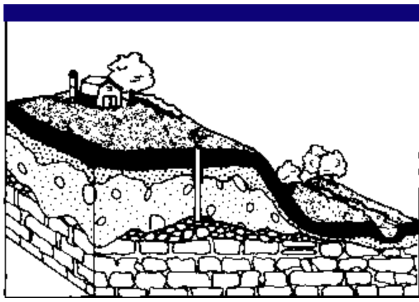

Soil Facts

An Overview of Nutrient Management with Economic Considerations

Nutrient management is the careful monitoring and amending of soil fertility to meet crops' needs with emphasis on maintaining productivity and profitability and protecting water quality. It is the most efficient nitrogen BMP since reductions occur at the source, prior to entering the environment. Unlike other BMPs, it is universal since it can be used in every field regardless of landscape and can focus on any nutrient, not just N. This publication provides an overview of nutrient management focusing primarily on N and evaluates nutrient management from an economic perspective.

Introduction

Most agricultural crops use nitrogen (N) inefficiently when it is applied as fertilizer and, on the average, take up only half of what is applied (Osmond, *et al*., 2000). As a result, carryover or residual N remains in the soil at the end of growing season. If nothing is done to change this situation, the excess nitrogen ultimately enters rivers and estuaries. Indeed, N loss from agricultural fields is blamed for increasing nitrogen levels in surface waters (NCDWQ, 1996) and for causing algal blooms, especially in estuarine systems (Paerl, 1983; Rudek, *et al*., 1991).

Currently, agriculture in North Carolina is facing rules and regulations in designated coastal river basins that address nutrient losses and require growers to implement best management practices (BMPs) to reduce N losses. The most efficient nitrogen-reducing BMP is nutrient management, the careful monitoring and amending of soil fertility to meet crops' needs, with emphasis on maintaining productivity and profitability and protecting water quality. Its biggest advantage is that reductions in nutrients occur at the source, before N or other nutrients enter the environment. Unlike other BMPs, it is universal, since it can be used in every field, regardless of landscape, and can focus on any nutrient, not just N. This publication provides an overview of nutrient management, focusing primarily on N, and evaluates the strategy from an economic perspective.

An important part of protecting water quality in North Carolina deals with limiting the amount of N that reaches groundwater. Nitrate is the predominant form of residual nitrogen, and it is highly water-soluble, thus, highly mobile, especially in coarse-textured or sandy soils. Its ultimate fate in these soils depends largely upon rainfall. In eastern North Carolina, annual rainfall exceeds the evaporation and transpiration processes by 12 to 20 inches. This excess precipitation flows from agricultural fields through a combination of natural and artificial surface and subsurface drainage processes, depending on the landscape and soils (Evans, *et al*., 1991). In well-drained soils, which predominate in eastern North Carolina, much of the excess water percolates through the soil profile and enters shallow groundwater, carrying residual nitrate (Evans, *et al.*, 2000). Approximately 95 percent of the nitrogen movement from agricultural fields is downward to shallow

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groundwater (Jacobs and Gilliam, 1985). If untreated, the nitrate-enriched shallow groundwater will flow into riverine and estuarine systems through a series of ditches, canals, creeks, and streams, potentially causing algal blooms.

The BMPs that are effective in reducing N losses from fields are nutrient management (described briefly above), cereal cover crops in combination with conservation tillage, riparian buffers, controlled drainage, and filter strips (*see Table 1*) (Osmond, *et al*., 2000). Cereal cover crops (small grains) serve as "catch crops" and sequester or hold residual nitrate before excessive leaching and transport can occur. Riparian buffers and controlled drainage primarily decrease concentrations of nitrate in shallow groundwater through the promotion of denitrification, the conversion of nitrate within groundwater to gaseous N, which escapes to the atmosphere. Additionally, controlled drainage may reduce outflow (drainage that may contain N), and both controlled drainage and buffers can enhance uptake of N by crops and vegetation, respectively. Ultimately, the effectiveness of buffers and controlled drainage is dependent on site-specific characteristics, such as drainage, slope, soil, and stream channel depth as related to landscape, and thus is limited to specific conditions (Gilliam, *et al*., 1997).

Table 1. BMPs by region in the Neuse River Basin and their effectiveness in nitrate reduction.

