# Site-Specific N Management for Direct-Seed Cropping Systems

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## Introduction

Cropping systems with inefficient N use are under increased scrutiny as N movement beyond agroecosystem boundaries results in degradation of air (Mosier et al., 1996) and water (Huggins et al., 2001) at watershed and global scales (Tilman et al., 2001) and as producers seek greater efficiencies in N use to reduce external farm inputs and costs. Tailoring N management to site-specific conditions could improve N use efficiency; however, successful implementation of site-specific N management has proven elusive as virtually every factor used to support N management decisions (i.e. crop yield, N availability, N uptake efficiency and losses) has substantial spatial and temporal variability (Pan et al., 1997). The large variation in within-field conditions suggests a large potential to significantly improve N use efficiency; however, characterization and prediction of crop performance and N-related processes is required if N management decisions are to be tailored to site-specific requirements.

## Objectives

Project objectives were to: (1) demonstrate and evaluate a suite of precision agricultural technologies that measure and predict site-specific variables required to make and improve N management decisions; (2) evaluate and improve site- and time-specific N management strategies on grower fields; (3) conduct economic and environmental cost/benefit analyses to evaluate conservation technologies and effectiveness of precision N management; (4) produce grower-oriented site- and time-specific N management monitoring, decision-aid and evaluation tools required to formulate N efficient and environmentally sound conservation strategies; and (5) disseminate outreach/extension materials and give presentations documenting the impact of precision N management in conservation systems. The following describes significant results, focusing on results over the past year.

## Results and Interpretation

### *Field Testing of Grain Quality Monitors, Yield Monitors and Variable Rate Application Equipment*

Precision agricultural technologies that may be required by growers to develop decision aids and to adopt precision N management include on-combine yield and protein monitors, variable rate application controllers, and geo-referencing (GPS) equipment. Both on-combine yield and protein sensors were mounted with GPS on a JD 6622 for the harvest of hard red spring wheat and winter wheat at the WSU Cook Agronomy Farm (CAF). Hand samples collected at 130 geo-referenced points were analyzed for grain yield and protein. Although interactions of slope affected yield monitor data (Figure 16.1), overall comparisons with hand samples showed comparable results (Figure 16.2).

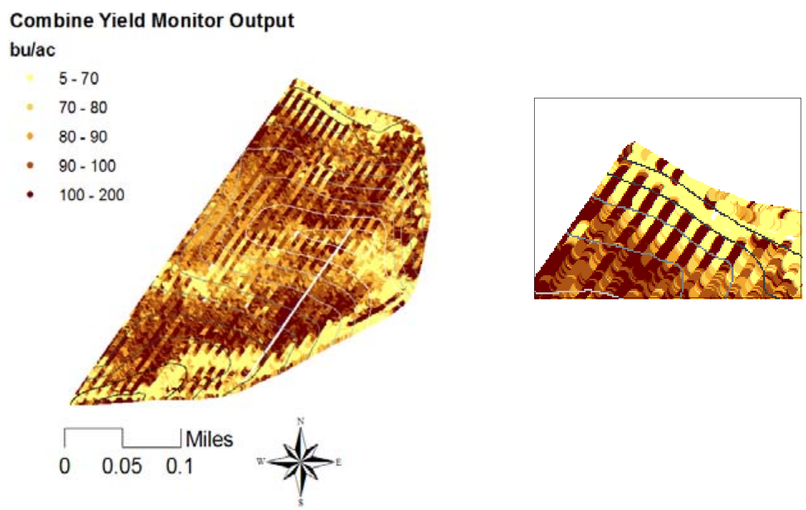


Figure 16.1. Yield monitor output for the Cook Agronomy Farm showing effects of slope (field striping).

