

Seasonal Soil Nitrogen Mineralization within an Integrated Crop and Livestock System

Larry Cihacek¹, Douglas Landblom², Songul Senturku^{2,3}, and Eric Brevik⁴

¹Associate Professor of Soil Science, NDSU School of Natural Resource Sciences, Fargo, ND

²Animal Scientist, NDSU Dickinson Research and Extension Center, Dickinson, ND

³Animal Scientist, Animal Science Department, Canakkale Onsekiz Mart Universitesi, Canakkale, Turkey

⁴Soil Scientist, Department of Natural Sciences, Dickinson State University, Dickinson, ND

Sustainable crop and livestock production systems depend on maintaining soil productivity and health through utilizing and enhancing natural soil processes. Sustainable systems also protect natural resources while maintaining or maximizing crop yield potential. Since a system's sustainability and productivity involves maintaining the soil organic matter and the processes that promote nutrient cycling, research at the North Dakota State University Dickinson Research Extension Center (DREC) is evaluating seasonal soil nitrogen (N) fertility while minimizing fertilizer inputs in an integrated crop and livestock system. The availability of soil N is the greatest limitation in most crop production systems. An integrated system attempts to sustain N availability through crop rotation, cover crops and utilization of livestock grazing and natural manure spreading by livestock while limiting expensive external inputs as fertilizer. The objective of this study is to evaluate soil N cycling related to individual cropping components in and integrated crop and livestock system.

Materials and Methods

The study site is at the DREC Ranch near Manning, ND on a complex of Savage (fine, smectitic, frigid vertic Argiudolls), Daglum (fine, smectitic, frigid vertic Natrustolls), Vebar (coarse-loamy, mixed, superactive, frigid typic Haplustolls), and Parshall (coarse-loamy, mixed, superactive, frigid pachic Haplustolls) soils.

A diverse 5-year crop rotation is being utilized to provide both cash crops as well as summer grazing for livestock. The rotation includes: i) sunflower (SF); ii) hard red spring wheat (HRSW); iii) fall seeded winter triticale-hairy vetch (THV), spring harvested for hay/spring seeded 7-species cover crop (CC); iv) corn (C) (85-90 day var.); and, v) field pea-barley intercrop (PBY). The HRSW and SF are harvested as cash crops and the PBY, C, and CC are harvested by grazing cattle. The THV is hayed and fed to the livestock. No supplemental fertilizer N is being applied. All cropping treatments are replicated three times in a randomized complete block

arrangement with the blocks arranged by soil type. All of the crops are managed as no-till crops. Triplicate plots in nearby undisturbed grassland pastures with similar soils are also being monitored as a control in this study. The vegetative cover in the pasture is dominated by western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), and Switchgrass (*Panicum virgatum* L.).

During the 2014 growing season, soil N was monitored by collecting multiple soil samples in each treatment plot to a depth of 2 feet (24 inches) as recommended by the NDSU Soil Testing Laboratory and NDSU Extension Service. Samples were collected eight times on a regular schedule between late May and mid-October except where weather (extreme soil wetness) interfered with sampling. In 2015, soil N was again monitored in the continuous hard red spring wheat plots (control plots) and the hard red spring wheat in the 5-year rotation. The samples were taken seven times on a regular schedule between late May and mid-October. Once the crops were established, three 8-inch aluminum rings were randomly driven into the ground to a depth of 2 feet in each plot to provide sampling areas where crop roots are excluded from N uptake. This was to establish an index of the total N mineralized without plant uptake. However, the N in the isolated areas was still subject to natural leaching, volatilization or immobilization processes in the N cycle. The soil samples were analyzed by the NDSU Soil Testing Laboratory for ammonium-N (NH₄-N) and nitrate-N (NO₃-N). A total of 8 sampling times were evaluated. Soil organic matter was also evaluated on the samples from the initial sampling date.

