Ammonia Emissions Related to Fertilizers on Field Crops Using Precision Application Practices in the Central Valley of California

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ABSTRACT

Precision agriculture is the term applied to the use of GPS for location and guidance of farm equipment in the field combined with GIS techniques to vary the application of seed, fertilizer and pesticides. These precision agriculture practices allow the grower to match the yield potential of the soil in parts of the field as small as 50 square meters by adjusting the amount of seed and fertilizer applied to that area. The primary advantage is economic because areas of the field with lower yield potential will only have the seed and fertilizer applied that are needed for those soil conditions. The advantage with regard to air quality is prevention of excessive application of nitrogen fertilizers that may result in higher emission factors either during application or later in the crop season. A series of cotton fields in the southern part of the San Joaquin Valley were used to compare precision agriculture practices with conventional practices. Ammonia flux sampling equipment was added to one of these trials in an attempt to detect differences in ammonia emissions from the different fertilization regimes. The primary collection method utilized active chemical filter packs or denuders at various elevations up to 10 meters. A tunable diode laser system was also employed to monitor ammonia during several of the fertilizer applications.

INTRODUCTION

Ammonia (NH_3) is the dominant gaseous base in the atmosphere. Volatilized NH_3 may react in the atmosphere to form ammonium nitrate and ammonium sulfate increasing fine particulate matter of 2.5 microns or less ($PM_{2.5}$). The San Joaquin Valley of California experiences periods of elevated levels of particulate matter in the fall and winter months causing increasing health concerns. These levels of PM 2.5 make the understanding of NH_3 in the environment important to the public.

In June of 2001, a report was submitted to the Emission Inventory Branch of the California Air Resources Board by Potter, Krauter, and Klooster with statewide inventory estimates of NH_3 emissions from chemical fertilizers in California. The project was funded by the ARB to generate a new emissions inventory of NH_3 volatilization from surface applied fertilizers using field measurements and computer modeling of major nitrogen transformations in the soil that can lead to NH_3 emissions. Field sampling was conducted in the Central Valley of California on commercial fields at the time of application. Using these new fertilizer source estimates, a detailed NH_3 emission inventory for California was developed. Emissions of NH_3 for a variety of fertilizer types and application methods were mapped with the major crop types in California's four main growing regions.

A wide variety of crops, fertilizer materials, and application methods were monitored to collect a wide breadth of data. Sampling was started a few days before application for background levels and was continued 3 to 4 days after application. An active sampling method was used with de nuders and anemometers located at sampling heights of 1,2,4,10, and 18.5 meters. A sampling system was constructed on a portable trailer with a tower mounted on it. Based on 15 sites analyzed, it was found that total nitrogen losses from fertilizer applications ranged less than 0.1 to 0.7 g $N\text{-}NH_3\ m^{-2}$. This is 0.05 to 6%, with an average of 3.6%, of the total amount of N applied that was lost by volatilization as NH_3.

Various factors are known to affect NH_3 volatilization. The pH of soil the fertilizer is applied to appears to be an important controlling factor. Soils having a pH from 7-9 are strongly associated with higher levels of NH_3 volatilization due to elevated pH and NH_4+ concentrations at wet microsites where surface applied urea fertilizer particles dissolve and hydrolyze (Fenn and Richards, 1986). Actions taken to adjust the pH of soils closer to a neutral pH may reduce NH_3 volatilization.

