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SOIL TEST LEVELS IN NORTH AMERICA

2010

Summary Update

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Soil Test Levels in North America, 2010

Introduction

With the assistance and cooperation of numerous private and public soil testing laboratories, the International Plant Nutrition Institute (IPNI) periodically summarizes soil test levels in North America (NA). Soil tests indicate the relative capacity of soil to provide nutrients to plants.

Therefore, this summary can be viewed as an indicator of the nutrient supplying capacity or fertility of soils in NA. This is the tenth summary completed by IPNI or its predecessor, the Potash & Phosphate Institute (PPI), with the first summary dating back to the late 1960s (Nelson, 1980). The summary offers a snapshot view of soil test levels in 2010, but also provides a comparison to the previous two summaries which were completed in 2001 and 2005 (Potash & Phosphate Institute, 2001; 2005). Since the 2010 summary is the third summary in which laboratories were asked to contribute complete frequency distributions of soil test results, temporal trends in soil test level distributions can be viewed for states and provinces.

Important to appropriate use of this report is recognition that nutrient management should occur on a site-specific basis where management objectives and the needs of individual fields and, in many cases areas within fields, are recognized. Therefore, a general soil test summary like this one cannot reflect the specific needs of individual farms. Its value lies in calling attention to broad nutrient needs, trends, and challenges, and in motivating educational and action programs that are in turn relevant to growers and their advisers.

For More Information...

For additional resources, check the IPNI website: >**http://info.ipni.net/soiltestsummary**<.

Technical questions concerning this summary should be directed to the IPNI Director representing the region of interest or to Dr. Paul Fixen.

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Abbreviations and notes: P = phosphorus; K = potassium; N = nitrogen; Mg = magnesium; S = sulfur; Zn = zinc; Cl^- = chloride; ppm = parts per million; Al = aluminum; Mn = manganese; Ca = calcium.

Laboratories Contributing to the 2010 Summary

PRIVATE LABORATORIES

A&L Analytical Labs, Inc. - Memphis, TN

A&L Canada Laboratories, Inc. - London, ON

A&L Eastern - Richmond, VA

A&L Great Lakes Labs, Inc. - Fort Wayne, IN

Agri-Food Laboratories - Guelph, ON

AgriQuanta - St-Ours, QC

AGVISE Laboratories - Northwood, ND

ALS - Calgary, AB

Brookside Lab, Inc. - New Knoxville, OH

Dellavalle Laboratory, Inc. - Fresno, CA

Frontier Labs - Clear Lake, IA

Laboratoire Géosol - Mont St-Hilaire, QC

GMS Laboratories - Cropsey, IL

La Coop fédérée - Longueuil, QC

LGI - Ellsworth, IA

Litchfield Analytical Services - Litchfield, MI

MDS Harris - Lincoln, NE

Midwest Laboratories, Inc. - Omaha, NE

Olsen's Ag Lab - McCook, NE

Precision Agri-Lab - Madera, CA

Rock River Lab - Watertown, WI

Servi-Tech, Inc. - Amarillo, TX

Servi-Tech, Inc. - Dodge City, KS

Servi-Tech, Inc. - Hastings, NE

SGS Alvey Laboratory, Inc. - Belleville, IL

SGS MWSS, Inc. - Brookings, SD

Spectrum Analytic, Inc. - Washington Court House, OH

SURE-TECH Laboratories - Indianapolis, IN

Ward Laboratories, Inc. - Kearney, NE

Western Laboratories - Parma, ID

William Houde, Ltd. - St-Simon, QC

PUBLIC LABORATORIES

Auburn University

Clemson University

Colorado State University

Department of Natural Resources Corner Brook, NL

Iowa State University

Kansas State University

Kentucky Division of Regulatory Services

Michigan State University

Mississippi State University

New Brunswick Agriculture and Aquaculture

New Mexico State University

North Carolina Department of Ag

North Dakota State University

Nova Scotia Department of Agriculture

Oklahoma State University

PEI Soil & Feed Testing Laboratory

South Dakota State University

Texas A&M University

The Pennsylvania State University

University of Arkansas

University of Connecticut

University of Delaware

University of Florida

University of Georgia

University of Guelph

University of Maine

University of Missouri

University of New Hampshire

University of Tennessee

University of Vermont

University of Wyoming

Virginia Tech

Summary Sample Volume, Procedures, and Cautions

This summary includes results of P, K, and pH tests performed on approximately 4.4 million soil samples, results of Mg tests on 2.7 million samples, results of S tests on 2.5 million samples, and results on Zn and Cl^- on 1.4 and 0.26 million samples, respectively. The samples were collected in the fall of 2009 or spring of 2010 and therefore reflect fertility status prior to the 2010 crop year.

The sample volumes mentioned above represent large increases from the 2005 summary that likely reflect increased soil sampling in North America. **Figure 1**, though based on limited U.S. data, helps place the sample volumes in an historical context. Soil testing began in earnest in North America in the 1950s and 1960s and experienced rapid growth at a rate of over 200,000 samples per year, driven by a combination of factors including the exuberance of the Green Revolution, great investment in agronomic personnel by the fertilizer industry, and emphasis by university Extension (Peck, 1990). Then industry margins plummeted, staff lay-offs occurred, and soil levels started building...resulting in a reduction in sample volume. Following this period of reduction which ended in the mid 1970s, slow growth in testing occurred at a rate of about 55,000 samples per year. This period included the introduction of grid and zone soil sampling as part of precision agriculture.

Since IPNI's 2005 summary, it appears a substantial increase in use of soil testing has occurred, assuming that the summary continues to represent about 75% of the total samples collected. This assumed percentage is based on the judgment of individuals knowledgeable about soil testing activity in North America and should be viewed as a rough estimate. For example, the volume of samples in the 2010 summary from the Corn Belt region (12 states plus Ontario) is 50% higher than in the 2005 summary. This likely represents one of the highest growth rates in soil testing ever experienced in North America. Though we do not have data to verify when the jump occurred during the last 5 years, it likely occurred during the last year or two out of concern over the impact of nutrient use decisions on soil fertility levels and market-driven interest in improving future nutrient use decisions. Growth in zone and grid sampling contributed to the increased sample volume.

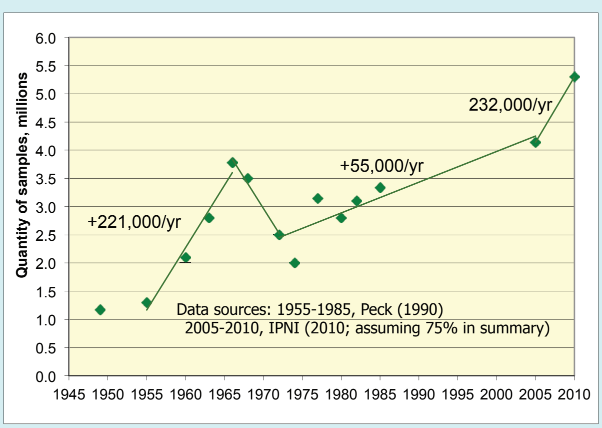


Figure 1. Soil sample volume in the U.S., 1949-2010.

Soil test data are reported in three forms.

Median P, K, or pH values. The median is the level occurring in the middle when values are arranged in order of magnitude. By definition, half the samples are greater than and half are less than the median. The median is a more accurate indicator of central tendency than the average when data do not follow a normal or bell-shaped distribution. Since soil test data are seldom normally distributed, the median is used in this report.

Relative frequency across soil test ranges for P, K, pH, Mg, S, Zn, and Cl^-. The 2010 frequencies are shown for states and provinces in tabular form. And the 2010, 2005, and 2001 frequencies are shown graphically for P, K, and pH to illustrate any shifts that might have occurred over this 9-year period.

Percent of samples below agronomic critical levels for P and K. Interpretation of the data reported in the summary requires appreciation of the agronomic meaning of soil test levels. Critical levels are useful for that purpose. In this report, a critical level is defined as the level where recommended nutrient rates generally drop to zero in sufficiency approaches or to a crop removal level in build-maintenance approaches (see text box on next page for more information on critical levels).

Critical Level: A critical level is the soil test level below which nutrient inputs are required to meet soil fertility management objectives. These objectives vary among states and provinces, with each representing considerations of short and long-term profit, market and environmental risks, accuracy, and precision in soil fertility assessments, as well as many other factors. Critical levels, therefore, vary from state to state as various aspects of management receive different levels of emphasis. Critical Bray P1 equivalent levels for the soils and typical cropping systems of the Great Plains and western Corn Belt are usually assumed to be around 20 ppm and to increase to 25 or 50 ppm for the eastern U.S. Certain crops, such as potatoes on some soils, will require much higher soil P levels with research showing agronomic response in the 100 ppm range. Critical ammonium acetate K equivalent levels for the relatively high cation exchange capacity (CEC) soils of western and central NA are generally in the 120 to 200 ppm range. Critical levels are usually lower in eastern NA, and on low CEC soils may drop to 60 ppm. State and province specific critical levels are shown in **Figures 2 and 3.**

Private and public laboratories that submitted data are listed on page 4. Great appreciation is extended to all the laboratories cooperating in the summary. Many had to create special summary routines to accommodate our protocol. The net effect of their extra effort is more and better information on soil fertility in this report.

Many soil test procedures are used for P and K determination in North America, although just a few are dominant. Four extractants accounted for 96% of the P analyses, and three accounted for over 99% of the K analyses in this summary (**Figure 4**). As in 2005, the Mehlich 3 procedures for both P and K are the most frequently used. In order for data to be pooled among laboratories using different procedures, ranges of agronomic equivalency for each test must be defined (**Table 1**). These ranges were either taken from the literature or estimated by soil fertility specialists in consultation with IPNI regional directors. In the summary, all soil test data are reported in terms of well known soil test procedures. Procedures used for reporting purposes are Bray P1, ammonium acetate extractable K and Mg, 1:1 water pH, calcium phosphate extractable S, DTPA extractable Zn, and water extractable Cl^- based on the transformations implied in **Table 1**.

