University of California
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Development of a field-based approach to estimate soil N mineralization for field-specific fertilizer N adjustments

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Technical Completion Report
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Overall project summary/statement:

Due to high groundwater nitrate concentrations, California growers are facing increasing regulatory pressure to improve nitrogen (N) use efficiency in crop production to reduce nitrate leaching. To maintain high yield levels, growers need accurate estimates of crop available N that doesn't come from fertilizer so that they can adjust fertilizer application rates with confidence. This project aims to determine N mineralization rates in a variety of agricultural soils from California. The data shall be used to develop a simple tool that allows estimating field-specific N mineralization rates.

In spring 2016 and 2017, we collected undisturbed soil cores from 57 fields under annual crops located in the northern half of California (Figure 1). The soil organic matter (SOM) contents in these soils differed widely, ranging from 1-23%. The soil cores were incubated at optimal moisture content and different temperatures for 10 weeks. A number of analyses were performed to characterize the soils. A greenhouse trial was also included in the study.

The results show that N mineralization increases exponentially within the investigated temperature range of 5-25 °C. The temperature response differed little across regions.

For soils with a high soil organic matter content, a model based on total soil C and N, particulate organic C and N and sand content was best in predicting N mineralization rates. For soils with a low SOM content, FDA hydrolysis, a measure for soil enzyme activity, and pyrophsphate extractable Fe were the best predictors. While the model predicted N mineralization very well in soils with a higher SOM content, it was less successful in low SOM soils, where interactions with soil minerals and cropping history may strongly affect N mineralization rates.

Preliminary results from this study were presented at numerous meetings and conferences in California.

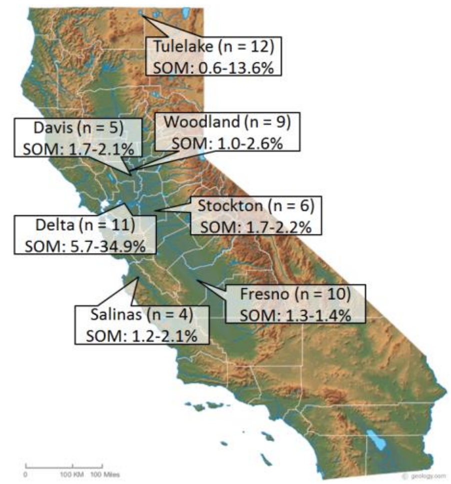

Figure 1: Location and range in soil organic matter content (SOM) of the sites sampled in spring 2016 and 2017.

1. Research program:

In collaboration with local farm advisors, we selected field sites in different regions of the state with widely different soils and climatic conditions (Figure 1). Undisturbed soil cores (2-in. diameter, 6 in. long) were collected from a depth of 3-9 inches, representing the top foot of the profile. Samples from the soil surrounding the cores were taken from the same layer at the same time. These samples were sieved and analyzed for a wide range of soil properties (Table 1). The soil cores were incubated for 10 weeks at different temperatures (5, 15 and 25 °C) and at an optimal moisture content of 60% water filled pore space to determine N mineralization rates and their temperature response. In addition, a pot trial was carried out in the greenhouse. The samples represented a wide range of soil properties (Table 1).

Table 1: Select properties of the samples taken in the different regions.

Soil property	**Region**					
	San Joaquin Valley	**Sacramento Valley**	**Salinas**	**Delta**	**Tulelake**	**Others [1)]**
Number of sites	16	14	4	11	10	2
Bulk density ($g\ cm^{-3}$)	1.19 (1.1 - 1.31)	1.28 (1.17 - 1.48)	1.45 (1.32 - 1.68)	0.84 (0.63 - 1.33)	0.71 (0.43 - 0.92)	1.36 (1.34 - 1.37)
Total C ($g\ kg^{-1}$)	10.1 (7.3 - 12.8)	11.1 (6 - 15.3)	9.2 (6.7 - 12)	90.4 (33 - 198.4)	49.8 (31.4 - 78.6)	7.4 (6 - 8.8)
Total N ($g\ kg^{-1}$)	1.16 (0.85 - 1.41)	1.18 (0.69 - 1.56)	1.12 (0.83 - 1.39)	6.22 (2.71 - 12.48)	4.65 (2.92 - 7.16)	0.71 (0.65 - 0.77)