	Region			
Design	Piedmont	Upper and Middle Coastal Plain	Lower Coastal Plain	N-reduction[e]
Trees 30 ft + Grass 20 ft[a]	X	X	X[d]	85%
Tree buffer ≥ 20 ft	X	X	X[d]	75%
Shrubs buffers ≥ 20 ft		X	X[d]	75%
Grass buffers ≥ 30 ft	X	X	X[d]	65%
Filter strips ≥ 20 ft[b]	X	X	X[d]	40%
Nutrient management	X	X	X	Variable
Cover crop	X	X	X	5-15%
Controlled drainage[c]		X	X	40%

[a] The forested area is next to the stream and the grass area is away from the stream.
[b] Only effective if the drainage area above the filter strip has greater than 1% but less than 10% slope. Filter strips have to be planted with permanent vegetation (grass, legumes, and/or other forbs).
[c] Only effective if slope in channel is less than 1% and water table can be kept within 36" of surface soil for 50% of field area.
[d] Buffers are effective in lower coastal plain but generally are opposed by growers and landowners.
[e] Reduction rates based on research and approval of the Neuse Basin Oversight Committee.
Source: Based on decisions by the Neuse River Basin Oversight Committee.

Basic Concepts of Nutrient Management. Nutrient management is based on fertilizing at crop needs without adding excessive nutrients. Two nutrients that can have large off-site impacts are N and phosphorus (P). Additionally, micronutrients such as zinc or copper, applied through animal waste utilization, can cause on-site concerns. Excessive soil levels of micronutrients can be toxic to plants and restrict the uptake and use of N, potentially impacting water quality.

Considering N as the priority nutrient in trying to protect water quality, the primary goal of nutrient management is to optimize N-use efficiency through selection of proper fertilizer rates and sources, correct fertilizer placement, and optimum timing of applications. Its proper implementation incorporates a balanced fertility plan for all 16 essential plant nutrients to ensure agronomic and economic responses are maintained while minimizing environmental impacts.

N rate. Nitrogen rates are based primarily on two measurements: realistic yield expectations (RYE) and specific nitrogen factors (NF). Realistic yield expectations estimate the potential soil productivity of specific sites and are defined as the expected average yield that can be produced on a field. Yield records, the average of the best three yields in a 5-year period, can be used to establish RYE. Alternatively, compilations of RYE estimates by soil scientists and agronomists are available for each soil series by crop (http://www.soil.ncsu.edu/nmp/). These estimates are based on the predominant soil type in the field, found by using county soil surveys published by the Natural Resources Conservation Service. Since soil loss influences productivity, RYE estimates must be adjusted by a slope and erosion factor, depending on the site.

Nitrogen factors are based on the efficiency of a specific crop in converting N into yield (*Table 2*). A crop's nitrogen use-efficiency is

Table 2. Nitrogen factors of various crops.

Crop	Nitrogen Factor lb/Unit of Yield
Corn (grain)	1.0 – 1.25 lb./bu.
Cotton	0.06 – 0.12 lb./lb. lint
Barley, Triticale	1.4 – 1.6 lb./bu.
Wheat	1.7 – 2.4 lb./bu.
Bermudagrass[ab]	40 – 50 lb./dry ton
Fescue[ab]	40 – 50 lb./dry ton

[a] Annual maintenance guidelines.
[b] If grazed, reduce factor by 50%.

affected by specific soil characteristics (drainage, available water-holding capacity, cation exchange capacity [CEC], and soil organic matter) that directly influence productivity and the fate of applied N. There are hundreds of soil series in N.C. with varying properties that require different management, so soils have been grouped into similar management categories, called Soil Management Groups (SMG), which are based on these soil characteristics. Although NFs may be assigned to each SMG as related to soil properties, these factors also depend on management practices that affect productivity and nutrient utilization. Because crop management influences N use-efficiency, flexibility is allowed in the final selection of an NF. Using corn as an example, the NF range is 1.0 to 1.25 pounds N per bushel of grain produced. A higher NF is advised on sandy soils where nutrient use-efficiency is low.

The total rate of N fertilizer to use is calculated by multiplying the RYE by the slope and erosion adjustment factor by the NF. For example, take corn grown on a Norfolk soil with a 0-2 percent slope, and an estimate of RYE at 115 bushels per acre. Soil productivity is not limited by soil erosion, so an erosion factor of 1.0 is used. Since this soil is reasonably productive with moderate N use-efficiency, an NF of 1.14 pounds N per bushel of grain is chosen, and the total N fertilization rate per acre is calculated as follows:

115 bushels per acre (RYE)
x 1.0 (Slope /Erosion Factor)
x 1.14 pounds N per bushel (NF)
= 131 pounds N per acre

Depending on the crop rotation, the total N rate may require a final adjustment if a legume such as soybeans precedes the crop to be fertilized.

