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Managing Nitrogen for Groundwater Quality and Farm Profitability

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FOREWORD

The very essence of agriculture is based on the capture of radiant (solar) energy and the stocks and flows of nutrients. Among the biogeochemical cycles governing agricultural productivity is the N cycle with its attendant pathways that can "leak" N forms to groundwater as well as to the atmosphere. Nitrogen ranks at or among the top of the agricultural crop production resource inputs based on both economics and thermodynamic energy equivalents. This production-governing resource coupled with its propensity to leak beyond the rooting zone under certain conditions requires management practices and protocols that will address the economics of its use as well as the potential for environmental and human health impacts. This volume makes a state-of-the-art assessment of the N cycle as applied to agriculture and presents N management strategies for minimizing leakages from production systems in the interest of maximizing N-use efficiency and minimizing environmental impacts, particularly on groundwater quality.

F. P Miller, *president*
Soil Science Society of America

PREFACE

High-quality drinking water is one of the most important, and possibly most valuable, natural resources. Maintaining this resource for present and future generations is a responsibility of all citizens. Identifying, directing, or conducting appropriate social and technological activities for minimizing drinking water degradation is a challenge that scientific, social, and political leaders must meet.

Groundwater is the drinking water source for approximately one-half of U.S. citizens and is the primary source of drinking water in many rural areas (CAST, 1985). This resource results from decades and even centuries of geologic and hydrologic activity. Degradation of groundwater would have major negative impacts on this, as well as future, generations.

Groundwater quality is on an accelerated decline in many places. Agricultural activities are increasingly being held responsible for contributing nitrate (NO_3) to groundwater, although groundwater NO_3 may originate from many sources. This decline has occurred concurrently with increased N use. The dilemma facing the agricultural industry and society is that crop production and agricultural economics are favorably affected by N fertilization, while groundwater quality may not be. Modern technologies, such as N fertilizers have allowed increased production per unit of cultivated land and thus have allowed poorer or more fragile land, that may be especially susceptible to wind and water erosion, to be removed from cultivation and placed under permanent cover. If U.S. farmers were still harvesting the same annual yields per acre in the 1980 to 1985 period that they did in 1938 to 1940, much more land would need to be cultivated to produce the same volume of agricultural crops produced now. Much of this additional land, if cultivated, would seriously affect other environmental problems (Barrons, 1988).

The task facing industry, producers, agricultural advisors, and others who are concerned about the environment is to develop efficient N-management systems that maintain economical production levels while minimizing groundwater degradation.

The goal of this book is to present current "state-of-the-art" information and its application to assist managers, producers, agricultural advisors, and others in making appropriate N-management decisions. Guidelines and management principles to minimize NO_3-N leaching while optimizing the economics for N-fertilization, water, and cropping system management alternatives are provided. Because of the scope of this book, the guidelines and principles presented are fairly general. Where possible, users of these procedures are encouraged to utilize their own local or site-specific data, rather than the more general "default" data provided, to increase the applicability of these procedures for local conditions.

Chapter 12 describes procedures to screen for potentially leachable NO_3-N. Chapter 13 describes the computer software for Nitrate Leaching and Economic Analysis Package (NLEAP) that was developed to implement theories, methods, and equations and to assist with N-management decisions that are described in Chapter 13 and the other chapters of this book.

This book and accompanying computer software are unique tools that should help users to economically and environmentally evaluate various aspects of N-management programs for individual farms. However, users of either this book or the NLEAP model need to be aware of the following disclaimer:

> The user assumes all risks and responsibilities for the use of the material in this book and application of the NLEAP model and the interpretation of the results therefrom obtained. The authors, the U.S. Department of Agriculture and affilitated institutions, and the Soil Science Society of America (as publisher) are not liable to users for any damages, including: lost profits, lost savings, actions by regulatory agencies, or any other incidental or consequential damages occurring from the use or inability to use the material in this book or the NLEAP model, their results, or their documentation for any purpose.

