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# Greenhouse Gas Emissions From Agriculture and Animal Operations

## Influencing Factors, Measurement Limitations, and Potential Mitigation Strategies

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## INTRODUCTION

- Gas emissions from anthropogenic sources are a major concern for environmental quality and global climate change. Nutrient-rich agricultural soils in conjunction with land-applied manures are known to be major emitters of greenhouse and regulated gases (Fig. 1). While greenhouse gases of concern include carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$), regulated air pollutants comprise ammonia ($NH_3$), nitrogen oxides ($NO_x$), hydrogen sulfide ($H_2S$), and non-methane volatile organic compounds (VOCs).
- Accurate quantification of these gases is essential for successful implementation of cost efficient and effective strategies to globally mitigate harmful gas emissions. Unfortunately, gas emissions are affected by a plethora of intertwined physical, chemical, and biological factors such as climate (i.e., temperature and precipitation), soil properties (i.e., texture and clay mineralogy, pH, moisture and temperature distributions) as well as microbial activity. Furthermore, the land-application of manure alters soil characteristics while increasing availability of nutrients, often leading to enhanced gas emissions.
- Understanding the influence of environmental variables affecting soil gas emission is a first step towards development of successful mitigation strategies. Literatures values for major soil gas emission rates under a wide variety of climatic and soil conditions and under differing rates of manure application are presented in an attempt to provide meaningful insights towards future quantification and mitigation efforts.

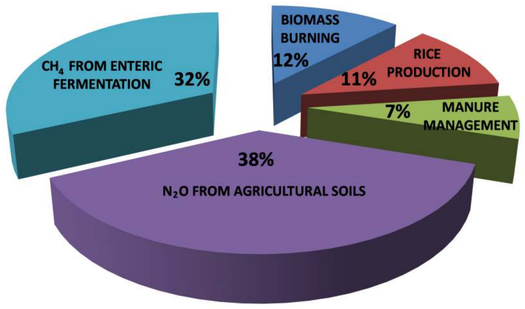



**Fig. 1:** Major Agricultural Greenhouse Gas Sources (IPCC, 2007).

## INFLUENCING FACTORS - CLIMATE AND SOIL PROPERTIES

- Soil temperature and moisture, which are a direct consequence of climate (i.e., precipitation, air temperature, and wind speed), dominate the timing, intensity, and duration of gas fluxes (Flechard et al., 2007). Temperature and moisture must be considered simultaneously and together with other physicochemical soil characteristics, as overall rainfall is less important than the soil temperature during rainfall events and the moisture retained in the soil afterwards. Climatic factors are particularly important for soil N cycling and gaseous N emissions, such as $NH_3$, $N_2O$, and $NO_x$. Figure 2 depicts optimum ranges for (a) soil temperature and (b) relative saturation for peak gas emissions compiled from relevant literature.

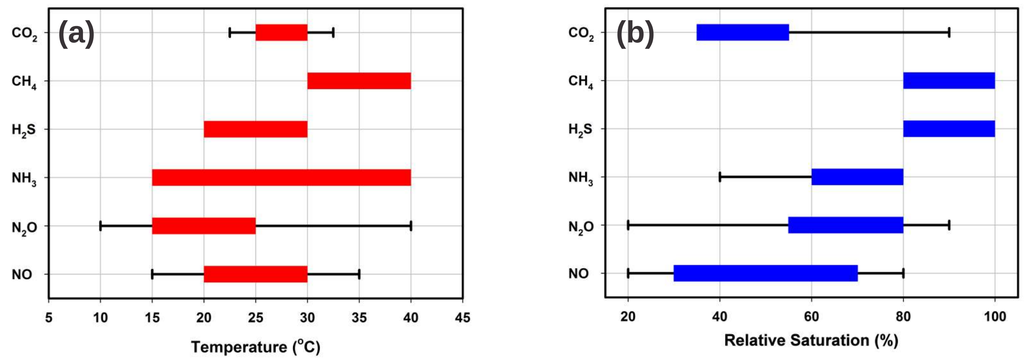



**Fig. 2:** Optimum ranges of (a) soil temperature and (b) relative saturation for peak gas emissions; solid bars indicate primary range for optimum emissions, error bars indicate range with lower, but still significant, emissions.

- Not only do temperature, precipitation, and wind speed affect soil gas emissions, but the properties of the soil itself also contribute to variations in emissions. Changes in soil physical, chemical, and biological properties can result in significant differences in gas emissions even when atmospheric conditions remain constant. Emission rates have changed by as much as one order of magnitude for $CO_2$ from different soils in the same experiment (Zhang et al., 2010).

  Maximum release rates for gaseous N compounds were reported for a wide range of soil pH (Fig.3) due to the complex process involved in N transformations. The pH for optimum $NH_3$ emissions is notably higher than that for other gases. The effect of pH on $NH_3$ emissions is very important for agriculture, as fertilization can temporarily change the pH of the soil (Sommer and Hutchings, 2001).