Particulate organic N (g kg^{-1})	0.14 (0.05 - 0.21)	0.16 (0.08 - 0.28)	0.09 (0.05 - 0.12)	1.62 (0.15 - 5.25)	0.89 (0.35 - 1.91)	0.15 (0.12 - 0.19)
Particulate organic C (g kg^{-1})	1.72 (0.78 - 2.55)	1.85 (1.01 - 3.1)	1.09 (0.56 – 1.76)	27.41 (2.32 - 90.87)	10.70 (4.64 - 25.13)	2.86 (1.8 - 3.93)
pH	7.58 (7.17 - 8.06)	7.68 (7.2 - 8.08)	7.46 (7.24 - 7.65)	6.54 (5.9 - 7.27)	7.07 (6.19 - 7.65)	6.54 (5.57 - 7.5)
Electrical conductivity (mS m^{-1})	90.3 (14.4 - 250)	15.2 (7.8 - 27.8)	20.0 (12.3 - 24.3)	29.4 (12.9 - 63)	42.1 (14.3 - 97.2)	12.3 (11.7 - 12.8)
Sand (%)	23.0 (8.7 - 35)	26.4 (5.5 - 64.9)	46.8 (38.5 - 60.3)	9.6 (0.9 - 18.9)	7.6 (2.3 - 16.1)	83.2 (80.2 - 86.1)
Clay (%)	36.6 (20 - 49.2)	29.4 (10.9 - 58.8)	16.0 (11.9 - 21.5)	43.1 (32.2 - 61.5)	56.2 (49.4 - 68.6)	8.6 (8.4 - 8.8)
Permanganese oxidisable C (mg kg^{-1})	345 (259 - 477)	369 (262 - 460)	333 (210 - 477)	1966 (775 - 3578)	776 (245 - 1564)	217 (192 - 241)
FDA hydrolysis (mg kg^{-1} h^{-1})	16.8 (9.8 - 30)	14.8 (4.8 - 33.6)	7.5 (3.4 - 10.3)	40.1 (25.1 - 68.8)	34.0 (20.4 - 76.7)	9.3 (9.1 - 9.5)
Pyrophosphate extr. iron (mg kg^{-1})	88 (34 - 154)	168 (101 - 276)	173 (136 - 261)	4236 (832 - 7623)	546 (179 - 2076)	135 (56 - 215)
Dithionite extr. iron (g kg^{-1})	10.80 (7.75 - 13.46)	14.64 (10.42 - 17.65)	7.18 (6.32 - 8.16)	9.77 (7.39 - 12.32)	3.14 (2.54 - 4.17)	2.63 (2.25- 3.01)

1) These are two soils sampled in the Tulelake area outside the basin

The amount of N mineralized in undisturbed soil cores incubated at 25 °C for 10 weeks varied considerably (Figure 2). Using multiple linear regression, we determined the best model to predict net N mineralization based on soil properties measured. For soils with a high soil organic matter content from the Delta and Tulelake basin, the amount of N mineralized during the 10-week incubation at 25 °C was best estimated based on total soil C and N, particulate organic C and N and sand content (Figure 3). For soils with a low SOM content, FDA hydrolysis, a measure for soil enzyme activity, and pyrophsphate extractable Fe were the best predictors. The model was less accurate in low SOM soils, where interactions with soil minerals and cropping history may strongly affect N mineralization rates.