Legumes with active nodules supply their own N through fixation of atmospheric N_2 gas and potentially leave N reserves in the soil that may be available for following crops. Hence, nutrient management guidelines recommend reductions in total N rates of 15 to 30 pounds per acre when crops follow soybeans (Zublena, *et al.*, 1990). More recent field studies, however, suggest that this allowance may overestimate actual N contributions to soil reserves from soybeans and possibly cause underfertilization (Israel and Burton, 1997). Residual N reserves are favored when plants have normal to excessive vegetative growth with compromised pod and seed development (yield). This may result from drought during pod set and development or from severe insect damage during the reproductive growth stage. Ultimately, residual N amounts that are available to crops following legumes depend on total N reserves and their release through mineralization (availability) in relation to crop demand. A conservative estimate using the lower end of the 15 to 30 pounds per acre range is advised unless strong evidence exists for greater contributions.

A simplified N rate calculation worksheet using a field with a Norfolk soil typical of the coastal plain is found in *Table 3*. In summary, the final N rate estimate requires:

- RYE data from actual yield records or an estimate selected from the RYE database based on the predominant soil series, with an adjustment for slope and erosion.
- Selection of an NF based on knowledge of soil productivity and management.
- N adjustments, if needed, from previous leguminous crops.

Potential confusion can exist between RYE rates and recommended N rates on soil test reports. Currently, the Agronomic Division of the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) does not use RYE to recommend N rates. The rates recommended on soil test reports are general rates based on N.C. research data compiled over many years. They are not derived from actual soil testing. Thus, choosing N fertilizer rates based on soil

Table 3. Example of an N worksheet used for successive crops in nutrient management planning.

FSA Tract	Field	Acres	Soil[a]	Slope	SMG	Crop	RYE[b]	N Factor	Total N Rate[c]	Reserve N	Adjust N Rate[d]
				%			bu or lb/acre	lb N/unit of yield	lb/acre	lb/acre	lb/acre
101	1	8.3	Norfolk	0-2	25	corn	115	1.14	131	0	NA
101	1	8.3	Norfolk	0-2	25	wheat	60	2.09	125	0	NA
101	1	8.3	Norfolk	0-2	25	soybeans	40	-		0	NA
101	1	8.3	Norfolk	0-2	25	tobacco	3,300	-	50-80	15	35-65

[a] Predomiant soil type in field.
[b] Adjustments for slope are made as follows: Multiplication factor used with RYE: 0-2% slope=1.0, 3-4% slope=0.98, 5-6% slope=0.96, 7-8% slope=0.94, 9-10% slope=0.92, 11-15% slope=0.89, 16-90% slope=0.87. If soils are mapped as eroded, factors are as follows: 0-2% slope=0.92, 3-4% slope=0.89, 5-6% slope=0.87, 7-8% slope=0.85, 9-10% slope=0.80, 11-15% slope=0.77, 16-90% slope=0.75.
[c] N rates for tobacco are based on soil texture and topsoil depth or depth to clay: 5” depth=50 lb. per acre, 10” depth=60 lb. per acre, 15” depth=70 lb. per acre, 20”+ depth=80 lb. per acre. Darker soils will require less N than light-colored, sandy soils.
[d] Adjusted N rate is calculated by subtracting the reserve N from the total N rate.
NA=not applicable

tests may not be accurate because the amount of residual soil N from a previous year is unpredictable and can change in humid climates such as in N.C.

Timing. The correct timing of nutrient applications should coincide with the anticipated demand by the crop to optimize nutrient use-efficiency. For many crops such as corn, small grains, and cotton, N demands are low during early plant development but rise dramatically as advanced development and reproductive stages occur. Correctly timed split N applications, with a small portion of the total N applied at planting and the remainder applied through side-dressing just before uptake increases, satisfy plant needs and also reduce potential losses (leaching on sandy soils or denitrification on poorly drained soils) that can occur if single applications are made at planting. Specific information on timing is found in Extension crop production guides.

Source, placement, and starter fertilizers. There are many sources of N, including commercial fertilizers and animal wastes. In selecting commercial fertilizers, nutrient content and price are primary considerations. It is important to distinguish the actual cost per ton of fertilizer materials (source) from the actual cost per pound or unit of specific nutrient in order to maximize economics. *Table 4* shows cost comparisons for the most commonly available fertilizers, which were compiled from a survey of three major fertilizer companies in the Neuse River Basin. In general, the cost per unit of nutrient is lowest with higher grades or analyses of fertilizers.

