Research News

Photoacoustics for efficient fertilization

New measurement method detects field emissions of nitrous oxide

Nitrous oxide is the third most significant greenhouse gas in terms of climate impact after carbon dioxide and methane. It is primarily generated as a result of nitrogen fertilization in agriculture. The Fraunhofer Institute for Physical Measurement Techniques IPM has developed a compact and cost-effective measurement system that detects nitrous oxide emissions from farmland directly in the field. The system will help make fertilization more efficient in the future.

Along with energy prices, import prices for urea, the world's most widely used nitrogen fertilizer, are also rising. In some cases the increase is more than 40 percent. To save valuable resources, nitrogen fertilization strategies must be optimized. This would also help protect the environment. While nitrogen is an important nutrient for plants, excess nitrogen in the soil leads to high nitrate levels in the groundwater. Furthermore, microbiological processes in the soil convert the nitrogen into nitrous oxide (N2O), a greenhouse gas that escapes into the atmosphere.

Cost-effective, portable field measurement system

High nitrous oxide emissions often indicate excessive fertilization. However, measuring emissions from the soil remains a very complex and expensive task. In the current state of the art, gas samples are collected in sampling chambers in the field. Subsequent laboratory analyses make the process time-consuming and costly. There are alternative methods for measuring nitrous oxide directly in the field. However, these methods are also highly complex and expensive.

Fraunhofer IPM researchers are working on a solution in the ESKILA project. "We are developing a compact, cost-effective, and portable measurement system that can quickly measure nitrous oxide emissions from the soil directly in the field," explains Gerrit Stiefvater, research scientist at Fraunhofer IPM. "This information helps us model soil processes. And also allows for a better assessment of how the soil responds to nitrogen fertilization and to what extent, ultimately enabling the optimization of fertilizer quantities."

During field tests, the team placed N_2O flux chambers in various locations across the field to capture the nitrous oxide emitted from the soil. Then, the concentrated gas was pumped from the chamber into the measuring cell of a portable, suitcase-shaped measuring system that weighs about 5.5 kilograms, where it was analyzed.

Measurements were taken using resonant photoacoustics, a highly sensitive and easily implemented method. Unlike traditional absorption spectroscopy, this method does not measure the absorbed light. Rather, the measurement signal is a sound wave generated by modulating the laser wavelength. "In photoacoustics, absorption causes the molecules to move wildly, increasing pressure. We can generate an acoustic signal by modulating this process," explains Raimund Brunner, Group Manager at Fraunhofer IPM. "We use the measuring cell as a resonator, which significantly amplifies the signal at the right modulation frequency. This enables a high degree of sensitivity in a compact design." The researchers acquire the signal using a simple MEMS microphone, like those installed in smartphones. "The greater the concentration of nitrous oxide in the cell, the louder the microphone signal. We can thus use the tone to indirectly measure how much nitrous oxide is in the measuring cell."

Environmental conditions in agriculture make measurements especially challenging. Soil moisture levels in particular vary greatly. To keep these levels constant in the measuring cell, the team has integrated a separate humidification system. This is the only way to ensure reliable data. Otherwise, humidity fluctuations in the measurement gas would cause problems for the photoacoustic measurement.

Optimized fertilization benefits the climate and the environment

The measurement system developed in the project is the first compact, field-capable setup that enables a direct and systematic analysis of different fertilization strategies and their effect on the climate directly in the field. Of particular interest is the comparison of conventional broadcast fertilization and special depot fertilization, where fertilizer is introduced into the soil at depths of up to 20 cm. Depot fertilization, in combination with optimized fertilizer quantities, not only reduces N2O emissions but also increases crop yields.

Photoacoustic measurement is not limited to nitrous oxide. The system can also be configured to detect other agricultural gases, such as ammonia (NH_3) and carbon dioxide (CO_2). This opens up a wide range of possibilities for future climate-aware agricultural applications.



Fig. 1 Field test: Fraunhofer researchers use N_2O flux chambers and a special portable system to measure nitrous oxide emitted from the soil in a field. © Fraunhofer IPM

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Contact

Monika Landgraf
Fraunhofer-Gesellschaft, Munich
Head of Communications
Phone. +49 89 1205-1333
presse@zv.fraunhofer.de

Holger Kock
Fraunhofer Institute for Physical Measurement Techniques IPM
Head of Communications and Media
Phone: +49 761 8857-129
holger.kock@ipm.fraunhofer.de
www.ipm.fraunhofer.de