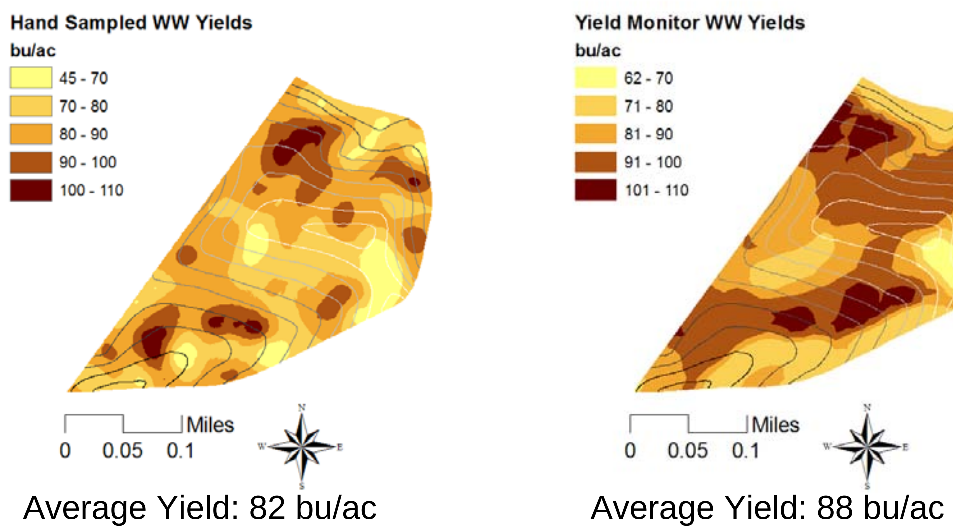


Figure 16.2. Comparison of hand samples versus yield monitor data for hard red winter wheat.

Analyses of on-combine grain protein monitoring using a Zeltex unit looked promising (Figure 16.3). Within-field grain protein patterns were similar between hand samples and monitor data. During the harvest of 2006, two additional grain protein monitors supplied by a different regional company were deployed on a demonstration basis to two area farms, one installed on a CNH combine on the John Aeschliman farm (Colfax, WA) and one on a JD combine on the Lee Druffel farm

(Colton, WA). On-combine sensing technology for grain quality (protein) is new technology. The main purpose of these efforts was to assess the technology under field conditions to determine if it would meet farmer expectations with the potential to purchase the technology if it operated satisfactorily.

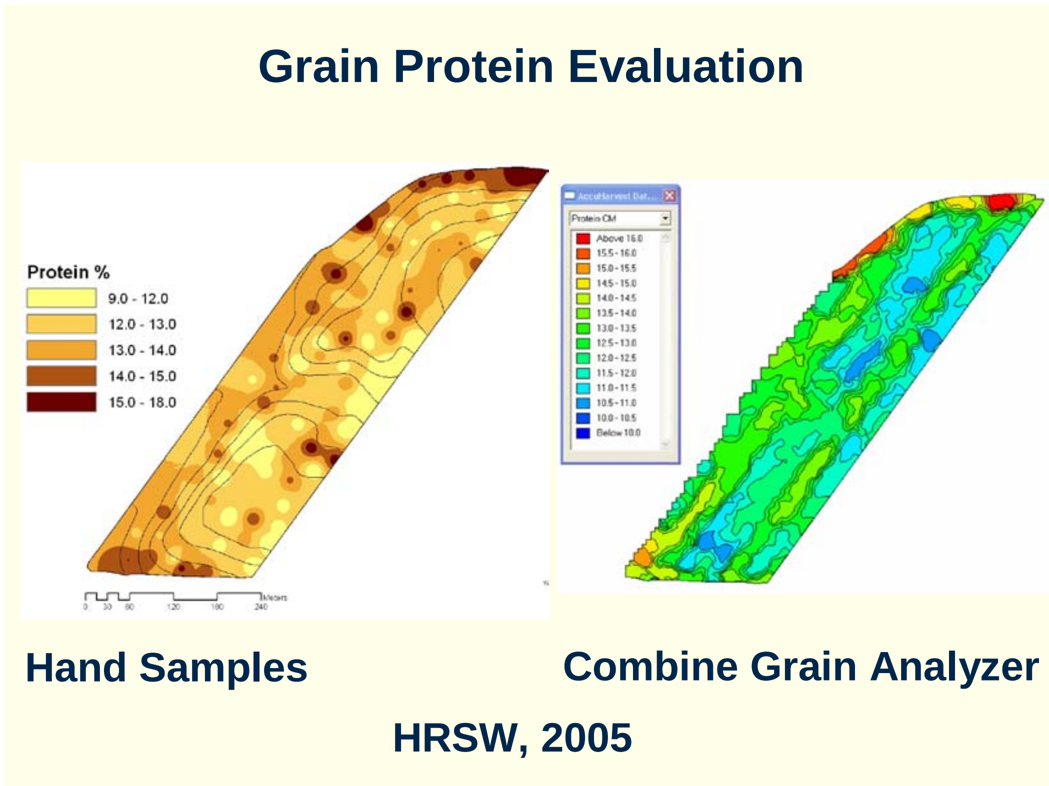


Figure 16.3. Comparison of hand samples and combine grain analyzer for grain protein of hard red spring wheat.