A challenge in pooling data from many laboratories over a period of years is to accurately account for changes in extractants, how the extractants are employed in a specific procedure, how the elements are detected in the extracted solution, and finally, how the results are reported to clients. Changes in or miscommunication about any of these steps can result in serious errors in the summary process. The IPNI staff and cooperating laboratories were diligent in maintaining the accuracy of these factors.

Though IPNI attempts to be comprehensive and consistent in conducting the summary and avoid distorting the contributed data in any way, weaknesses exist in the summary process due to the diversity and dynamic nature of soil testing services:

- Quantity of sample results is low in several states and provinces.
- An inexact time frame was given to labs. They were asked to contribute samples collected for decision-making for the 2010 crop year, but the exact dates used in queries were left to individual interpretation.
- Not all sample results could be definitively associated with a particular state.

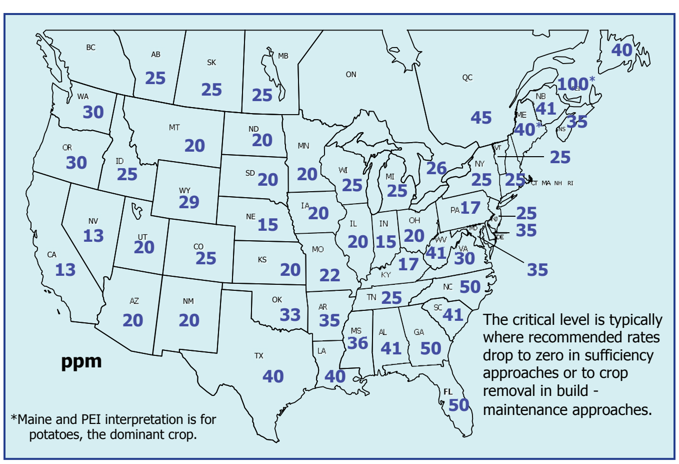


Figure 2. Critical Bray P1 equivalent soil test levels, 2010.

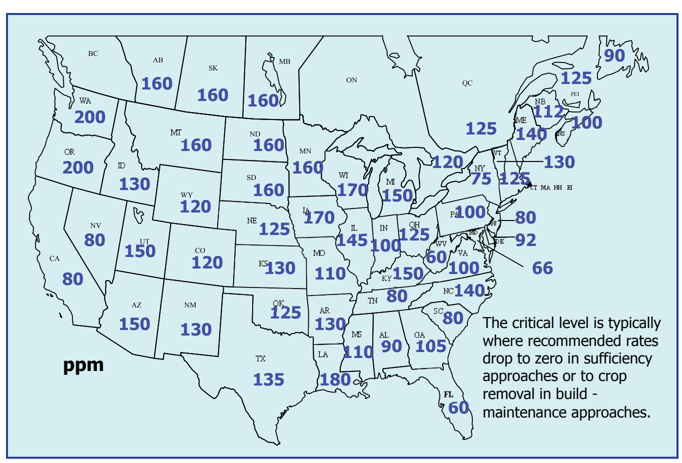


Figure 3. Critical ammonium acetate equivalent soil K levels, 2010.

Table 1. Soil test range equivalents assumed in the summary.

Soil test	Categories requested or received from participating laboratories, ppm*														
Phosphorus															
Ammonum Bicarbonate-DTPA	0-1	2-3	4-5	6-7	8-9	10-11	12-15	16-19	20-29	30-39	40-58	59-77	78-116	117-194	>194
Bray and Kurtz P1	0-5	6-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	101-150	151-200	201-300	301-500	>500
Bray and Kurtz P2	0-9	10-18	19-27	28-35	36-40	41-45	46-55	56-65	66-90	91-115	116-165	166-215	216-315	316-515	>515
Kelowna, Modified	0-5	6-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	101-150	151-200	201-300	301-500	>500
Lancaster P	0-5	6-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	101-150	151-200	201-300	301-500	>500
Mehlich 1 P	0-3	4-6	7-9	10-12	13-15	16-18	19-24	25-30	31-45	46-60	61-90	91-120	121-180	181-300	>300
Mehlich 2 P	0-5	6-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	101-150	151-200	201-300	301-500	>500
Mehlich 3 P (colorimetric)	0-5	6-10	11-15	16-20	21-25	26-30	31-40	41-50	51-75	76-100	101-150	151-200	201-300	301-500	>500
Mehlich 3 P (ICP)	0-9	10-18	19-27	28-35	36-40	41-45	46-55	56-65	66-90	91-115	116-165	166-215	216-315	316-515	>515
Morgan, Cornell		0-0.9	1.0-2.3	2.4-3.6	3.7-4.4	4.5-5.3	5.4-6.9	7.0-8.6	8.7-13	14-17	18-25	26-34	35-50	51-84	>84
Morgan, Modified	0-2.5	2.6-3.4	3.5-4.9	5.0-6.3	6.4-7.1	7.2-8.0	8.1-9.7	9.8-11	12-16	17-20	21-29	30-37	38-55	56-89	>89
Olsen P (sodium bicarbonate)	0-3	4-7	8-11	12-15	16-19	20-23	24-30	31-38	39-57	58-77	78-116	117-154	155-232	233-387	>387
Potassium															
Ammonium Acetate K	0-40	41-80	81-120	121-160	161-200	201-240	241-280	281-320	>320						
Ammonum Bicarbonate-DTPA	0-30	31-60	61-90	91-120	121-150	151-180	181-210	211-240	>240						
Kelowna, Modified	0-40	41-80	81-120	121-160	161-200	201-240	241-280	281-320	>320						
Lancaster	0-40	41-80	81-120	121-160	161-200	201-240	241-280	281-320	>320						
Mehlich 1 K	0-40	41-80	81-120	121-160	161-200	201-240	241-280	281-320	>320						
Mehlich 3 K	0-40	41-80	81-120	121-160	161-200	201-240	241-280	281-320	>320						
Water (NMSU only)	0-15	16-30	31-45	46-60	61-75	76-90	91-105	106-120	>120						
Magnesium															
Ammonium Acetate Mg	0-25	26-50	51-75	76-100	>100										
Mehlich 3 Mg	0-25	26-50	51-75	76-100	>100										
Sulfur															
Calcium phosphate S	0-3	4-6	7-9	>9											
Mehlich 3 S	0-6	7-12	13-18	>18											

*The above equivalencies were assumed for the purpose of estimating soil test level frequency distributions across wide areas. They are not recommended for use in converting soil test values for individual fields for the purpose of determining appropriate rates to apply.

- It is likely that the better managers regularly test their soil and that their results may not be representative of those that do not soil test.
- Due to the requirement of nutrient management plans for many livestock operations, the percent of samples in the summary from manured fields could be higher than in the past for some regions and inflate soil test levels, especially for P. Summary protocol included separation of samples into manured and non-manured fields, but these categorizations were left to individual laboratories to define and very few laboratories had those metadata.
- Although an attempt was made to define calibration equivalency for each of the soil test categories among the various testing procedures, it is likely that error was introduced in this process.
- Some laboratory data were submitted using categories other than those specified in the sampling protocol, and interpolation routines were created and used to translate between the two systems.

These weaknesses need to be considered in interpreting and using the results of the summary.

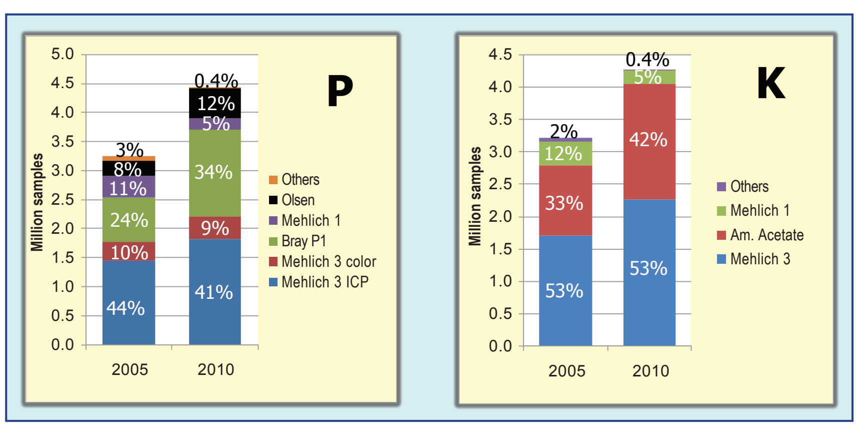


Figure 4. Fraction of samples analyzed by specific P and K soil tests.

Current Status of Soil P and Soil P Changes

The median P level for NA for the 2010 crop was 25 ppm, a 6 ppm decline from 2005 **(Table 2; Figure 5)**. Phosphorus levels vary markedly among states and provinces as well as within most states and provinces **(Figure 6)**. The agronomic or crop management implications of these levels can be better appreciated by considering the percent of samples testing below critical levels for major regional crops **(Table 2; Figure 7)**. These values take into account regional differences in interpretation of laboratory measurements due to field research on nutrient needs of major crops in each region. Thus, in North Dakota, 86% of P soil test results indicated that yield loss would be expected if P is not applied annually, whereas only 13% of the test results from New Jersey indicated this was the case.

In general, the northern Great Plains has the lowest P levels in NA, as has been the case in past summaries. However, unlike much of the rest of the intensively cropped regions of the country, this region tended to show increases in soil P or at least no declines from the 2005 summary **(Table 2: Figure 8)**. Therefore, the northern Great Plains region is not as different from most of the rest of NA as in the past. The far eastern regions continue to have the highest soil P levels in NA, with some medians climbing higher in 2010.