Another important point to consider is the inclusion of other nutrients in addition to the N, P, K that are known through the fertilizer analysis or grade. As an example, the fertilizer 21-0-0 (ammonium sulfate) contains 24 percent sulfur by weight but this fact is not indicated in its N-P-K analysis. Additional attention is needed to micronutrient sources. Some products contain negligible concentrations, too low for practical rates to provide agronomic benefits. Growers who want to make the most economical choice of sources should select the fertilizer analysis that most cheaply meets their nutrient needs, calculate the cost per unit of nutrient, and estimate total costs of the fertilizer programs on a per-acre basis.

Table 4. Comparative costs of nutrients from commonly available fertilizer sources.[a]

Fertilizer Source	Bulk Cost Price/ton	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_2O)
		Cost/lb of nutrient[b]		
34-0-0	$270	$0.40	NA[c]	NA
30-0-0	$166	$0.28	NA	NA
25-0-0-3	$144	$0.29	NA	NA
21-0-0	$188	$0.45	NA	NA
0-46-0	$224	NA	$0.24	NA
0-0-60	$159	NA	NA	$0.13
0-0-22	$210	NA	NA	$0.48
18-46-0	$210	$0.58	$0.23	NA
17-17-0	$172	$0.51	$0.51	NA
10-34-0	$240	$1.20	$0.35	NA
16-0-0	$255	$0.80	NA	NA
13-0-44	$384	$1.48	NA	$0.44
15-0-14	$288	$0.96	NA	$1.03
8-0-24	$223	$1.39	NA	$0.46
5-10-30	$155	$1.55	$0.78	$0.26
8-8-24	$230	$1.44	$1.44	$0.48
6-6-18	$211	$1.76	$1.76	$0.59
3-6-36	$149	$2.48	$1.24	$0.21

[a]Average costs attained through a phone survey of three major fertilizer companies in the Neuse River Basin conducted in June 2001.
[b]Assumes all costs are associated to a single nutrient in comparing sources.
[c]NA = not applicable

Considerations beyond cost are also important, including application equipment, ease of handling, and safety. Additionally, N from sources containing urea and ammonia can be lost as a gas to the atmosphere (volatilization) if surface-applied. The potential for gaseous losses is greater under prolonged hot, dry conditions at or soon after application when the soil has a high pH. In reduced or no-tillage systems, gaseous losses may increase because the contact between soil and fertilizer is often minimized. Volatilization can be eliminated by placing N below the soil surface through incorporation or injection.

Placement considerations are also related to the proximity of roots to available fertilizer. Rooting patterns and uptake can be affected by physical compaction, chemical restrictions (low soil pH), and rainfall. Broadcast applications generally ensure that a portion of the roots will encounter the fertilizer. Banding can be advantageous on sands where greater potential for leaching exists. A 2 x 2 band (2 inches to the side and 2 inches below the seed) is normally recommended for fertilizers applied at planting in corn, soybeans, and cotton. Side-dress N solutions applied to corn and cotton may be surface-dribbled or injected, but information on specific placement is limited. Growers often place N solutions at the edge of the crop canopy (approximately 8 inches from the row) or in row middles with good results.

The use of starter fertilizers containing N and P at planting may benefit production of crops. Several years of research in the southeastern United States found cotton lint increases of approximately 60 pounds per acre when starter fertilizers were used on high P soils (Hodges, 2001). Similarly for corn, research in the Southeast generally supports positive yield responses, even on high P soils (Zublena and Anderson, 1994). Other agronomic advantages for both cotton and corn are also noted, such as enhanced early plant vigor and improved insect and weed control. Early crop maturity (early grain dry-down) is noted for corn. While responses on high P soils have occurred with starters consisting of only N, the general recommendation is to apply equal rates of N and phosphate (P_2O_5)—approximately 20 pounds per acre. More consistent results have generally occurred with a 2 x 2 band placement. Certain environments also favor yield responses to starter fertilizers: cool, wet soils especially, with low to moderate soil P levels; reduced tillage systems; and well-managed crops.

Soil and tissue testing programs. A vital component of a nutrient management plan is a current soil test report to ensure proper soil pH and adequacy of essential nutrients. Typically, NCDA&CS recommends a fall soil sampling program with sampling every 3 to 4 years on piedmont soils and every 2 to 3 years on the more sandy coastal plain soils. More frequent sampling in years following high rainfall or extreme weather events (hurricanes) can be advantageous. These concerns are especially important on deep sandy soils (16 inches or more to clay) with low levels of organic matter, where high potential for leaching of K and S exists. In addition to soil testing, plant tissue testing can be a valuable nutrient management tool.