Problems with grain protein sensing technology identified were: (1) interference of non-crop biomass (weed and other green material) and foreign materials (dust) with sensor readings/output; (2) sensitivity of equipment to positioning within the combine to ensure self-cleaning; (3) lack of farmer based software to download and display data or to post-process data if needed. Our conclusion following the farm demonstrations and our own testing at the WSU CAF was that the technology was promising but was not field-ready and would need further testing and development to meet farmer needs.

Variable rate fertilizer application equipment was tested for its ability to achieve targeted N rates across the field (Figure 16.4). Dry fertilizer applications were made with a Midtech unit coupled with a Barber spreader while liquid applications were made with the same Midtech unit attached to a Great Plains direct-seed drill. The liquid system was able to achieve target N levels with more accuracy. These results indicate that although not perfect these technologies will likely prove to be useful for precision N management.


Figure 16.4. Target *versus* actual amounts of applied N for dry and liquid systems.

*Decision Rule Development*

Development of precision N management strategies requires managers to evaluate their grain yield and protein goals as well as N use efficiency (NUE) goals. Evaluation of yield, protein and NUE will result in definition of an N requirement as well as aid overall development of strategies to effectively vary N applications at different times and field locations during the course of cereal crop management. During the 2005, 2006 and 2007 season, variable rate and timing of N were tested and compared to uniform N applications at the CAF. The precision N management treatments were derived from historic relative yields for all crops grown from 1999 through 2004 (Figure 16.5).

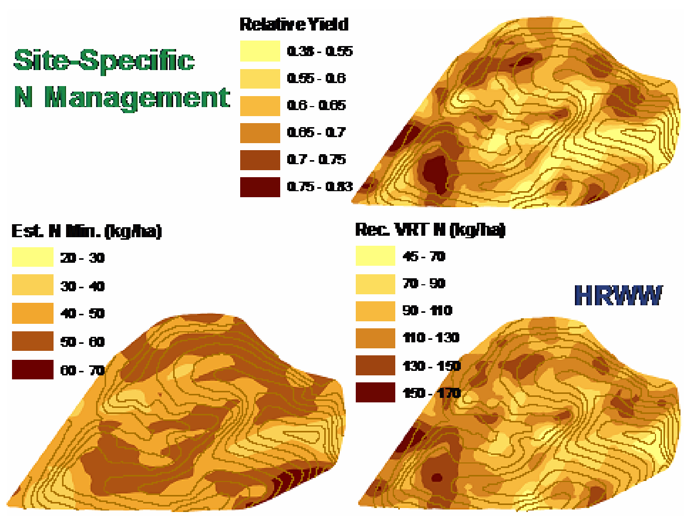


Figure 16.5. Relative yield, estimated N mineralization and recommended variable N fertilizer application for hard red winter wheat at the Cook Agronomy Farm.

Relative crop yields were used to define yield goals across the landscape in a process that can be applied generally to farms seeking to better manage N. Additional research is currently being conducted to evaluate the stability of yield goals across a given field over time. Once relative yields were defined, historic yields for a field were used to distribute the yield variability across the field. For example, given average field yields for hard red winter wheat of 85 bu/ac, the relative yield map can was used to distribute this overall historic yield across the field (Figure 16.6.) The average hard red winter wheat yield for the field was 85 bu/ac; however, the range in yield varied from 50 to over 100 bu/ac. The site-specific yield values then served as the yield goals for this location.