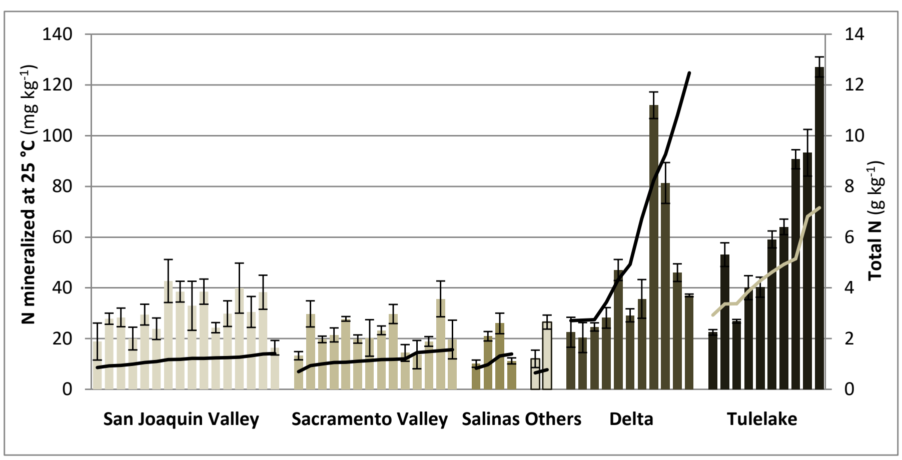

Figure 2: Nitrogen mineralization in undisturbed soil cores. The cores were incubated at optimal moisture content at 25 °C for 70 days. Within the regions the sites are arranged in order of increasing total soil N. Error bars represent standard error (n = 3).

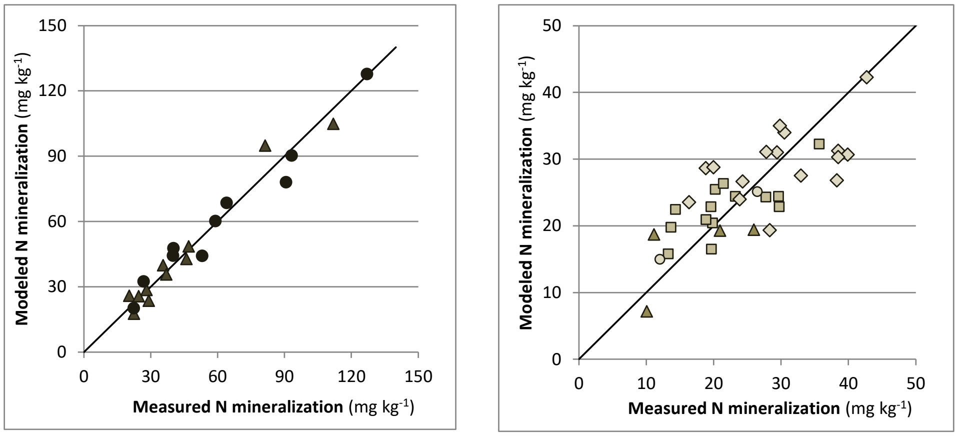

Figure 3: Comparison between measured and modeled N mineralization. Left panel, soils with a high SOM content (adjusted R^2: 0.95); right panel, soils with a low SOM content (adjusted R^2: 0.55).

One goal of the project was to determine N mineralization in the field by taking pre-plant soil samples twice in spring, with the two sampling events being approximately 6-8 weeks apart. In both years, 2016 and 2017, relatively late rainfalls prevented us from taking early samples. As soon as the soils were dry enough, growers started preparing the fields, so that it was not possible to take samples twice pre-plant several weeks apart. Based on this experience, this approach of determining N mineralization in the field is not practical.

2. Information transfer/outreach program:

The preliminary results from this study were incorporated into oral presentations held at nine meetings and conferences. The audience at these outreach events included growers, crop advisors and scientists. In addition, two posters were presented at the California Plant and Soil Conference.

In collaboration with farm advisors, summaries of the first-year results were also published online on their blogs.

3. Notable achievements:

Discussions at meetings with stakeholder showed that interest in the project is strong. The data generated from this report will be a very valuable component of nutrient management decision support tools for growers and crop advisers. We successfully applied for a University of California Agricultural and Natural Resources (UC ANR) grant which will allow us to investigate the effects of crop residues on N mineralization and to improve the models.