In **Table 2**, P ranges are shown above 50 ppm where laboratories in the state or province reported distributions for the higher levels. Note that all categories are 5 ppm wide under 50 ppm, but range from 25 to 200 ppm wide above 50 ppm. The NA row near the bottom of **Table 2** and the first two frequency distributions in **Figure 6** that pool all results for NA indicate why an average is inappropriate for describing most soil P distributions. Usually, an average will over-estimate the central tendency of the data due to a high degree of skewness caused by long "tails" towards the high ranges. It also shows the dominance of the lower categories of soil P in North America with over 74% testing below 50 ppm in 2010.

Comparing the 2010 P distribution to the 2001 and 2005 distributions for NA reveals increased frequencies for the lowest three categories and reduced frequencies for the six highest categories **(Figure 6, first graph)**. Over 60% of the samples

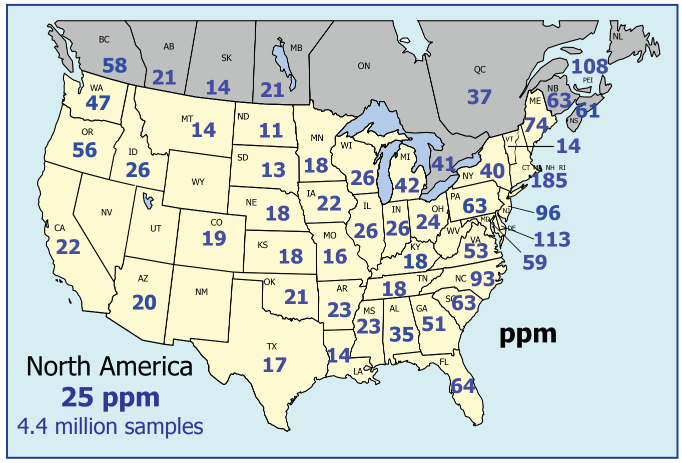


Figure 5. Median Bray P1 equivalent soil test levels in 2010 (for states and provinces with at least 2,000 P tests).

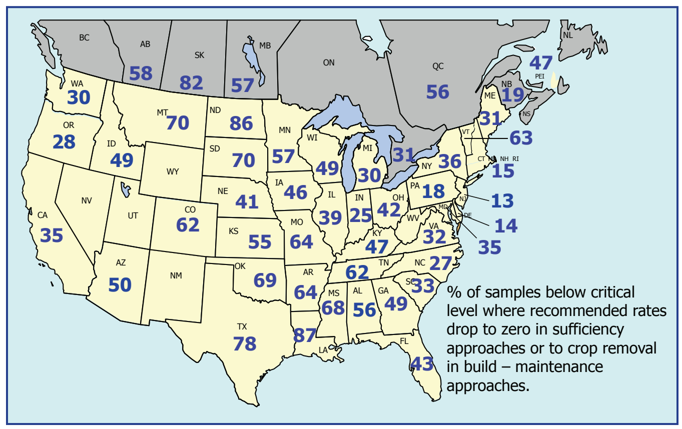


Figure 7. Percent of samples testing below critical levels for P for major crops in 2010.

testing >50 ppm were in the 50 to 100 ppm range.

Distributions for individual states or provinces shown in **Figure 6** should be interpreted with caution since they may be influenced by changes in geographic sample sources due to changes in participating laboratories among the three summaries. Low sample volume in a state or province increases the impact of such changes. Because of this, states or provinces with samples totaling less than 1,000 in 2010 are not included in the frequency distribution graphs.

A consistent regional trend in median soil test level change is a good indication of real change in soil fertility. Several such regional trends are apparent for P. The northern Great Plains, including the Prairie Provinces, shows small increases in median P levels or no change. Since this is also the region of lowest P levels in North America, it makes sense that growers would be building levels or at least not allowing them to drop.

The most consistent P declines since 2005 occurred across the Corn Belt and Central Great Plains. The median P level for the 12 major Corn Belt states plus Ontario declined from 28 ppm in 2005 to 22 in 2010. This decline has major agronomic significance since a high percentage of samples from this region now test below critical levels **(Figure 7)**. Considering that soil P levels are highly buffered, such large declines for a population of over 3 million samples over a 5-year period are surprising. The high sample volume and limited diversity in cropping systems of the Corn Belt offers opportunities for additional evaluation of aggregate data to gain insights into the cause of these declines.

A separate IPNI project that is evaluating partial nutrient balances in the U.S. (IPNI, 2010) was used to evaluate the relationship between P balances in the U.S. Corn Belt and changes in soil test P **(Figure 9)**. The resulting regression coefficient indicates that 62% of the variability in soil P changes could be explained by state P balances and the regression line passed very close to the origin where a balanced P budget equates to no change in soil P. This is evidence that much of the measured decline in soil P levels is due to the cumulative effects of crop removal exceeding P use across this region.

With the exception of Vermont, the states in the northeastern U.S. show increases in soil P. This is a region with significant manure production relative to crop land area, frequently resulting in surplus P balances. An increase in the number of samples collected from manured fields due to increased regulatory emphasis on P-based nutrient management plans is another possible factor behind these reported increases.

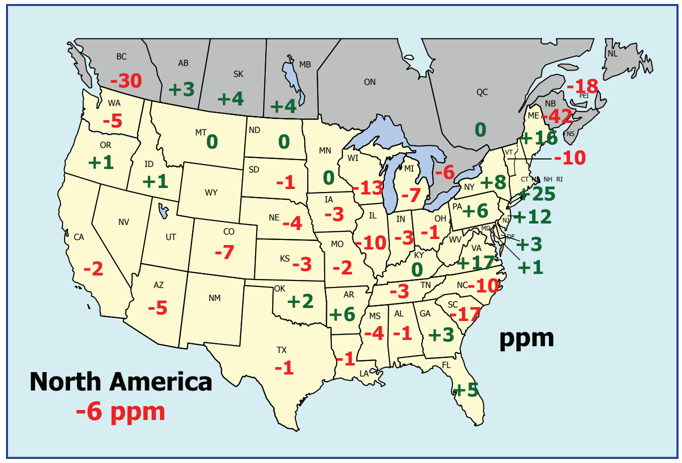
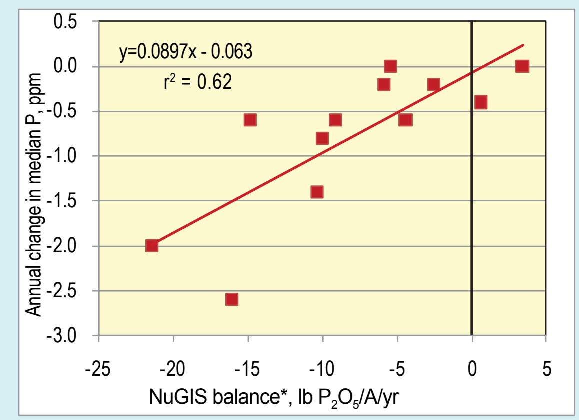


Figure 8. Change in median Bray P1 equivalent soil test levels from 2005 to 2010.



*NuGIS is a GIS nutrient balance model (IPNI, 2010).

Figure 9. Annual change in median soil P level for 12 Corn Belt states as related to state P balance (fertilizer + recoverable manure - crop removal), 2005-2009.

Table 2. Relative frequencies and median soil test P in North America by state or province.