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Conversion Factors for Acceptable Units

Conversion Factors for Acceptable Units

To convert Column 1 into Column 2 multiply by	Column 1 Acceptable Unit	Column 2 SI Unit	To convert Column 2 into Column 1 multiply by
		Length	
0.304	foot, ft	meter, m	3.28
2.54	inch, in.	centimeter, cm (10^{-2} m)	0.394
25.4	inch, in.	millimeter, mm (10^{-2} m)	3.94×10^{-2}
1.609	mile, mi	kilometer, km (10^{3} m)	0.621
0.914	yard, yd	meter, m	1.094
		Area	
0.405	acre	hectare, ha	2.47
4.05×10^{3}	acre	square meter, sq m	2.47×10^{-4}
9.29×10^{-2}	square foot, sq ft	square meter, sq m	10.76
6.45	square inch, sq in.	square centimeter, sq cm $(10^{-4}\ m)^2$	0.155
645	square inch, sq in.	square millimeter, sq mm $(10^{-6}\ m)^2$	1.55×10^{-3}
2.590	square mile, sq mi	square kilometer, sq km $(10^{3}\ m)^2$	0.386
		Volume	
102.8	acre-inch	meter^3, m^3	9.73×10^{-3}
35.24	bushel (dry), bu	liter, L (10^{-3} m^3)	2.84×10^{-2}
28.3	cubic foot, cu ft	liter, L (10^{-3} m^3)	3.53×10^{-2}
2.83×10^{-2}	cubic foot, cu ft	cubic meter, cu m	35.3
1.64×10^{5}	cubic inch, cu in.	cubic meter, cu m	6.10×10^{4}
3.78	gallon, gal	liter, L (10^{-3} m^3)	0.265
2.96×10^{-2}	ounce (liquid), oz	liter, L (10^{-3} m^3)	33.78
1.82	pint (dry), pt	liter, L (10^{-3} m^3)	0.55
0.473	pint (liquid), pt	liter, L (10^{-3} m^3)	2.11
0.908	quart (dry), qt	liter, L (10^{-3} m^3)	1.101
0.946	quart (liquid), qt	liter, L (10^{-3} m^3)	1.057

	Mass		
454×10^{-1}	hundredweight (short), cwt	kilogram, kg	2.20×10^{-2}
28.4	ounce (avdp), oz	gram, g	3.52×10^{-2}
454	pound, lb	gram, g (10^{-3} kg)	2.20×10^{-3}
0.454	pound, lb	kilogram, kg	2.205
907	ton (2000 lb), ton	kilogram, kg	1.10×10^{-3}
0.907	ton (2000 lb), ton	megagram, Mg (tonne)	1.102
	Yield and Rate		
35.84	32-lb bushel per acre, bu/acre	kilogram per hectare, kg/ha	2.79×10^{-2}
53.75	48-lb bushel per acre, bu/acre	kilogram per hectare, kg/ha	1.86×10^{-2}
62.71	56-lb bushel per acre, bu/acre	kilogram per hectare, kg/ha	1.59×10^{-2}
67.19	60-lb bushel per acre, bu/acre	kilogram per hectare, kg/ha	1.49×10^{-2}
9.35	gallon per acre, gal/acre	liter per hectare, L/ha	0.107
1.12×10^{-2}	hundredweight per acre, cwt/acre	kilogram per hectare, kg/ha	0.892×10^{2} or 893
1.12	pound per acre, lb/acre	kilogram per hectare, kg/ha	0.893
1.12×10^{-1}	pound per acre, lb/acre	megagram per hectare, Mg/ha	893
12.87	pound per bushel, lb/bu	kilogram per cubic meter, kg/cu m	7.77×10^{-2}
16.02	pound per cubic foot, lb/ft	kilogram per cubic meter, kg/cu m	6.25×10^{-2}
2.24	ton (2000 lb) per acre, ton/acre	megagram per hectare, Mg/ha	0.446
	Angles		
1.75×10^{-2}	degree (angle)	radian, rad	57.296
	Pressure		
0.101	atmosphere, atm	megapascal, MPa (10^{6} Pa)	9.90
0.1	bar	megapascal, MPa (10^{6} Pa)	10
47.9	pound per square foot, lb/sq ft	pascal, Pa	2.09×10^{-2}
6.90×10^{3}	pound per square inch, lb/sq in.	pascal, Pa	1.45×10^{-4}
6.90	pound per square inch, lb/sq in.	kilopascal, kPa	0.145
	Temperature		
5/9 (°F − 32)	Fahrenheit, °F	Celsius, °C	(9/5 °C) + 32