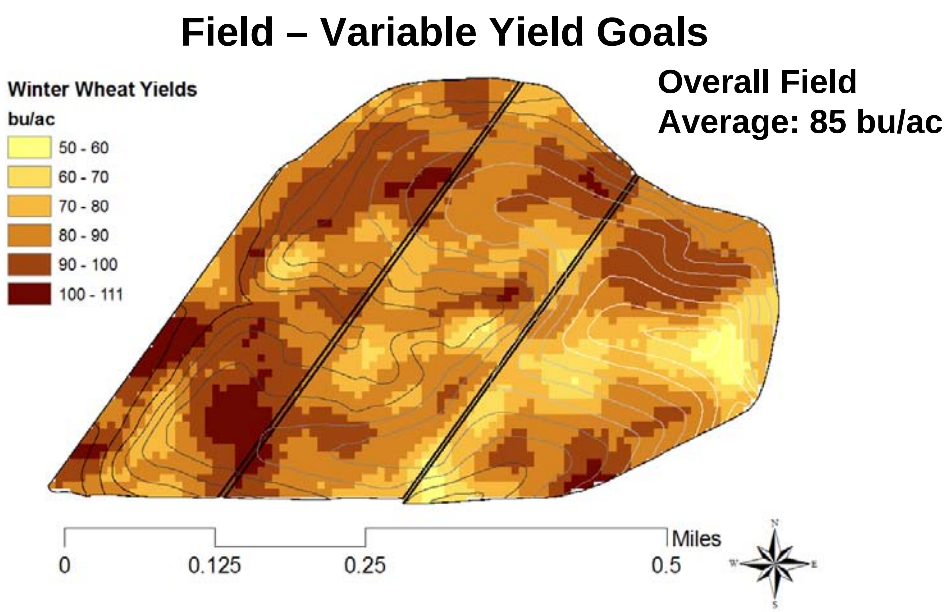


Figure 16.6. Field distributed yield goals for hard red winter wheat based on relative yield map and overall historic yield of 85 bu/ac.

Estimates of N mineralization were based on 369 geo-referenced soil samples analyzed for organic matter (Figure 16.5). This amount of detailed information is likely cost-prohibitive for individual producers; however, we are examining the use of relative yields to predict soil mineralization from soil organic matter.

Variable N fertilizer rates for hard red spring and winter wheat were based on yield and protein goals and the unit N requirement defined for each: 3.65 lbs N/bu for hard red spring wheat (HRS) and 3.0 lbs N/bu for hard red winter wheat (HRW). These rates were applied and compared to uniform N applications based on the overall yield goal for the field. In 2005, results for hard red winter wheat showed a distinct advantage for precision N management (Table 16.1). Similar yield and grain protein were achieved with 18% less applied N. This primarily occurred as N rates were adjusted downward following less than normal precipitation during the winter of 2005. Wheat yields, however, were fairly typical as above normal rainfall occurred in late spring and early summer. The N balance efficiency (Ng/Nf) is a measure of N removal in harvested grain divided by fertilizer N input. Values above 1 for Ng/Nf of precision-applied nitrogen (PAN) in 2005 indicate that soil and fertilizer sources of N were important for meeting crop requirements. Further research and discussion of the N balance index as well as other NUE components is reported the following chapter entitled "Yield, Protein and Nitrogen Use Efficiency of Spring Wheat: Evaluating Field-Scale Performance".

In 2006, winter precipitation was more normal and N rates were actually increased in high producing areas of the field to meet the expected demand. The range of N applied in the PAN treatment was 77 to over 300 lbs N/ac. Summer heat stress, however, limited yield and areas where high rates of N were applied for PAN did not respond to added N. Currently, we are considering an upper bound on N application rates may be more appropriate with soil derived N supplying more or less N to meet crop demands under variable spring and summer conditions. In 2007, hard red winter wheat performance was generally higher with the uniform application as compared to PAN strategies. Further analyses of these data are still pending. Hard red spring wheat has also been a challenge for PAN. Spring wheat yields are less stable from year-to-year than winter wheat yields and consequently, it is more difficult to predict yield goals. Results for 2005 and 2006 both show slight reductions in applied N while similar grain yield and protein levels were obtained (Table 16.2). In 2007, split and PAN treatments performed better than the spring applied N strategy.

