
Contents

Acknowledgments xi

Transforming the World xiii

1 Nitrogen in Agriculture 1

Discovering the Basics

Discovering Nitrogen 2

Nitrogen in Crop Production 5

Nitrogen and Legumes 13

Completing the Nitrogen Cycle 16

2 Traditional Sources of Nitrogen 21

Preindustrial Agricultures

Recycling of Organic Matter 22

Farmyard Manures 25

Cultivation of Legumes 28

Nitrogen Balances in Traditional Farming 31

Limits to Recycling and Legume Cultivation 35

3 New Sources of the Nutrient 39

Searching for Fixed Nitrogen

Guano 40

Sodium Nitrate 43

By-product Ammonia from Coking 48

Synthesis of Cyanamide 51

Electric Arc Process 53

Plant Nutrients and Future Food Supply 55

4	A Brilliant Discovery	61
	<i>Fritz Haber's Synthesis of Ammonia</i>	
	Haber's Predecessors	61
	Fritz Haber	65
	Haber's First Experiments with Ammonia	68
	Nernst and Haber	70
	BASF and Haber	74
	High-Pressure Catalytic Synthesis	77
5	Creating an Industry	83
	<i>Carl Bosch and BASF</i>	
	Carl Bosch	85
	Designing High-Pressure Converters	87
	Finding New Catalysts	93
	Producing the Feedstocks and Oxidizing Ammonia	97
	The First Ammonia Plant at Oppau	99
	Ammonia Synthesis for War	103
6	Evolution of Ammonia Synthesis	109
	<i>Diffusion and Innovation</i>	
	Slow Diffusion of Ammonia Production: 1918–1950	111
	Expansion and Changes Since 1950	116
	Natural Gas–Based Ammonia Synthesis	118
	Single-Train Plants with Centrifugal Compressors	122
	Continuing Innovation	127
7	Synthetic Fertilizers	133
	<i>Varieties and Applications</i>	
	Nitrogen Fertilizers	134
	Fertilizer Applications: Global Views	138
	Fertilizer Nitrogen in Global Crop Production	143
	Regional and National Perspectives	145
	The Most Productive Agroecosystems	152
8	Our Dependence on Nitrogen	155
	<i>Agricultures and Populations</i>	
	How Many People Does Fertilizer Nitrogen Feed?	156
	Human Protein Requirements	161

Nitrogen in U.S. Agriculture	164
Nitrogen in Chinese Farming	167
Growing Dependence during the Twenty-first Century	172
9 Consequences of the Dependence	177
<i>Human Interference in Nitrogen's Biospheric Cycle</i>	
Intensifying the Global Cycling of Nitrogen	178
What Happens to Fertilizer Nitrogen	180
Nitrogen Losses in Modern Farming	184
Excess Nitrogen and Human Health	188
Nitrogen and Natural Ecosystems	192
10 Nitrogen and Civilization	199
<i>Managing the Nitrogen Cycle</i>	
What Has Been Accomplished	201
More Efficient Fertilizing	206
Stabilized Populations	211
Rational Diets	214
A Long View	217
Postscript	223
Appendixes	233
Notes	253
Name Index	329
Subject Index	331