Results and Discussion

The average 2-year seasonal changes in continuous and rotation hard red spring wheat (HRSW) are shown for NO₃-N, and total mineral N (NH₄-N + NO₃-N) in Figures 1 through 4, respectively.

In continuous HRSW (Figure 1), average 2-year soil NO₃-N declines in the early part of the growing season as the crop takes up nitrogen. The grassland began the season with an availability of 12 kg NO₃-N/ha, then declined slightly, but remained relatively constant throughout the growing season. The average HRSW NO₃-N levels were 38 kg NO₃-N/ha at the beginning of the growing season but decreased to low of 20 kg NO₃-N/ha by mid-July. As the season progresses and the crop reaches maturity, soil N levels slightly increase to 34 kg NO₃-N/A after the crop ceases to grow and take up nutrients. The soil N increases in the exclusion area from 49 kg NO₃-N/ha in mid-July and reaches 111 kg NO₃-N/ha by the end of the season. Soil NO₃-N accumulates in the exclusion area because mineralizing N is not being utilized by the crop.

Where the HRSW is grown in a 5-year rotation (Figure 2), the average 2-year amount of soil NO₃-N is much higher in both the cropped areas as well as in the exclusion areas. Soil NO₃-N level was 73 kg NO₃-N/ha at the beginning of the growing season, declines to 44 kg NO₃-N/ha at mid season and increased to 109 kg NO₃-N/ha at the end of the season. In the exclusion areas, soil NO₃-N increased from 88 kg NO₃-N/ha in mid-July to 124 kg NO₃-N/ha at the end of the season. This can be attributed to the inclusion of legumes in the various cropping treatments that provide diverse soil N sources that can mineralize during the growing season. Here, available soil N again increases after the crop begins maturing and its N needs decrease.

Figure 3 shows the average plant available mineral N (NH₄-N + NO₃-N) across the growing season for continuous HRSW. In the native grassland, mineral N at the beginning of the sampling season was 46 kg N/ha, then increased to 84 kg N/ha during mid-season, and then declined to 74 kg N/ha at the end of the season. The increase in plant available soil N at mid-season is due to some of the native range plants becoming dormant or semi-dormant during the hottest and driest part of the growing season. Increased range plant growth during cooler and moister conditions in late season resulted in increased plant uptake of N. Plant available N in the HRSW at the beginning of the growing season was 107 kg N/A, then declined to a low of 70 kg N/A during mid-season and then increased to 102 kg N/A at the end of the season. The plant available mineral-N in the exclusion areas increased from 97 kg N/A in mid-July to 175 kg N/A at the end of the season. The higher N levels at the beginning of the growing season reflects the combined effects of winter and spring N mineralization as well as very modest levels

of supplemental fertilizer N applied prior to seeding of the HRSW.

Figure 4 shows the average plant available mineral N across the growing season for HRSW grown in a 5-year rotation. Soil N levels appear to have a similar trend to the continuously cropped spring wheat. However, the mineral-N levels are higher in the rotation containing legumes at various points in the rotation than in the continuous wheat. The plant available mineral N at the beginning of the season was 144 kg N/ha and declined to 53 kg N/ha by mid-season. By the end of the season, N levels increased to 117 kg N/ha. In the exclusion areas, plant available N increased from 129 kg N/ha in mid-July to 181 kg N/ha by the end of the season. Again in this case, the isolated soil has the highest mineral-N levels when compared to the cropped soil.

Figure 5 illustrates the relationship between soil organic matter (SOM) and average seasonal available mineral N. The relationship shows that each % increase in SOM is equivalent to 8.8 kg N/A. However, the relationship is relatively weak because due to the location and climate of soils in western North Dakota are highly variable but relatively stable regarding the soil biological environment.