State or Province	Samples	5	10	15	20	25	30	35	40	45	50	>50	75	100	150	200	300	500	>500	Critical level ppm	Critical level %**	Median 2001	Median 2005	Median 2010
		Bray P-1 equivalent, ppm – Relative Frequency, %																				ppm		
Alabama	50,145	8	9	8	8	6	6	6	6	4	4	**37**	14	7	8	3	3	2	0	41	56		36	35
Alaska	7	0	0	14	0	0	0	7	7	0	0	**71**	0	14	14	0	43	0	0					125
Alberta	26,877	5	16	16	12	9	8	8	8	3	3	**13**								25	58	17	18	21
Arizona	2,186	6	11	9	24	21	12	4	4	2	2	**6**	3	1	1	0	0	0	0	20	50	15	25	20
Arkansas	124,718	5	14	16	12	7	6	5	5	4	4	**24**	12	5	3	1	1	1	0	35	64	21	17	23
British Columbia	1,758	0	1	2	3	3	4	5	5	5	5	**68**											88	58
California	36,192	15	14	10	9	6	5	3	3	3	3	**28**	10	7	6	2	1	1	0	13	35	22	24	22
Colorado	24,347	8	16	17	13	9	6	4	4	2	2	**19**	7	4	5	1	1	0	0	25	62	25	26	19
CT-MA-NH-RI	6,284	2	3	4	3	2	2	2	2	2	2	**77**	6	5	9	8	13	17	17	25	15	>50	160	185
Delaware	10,854	1	1	2	3	2	2	2	2	2	2	**79**	12	13	16	11	14	12	2	35	14	>50	110	113
Florida	4,698	9	6	5	5	4	3	3	3	3	3	**57**	12	9	10	7	8	7	5	50	43	>50	59	64
Georgia	67,202	1	3	4	4	5	5	6	6	7	7	**51**	27	12	7	2	1	1	1	50	49	48	48	51
Hawaii	674	32	14	10	7	3	3	3	3	2	2	**22**	5	3	5	3	2	1	1					12
Idaho	36,558	2	10	13	13	11	9	6	6	4	4	**21**	10	5	4	1	1	0	0	25	49	19	25	26
Illinois	224,860	2	8	15	15	10	9	7	7	5	5	**20**	11	4	3	1	1	0	0	20	39	36	36	26
Indiana	418,585	2	10	13	14	9	9	6	6	4	4	**23**	12	5	4	1	1	0	0	15	25	33	29	26
Iowa	775,401	5	13	15	13	11	9	6	6	4	4	**15**	8	3	2	1	0	0	0	20	46	25	25	22
Kansas	82,482	8	16	17	14	10	7	5	5	3	3	**13**	6	3	2	1	1	0	0	20	55	20	21	18
Kentucky	65,081	8	17	17	12	6	5	4	4	3	3	**21**	8	4	4	2	2	1	0	17	47	21	18	18
Louisiana	20,743	10	24	22	14	6	5	4	4	2	2	**8**	5	2	1	0	0	0	0	40	87	16	15	14
Maine	6,905	8	3	5	4	2	3	3	3	3	3	**64**	14	20	14	5	5	4	3	40	31	52	58	74
Manitoba	42,392	5	13	16	13	9	7	5	5	4	4	**18**								25	57	15	17	21
Maryland	42,609	2	5	8	7	5	5	4	4	3	3	**55**	14	11	12	6	6	5	2	35	35	53	58	59
Michigan	189,915	1	5	9	9	6	6	6	6	5	5	**42**	17	10	8	4	2	1	0	25	30	50	49	42
Minnesota	216,566	6	18	19	14	10	7	4	4	3	3	**12**	6	3	2	1	0	0	0	20	57	16	18	18
Mississippi	42,213	3	12	17	14	8	7	6	6	4	4	**20**								36	67	32	27	23
Missouri	152,391	12	19	17	13	10	7	5	5	3	3	**8**	5	2	1	0	0	0	0	22	64	17	18	16
Montana	13,021	9	23	22	16	11	6	3	3	1	1	**4**	3	1	1	0	0	0	0	20	70	12	14	14
Nebraska	363,140	8	17	16	13	10	7	5	5	3	3	**13**	7	3	2	1	1	0	0	15	41	21	22	18
Nevada	46	0	9	9	2	2	13	10	10	7	7	**33**	26	2	2	2	0	0	0	13	14	20	16	38
New Brunswick	5,385	1	2	3	3	2	2	3	3	3	3	**75**								41	19	>50	105	63
New Jersey	5,431	2	3	3	3	2	2	2	2	2	2	**78**	9	23	20	9	8	6	3	25	13	>50	84	96
New Mexico	1,144	7	15	13	10	9	4	3	3	3	3	**28**	9	6	7	5	1	1	0	20	45	21	17	23
New York	30,480	2	9	11	9	5	5	4	4	4	4	**43**	14	10	10	4	3	2	1	25	36	35	32	40
Newfoundland	697	2	4	3	5	3	2	2	2	2	2	**76**	11	12	12	6	31	4	0				121	112
North Carolina	287,126	2	2	3	3	2	3	3	3	3	3	**73**	15	12	16	11	12	6	2	50	27		103	93
North Dakota	75,279	7	37	28	14	6	3	1	1	0	0	**1**	1	0	0	0	0	0	0	20	86	10	11	11
Nova Scotia	6,502	5	8	8	6	4	3	3	3	3	3	**55**	11	6	8	7	8	10	4	35	37			61
Ohio	248,760	2	10	15	15	10	9	6	6	4	4	**19**	10	4	3	1	1	0	0	20	42	23	25	24
Oklahoma	22,759	6	14	14	13	10	8	5	5	2	2	**20**	10	4	3	1	1	1	0	33	69	20	19	21
Ontario	101,964	0	4	8	9	8	8	6	6	5	5	**41**								26	31	51	47	41
Oregon	6,297	3	5	5	6	5	4	5	5	4	4	**55**	19	14	13	5	2	1	0	30	28	36	55	56
Pennsylvania	58,972	3	5	7	7	4	4	4	4	3	3	**57**	13	10	14	9	5	4	2	17	18	50	57	63
Prince Ed. Is.	5,101	1	0	1	1	1	1	1	1	1	1	**92**								100	47	>50	126	108
Quebec	55,732	5	9	11	9	5	5	4	4	4	4	**40**								45	56	45	37	37
Saskatchewan	24,430	11	24	21	16	10	7	3	3	1	1	**2**								25	82	10	10	14
South Carolina	61,490	6	6	4	4	4	3	3	3	3	3	**62**	22	9						41	33		80	63
South Dakota	81,323	13	23	21	14	9	6	3	3	2	2	**6**	3	1	1	0	0	0	0	20	70	11	14	13
Tennessee	84,921	6	16	18	14	8	6	5	5	3	3	**16**	8	3	2	1	1	1	1	25	62	15	21	18
Texas	41,322	14	18	14	10	7	6	4	4	3	3	**17**	7	3	3	1	1	1	0	40	78	23	18	17
Utah	-																			20		17	21	
Vermont	2,171	34	8	11	6	4	3	2	2	2	2	**26**	7	5	5	3	3	3	1	25	63	13	24	14
Virginia	70,744	3	5	6	7	6	6	5	5	4	4	**51**	12	13	11	5	5	3	2	30	32		36	53
Washington	4,832	2	3	6	7	6	6	6	6	5	5	**47**	20	11	9	3	3	1	0	30	30	24	52	47
West Virginia	1,197	10	10	11	9	4	4	3	3	2	2	**40**	10	10	9	4	3	2	1	41	56		52	32
Wisconsin	102,950	3	12	15	12	7	6	4	4	3	3	**30**	10	6	7	3	2	1	0	25	49	41	39	26
Wyoming	1,161	27	22	18	10	6	5	2	2	2	2	**5**	3	1	0	0	0	0	0	29	86	19	15	10
North America	4,437,020	4.7	12.1	13.4	11.7	8.3	6.9	5.0	5.0	3.6	3.6	**25.7**	10.6	5.0	4.8	2.1	1.8	1.0	0.4			27	31	25
Corn Belt*	3,023,418	4.5	12.5	14.4	12.9	9.4	7.7	5.4	5.4	3.6	3.6	**18.5**	9.5	3.8	2.9	1.1	0.7	0.3	0.1					22

*Corn Belt = IL, IN, IA, KS, KY, MI, MN, MO, NE, OH, ON, SD, WI.

**Percent of samples testing below the indicated crtical level.

Figure 6. Soil test P frequency distribution in 2001, 2005, and 2010 (sample volume >1,000 in 2010).

