Site-Specific Nutrient Management

For Nutrient Management Planning To Improve Crop Production, Environmental Quality, and Economic Return

Presentation Script: Economics and Environment - Chapter 10

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Economics and Environment

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This module will cover important economic aspects of nutrient management and environmental issues in agronomic systems. These principles are general and apply for most regions of the U.S., however, viewers are encouraged to review locally developed information to understand and adopt the best nutrient management practices for profitable and environmentally safe crop production.

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The objective of nutrient management is to apply the proper nutrients at the correct rates, and place them appropriately and at the right time to best supply crop needs for profitable production. Properly managed nutrients can also help protect the environment. Nitrogen, phosphorus, and potassium are typically the largest fertilization expenses in crop production. The application of these nutrients is critical because it can significantly improve crop yield in many crop rotations. However, unneeded application or poor efficiency results in increased production cost and lost economic return. In addition, nitrogen and phosphorus management has environmental importance since their losses from agricultural systems have been identified as likely contributors to elevated surface or groundwater nitrate concentrations, impairment of freshwater bodies, and also hypoxia of coastal waters. Therefore, when choosing nitrogen and phosphorus application, rate, timing, source, and placement, producers need to carefully consider options to achieve the most profitable economic return while minimizing impacts on water quality.

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Proper nitrogen management for crop production involves the integration among adequate rate, source, timing, and placement. When managing nitrogen, interactions among these four factors are perhaps more important than for any other nutrient. However, considering in-field management practices, rate often has the greatest influence on leaching losses of nitrate-nitrogen.

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Crop response to applied nitrogen varies among crops. Before deciding on a nitrogen rate to apply, it is very important from the management point of view to have an approximate idea of the shape of the yield-nitrogen fertilization response curve for each crop and specific conditions affecting response to applied nitrogen. This figure shows a typical nitrogen response curve for yield response in crops like corn and wheat. For corn, over applying nitrogen beyond the rate at which the maximum agronomic yield is reached (within a certain range) usually does not cause a yield decrease or quality issues. For small grain crops, like wheat, barley and others, however, over-application of nitrogen may cause yield decreases due to plant lodging and harvesting problems and in some cases too high grain nitrogen or poor grain quality for end uses. Not only is fertilizer rate important, but also consideration of other nitrogen inputs that may result in too-high crop available nitrogen in the soil, such as carry-over nitrate, residual manure nitrogen, and previous legume crops.

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From an economical point of view, rather than applying nitrogen to produce maximum yield, producers should apply nitrogen rates that return the most profitable yield, where the yield gain from nitrogen application will more than pay for the invested nitrogen or where the rate maximizes return. Applying nitrogen at rates that produces maximum yield always causes lower net return, although the return loss can vary from small to large depending on crop/nutrient price ratios, crops, and the shape of the response curve for specific conditions. From an environmental point of view, applying nitrogen to produce maximum yield will result in greater nitrogen loss than application at the most profitable rate. Therefore, both economic and environmental perspectives need to be considered together when making nitrogen management decisions. Applying more nitrogen than needed by crops to assure maximum yield is not considered an acceptable management practice. With current nitrogen fertilizer costs, it is neither cheap production insurance nor environmentally benign to apply too-high rates. High nitrogen fertilizer costs, uncertainty about crop prices, and environmental effects should encourage growers to critically consider application rates.

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The figure shows how nitrate-nitrogen loss via tile lines increases rapidly as fertilizer nitrogen rate increases beyond the economic optimum nitrogen rate. This concept applies for all crops fertilized with nitrogen and most production scenarios, which highlights the importance of accurately determining the optimum nitrogen rate to maximize profitability and minimize environmental impacts within specific crops and production systems. In spite of much research, this is much easier to say than actually achieved in production fields due to the numerous and unpredictable factors that affect the optimum nitrogen rate and the crop response to applied nitrogen.

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Since nitrate-nitrogen in subsurface drainage increases with increasing nitrogen application rate, there is potential to affect nitrate-nitrogen losses through change in nitrogen rate. However, the level of change will be related to the rate comparison and starting rate. In addition, the success relative to water quality goals is not likely to be achieved solely through rate adjustment. Research shows that if no nitrogen is applied, nitrate-nitrogen will exceed the proposed Environmental Protection Agency nutrient criteria for total nitrogen in surface waters. There are also questions regarding costs associated with reducing nitrate losses, and how those costs are to be paid. If nitrogen application rates being used are above the economic optimum nitrogen rate, then producers can gain economically by reducing rates to those levels. They will achieve a net economic positive due to reduced nitrogen input and no associated loss in yield. However, if producers are already applying nitrogen at the economic optimum nitrogen rate, then reduction below those rates will impose an economic penalty through yield loss.