Summary and Conclusions

The data shown in these figures illustrates the fact that significant amounts of N are available in the soil across the growing season. However, not all of the N is available to plants at a given point in time. Each sampling point is a point in time and the N values for that sampling date would be what the plant has available at the time of sampling. Plant growth stage influences root development and distribution so that plants cannot access soil N where roots are not growing. In addition, new roots do not grow in dry soil so that, again, plants cannot access N in dry soil. Plants also do not access N well in excessively wet soils because of a lack of soil oxygen affects root activity. Wet or dry weather (soil) changes the potential for microbial mineralization, immobilization, or N transformations in soil as well as N movement into or out of the rooting zone as soil moisture conditions change. All of these affect the availability of N to crops. Further research is necessary to better establish how the N availability changes from season to season in response to changing conditions over time.

Note: To convert kg/ha to lb/A, multiply kg/ha by 0.893.

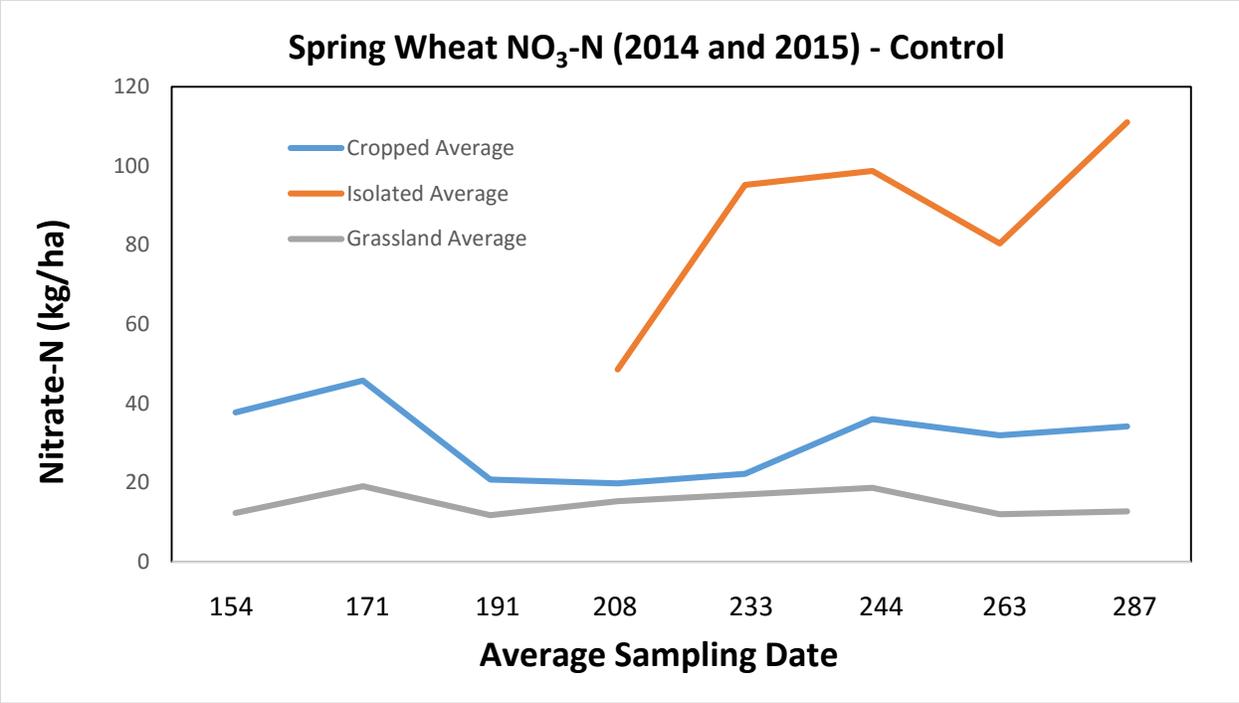


Figure 1. Average soil NO₃-N levels in continuous HRSW (2014-2015).