Table 16.1. Hard Red Winter Wheat.

| Year | N Mgmt. | Yield bu/ac | Protein % | Applied N lb/ac | Ng/Nf |
|---|---|---|---|---|---|
| 2005 | Uniform | 92 | 12.2 | 141 | 0.72 |
| 2005 | PAN | 91 | 11.8 | 116 | 1.29 |
| 2006 | Uniform | 83 | 12.0 | 197 | 0.47 |
| 2006 | PAN | 81 | 12.2 | 212 | 0.47 |
| 2007 | Uniform | 92 | 12.6 | 170 | 0.63 |
| 2007 | PAN 1/3 | 90 | 10.6 | 188 | 0.47 |
| 2007 | PAN 2/3 | 85 | 10.1 | 171 | 0.47 |

Comparisons of uniformly applied N (primary fall application with spring topdress) or split between fall and spring with the precision applied N (PAN) that included a fall N application based on historic yields coupled with variable topdress-applied N in the spring dependent on an updated yield potential that considered winter precipitation. Ng equals the N exported in the harvested grain, Nf equals applied N, and Ng/Nf is a measure of N use efficiency. In 2007, PAN treatments consisted of split applications with either 1/3 or 2/3 of the total variable rate N applied in the fall.

Table 16.2. Hard Red Spring Wheat.

| Year | N Mgmt. | Yield bu/ac | Protein % | Applied N lb/ac | Ng/Nf |
|---|---|---|---|---|---|
| 2005 | Control | 53 | 10.4 | 0 | n.a. |
| 2005 | Spring | 62 | 12.7 | 137 | 0.53 |
| 2005 | Split | 62 | 12.6 | 136 | 0.52 |
| 2005 | PAN | 64 | 12.5 | 131 | 0.57 |
| 2006 | Control | 50 | 11.5 | 0 | n.a. |
| 2006 | Spring | 51 | 14.8 | 178 | 0.39 |
| 2006 | Split | 54 | 14.3 | 177 | 0.40 |
| 2006 | PAN | 51 | 13.5 | 159 | 0.41 |
| 2007 | Control | 53 | 11.4 | 17 | 3.3 |
| 2007 | Spring | 53 | 16.0 | 188 | 0.45 |
| 2007 | Split | 61 | 15.4 | 188 | 0.45 |
| 2007 | PAN | 60 | 15.3 | 188 | 0.45 |

Comparisons of control (0 applied N), all spring uniform and split fall (80 lbs N/ac)-spring applied N, and variable rate N (PAN) where 80 lbs N/ac were applied in the fall and N was applied according to variable yield goals in the spring during planting. Ng equals the N exported in the harvested grain, Nf equals applied N, and Ng/Nf is a measure of N use efficiency.

*Field Trials of Precision-N Management*

Field trials of precision N management were conducted at the Aeschlimen and Druffel farms in the Palouse region of Washington. At the Aeschlimen farm, N treatments consisted of low (19 gal urea/ac) uniform (32 gal urea/ac) and high (52 gal urea/ac) where comparisons between the uniform and either low or high N inputs were made at selected geo-referenced locations (Figure 16.7). High and low yielding areas were identified from farmer experience with this field. Hard red spring wheat grain yield and protein data were collected by taking hand samples (5 locations in each treatment where grain was collected from 4 rows, 2-m in length) for each paired comparison (low N versus Uniform N and High N versus Uniform N). In addition, a digital elevation model (DEM) was constructed using a GPS from which slope (degrees) was calculated and yield monitor data from the farmer's combine were collected for the field (Figure 16.7). Data from the Aeschlimen farm showed that lower N rates (40% lower) applied to poorer yielding field areas yielded 7 bu/ac more than the uniform application while grain protein was not affected (Figure 16.7). Over application of N in field areas with low yield potential likely results in greater growth and soil water consumption by wheat during vegetative stage leaving less water available for the reproductive stage when grain is filling. The yield monitor and slope data show that poor yielding areas were correctly identified as steep sloping areas that likely have shallower soil depths and less potential to store soil water (Figure 16.8). Higher N rates (63% higher) applied to field areas with greater yield potential increased yield by 5 bu/ac as compared to uniformly applied N while grain protein was unaffected. The high yielding areas were associated with relatively flat upland positions that likely have greater soil depth and water holding capacity. Overall, these results indicate that field attributes such as slope and soil type combined with farmer experience will likely be very useful as decision aids for precision N applications. In this case it appears that two different N rates would suffice: one rate for low yielding areas and one rate for high yielding areas. From an economic standpoint, reducing N rates while increasing yields as found on the low yielding field locations will definitely result in greater returns. Less clear is whether or not greater N inputs on higher yielding areas will be economically justifiable. This will be dependent on the price of wheat and N as well as the certainty of actually realizing a yield increase.