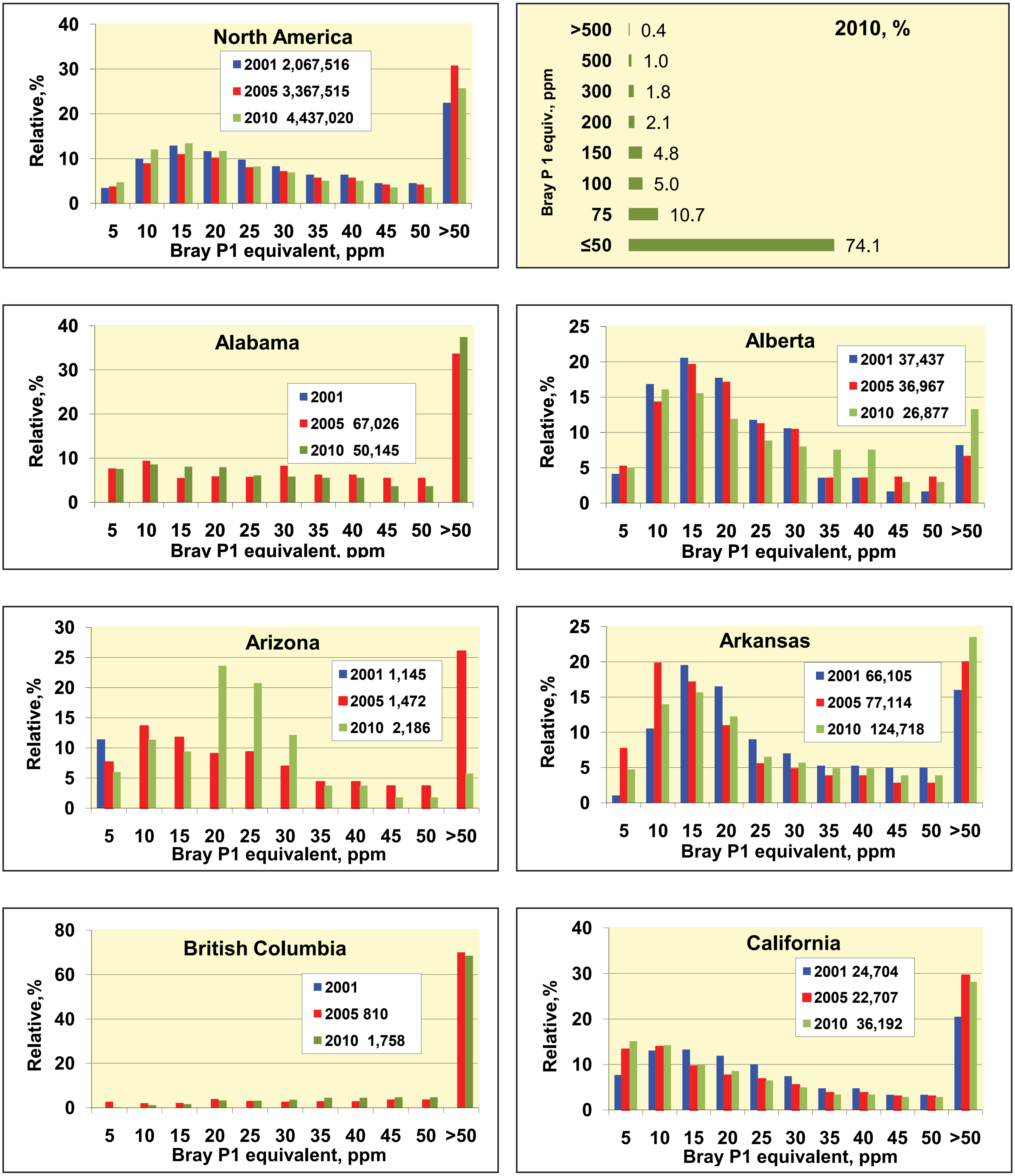


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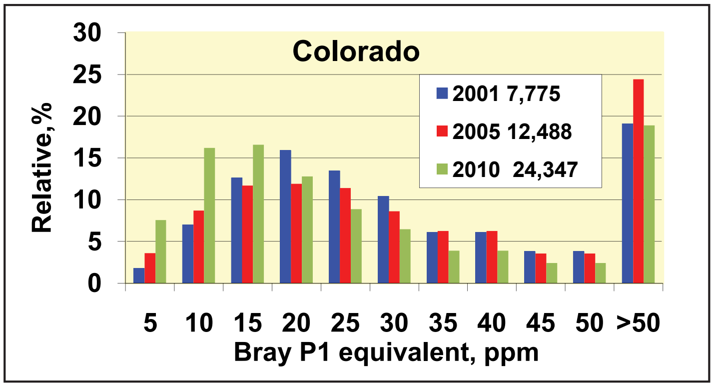
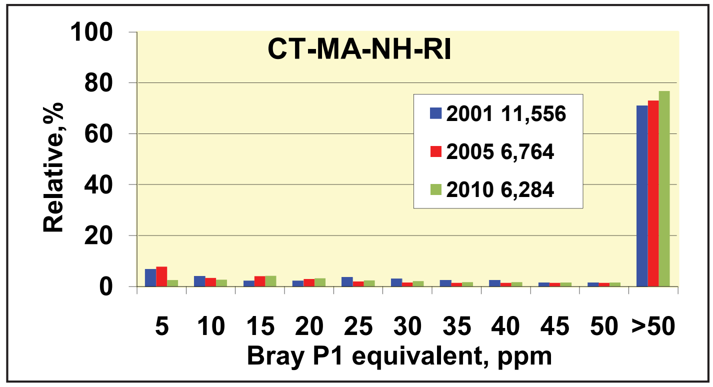
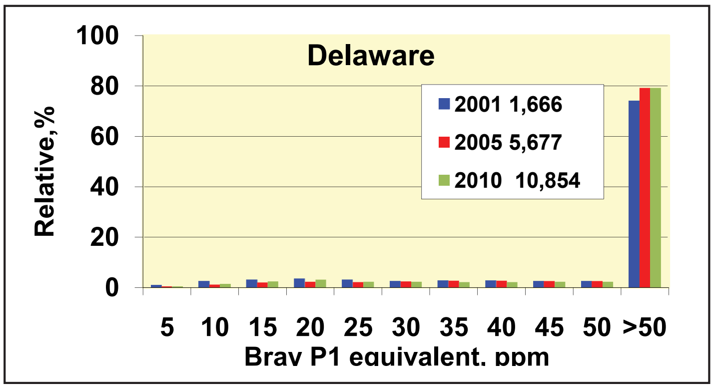
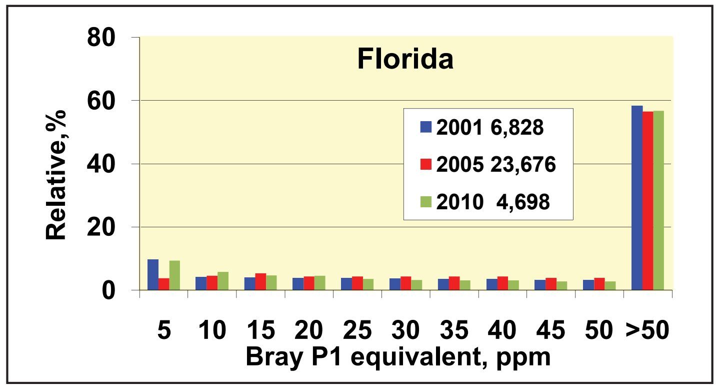
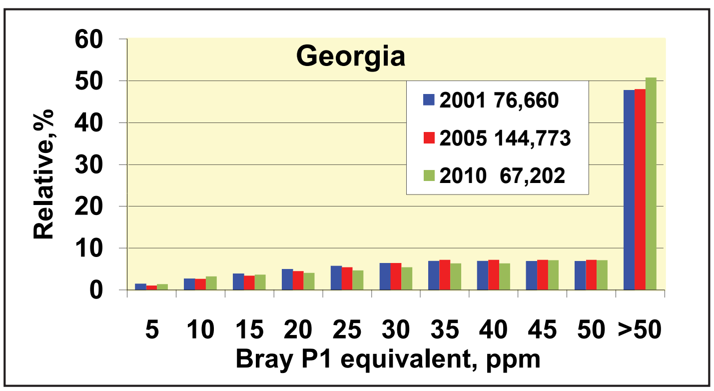
Figure 6. Continued

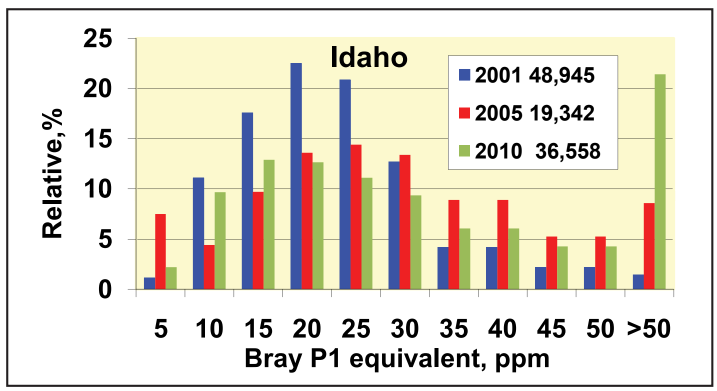


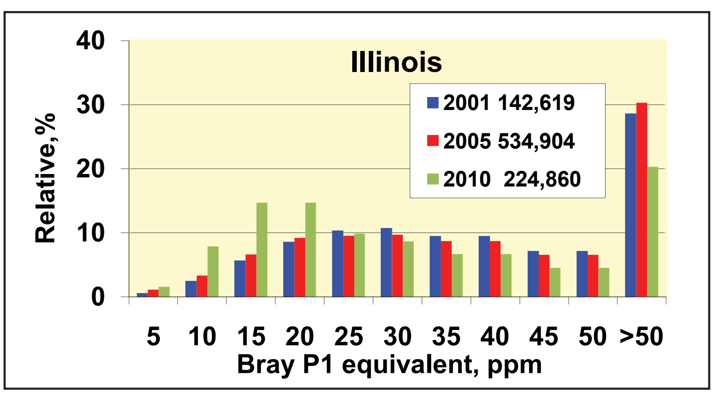


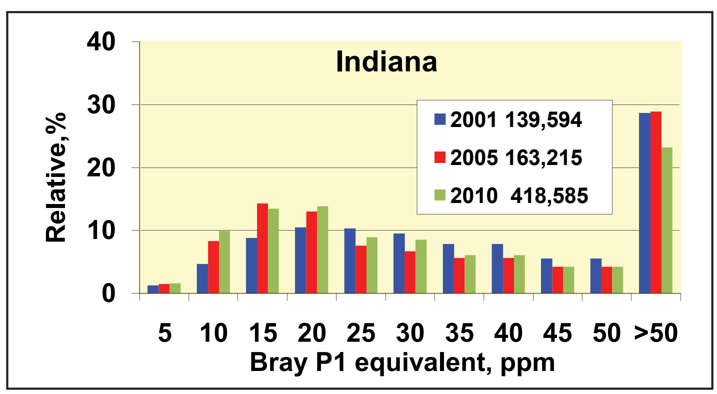












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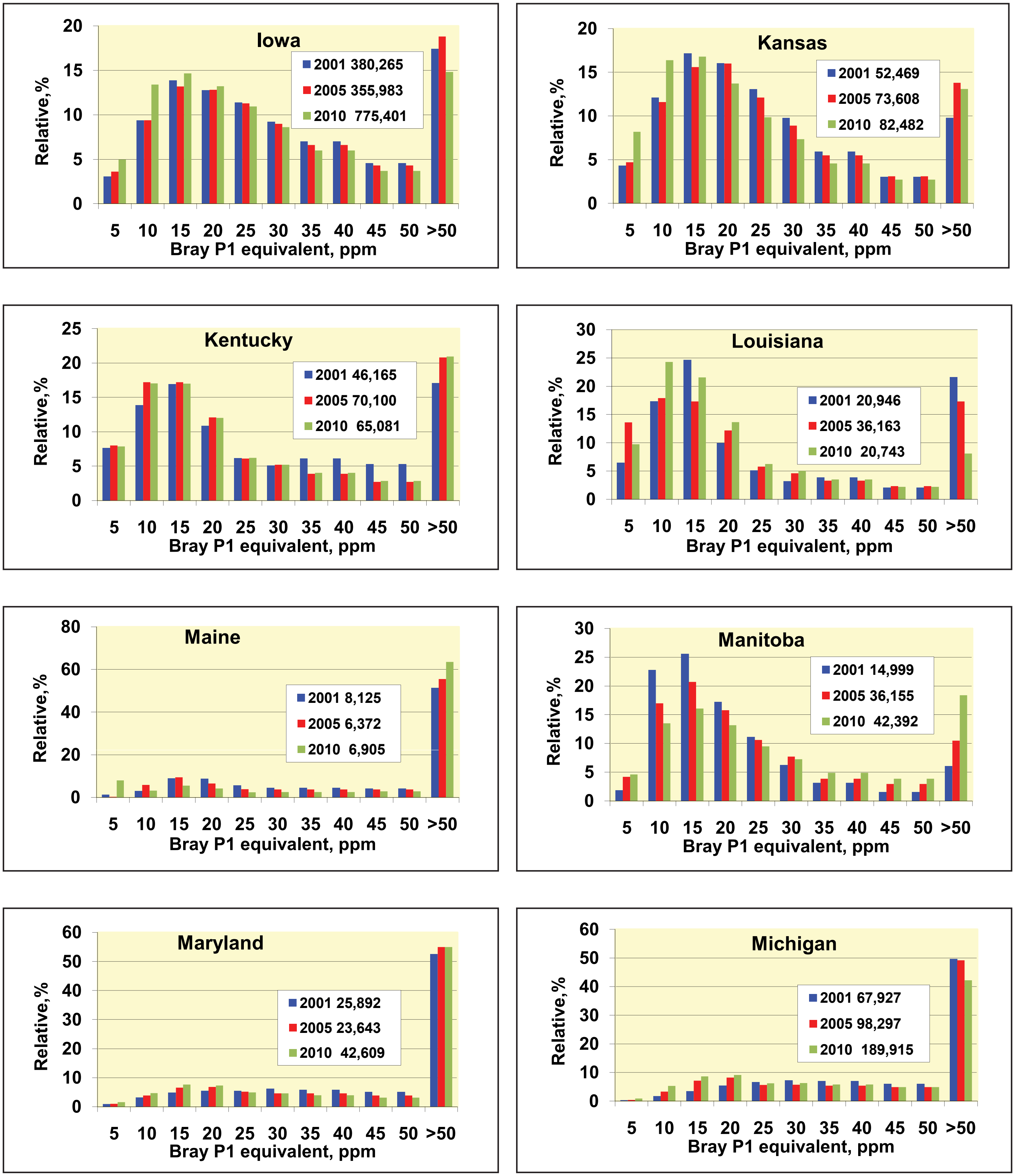