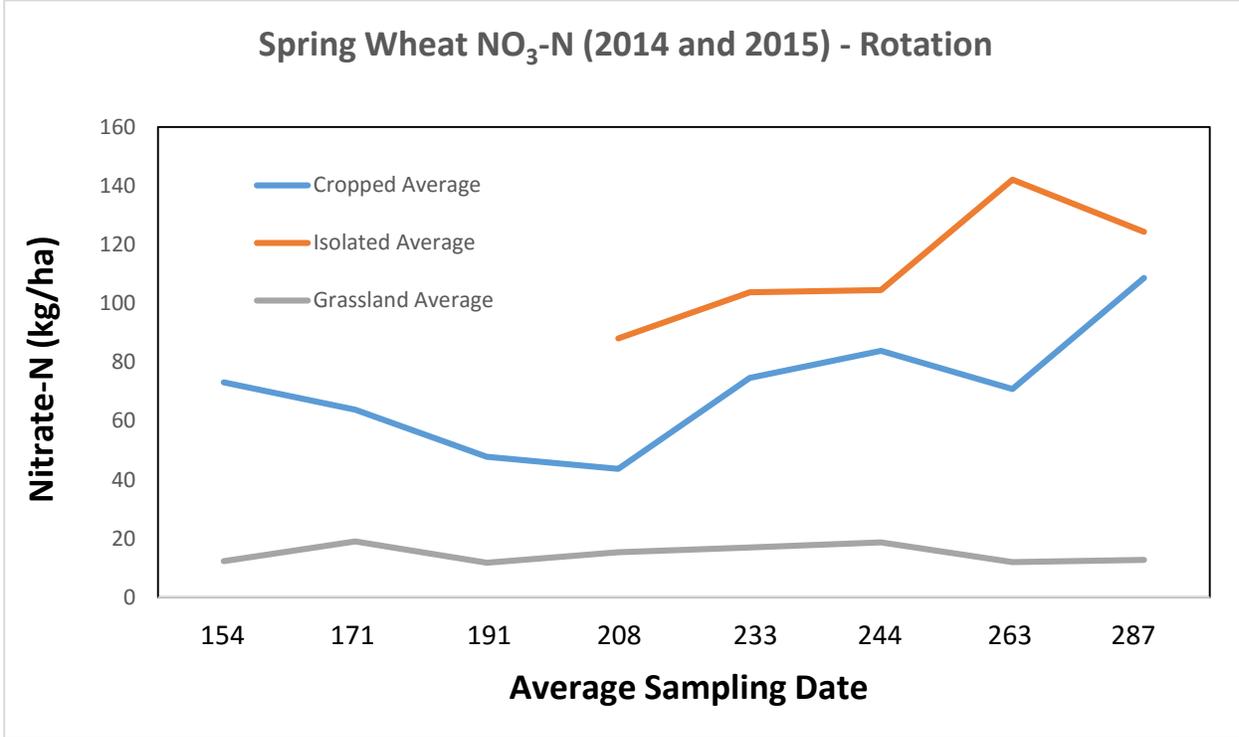


Figure 2. Average soil NO₃-N levels in HRSW in a 5-year rotation (2014-2015).