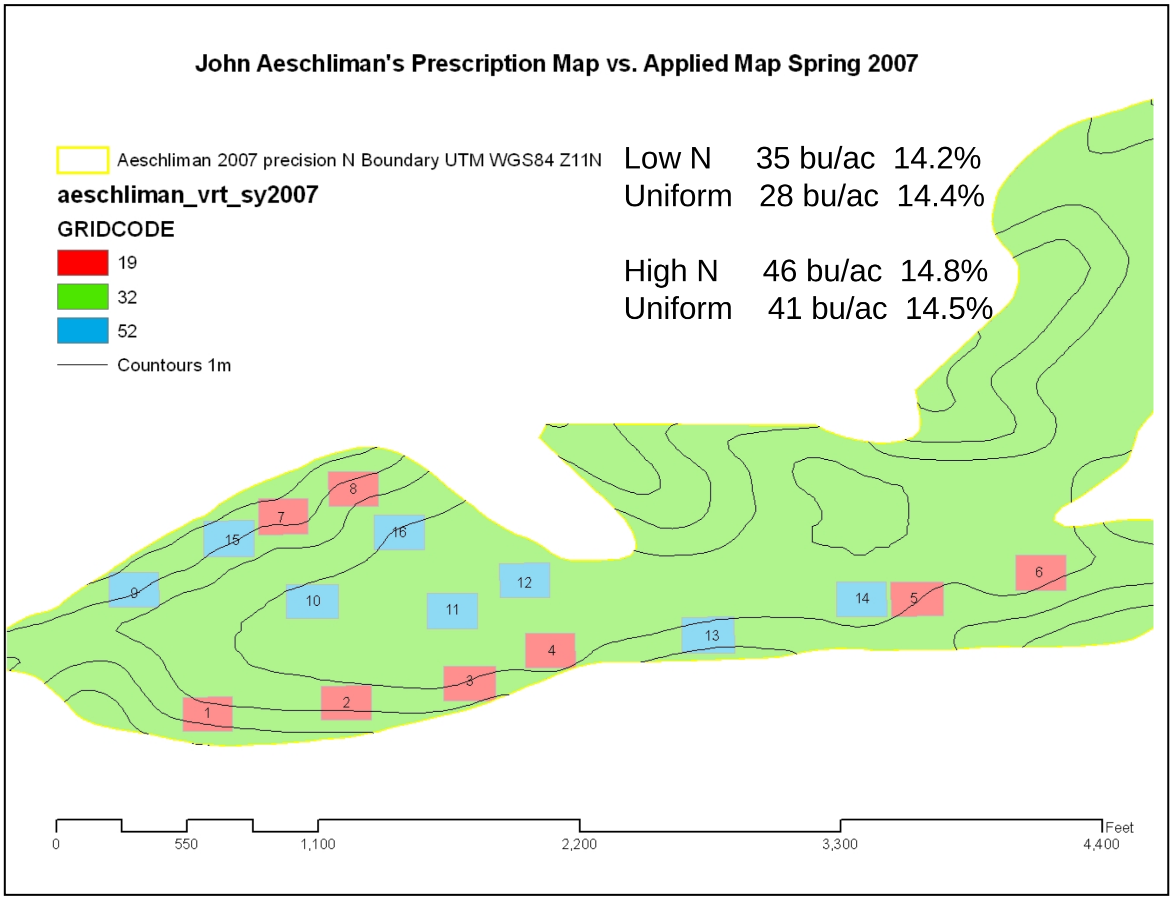


Figure 16.7. Field-plot layout at Aeschliman farm showing number and location of field plots where low and high applications of N (red colored plots: 19 gal urea/ac and blue colored plots: 52 gal urea/ac colored plots) were compared to uniformly applied N (green area of remaining field: 32 gal urea/ac). Average grain yield and protein measurements are shown in upper right for each of these comparisons.