Crop consultants and growers may feel more secure with nutrient management and RYE-based N rates if they use plant tissue tests to affirm that N is present at adequate levels. These tests can be the basis for additional applications of nutrients, if recommended. Timing in relation to crop growth stage is extremely important in sample collection, along with prompt corrective action through soil or foliar fertilization. Tissue analysis is offered by the NCDA&CS for $4 per sample. Additional information may be found at http://www.agr.state.nc.us/agronomi/index.htm and in Extension crop production guides.

With these general nutrient management concepts in mind, our focus now will turn to the economic considerations. In order to estimate the economic benefits that nutrient management can offer agriculture today, it is necessary to discuss the standard grower fertilizer programs now in use.

Standard Fertilizer Programs and Decisions

Over the past 60 years, fertilizer programs have evolved through agronomic research and Extension trials, industry support, and grower experience. Today, growers' use of soil testing is at an all-time high, especially since the advent of precision agriculture. Although unprecedented knowledge and resources exist in the agricultural community, a survey of 15 Cooperative Extension agents in piedmont and coastal plains counties found that at least 50 percent of growers use standard fertilizer programs to supply P and K to their crops and do not use soil tests (Hardy, 2001). It seems that many farmers use soil test recommendations primarily for lime and pH adjustment and not for other nutrient recommendations.

Table 5. Fertilizer programs commonly used by growers in eastern North Carolina. [a]

Crop	Program	At-Plant Fertilizer	Rate	In-season Fertilizer[a]	Rate
			lb/acre		lb/acre
Corn	A	5-10-30	300	30-0-0	350
		30-0-0	100		
	B	5-10-30	300	25-0-0-3[b]	425
		30-0-0	100		
	C	18-46-0	125	30-0-0	430
		0-0-60	300		
Cotton	A	10-34-0	200	25-0-0-3[b]	280
		0-0-60	180		
	B	10-34-0	200	30-0-0	200
		0-0-60	150		
	C	17-17-0	120	30-0-0	200
		0-0-60	175		
Tobacco	A			8-8-24	600
				16-0-0	200
	B			6-6-18	700
				15-0-14	200
	C			6-6-18	1000
				16-0-0	250
Wheat	A	5-10-30	300	30-0-0	350
	B	5-10-30	300	25-0-0-3[b]	425
Soybeans	A	0-0-60	150		
	B	5-10-30	300		
	C[c]	-	-	-	-

[a]Information obtained through electronic mail survey of 15 county Extension Agents in the piedmont and coastal plain of N.C.
[b]Contains 3% sulfur by weight.
[c]No fertilization in many double-cropped situations.

A variety of standard fertilizer programs are used throughout the state today, the choice largely determined by past experience and the availability of common fertilizer grades. Although highly variable, there are some programs (Hardy, 2001) that typically represent growers (*Table 5*). Based on these programs, average total annual applications of 150 pounds of N per acre are made for corn, 80 for cotton, 85 for flue-cured tobacco, and 120 for small grain- wheat (*Table 6*). Although these are average rates of N, growers in the Neuse River Basin reported this range of total N fertilization in pounds per acre: 130 to 190 for corn, 75 to 115 for cotton, 45 to 110 for tobacco, and 100 to 150 for wheat (Line and Osmond, 1999). Soybeans need no nitrogen from fertilizer, but applications of 5 to 10 pounds of N per acre often are made at planting as a starter fertilizer or incidentally due to available fertilizer grades.

Table 6. Nutrients supplied and costs of standard fertilizer programs used by growers in eastern North Carolina.[a]

Crop	Program	Nitrogen	Phosphate (P_2O_5)	Potassium (K_2O)	Sulfur	Total Cost
		lb/acre				
Corn	A	150	30	90	0	$60.60
	B	151	30	90	13	$62.15
	C	152	58	180	0	$72.67
	Average					**$65.14**
Cotton	A	90	68	108	8	$58.47
	B	80	68	90	0	$52.53
	C	80	20	105	0	$40.83
	Average					**$50.61**
Tobacco	A	80	48	144	X[b]	$94.50
	B	72	42	154	X[b]	$102.65
	C	100	60	180	X[b]	$137.38
	Average					**$111.51**
Wheat	A	120	30	90	0	$52.30
	B	121	30	90	13	$53.85
	Average					**$53.08**
Soybeans	A	0	0	90		$11.93
	B	15	30	90		$23.25
	C[c]	-	-	-		0.00
	Average					**$11.73**

[a]Fertilizer programs presented in Table 5.
[b]Premium grades will contain approximately 3-5% sulfur by weight.
[c]No fertilization in many double-cropped situations.