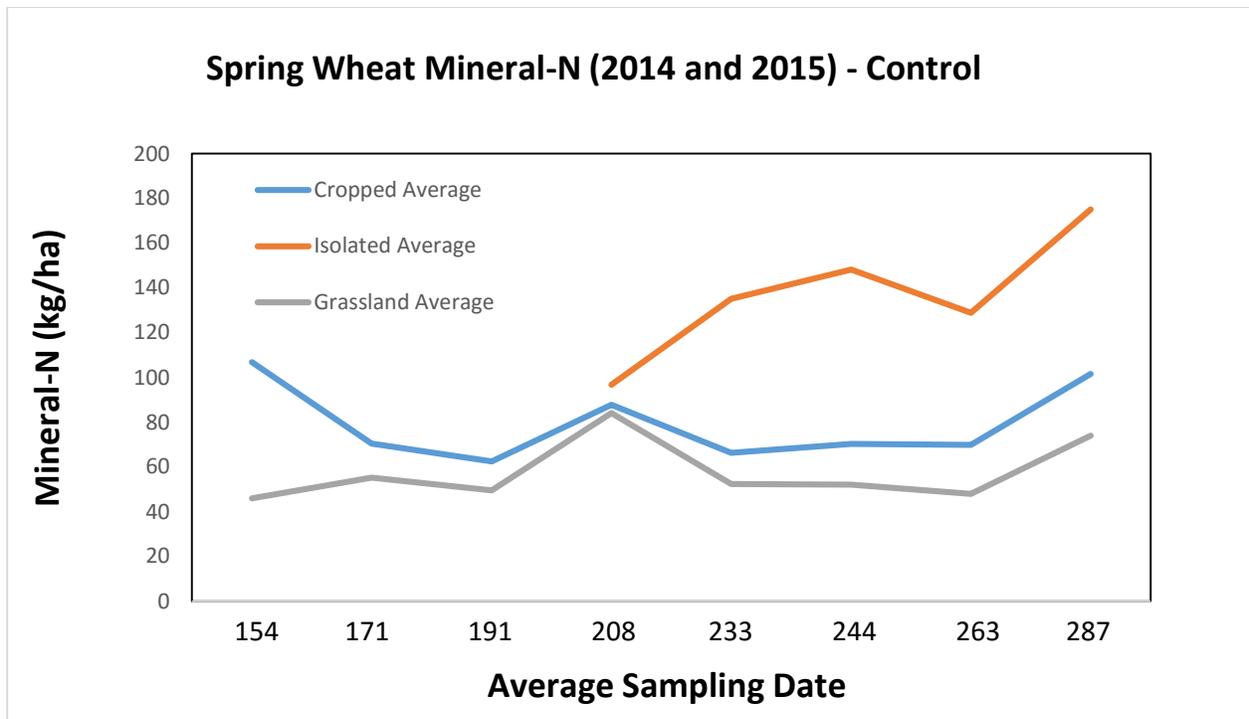


Figure 3. Average plant available soil mineral N ($\text{NH}_4\text{-H} + \text{NO}_3\text{-N}$) in continuous HRSW (2014-2015).