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Many corn producers in the U.S. Corn Belt apply nitrogen in the fall. Reduction in nitrate-nitrogen concentration in tile drainage water can be observed with use of a nitrification inhibitor or when moving from fall to spring application, considering the same application rate. Any additional fertilizer application in the fall to compensate for anticipated losses would further increase nitrate-nitrogen loss, and therefore moving from fall to spring in conjunction with a rate reduction would be an even larger benefit. Sidedressing nitrogen in corn can potentially increase nitrogen use efficiency and reduce losses. This can be done in different ways and with different sources of nitrogen; however, the concept of applying fertilizer after crop emergence is consistent. In small grain crops, nitrogen sufficiency during tiller initiation is very important because potential head number is determined by tillering success. However, the nitrogen requirement when stem elongation begins is only about one third of the total season uptake. Thus, split nitrogen applications often produce better results due to avoidance of potential nitrogen loss conditions such as volatilization, denitrification, and leaching. Research in general shows a reduction in nitrate-nitrogen concentration in tile drainage water when moving from fall to spring/split applied nitrogen fertilizer. In season nitrogen applications also allows the nitrogen rate to be adjusted through either soil sampling or crop canopy sensing.

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Research suggests there is little, if any, difference in nitrate-nitrogen leaching or crop yield when using different traditional sources of fertilizer or manure, provided similar plant available nitrogen application rates are used and management is appropriate for the source. Using slow or controlled release fertilizer sources may have an impact on improved crop efficiency and nitrate-nitrogen leaching, similar as with sidedressing nitrogen, but little water quality data is available to quantify this. Besides potential impact on nitrate-nitrogen leaching, some manure sources high in solids content may have a positive impact on soil organic carbon, soil structure, and surface runoff.

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Several in-field and edge-of-field practices can add significantly to reduction in nitrate-nitrogen loss from production fields. These practices will likely need to be utilized in addition to traditional in-field nitrogen management in order to meet nitrate-nitrogen reduction and water quality goals. Cover crops have the potential to reduce nitrate-nitrogen leaching in corn-soybean rotation by taking up water and nitrate-nitrogen during the time between corn and soybean maturity and planting the next crop. However, effect on nitrate-nitrogen leaching is greater in areas with potential for more fall and wintertime cover crop growth, and less in northern climates where the period for cover crop growth is more limited. Crop rotation changes can help in reducing nitrate-nitrogen losses by including perennial crops or crops that require minimal or no nitrogen fertilization. Even though this alternative does not seem possible at a large scale, it may be an option for specific areas where nitrogen contamination of water sources is severe. In extreme cases, land may need to be taken out of crop production, retired, or converted to permanent pastures in sensitive areas. The establishment of buffers at the edge of fields, wetlands, or bioreactors to treat tile-flow water could also be complementary strategies to help reduce nitrate-nitrogen loss to surface waters and help with Gulf hypoxia and local water quality concerns.

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Proper management of phosphorus applications is a key for optimizing yield, profitability, and water quality. In most regions, key phosphorus management issues for crops involve knowing the optimum soil-test phosphorus level, applying fertilizer to avoid deficiencies, and achieving the optimum soil-test level over time by using various strategies considering fertilization rates and the frequency of application. Therefore, in the vast majority of fields, the fertilizer phosphorus application rates being used are the rates that maintain desirable soil-test phosphorus values based on removal or empirical information. In practice then, the historical phosphorus application rates and current soil-test phosphorus level a farmer maintains is the most important and widespread issue for the economics of phosphorus management and water quality.

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The figure shows the general relationship between soil-test phosphorus level and crop yield. Soil test levels are generally distributed into interpretation categories referred to as very low, low, medium (or optimum), high, and very high (or excessive). The critical level or range separates soil-test values for which there is a high probability of large to moderate crop response to fertilization (very low and low) from values for which there are small and infrequent responses (high and very high). The critical level will vary with the test method, crop, soils, climate, and fertilizer/grain price ratio; and sometimes even with the philosophy of researchers that establish interpretations and recommendations. For example, the Bray-1 phosphorus level considered adequate for crops, and at which no fertilization is recommended, vary from about 12 to 30 ppm for forages or grain crops across the U.S.

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Because nutrient and crop prices influence the profitability of nutrient application and crop production, economic considerations together with producers' management and business philosophies further influence the optimum soil-test levels for crops. The optimal soil-test phosphorus level from an economic perspective will depend largely on the nutrient and fertilizer price ratios, producer management, and other enterprise decisions. This figure shows how different crop/fertilizer price ratios influence the corn and soybean response to phosphorus fertilization, and how prices may influence the optimum soil test level to maintain.