Along with N, annual applications of 20 to 65 pounds of phosphate (as P_2O_5) and 90 to 180 pounds of potash (K_2O) per acre are common, depending on the fertilizer grade, rate, and crop (*Tables 5 and 6*). Although North Carolina soil test data (*Table 7*) reveal high to very high P and K index values in more than two-thirds of the soils from eastern, coastal plain, and piedmont regions (NCDA&CS, 2001), many growers believe that P and K additions are essential to the current crop and to maintain soil levels for future crops. At these high soil test levels, recommendations for phosphate (as P_2O_5) and potash (K_2O) for cotton and grain crops (corn, soybeans, and small grains) range from zero to a high of 30 pounds P_2O_5 per acre or 50 pounds K_2O per acre, obviously lower than the rates in the standard grower programs listed in *Tables 5 and 6*. In many instances, excessive nutrient applications occur when compared to crop removal rates (*Table 8*) and total uptake.

Growers may be reluctant to utilize P and K soil test data because of the high number of fields to be managed, small size of fields, or potential dealer resistance to fertilizer blending. Additionally, there is often a belief that "mining," or depletion of nutrient reserves, will occur without annual applications of nutrients such as P. Certainly, without fertilization soil nutrient levels will decline, but research finds a slow rate of decline and no reason for concern about nutrient mining if a routine soil test program is followed. Kamprath (1999) studied corn and soybean yield responses to P fertilizer over a 14-

Table 7. Mean percentages of soils testing high to very high in P and K by crop, 2001.[a]

Crop	P-I Value > 50	K-I Value > 50
	—%—	—%—
Corn	72	75
Cotton	81	80
Small Grains	75	75
Soybeans	72	71
Flue-cured Tobacco	88	64

[a]*Data compiled by NCDA&CS yearly summary reports; mean index values compiled across eastern , coastal plain, and piedmont . NCDA&CS, 2001.*

Table 8. Estimated nutrient removal rates of N, P, K, and S by crops.[a]

Crop	Yield	N	P_2O_5	K_2O	S
		lb acre			
Corn (grain)	150 bu	112	53	40	10
Cotton	2,600 lb (seed and lint)	63	25	31	5
Potatoes, sweet	300 bu	40	18	96	6
Tobacco, flue cured	3,000 lb	85	15	155	12
Wheat (grain)	40 bu	50	25	15	3

[a]*Condensed from Zublena, 1991.*

year period on sandy and clayey mineral soils within the NC coastal plains and piedmont. After soil P levels were raised to a very high status, plots receiving no P were compared with plots receiving various rates of P. After the study was complete, the data indicated yields in nonfertilized plots were equal to yields in fertilized plots until the 13th and 14th years, when yields in nonfertilized plots declined slightly, depending on soil type. These data indicate that crop yield is not compromised by using soil test recommendations, especially given that the recommended rates are chosen in order to maintain soil-critical levels of nutrients so yield will not be affected. Although K is more mobile than P in most soils, growers can still utilize soil test K recommendations to reduce inputs without fear of excessive depletion and reduced yields.

Nutrient Management Fertilizer Programs

The nutrient management approach considers basing N rates on RYE and basing P and K applications on soil test recommendations. With nutrient management, the use of starter fertilizers is a standard practice in corn and cotton, regardless of soil P levels. Furthermore, it is assumed that implementing nutrient management is possible in each field. Complete implementation is entirely possible with variable N rate applicators integrated with yield-monitoring data and applications of P and K made by suppliers with precision application equipment. Without such equipment, the practicality of changing rates from field to field may be limited. If these possibilities do not exist, growers still will find it practical to group fields that require similar N, P, and K rates in order to more accurately apply nutrients.

We will see below that many growers can reduce costs through nutrient management. Reducing inputs not only protects the environment but also helps sustain agriculture during low commodity price cycles. The benefits are evaluated by focusing solely on N and then on the utilization of soil test recommendations for P and K.

Comparative Costs and Benefits

Nitrogen rates and source considerations: Assuming no additional costs are incurred, the economic benefit between nutrient management and standard grower programs can be evaluated by simply comparing the difference in fertilizer costs. The magnitude of savings depends upon several factors: the difference between traditional N rates versus RYE rates; the costs of fertilizer, which vary seasonally and with source; and the degree of nutrient management implementation.

Table 9 presents the economic benefit of adjusting N rates (RYE versus grower) and source (30-0-0 versus 25-0-0-3) in corn and cotton production on a Norfolk soil typical of the coastal plain. Here our assumption is that similar fertility programs for P and K are used, so the focus is on N only. Three observations are important.