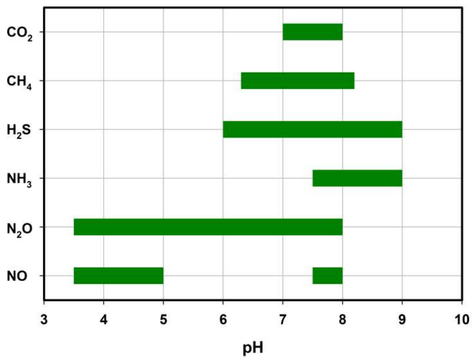
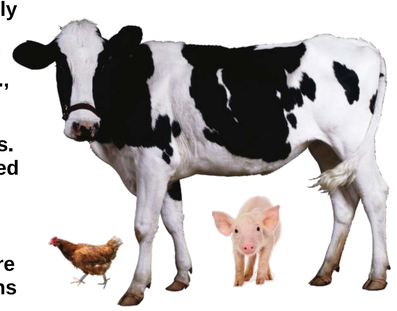



**Fig.3:** Optimum ranges of soil pH for peak gas emissions reported in literature.

## INFLUENCING FACTORS - ANIMAL MANURE

- Addition of fertilizer or animal manures does not change the factors affecting emissions, such as climatic and soil variables, but does change the response of the system. In general, fertilizer application adds available nutrients, notably N compounds, to the soil, which increase the potential for gaseous transformations and soil gas emission. Understanding potential responses of agricultural systems to manure application based on climatic and soil variables discussed above will lead to better regulatory and mitigation strategies.
- Gas fluxes following land application of manures are of course driven by the complex interactions of climate, soil characteristics, as previously discussed, and additionally other unique factors such as application methodology and manure characteristics.
- Manures are commonly applied on the soil surface and subsequently incorporated or injected in the subsurface. In either case, gas emissions typically increase immediately after application, and over time decrease to background environmental emissions (Meade et al., 2011).
- The type of manure-producing animal also affects surface emissions. Also the form of manure, whether slurry, liquid manure, or composted manure affects nutrient availability and therefore the potential for gaseous losses. Akiyama and Tsuruta (2003) showed that $N_2O$ emission from poultry manure was higher than from cattle manure. Some research indicates that application of pig slurry produces more $CH_4$ than cattle slurry, and may cause elevated rates of $CO_2$ emissions for far longer than cattle slurry application.



## MEASUREMENT METHODS AND LIMITATIONS

- To mitigate emissions of greenhouse and other regulated gases from agriculture and animal feeding operations (AFOs), reliable and economically feasible measurement platforms that are capable of continuous and simultaneous monitoring of all gases of interest are required.
- Although a vast array of technologies exist for measurement of gas emissions, they are either too expensive for continuous measurements, capture only a single gas, or do not allow accurate quantification of gas fluxes. In general, measurement and monitoring techniques are divided into chamber methods, both open and closed, and micrometeorological approaches. Although micrometeorology has the advantage of being truly in situ, implementation of such measurements is limited due to the cost and complexity of the required equipment. A thorough literature review suggests that available measurement technology for gas emissions from agricultural operations do not include real-time, continuous monitoring capabilities. Future research should focus on technologies such as solid-state sensors in an effort to design low-cost real-time monitoring systems (Fig.5).

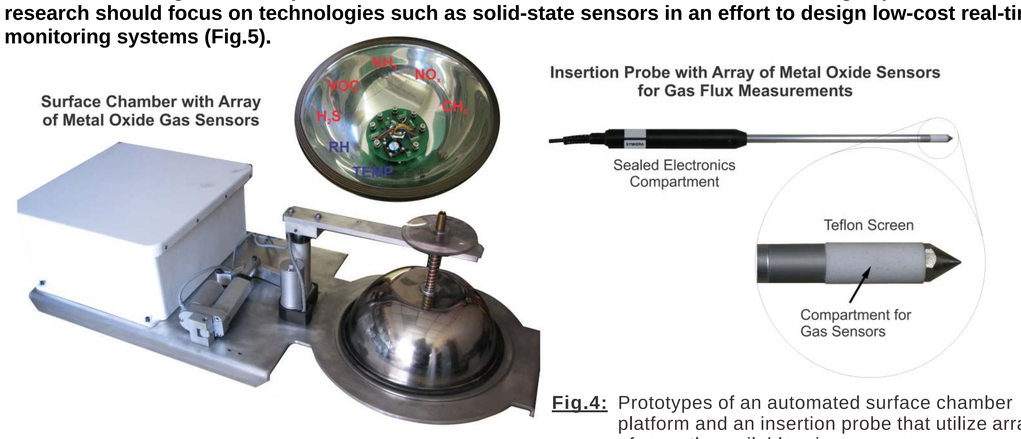



**Fig.4:** Prototypes of an automated surface chamber platform and an insertion probe that utilize arrays of recently available micro gas sensors are currently being developed at USU and at the UofA.

## SUMMARY AND CONCLUSIONS

- The impact of climatic conditions, soil properties, and manure applications on gas emissions from agricultural soils is undeniable. The complexity of the system, including the interactions of soil, manure, and climatic variables, dictates a whole-system approach to GHG monitoring and mitigation in agricultural settings. If regulatory measures are to be implemented, new reliable and cost-efficient technology needs to be developed to allow real-time, continuous monitoring of gas emissions for $NH_3$, $CO_2$, $CH_4$, $N_2O$, and $NO_x$, at a minimum. Including the full spectrum of gases along with analysis of all variables discussed will provide the most accurate picture on the total contribution of agricultural operations to emissions of greenhouse and other regulated gases.

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