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Phosphorus is lost from fields as dissolved forms in surface runoff or subsurface drainage and as phosphorus bound to soil particles. Therefore, soil and water conservation practices are as important, and often more important, than phosphorus management practices concerning phosphorus loss from fields. This is the reason that in most states phosphorus risk assessment tools or phosphorus indices have been developed that consider all these factors to classify fields or field areas according to risk of phosphorus loss. The phosphorus index or related risk assessment tools are being required as part of the nutrient management planning process by federal or state agencies when manure is applied or when any phosphorus source is applied within watersheds with impaired water quality. Different types of phosphorus indices have been developed regionally or by states. P-Indicies are a practical quantitative tool that provides reasonable estimates of phosphorus loss risk while they can be used by advanced farmers, crop consultants, and nutrient management planners. They use an integrated approach to consider soil and landscape features as well as soil conservation and phosphorus management practices in individual fields or different areas within fields. Phosphorus source factors include soil test phosphorus, total soil phosphorus, and the rate, method, and timing of phosphorus application using commercial fertilizer, manure, and other organic sources. Phosphorus transport factors include precipitation, erosion and sediment delivery, surface runoff, distance from the field to the nearest stream, a variety of soil conservation practices, and subsurface drainage.

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Interpretation of soil-test phosphorus values for water quality issues must be different than for crop production. There is general agreement that soil-test levels higher than adequate for crops may significantly increase the risk of phosphorus loss and water quality impairment. The concept of soil-test calibration used for crop production also applies to interpretations for risk of water quality impairment. In general, the increasing risk of phosphorus loss becomes consistent for soil-test values higher than about 30 to 50 ppm (Bray-1 or Mehlich-3 tests, 6 to 8 inch sampling depth), which higher than optimum levels for most crops. Therefore, the economics of crop production and environmental concerns should discourage management strategies that increase soil-test phosphorus to levels much higher than optimum levels for crops.

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In general, the phosphorus application timing does not have a significant effect on crop yield where the soil properties do not result in extensive conversion of applied phosphorus to crop unavailable forms. This means that in most soils of the U.S., phosphorus application can be made at varying times before planting of crops. However, the time of phosphorus application during the year and also the time between the application and a runoff event can significantly influence phosphorus loss with surface runoff. Therefore, the risk of phosphorus runoff can be substantially reduced by applying phosphorus when runoff events are unlikely for one to three weeks after phosphorus application. The probability of runoff phosphorus loss in the Midwest is typically greatest in late winter and spring due to increased frequency and intensity of rainfall for already wet soils, and in northern areas also due to snowmelt runoff events.

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Research has shown reduced runoff phosphorus losses with manure compared to fertilizer, especially with runoff events soon after application. Manure phosphorus typically is less soluble in water than fertilizer phosphorus due to organic phosphorus fractions, and that results in less dissolved phosphorus in runoff occurring immediately after surface application. Also, some manure types can result in reduced erosion and surface runoff due to increased water infiltration when manure contains considerable bedding.

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Research has shown little to no differential response to phosphorus placement methods for most crops in soils with low phosphorus-fixing capacity and where initial soil-test phosphorus levels are not very deficient. In severe phosphorus-deficient conditions, high clay soils, and high fixing soils such as those with high content of aluminum and iron oxides or reactive calcium carbonate, phosphorus banding is generally recommended over broadcast application to increase plant availability of applied phosphorus and to obtain higher phosphorus use efficiency and economic return. From a water quality perspective, however, phosphorus banding or injection always reduces particulate or dissolved phosphorus loss with erosion or surface runoff compared to surface application unless the operation increases soil erosion significantly. This is because surface application of phosphorus increases soil phosphorus levels at the soil surface (in the soil-runoff water mixing zone). Runoff phosphorus loss may or may not be reduced with incorporation of manure or fertilizer with tillage because of usually increased soil erosion rates. Precipitation, slope, infiltration rate, surface residue cover, application rate, distance to stream, and many other factors influence the benefit of incorporating phosphorus with tillage at reducing phosphorus loss with runoff. Dissolved phosphorus in runoff is generally higher with surface application if a runoff event occurs shortly after application. The risk decreases with time after application before a runoff event occurs, and can decrease further when rainfall that do not cause runoff occurs before a runoff event.