- The economic benefit from nutrient management depends greatly on the current N rates in the grower programs, as compared to nutrient management. In the cotton example, the two programs use similar N rates, and no benefit is seen.
- In the corn example, a N rate reduction of 20 pounds per acre leads to a savings of approximately $5 per acre, a benefit of nutrient management. This savings can become very significant when multiplied by many acres on a large farm.
- Although there are many nitrogen sources for growers to select at side-dress, the most popular choices, due to available applicators, handling, safety, and costs per unit pound, are 30-0-0 and 25-0-0-3, the latter often used to apply sulfur to sandy soils. Two corn examples (one grown with 30-0-0 and one with 25-0-0-3) are used in *Table 9*. Because the chemical composition of the two materials is similar (except that 25-0-0-3 contains 3 percent sulfur by weight), our comparisons can focus solely on economic considerations, not source selection based on agronomic benefit. Note that the price per ton of the two sources differs ($22) but the costs per unit-pound of N are similar (*Table 4*). Therefore, the costs of equal N rates from the two sources are about the same, as noted by comparing similar savings per acre ($5.26 versus $5.47) in the two corn examples (*Table 9*).

Nutrient management using soil-test recommendations. As discussed earlier, too much P and K are likely to be applied when com-

Table 9. Nutrient management savings through N rate reductions and source selection, as compared to average of standard grower programs.[a]

Crop	Soil	Final N Rate Grower	Final N Rate RYE	N Source	Price/Ton	Savings/Acre
		lb/acre				
Cotton	Norfolk	80	79	30-0-0	$166	$0.00
Corn	Norfolk	150	131	30-0-0	$166	$5.26
Corn	Norfolk	150	131	25-0-0-3	$144	$5.47

[a]Assumes 20 and 40 pounds N per acre applied to cotton and corn at planting from the same source, respectively, and rate differences are in side-dress N. Also assumes that other nutrient applications are the same.

monly available fertilizer grades are used in standard grower programs. However, nutrient management can take into account P and K applications, in addition to N, in a total program. In *Table 10*, the costs of standard grower programs in fertilizing corn, cotton, wheat, and soybeans with P and K (based on average costs found in *Table 6*) are compared to utilization of soil test recommendations in a nutrient management program. The assumption with nutrient management is that soil P and K levels are sufficient, based on soil testing; however, a starter to supply P is used with the corn and cotton examples. Depending on the crop, substantial savings, ranging from $12 to $55 per acre, are seen in the comparison. These nutrient reductions provide a much greater benefit than simply reducing N rates (*Table 9*), as discussed earlier. During periods of low commodity prices, these savings may be critical to economic sustainability.

Crops with high economic potential: flue-cured tobacco. Growers typically are more receptive to reducing inputs on lower-value crops with small profit margins, as compared to high-value crops, such as flue-cured tobacco. The importance of tobacco to the overall farm income of growers cannot be taken lightly and may not be fully realized except by growers. Currently, data do not exist to establish nitrogen recommendations for tobacco, based on nutrient management principles, as explained previously. There are leaf quality factors involved with yield and selling price that further complicate this approach. Growers are advised to select total N rates based on topsoil depth or depth to the clay, as found in Peedin (2002).

Tobacco is most economically fertilized by using complete fertilizers (those containing N, P, and K) at a rate to supply all of P and K, as recommended by the soil test, and 40 pounds of N per acre. The additional N is most economically supplied through sources such as 16-0-0, 34-0-0, 25-0-0-3 and 30-0-0, with the cheapest sources being those with higher grades. If additional K is needed beyond that supplied by the complete fertilizer, a side-dress material with a grade that most appropriately matches the desired final rates of N and K is suggested. This approach is recommended and discussed in detail by Peedin.

Typically growers produce tobacco on productive, well-drained soils with high fertility, especially P, but also K. When P is not recommended by soil tests, fertilizers that do not contain P, such as 8-0-24, should be used. Research shows no advantage to applying additional P, and tobacco seldom removes more than 15 pounds per acre of P_2O_5 (*Table 8*). At a constant fertilizer rate, the pure economic savings realized by using grades without P (8-0-24), as compared to a similar phosphorus-containing fertilizer (8-8-24), are low—$1.75 per acre at 500 pounds per acre—even when considering the potential savings from a large farm.

The average cost of the grower's tobacco fertility programs presented here is $111 per acre (*Table 6*). On high P soils, a fertilizer program that would agronomically satisfy nutrient needs in most cases costs approximately $80 per acre (500 pounds of 8-0-24 at $223 per ton and 190 pounds of 16-0-0 at $255 per ton). Savings are enhanced when environmental and economic benefits are considered, since soils with high P levels have great potential for supplying P while maintaining yield.