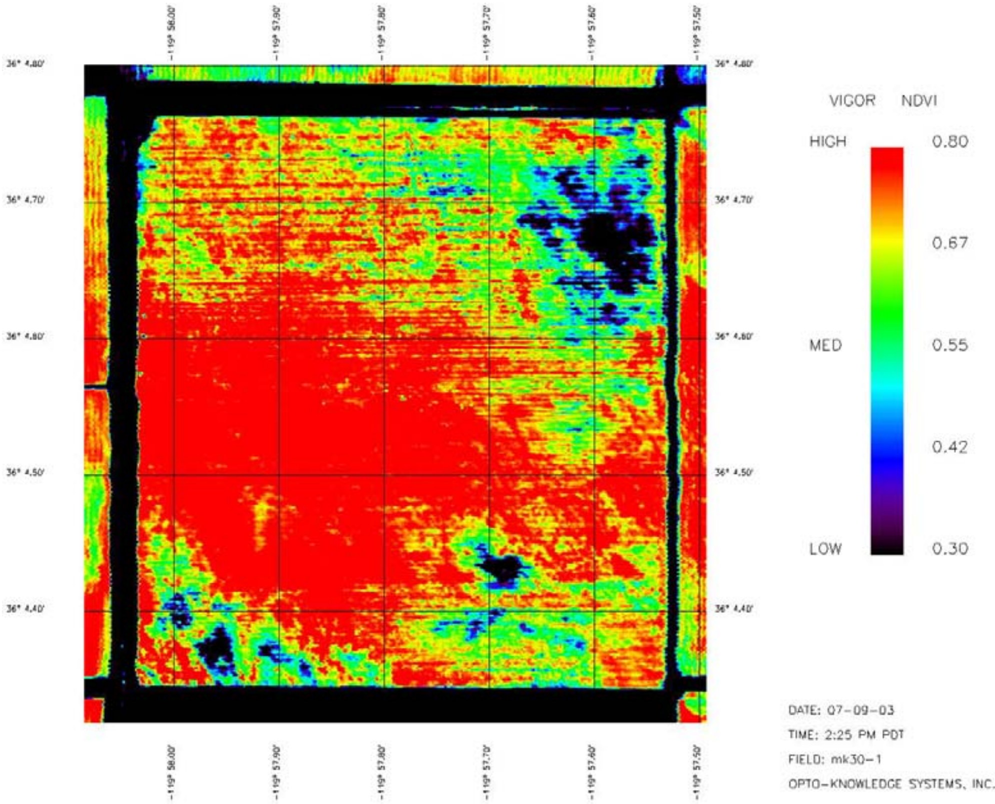
The method of application can have a significant effect on the amount of NH_3 loss from fertilizer applications. Generally applications that effectively bury the fertilizer are better at reducing NH_3 loss. Potter et al. 2001 monitored an application of anhydrous ammonia injected 15cm. into the soil on a cotton crop having a loss of 3.9% of the total amount of N applied while another application with ammonium sulfate applied to soil surface in an almond crop resulted in a loss of 6.6%. Another application was an injection of urea-ammonium nitrate through a buried drip irrigation system in almond crop where no measurable NH_3 was lost by volatilization.

Moisture content of soils can also have an effect on NH_3 volatilization with moist soils tending to emit less $NH_{3.}$ Moist soils seal in NH_3 by reducing gas diffusion through the soil. This effect can be especially appreciated with an application method that buries the fertilizer such as an injection behind a shank or knife. Another example of moisture affecting NH_3 emissions occurs when urea is used as a fertilizer source. Urea when exposed to high levels of moisture tends to hydrolyze, emitting more NH_3 than if moisture levels were lower in the soil.

Precision agriculture combines the use of global positioning systems, geographic information systems, yield monitors, and other tools to make farm management decisions on a site specific level instead of a field-by-field basis. Precision or “site specific” agriculture has been widely used in the Midwest for several years on a number of crops. Until recently California farmers had not implemented precision agriculture methods but now some farmers are experimenting with the technology in search of benefits. The technology has been available for years to in California but in most cases the economic benefits were not obvious and the operation of the equipment was too technical for many growers.

Field variability is one of the main reasons growers are beginning to adopt precision agriculture in California. In some of the cotton growing areas in the Central Valley of California fields are highly variable in many soil properties. Variations in soil salinity can affect cotton yield greatly from site to site in a field. Growers’ use of yield monitors can effectively illustrate variable soil salinity, which translates into yield variability at the end of the season. Traditionally in the spring, cotton crops in the Central Valley would have an application of nitrogen fertilizer injected under the soil surface approximately 15 cm. Common practice for farmers would be to apply a uniform application of nitrogen fertilizer over the field at a rate ensuring all plants will receive enough fertilizer. This rate is determined by the amount of nitrogen that was required to produce the desired yield. An example would be a cotton yield of 3 bales per acre, about 1600 kg./Ha. That yield level will require 50 lbs. N per bale of cotton produced plus another 150 lbs. N/acre to support the vegetative growth of the plant, for a total application of 300 lbs.N/acre (337kg/Ha.). Soil samples before planting would be taken to determine the average amount of residual nitrogen in the soil profile and would be subtracted from the calculated rate for the field. This formula would work efficiently if fields were fairly uniform. But variability causes some areas of the field not to yield the targeted amount and the crop does not fully use all of the applied nitrogen fertilizer. When this process has been repeated two or three seasons, residual nitrogen builds up in the low yielding areas of the field where the fertilizer was applied for a desired yield that was not acheived.

