the sensors do not change - and are not changed by - the analytes or system. The indicator dye chemistry and optics allow for accurate analyte measurements over several orders of magnitude. The measurement technique is common in biotechnology and fermentation and has also been applied to ecophysiology studies looking at plant:soil interactions (Blossfeld and Gansert, 2007).

The first application of the N-sight technique is to quantify and visualize pH changes in the soil caused by hydrolysis of urea and to determine the correlation between soil pH changes and ammonia volatilization.

Materials and Methods

A low pH sandy-loam grassland soil was collected from a site in Northern Ireland. It was partially air-dried to pass through a 2 mm sieve. The soil was divided into two, with one batch treated with 18.9 kg $CaCO_3$ kg^{-1}. The two soil batches were incubated under aerobic conditions at 4º C for 18 months prior to the commencement of the study. Bulk pH values for unaltered soil labelled 'L0' was 4.6 and soil labelled 'L3' was 7.5. Soils were adjusted to 60% water-filled pore space. Sealable rhizotron boxes were constructed from PVC with one side of 2mm thick clear polycarbonate to show the soil profile. Each rhizotron contained 250g of soil with a 35mm x 35mm pH sensor foil between the polycarbonate and soil with the top edge level with the soil surface. One granule of urea weighing approximately 35mg was placed in the soil at the centre and 1 cm away from the foil:soil interface. Half of the fertilizer treatments were with normal urea and half with urea treated with 0.3% Agrotain^{TM} urease inhibitor (active ingredient (N-(n-butyl)thiophosphoric triamide)). Shallow trays containing 10ml of 0.02M H_3PO_4 were suspended in the headspace to trap volatilized NH_3 and these were replaced daily. Sensor foils were scanned every 20 minutes with a detector on an x-y table to provide a 2-dimensional matrix of point data across the foil. To visualize the magnitude and gradients of pH change, the data matrices were converted to colour contour plots with SigmaPlot^{TM} statistical software.

Results

The N-sight technique visualized urea hydrolysis in soil by documenting a pH rise in L0 soil from the initial value of approximately 4.6 to 9.0 or higher within 1 day (Fig. 1). The gradient of high pH quickly spread to fill or exceed the $35mm^2$ area of the sensor foil. The corresponding NH_3 volatilization measurements from the trapping system correlated with the onset and magnitude of the pH change. Agrotain treatment of urea slowed the rate and magnitude of soil pH changes and this corresponded to a large reduction in NH_3 volatilization. The L3 soil (bulk pH 7.5) showed similar patterns regarding the onset of pH change and NH_3 emission with urea (data not shown). Agrotain-treated urea in the L3 soil again showed a delay in onset and reduced the magnitude of pH change

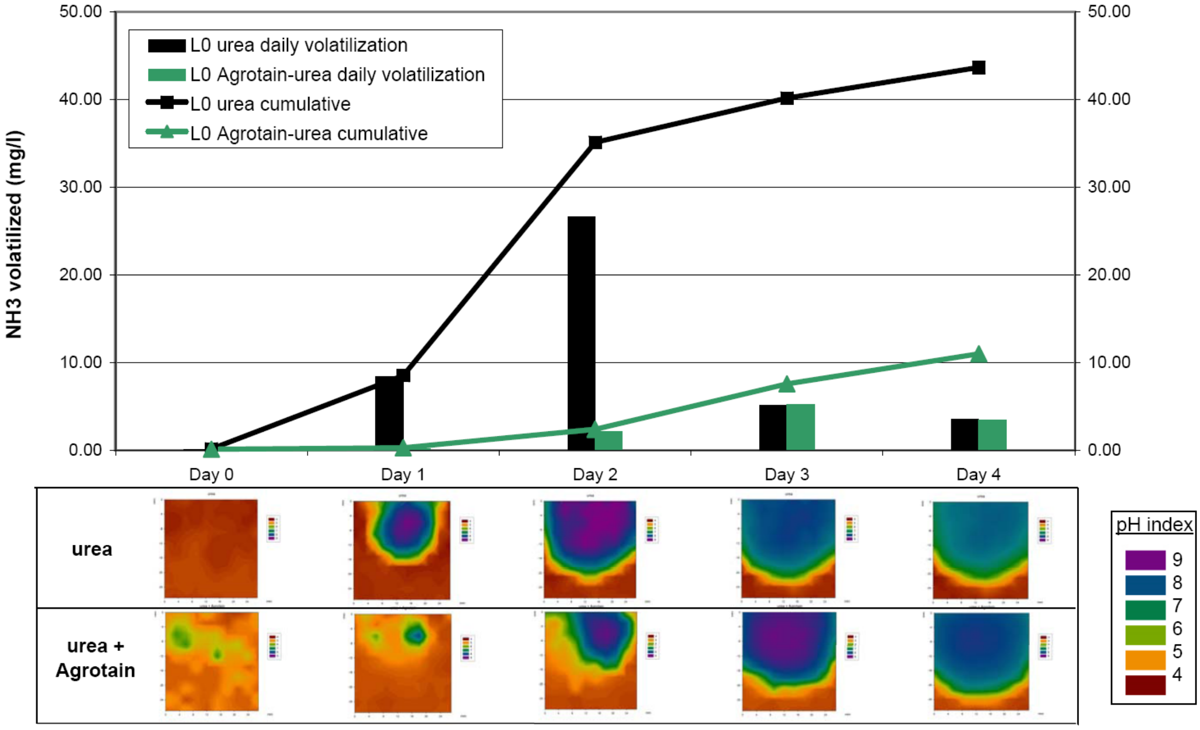

Fig. 1. Ammonia volatilization and soil pH changes in soil "L0" (bulk pH = 4.6) for four days following the application of one granule of urea or one granule of Agrotain-treated urea in the centre and 1 cm back from the senor foil..

Conclusions

Non-invasive measurement of the chemical conditions of the soil with senor foil is a novel and powerful technique to understand nitrogen transformations. The example shown with soil pH is the first step in a range of possibilities with sensor foils. Sensor foils for O_2 measurement have been demonstrated in soil (Blossfeld and Gansert, 2007) and sensors for NH_3 measurement have been developed (Waich et al. 2008). There is a solid theoretical basis for developing at urea sensor and, although complicated by Cl^- interference, a NO_3^- may be possible. By combining sensor technologies for nitrogen analytes and trapping emission of NH_3 or N_2O gases, most of the crucial step or states in nitrogen transformation and associated soil conditions could be quantified and visualized with the N-sight technique. N-sight is a promising tool for improve the understanding nitrogen transformations and potentially lead to new technology or techniques that improve nitrogen fertilizer efficiency.

References

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