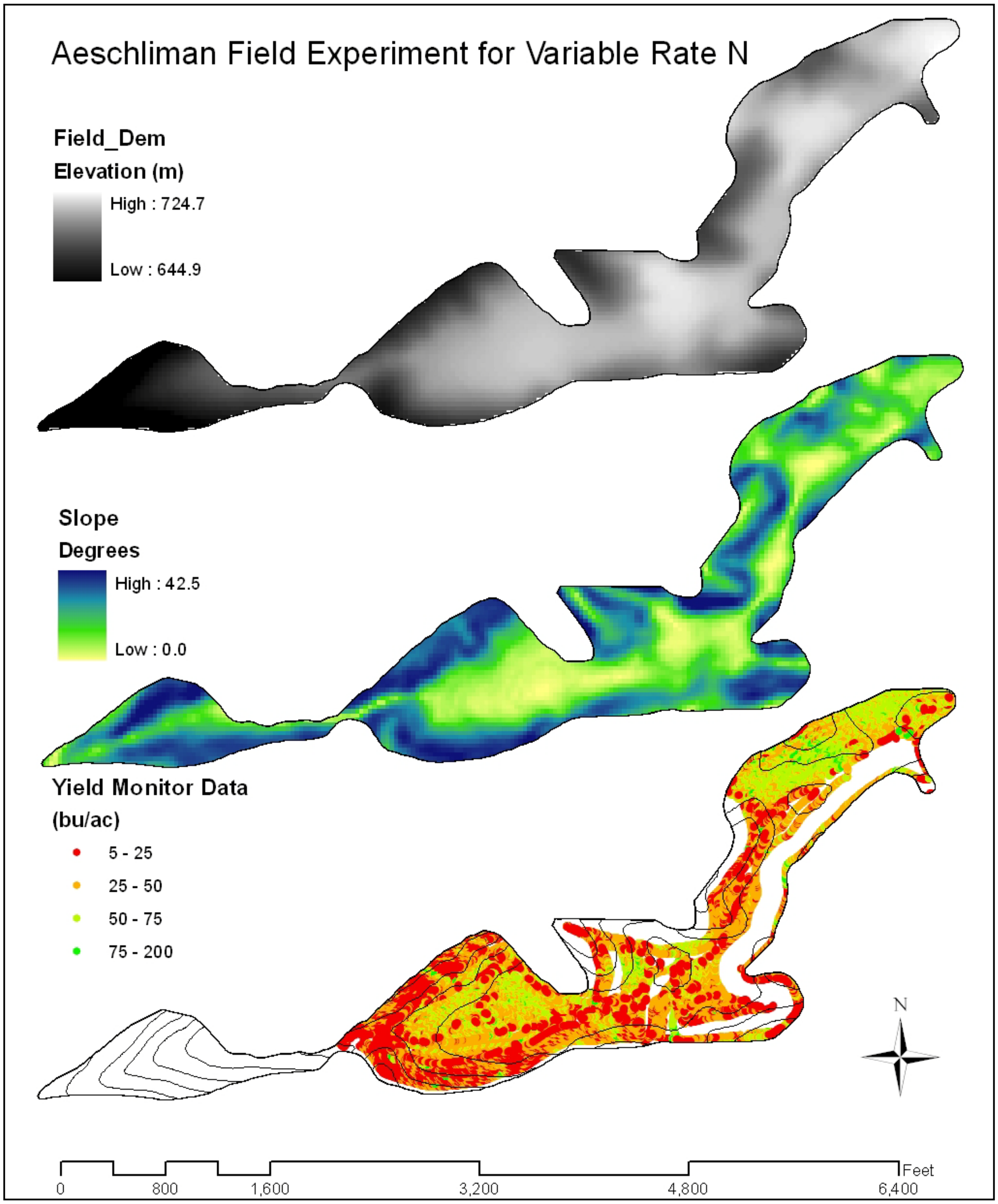


Figure 16.8. Field elevation, slope (degrees) and combine yield monitor data (hard red spring wheat) for Aeschliman farm.