Figure 1. NDVI satellite image of the plot field illustrating the variability of the crop within the field. Areas of red, green, and black represent high, medium, and low crop vigor. Areas of black indicate no crop stand because of high salinity.



In Figure 1 an image was taken from a field where a University of California research group was conducting a large scale trial testing variable rate applications of nitrogen on cotton. The farm is owned and managed by Ted Sheely near Leemore, California. The overall project is a cooperative effort among researchers from NASA, University of California, United States Department of Agriculture, CSU Fresno and grower associations to take available technology and help growers implement it. The studies include a range of technology applications such as variable nitrogen, growth regulators, soil amendments, and the use of remote sensing data to help make decisions during the season on topics such as pest management. To apply the appropriate rate of nitrogen fertilizer, a prescription map was made by taking inputs from residual soil nitrogen available obtained through soil sampling and an EC map of the field which measured soil salinity. The EC map was made from an EM-38 instrument. Once the prescription map was made the variable rate application could be made. The field in Figure 1 was the site in the 2003 season of a trial to test a variable rate application against 3 rates of nitrogen fertilizer. The treatments were 50,113,177, lbs. N/acre (56, 127, 198 kg/Ha) plus plots with a variable rate of anhydrous ammonia applied according to the prescription map.

Figure 2. Prescription/application map of variable rate nitrogen trial. Colored grids represent recommended rates of application and overlayed colored dots are actual applied amount in lbs. nitrogen/acre.