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Dense within-field soil sampling has shown very large spatial variability of soil test phosphorus. Precision agriculture technologies available to producers or custom applicators facilitate application of fertilizer and manure at rates adequate for different parts of a field. Research has shown that grid or zone soil sampling methods combined with variable rate application based on soil-test phosphorus may not increase crop yield compared with traditional methods but always reduces spatial variability by minimizing phosphorus application to high-testing areas within fields. Variable rate application of fertilizer phosphorus is common, and some custom applicators are beginning to apply manure using variable-rate technology. Therefore, dense soil sampling and this technology can be implemented to address environmental as well as economic concerns.

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Tillage practices generally have an impact on soil erosion, which is the primary source of phosphorus delivery to surface waters with sloping ground. Although the results of phosphorus loss with different tillage systems is site specific, research suggests less phosphorus loss generally occurs with minimum tillage than conventional tillage systems. Systems such as no-till, for example, decrease significantly the particulate phosphorus loss but usually increase the proportion of dissolved phosphorus.

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Cover crops can reduce phosphorus loss mainly by reducing soil erosion, and the effect of phosphorus uptake varies widely with the amount of growth allowed and the cover species. Cover crops can increase soil stability from root growth in addition to providing a physical barrier between rainfall and the soil surface. Cover crops can be seeded in the fall using a variety of methods including drilling or broadcasting the seed after crop harvest, or aerially broadcasting the seed before harvest. In northern regions the efficacy of cover crops is diminished because there is no winter growth, and growth in the fall and early spring (before optimum crop planting dates) is limited. Research suggests that when using a cereal rye cover before corn, the cover should be terminated about 2 weeks before corn planting in order to limit negative impact on corn growth and yield. On the other hand, there is no effect on soybean yield, so rye growth can continue longer in the spring and potentially provide more benefit in reducing erosion and phosphorus loss during a period with high rainfall intensity.

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Terraces and ponds are well known practices that result in significant reduction of soil and phosphorus loss from fields, although their efficacy is highly dependent on the landscape and maintenance. Contour cropping and strip cropping that alternate summer and winter grain crops or grain crops with hay can significantly reduce soil erosion, surface runoff, and mainly particulate phosphorus loss. Buffers come in many sizes and shapes, and may involve diverse plant species. Buffers reduce sediment transport from fields and stabilize stream banks, and physically remove particulate phosphorus from runoff water. The impact on dissolved phosphorus loss usually is minor, and is more effective when phosphorus flows through the soil and buffer rooting depth. The performance of installed wetlands is very dependent on the wetland-to-watershed ratio (how large the wetland is compared to the watershed). The larger the wetland-to-watershed ratio, the greater will be the percentage of phosphorus removal.

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Adequate nutrient management permits efficient and economical crop production while reducing potential for water quality degradation. A nutrient management plan is a site-specific decision process that integrates appropriate rate, source, timing, and placement. This permits efficient nutrient use by crops and helps reduce nutrient losses to the environment. The issues associated with development and implementation of nutrient management plans are many and complex. Some amount of nutrient loss will occur even when the best nutrient management practices are employed, but these losses should be lower than would occur without nutrient management.

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For nitrogen management, of greatest importance is for crop producers to carefully consider the rate of application, and apply rates that provide maximum return to the nitrogen investment. Applying economic optimal rates maximizes return and reduces nitrogen effects on water quality. Because nitrogen of most environmental concern is nitrate, other management practices need to focus on improving crop nitrogen use, that is high yield production, and limiting nitrate accumulation or keeping nitrate in the soil system. These practices, such as overall optimal crop production practices, time of application, nitrification inhibitors, slow-release products, cover crops, and in-season tools such as soil nitrate testing and crop sensing, will help with improving use efficiency and lower chance of nitrogen loss. Phosphorus management is somewhat simpler than for nitrogen in humid regions, due to differences in the type of chemical transformations, no gaseous phase or volatilization risk, and less influence of environmental factors on processes that control crop-available forms and losses. The goal of sound phosphorus management in most regions of the U.S. should be to keep the soil-test phosphorus level at optimal ranges for maximum economic crop yield, and utilize application methods and timing that optimize phosphorus use efficiency and economic profitability, while minimizing the risk of excess phosphorus loss from fields that can impair water resources. Due to the strong dependence of phosphorus loss on soil and water runoff from fields, crop, soil, and phosphorus management systems should employ practices that minimize soil erosion and surface runoff, and cannot simply address soil-test phosphorus or phosphorus application rate and method. Use of the phosphorus index, or similar phosphorus risk assessment tools that estimates in a comprehensive way risk of phosphorus loss is the best way by which producers can evaluate how economically optimum phosphorus management practices interact with soil conservation practices so that they can minimize water quality impairment.