The field experiment at the Druffel farm compared three levels of foliar N (URAN at 16, 25 and 33 lbs N/ac) applied to growing hard red spring wheat. The experiment was laid out as large blocks with each treatment randomized within four replications (Figure 16.9). Five hand samples consisting of 4 rows, each 2-m in length, were collected in each replication of each treatment. Average treatment yields of hard red spring wheat decreased from 71 to 64 bu/ac with increasing levels of applied N, while grain protein was not significantly affected by treatment and averaged 13.4% (Figure 16.9). These data indicate that variable applications of foliarly applied N may not be justifiable and may decrease yields.

| Foliar N rate (lb N/ac) | Yield (bu/ac) | Protein (%) |
|---|---|---|
| 16 | 71 | 13.4 |
| 25 | 68 | 13.1 |
| 33 | 64 | 13.6 |

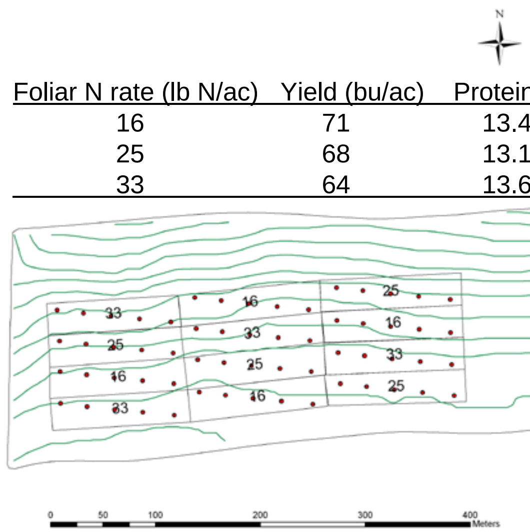


Figure 16.9. Experimental design, treatments and results of foliarly applied N at the Druffel farm.

*Outreach/Extension Materials and Presentations on Precision N Management in Conservation Systems*

Presentations on precision N management were given at the annual STEEP Conference, the PNW Direct Seed Conference, the InfoAg Conference, the Western Nutrient Management Conference, an Extension meeting in Pasco, the WSU CAF Field Day, the Umatilla County Soil and Water Conservation District's Sustainable Ag Seminar, Pendleton OR, and NRCS organized grower meetings in Clarkston, Dayton, Walla Walla and Connell, WA. The overall project results show considerable promise for precision N management; however, it is expected that decision aids will continue to develop as growers and researchers continue to gain experience over time. At the NRCS organized grower meetings, a presentation was given that outlined the overall strategy of precision farming and the results to date. This presentation represents state-of-the-art considerations for applying precision farming practices within the dryland cropping region of the Pacific Northwest and is included as a separate file in this report (NRCS.ppt).

In addition to the outreach presentations, field days, etc. Precision Nitrogen practices have been "codified" for recommendation as a strategy to reduce greenhouse gas emissions to the Washington legislature as a piece of the agricultural section of the State's Climate Advisory Team Report (2007) and additional evaluation of specific policy recommendations for supporting Precision Nitrogen management technology were developed for the 2008 Recommendations.

During presentations and interactions with growers, agencies, agribusiness and other professionals, it is apparent that considerable interest exists across multiple parties to apply science-based precision N strategies to fields in the Pacific Northwest. Given this interest, we think there is a tremendous future leadership role that NRCS can provide to help coordinate and guide the development of sound precision farming practices. Potential next steps include continued development of decision-support aids, documentation of grower experiences and organized meetings among interested groups to discuss results. During this process, it will be useful to survey producers to determine the extent and characteristics of adoption of Precision Nitrogen management technology over the next 3 years.

## The Potential for Transferability and Conclusions

The potential for Precision Nitrogen as well as other precision management technologies to be widely used by producers is high and continues to increase as the cost of nitrogen fertilizers and other external farm inputs increase. During the course of the project, there was a tremendous increase in interest about precision farming technologies and in individual farmer investments in precision agricultural technologies. Subsequently, they have reported significant savings in agrichemical applications (including nitrogen) primarily due to reduced overlap of chemical applications that is now possible using spatially explicit technologies. Continued refinement and extension of decision-support aids will improve the results that producers achieve with the hardware investments they are now making.

## References

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