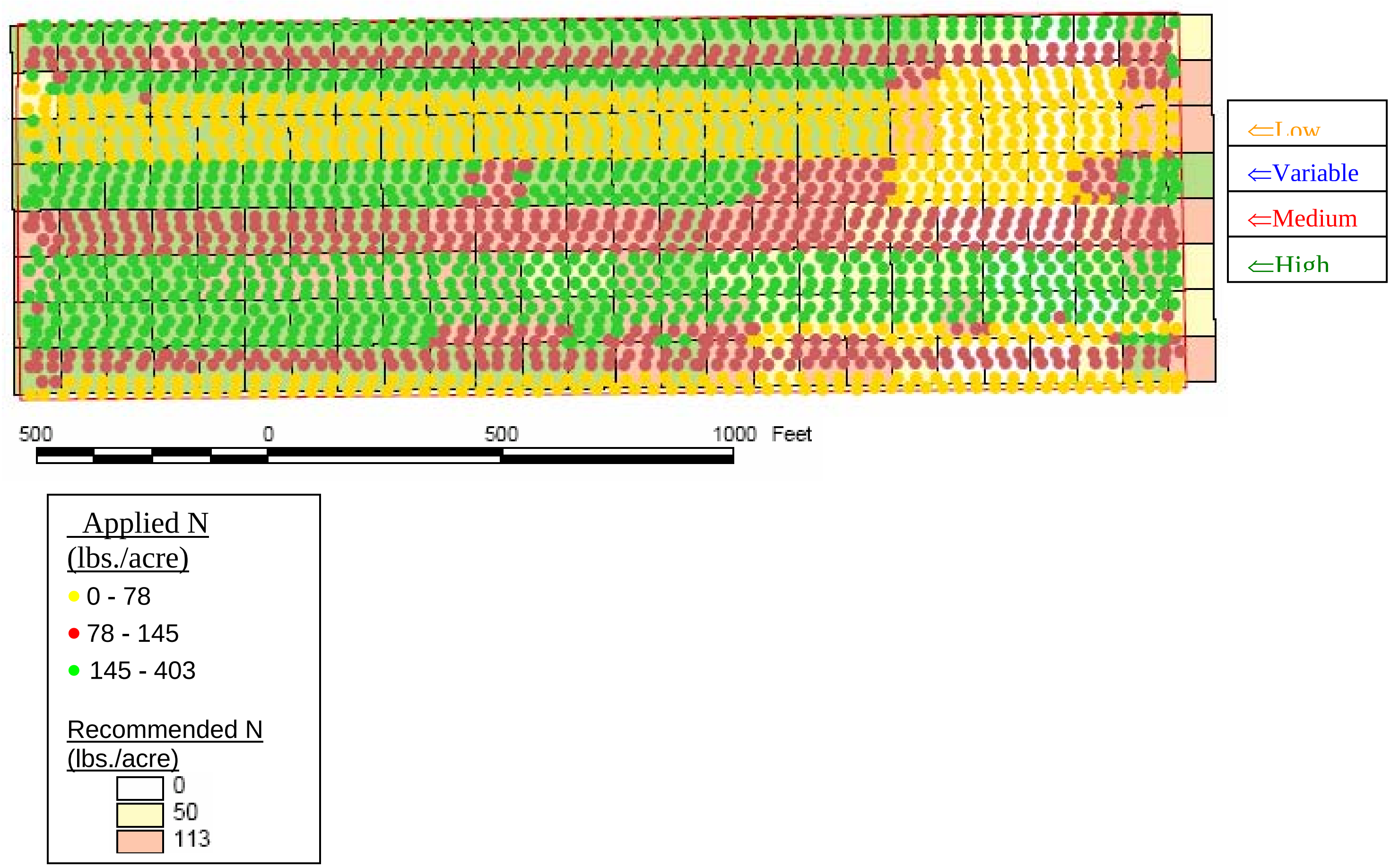


Figure 2. is the prescription/application map for the trial. Each grid represents a unit of the field able to receive a different rate of fertilizer. The rows of dots with a constant color or applied rate all the way across the field are one of the low, medium, or high, nitrogen rate treatments. Rows that have different colored dots across them are the variable rate treatments. White grids in the map are areas where a zero rate was recommended but the farmer wanted an application of 50 lbs. N/acre.

Ammonia emissions were monitored before, during, and after the application by California State University, Fresno researchers as an addition to the other research going on in the program. The following portion of this paper details the methodology of the ammonia emissions monitoring. Each treatment plot was 31m across. Ammonia sampling towers were placed in the high, low, and variable rate plots to see if lower applications of nitrogen fertilizer emitted lower amounts of ammonia.

Active de nuder methodology was used to sample for ammonia by pulling air by pumps through 47mm glass microfibre filters treated with a 3% citric acid solution using ethyl alcohol as a carrier. A second 47mm glass microfibre filter was used to remove any dry deposition nitrogen before sample air came into contact with the treated filter. Anemometers were co-located with de nuders at sampling heights of .5, 1, 2, 4, and 10 meters. Sampling equipment was set up on June 4 and sampling commenced to monitor background levels of ammonia. The application of nitrogen fertilizer was made on June 6 with sampling continuing until June 12. Sample changes were made at sunrise and sunset in order to capture diurnal variations in NH_3 emissions.

During the application a second method of monitoring NH_3 was used giving real time levels of NH_3. Tunable diode lasers (Boreal Laser Inc.) were used during and multiple hours after the application. The lasers are tuned to a wavelength of light specific to NH_3 and take measurements of NH_3 levels as rapid as every second.]

Currently only concentration data from treated filters is available. This preliminary data shows an increase in NH_3 concentrations in the high rate plot over the variable and low plot when comparing samples taken the day before application (background) and the day after application. Flow rates on all sample pumps were consistent and wind speeds were uniform from site to site. This increase is most significant at sample heights of 1, 2, and 4m but not at 10m, indicating that concentrations of NH_3 at 10m in all treatments is at background levels.

CONCLUSIONS

Further analysis of last year's data will be made to draw better conclusions on the results of the research. Therefore, no definite conclusions can be made at this time. Sampling will be conducted again this year with the integration of more intense monitoring with tunable diode laser technology as an addition to last year's sampling protocol.

REFERENCES

1. Potter, C., C. Krauter, and S. Klooster. Statewide Inventory Estimates of Ammonia Emissions From Fertilizer Applications in California. Project report to California Air Resources Board, Sacramento, CA. Contract# ID98-76. June, 2001.

2. Fenn, L.B. and J. 1986. Richards. Ammonia loss from surface applied urea-acid products. *Fert. Res.* 9:265-275.

Keywords
Ammonia
Precision Agriculture

Description – Ammonia was monitored during a precision agriculture trial. Anhydrous ammonia was applied at different rates including a variable rate and monitoring was done before, during, and after the application. Ammonia emissions, was compared according to the different application rates.