Table 10. Nutrient management savings through use of soil tests, assuming high soil-test levels of P and K with no recommendation, as compared to average of grower programs.[a]

Crop	Grower	Nutrient Management	Savings
	$/acre		
Corn	$65.14	$10.32[b]	$54.82
Cotton	$50.61	$10.32[b]	$40.29
Wheat	$53.08	$0.00	$53.08
Soybean	$11.73	$0.00	$11.73

[a] Assumes that N is applied at same rates and the saving is a function of no application of P and K, as compared to grower programs found in Table 6.
[b] Assumes that a starter of 17-17-0 at 120 pounds per acre is used at planting for both corn and cotton to supply 20 lbs of N and P_2O_5.

Implementation Cost and Economic Considerations

The process of nutrient management involves several distinct activities requiring management, labor, and capital. These processes are listed in *Table 11*. Some activities occur only in the first year, while others may occur yearly (such as yield monitoring) or may occur over two or three years (such as soil sampling). The costs of implementing nutrient management are variable on each farm, depending specifically on its size, complexity of soils and cropping systems, and existing management. The economic analysis of implementation involves a calculation of differences in management and comparing any added costs with expected benefits.

As an example, *Table 12* presents the economic assessment of nutrient management for corn on a Norfolk soil as originally presented in *Table 6*. In the benefits section, expenses are reduced by $5.26 per acre when reduced rates of 30-0-0 are used. As noted earlier, if soil levels of P and K are sufficiently high, additional savings due to decreased fertilizer inputs of approximately $50 per acre (corn data, *Table 10*) are possible. In the costs section there are additional expenses for soil sampling and time management, estimated at $2.50 per acre. A net profit of $2.76 to $52.76 per acre is possible, depending on the utilization of nutrient management principles.

Further economic benefits can be obtained by using cost-share assistance for nutrient management. Funding is available through the Division of Soil and Water Conservation in some Soil and Water Conservation districts at a rate of $18 per acre, covering a three-year period.

Table 11. Economic considerations of nutrient management.

Activity	Additional Costs: Management	Additional Costs: Labor	Additional Costs: Capital	Potential Returns[a]
Attain tract maps; identify tracts, fields, predominant soil type for each field, rotation[b]	✓		✓	
Soil sampling[c]		✓		
Soil test[d]				
Realistic Yield Expectations (RYE) by crop and site[e]	✓	✓		+
Calculate N rates for each crop and RYE	✓			
Develop a nutrient management plan	✓			
Cost-share application	✓			
Split N applications[f]	✓	✓		

[a]Returns will vary by field, crop, year (weather), and management.
[b]Activity will be required only in the first year.
[c]Cost depends on current management.
[d]Free service provided by NCDA&CS Agronomic Division.
[e]Labor involved if monitoring is used to establish RYEs.
[f]Potential cost if not currently implemented.

Table 12. Example of partial budget for nutrient management in corn.[a]

		PER ACRE PER YEAR
BENEFITS[b]		
Reduced Inputs or Increased Income	$5.26 (N only) $50 (no P and K inputs)	
Subtotal		$5.26 – 55.26
COSTS		
Additional Expenses or Reduced Income	$0.75 (soil sample)[b] $1.75 (management)[c]	
Subtotal		$2.50
NET PROFIT		**$2.75 – $52.75**

[a]Based on corn data presented in Tables 6 and 9.
[b]Based on soil sampling every 2 years; cost per sampling event is $1.50 per acre.
[c]Assuming nutrient management requires 5 days of management time @ $8.50 per hour for a 200-acre farm.

Nutrient Credits

Table 1 lists specific N reduction credits for BMPs other than nutrient management. Just as for economic benefit, the amount of credit that is allowed for N management is variable and depends on the difference in rates between N management and a grower's program. In the examples in *Table 9*, a 13 percent reduction in N use occurred in the corn example with nutrient management, but no reduction occurred in the cotton example.

Growers are encouraged to utilize nutrient management, since a reduction of N or P at the source is the most efficient method of reducing potential losses to rivers and estuaries and attaining economic benefits. Implementation of other BMPs will require additional resources and will potentially reduce income, as noted by Wossink and Osmond (2001a, 2001b, 2001c).

Assistance

Assistance in nutrient management planning may be obtained at any local Cooperative Extension Center, Soil and Water Conservation District office, or Natural Resources Conservation Service office. Cost-share information may be obtained from the N.C. Department of Environment and Natural Resources' Division of Soil and Water Conservation, 919-715-6103.

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