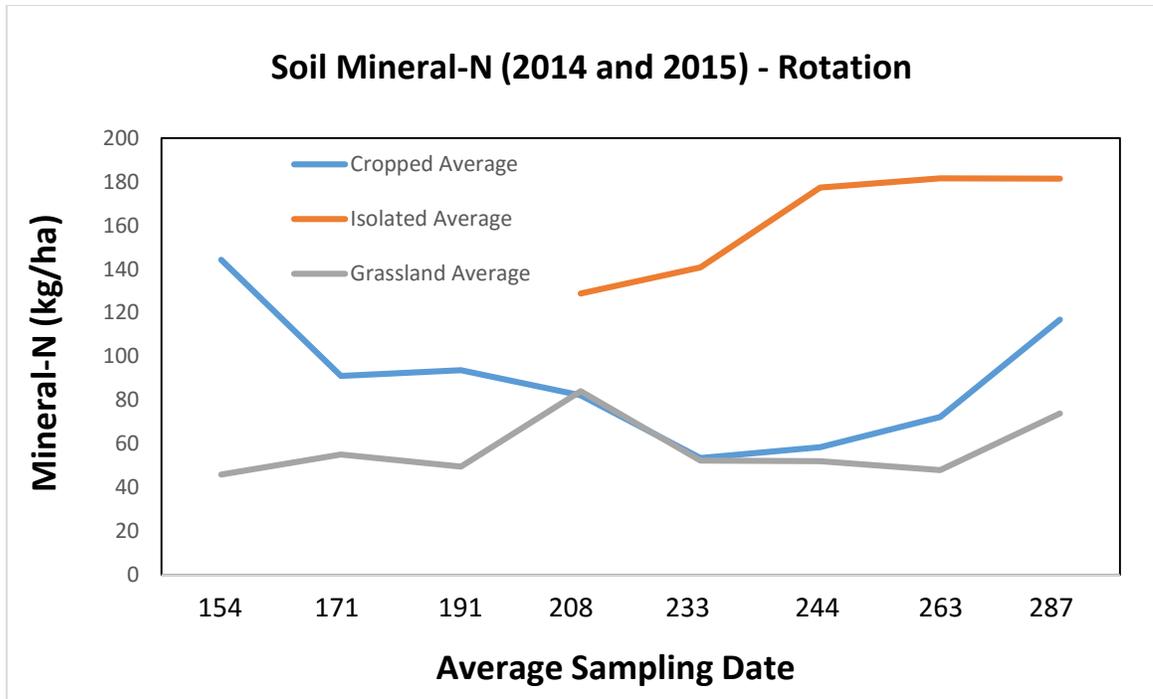


Figure 4. Average plant available soil mineral N ($\text{NH}_4\text{-H} + \text{NO}_3\text{-N}$) in HRSW in a 5-year rotation (2014-2015).

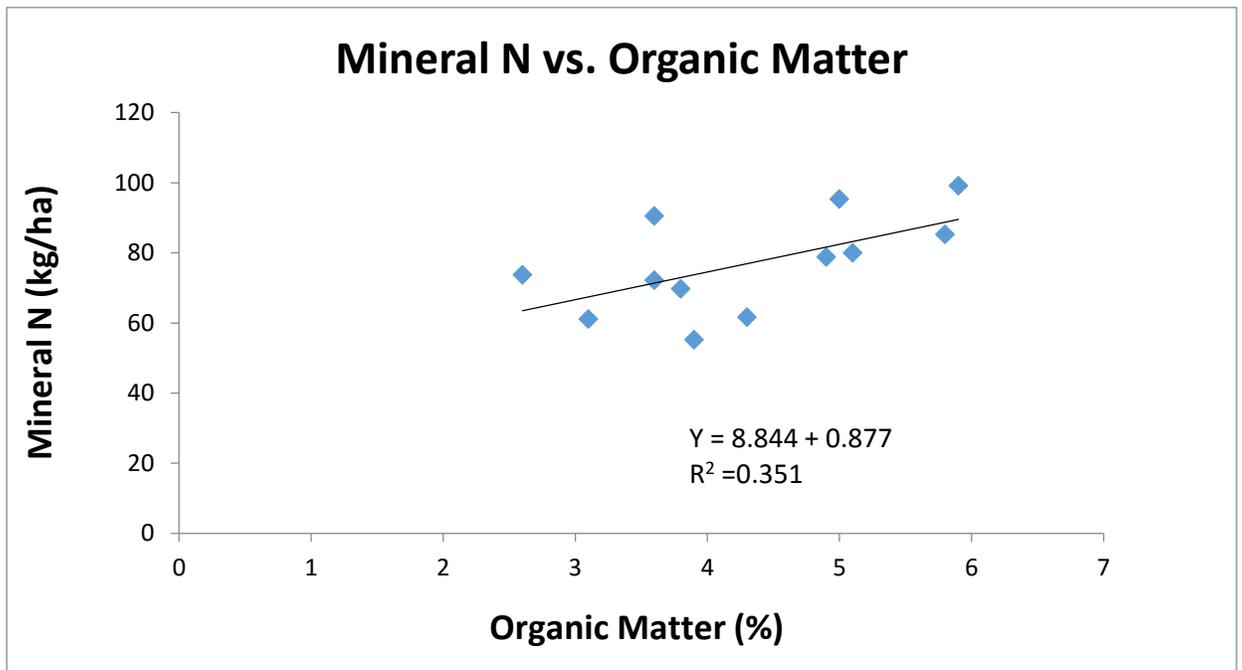


Figure 5. Relationship between SOM level and two-year average soil mineral N levels for the control and rotation HRSW cropping treatments.