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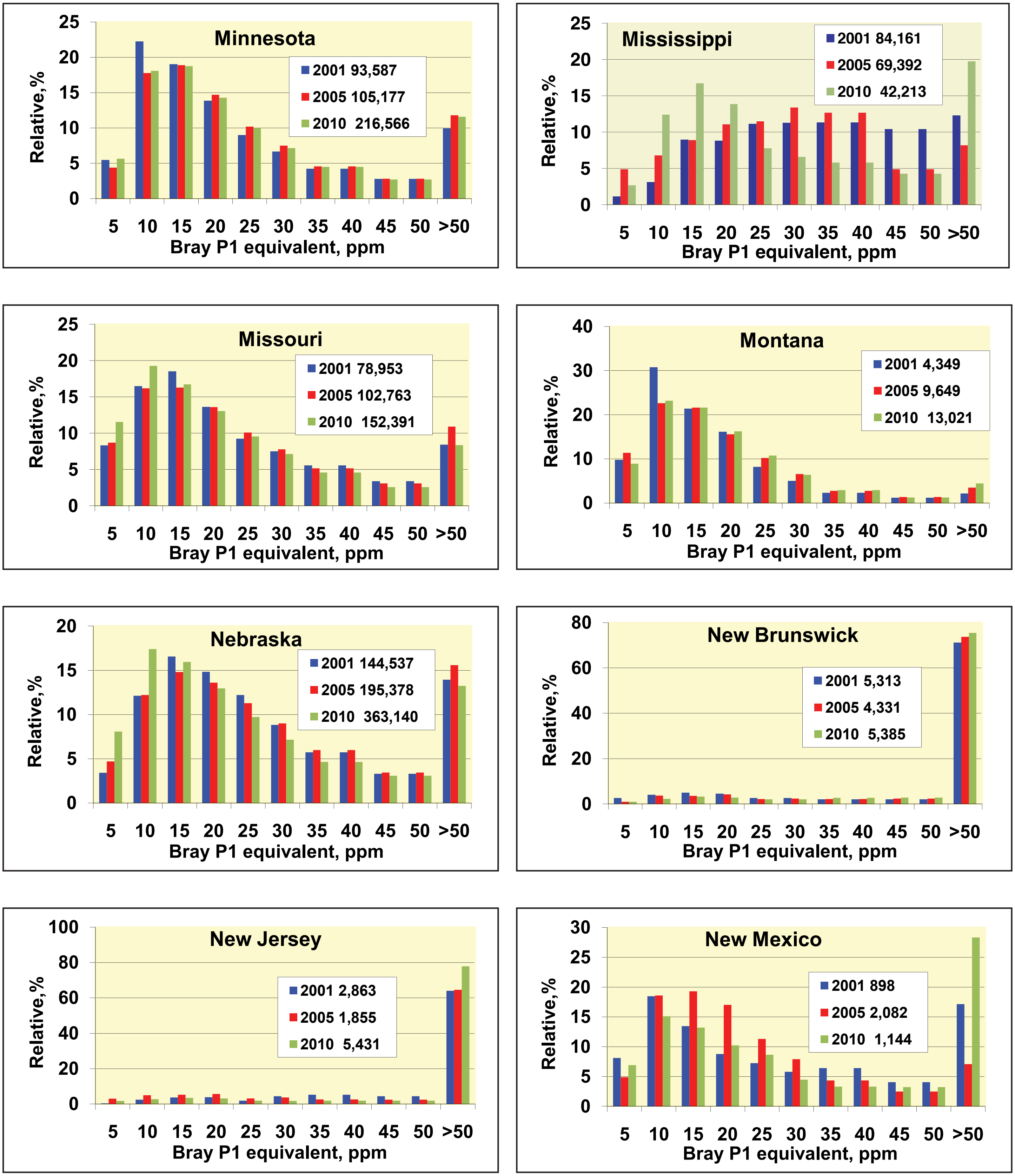

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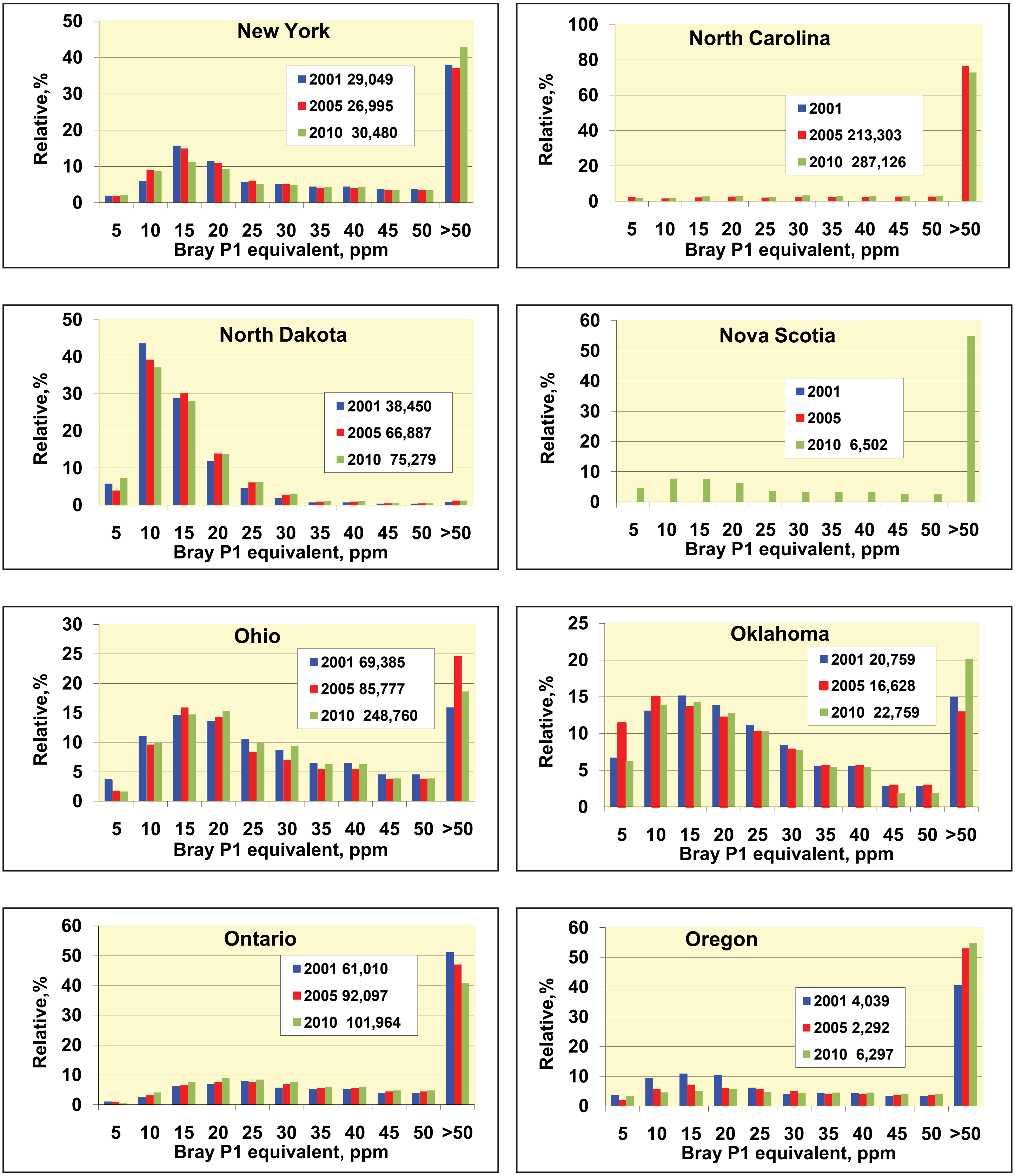