(continued on next page)

Conversion Factors for Acceptable Units

To convert Column 1 into Column 2 multiply by	Column 1 Acceptable Unit	Column 2 SI Unit	To convert Column 2 into Column 1 multiply by
		Energy, Work, Quantity of Heat	
1.05×10^{3}	British thermal unit, Btu	joule, J	9.52×10^{-4}
4.19	calorie, cal	joule, J	0.239
4.19×10^{4}	calorie per square centimeter (langley), cal/sq cm	joule per square meter, J/sq m	2.387×10^{-5}
698	calorie per square centimeter per minute, cal/sq cm/min	watt per square meter, W/sq m	1.43×10^{-3}
1.36	foot-pound, ft-lb	joule, J	0.735
		Water Measurement	
102.8	acre-inch, acre-in.	cubic meter, cu m	9.73×10^{-3}
101.9	cubic foot per second, cu ft/s	cubic meter per hour, cu m/h	9.81×10^{-3}
0.227	U.S. gallon per minute, gal/min	cubic meter per hour, cu m/h	4.40
0.123	acre-foot, acre-ft	hectare-meter, ha-m	8.11
12.33	acre-foot, acre-ft	hectare-centimeter, ha-cm	8.1×10^{-2}
1.03×10^{-2}	acre-inch, acre-in.	hectare-meter, ha-m	97.28
9.35	U.S. gallon per acre, gal/acre	liter per hectare, L/ha	0.107
10^{2}	bar (water potential)	joule per kilogram, J/kg	10^{-2}
10	water content of plant, %	gram water per kilogram wet or dry (specify) tissue, g/kg	0.1
10	water content of soil, %	kilogram water per kilogram dry soil, kg/kg	0.1
		Speed	
0.447	miles per hour, mi/h	meter per second, m/s	2.237
		Light	
10.764	foot-candle, ft-c	lux, lx	0.0929

		Density	
12.87	grain test weight, pound per bushel, lb/bu	kilogram per cubic meter, kg/cu m	7.78×10^{-2}
1.0	soil bulk density, gram per cubic centimeter, g/cu cm	megagram per cubic meter, Mg/cu m	1.0
		Concentration	
10^4/(mol wt)	percent, % [must specify the base and if by weight (w/v or w/w) or volume (v/v or w/v)]	liquid, known molar mass mole per cubic meter, mol/cu m	$10^{-4} \times$ (mol wt)
10^4	percent, % (must specify the base and if by weight or volume)	liquid, unknown molar mass gram per cubic meter, g/cu m	10^{-4}
10^4/(mol wt)	percent, % (must specify the base and if by weight or volume)	ion uptake, mole per cubic meter, mol/cu m	$10^{-4} \times$ (mol wt)
10/(mol wt)	percent, % (must specify the base and if by weight or volume)	known molecular weight in fresh or dry (specify) plant material, mole per kilogram, mol/kg	$0.1 \times$ (mol wt in g mol^{-1})
10	percent, % (must specify the base and if by weight or volume)	unknown molecular weight in fresh or dry plant material, gram per kilogram, g/kg	0.1
10	percent, % (must specify the base and if by weight or volume)	soil texture composition, gram per kilogram, g/kg	0.1
1.0	parts per million, ppm	extractable ions, milligram per kilogram, mg/kg	1.0
0.5	pounds per acre, lb/acre	extractable ions, milligram per kilogram, mg/kg	2.0 (assume 2×10^6 lbs soil per acre 6⅔ in.)
1	milliequivalents per 100 grams, meq/100 g	centimole per kilogram, cmol/kg (ion exchange capacity)	1
10	percent, %	gram per kilogram, g/kg	0.1
1	parts per million, ppm	milligram per kilogram, mg/kg	1
		Plant Nutrient Conversion	
	Oxide	*Elemental*	
0.437	P_2O_5	P	2.29
0.830	K_2O	K	1.20
0.715	CaO	Ca	1.39
0.602	MgO	Mg	1.66