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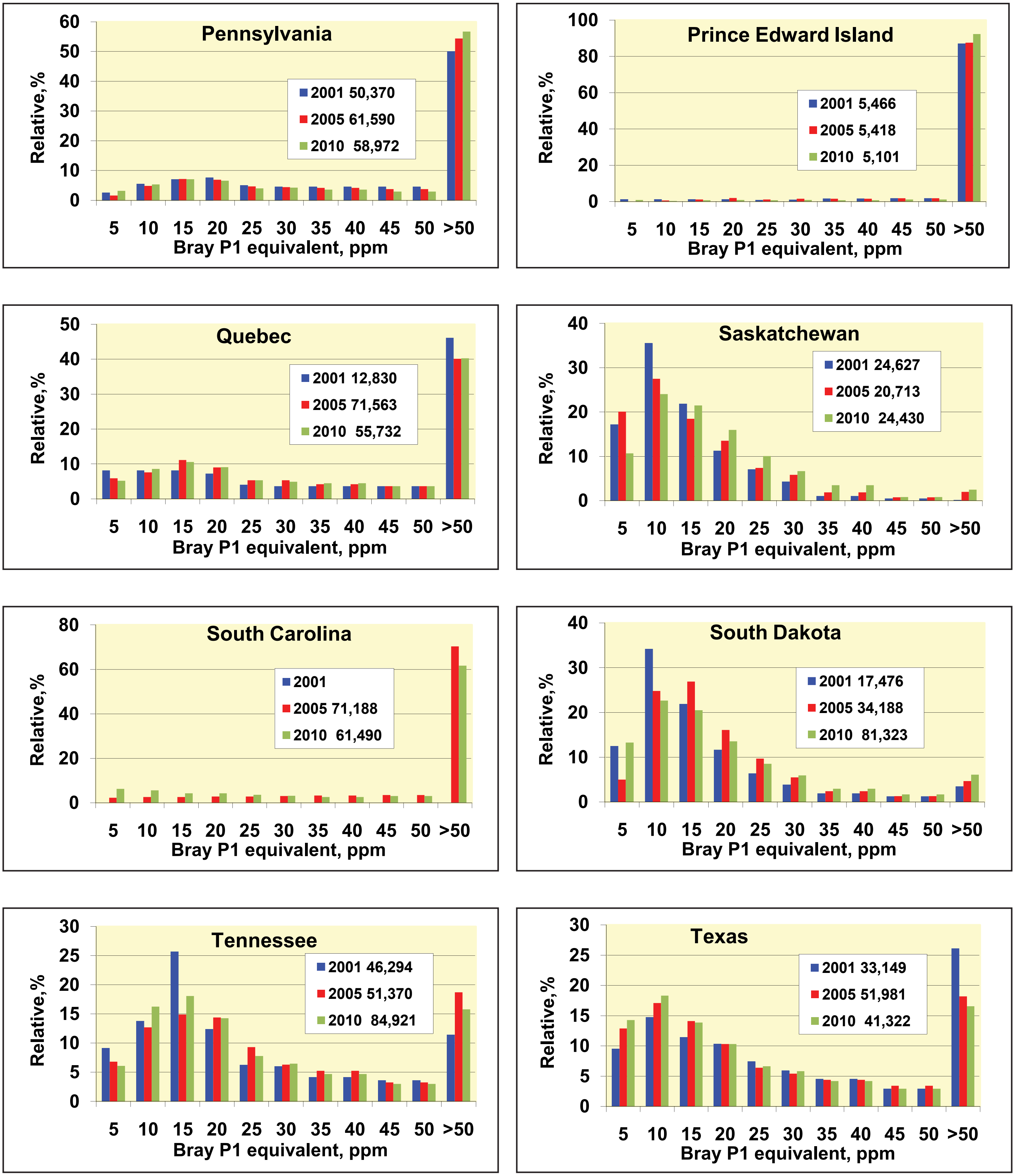

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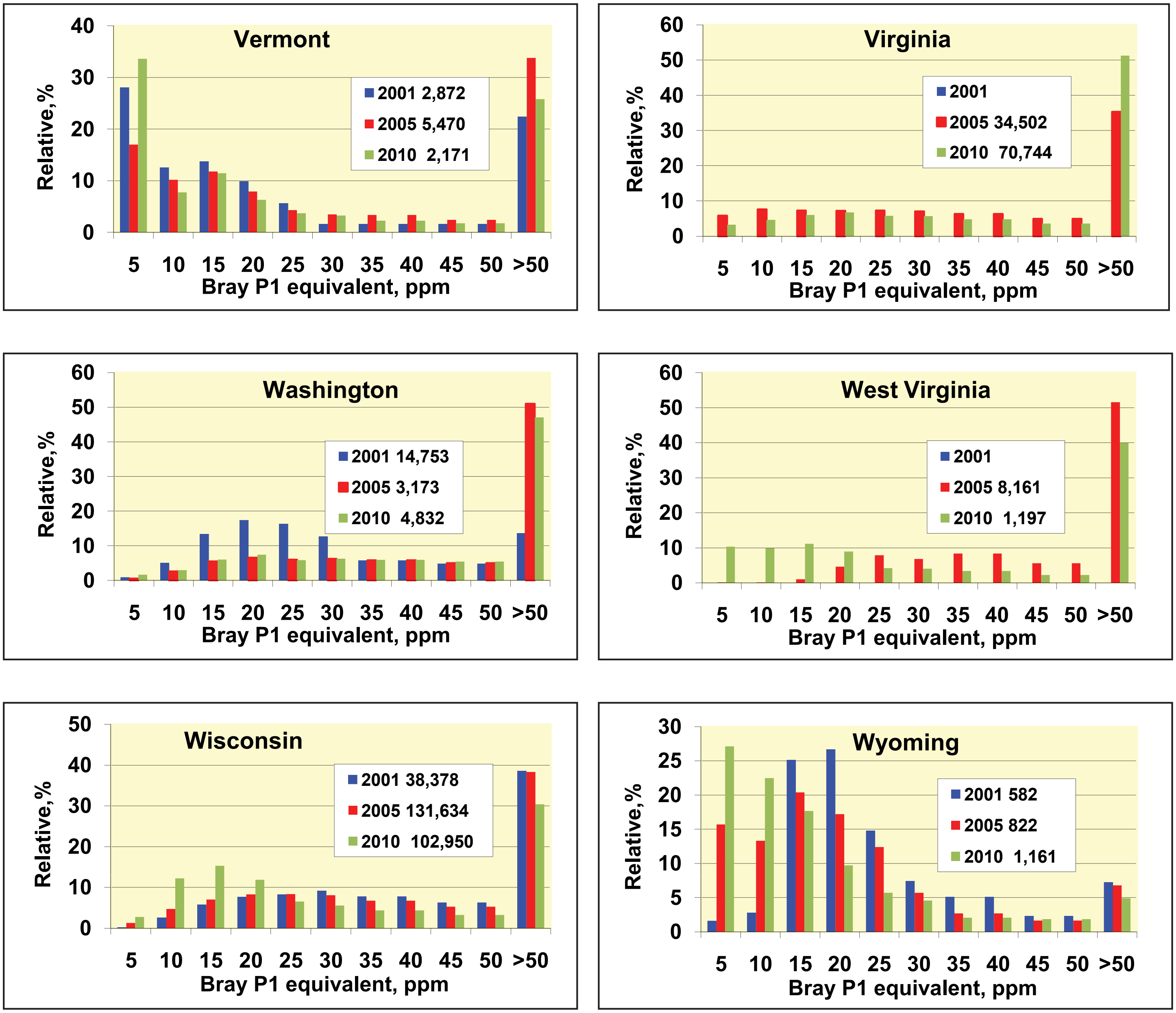


The median K level for NA for the 2010 crop was 150 ppm, a 4 ppm decline from 2005 (**Table 3; Figure 10**). Median K levels in many states east of the Mississippi River and in the provinces of eastern Canada are at or below agronomic critical levels, indicating that 50% or more of the sampled areas represented likely require annual K application to avoid yield losses (**Figures 11, 12**). The higher K levels in the West reflect the less weathered status of western soils.

Along the western Corn Belt and much of the Great Plains, crop removal far in excess of K additions (IPNI, 2010) are consistent with the declines in soil tests observed from 2005 to 2010 (**Figure 13**). Exceptions were MB, MT, ID, and WA. However, all four of these areas showed unusually large reductions in soil K from 2001 to 2005 so the increases reported in this summary may in part be reflecting a return to more normal K levels. Many areas in the East also experienced significant K declines.

In the Corn Belt, nutrient balance was not a good indicator of the observed changes in soil test K levels from 2005 to 2010, since it explained only 9% of the variability (data not shown). Numerous factors other than nutrient balance can influence soil test K changes over a 5-year period, including soil moisture relationships and temperature or freeze-thaw cycles. These weather associated factors can influence the equilibrium between soil test extractable and non-extractable forms of soil K. Though several shifts in K are larger numerically than the P changes, the agronomic significance of most of the Corn Belt K changes is considerably less than for P, especially when considering that the calibration scale for K is approximately 10 times that for P.

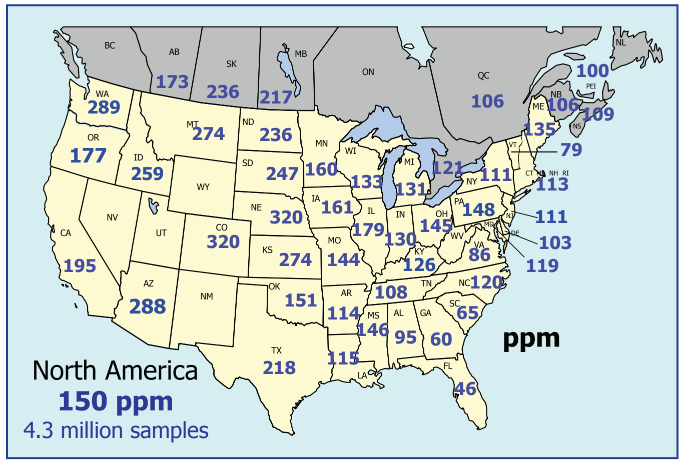


Figure 10. Median soil test K levels in 2010 (for states and provinces with at least 2,000 K tests).

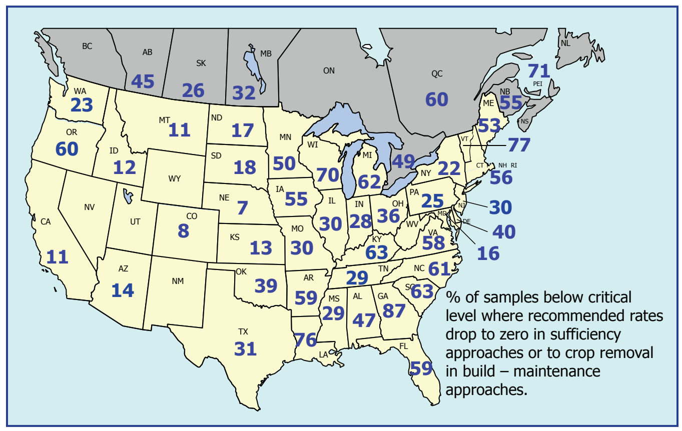


Figure 12. Percent of samples testing below critical levels for K for major crops in 2010.

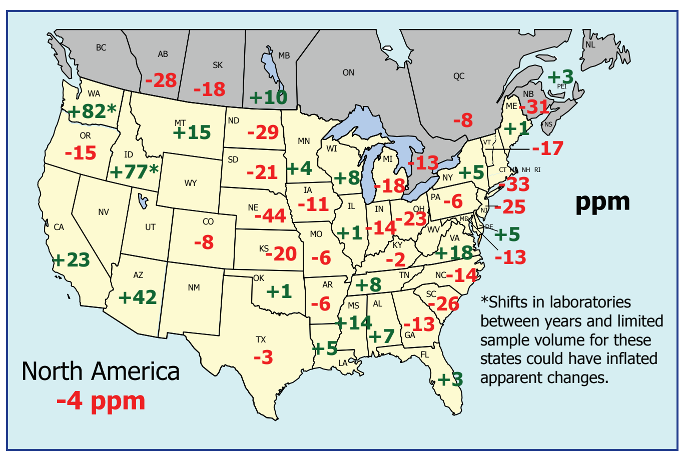


Figure 13. Change in median soil test K levels from 2005 to 2010.

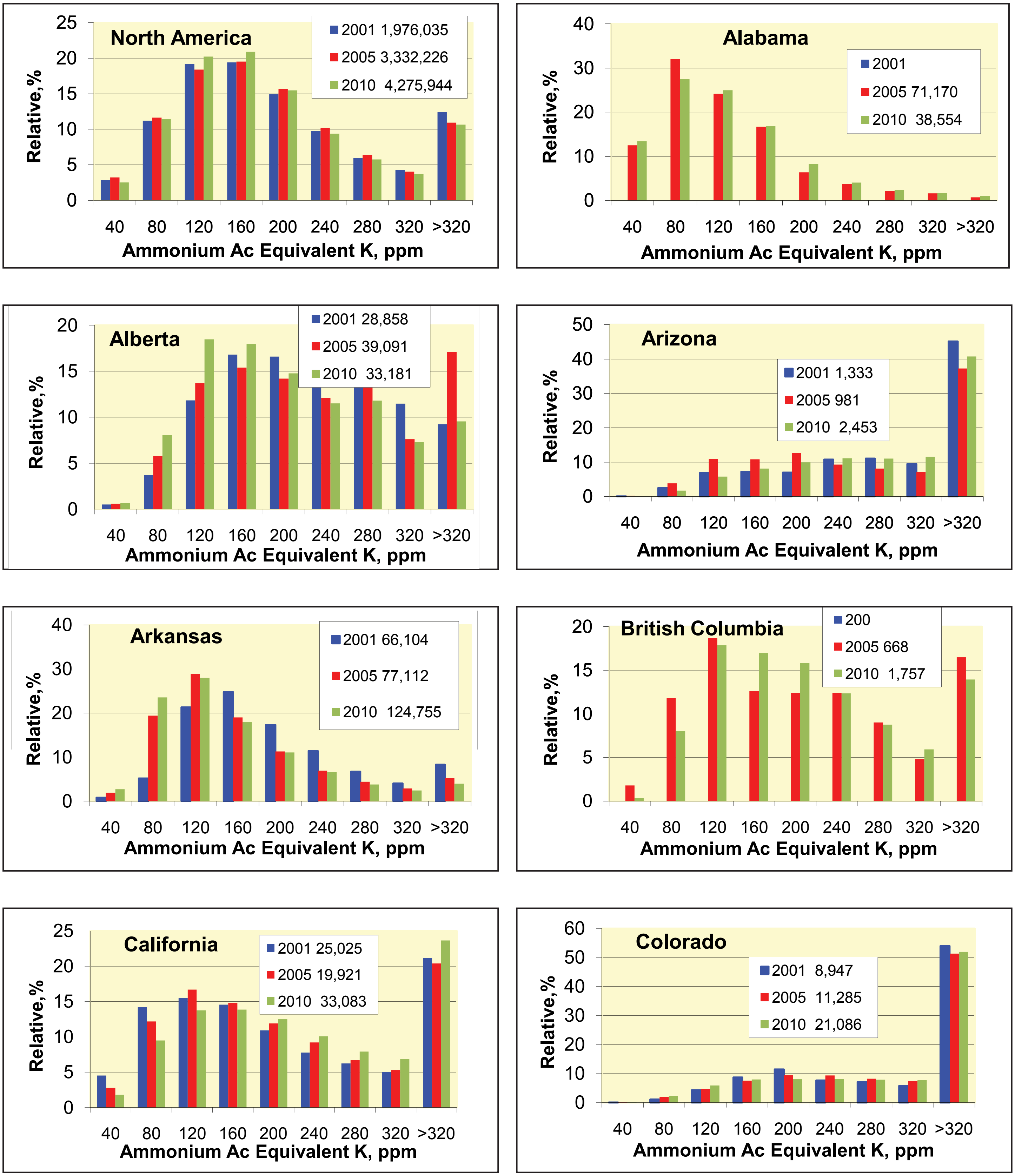
Table 3. Relative frequencies and median soil test K in North America by state or province.

State or province	Samples	0-40	41-80	81-120	121-160	161-200	201-240	241-280	281-320	>320	Critical Level PPM	Critical Level %**	Median 2001	Median 2005	Median 2010
		Ammonium acetate equivalent K, ppm – Relative Frequency %											ppm		
Alabama	38,554	13	27	25	17	8	4	2	2	1	90	47		88	95
Alaska	7	0	0	0	29	0	0	0	29	43					310
Alberta	33,181	1	8	18	18	15	12	12	7	10	160	45	201	201	173
Arizona	2,453	0	2	6	8	10	11	11	12	41	150	14	298	246	288
Arkansas	124,755	3	24	28	18	11	7	4	2	4	130	59	156	120	114
British Columbia	1,757	0	8	18	17	16	12	9	6	14				176	177
California	33,083	2	10	14	14	13	10	8	7	24	80	11	164	172	195
Colorado	21,086	0	2	6	8	8	8	8	8	52	120	8	348	328	320
CT-MA-NH-RI	6,284	9	21	24	19	14	7	3	1	2	125	56	116	146	113
Delaware	10,909	7	23	35	22	8	3	1	1	1	92	40	98	98	103
Florida	4,698	46	25	9	6	5	3	2	1	3	60	59	33	43	46
Georgia	67,219	23	55	16	3	1	1	0	0	1	105	87	63	73	60
Hawaii	669	5	11	11	10	8	6	4	7	38					232
Idaho	35,944	0	2	7	11	13	12	10	8	36	130	12	202	182	259
Illinois	225,322	0	3	13	23	23	17	10	5	7	145	30	149	178	179
Indiana	417,714	1	13	30	27	16	7	3	2	2	100	28	128	144	130
Iowa	720,353	0	4	18	27	21	13	7	3	7	170	55	152	172	161
Kansas	86,628	0	3	7	10	11	11	9	7	42	130	13	332	294	274
Kentucky	65,076	1	16	29	22	14	8	4	2	3	150	63	135	128	126
Louisiana	20,743	5	22	26	17	11	7	5	3	3	180	76	114	110	115
Maine	8,335	5	17	20	23	16	10	5	2	3	140	53	106	134	135
Manitoba	44,787	1	7	11	12	13	12	11	8	24	160	32	282	207	217
Maryland	42,622	6	15	29	24	13	6	3	1	1	66	16	92	132	119
Michigan	188,810	2	15	27	25	16	8	4	2	2	150	62	128	149	131
Minnesota	187,638	0	4	18	28	24	11	6	3	5	160	50	158	156	160
Mississippi	42,214	1	12	21	25	19	11	5	3	3	110	29	158	132	146
Missouri	140,786	1	12	23	23	16	9	5	3	7	110	30	147	150	144
Montana	12,309	0	0	3	8	15	13	14	13	34	160	11	276	259	274
Nebraska	318,665	1	1	4	6	7	8	9	10	55	125	7	362	364	320
Nevada	46	0	0	13	13	7	20	4	11	33	80		256	220	236
New Brunswick	4,858	5	24	32	20	9	4	2	1	2	112	55	131	137	106
New Jersey	5,401	12	18	26	20	11	5	3	2	4	80	30	155	136	111
New Mexico	1,043	0	1	3	4	9	9	9	8	57	130	5	247	229	320
New York	30,474	3	21	33	20	10	5	3	2	2	75	22	106	106	111
Newfoundland	697	16	27	16	16	9	6	9	0	0	90	47		127	98
North Carolina	287,288	4	20	27	23	13	7	3	2	3	140	61		134	120
North Dakota	73,357	0	1	5	11	20	14	15	12	22	160	17	274	265	236
Nova Scotia	6,502	7	27	23	15	11	7	5	3	4	100	45			109
Ohio	247,891	0	7	25	29	20	11	5	2	2	125	36	150	168	145
Oklahoma	26,867	2	15	20	17	13	10	7	4	11	125	39	164	150	151
Ontario	102,096	2	18	29	24	14	7	3	1	2	120	49	132	134	121
Oregon	5,900	1	4	18	20	17	12	9	6	14	200	60	175	192	177
Pennsylvania	59,275	3	13	19	22	16	11	6	4	7	100	25	144	154	148
Prince Edwards Is.	5,104	4	27	37	20	7	2	1	1	0	125	71	102	97	100
Quebec	56,901	10	25	23	16	10	6	4	2	4	125	60	112	114	106
Saskatchewan	27,952	0	4	10	11	13	13	22	11	15	160	26	251	254	236
South Carolina	61,509	29	33	26	7	2	1	1	0	0	80	63		91	65
South Dakota	67,426	0	0	4	13	18	13	11	9	32	160	18	278	268	247
Tennessee	84,986	6	23	30	22	11	4	2	1	1	80	29	99	100	108
Texas	39,910	5	12	10	11	9	8	7	7	32	135	31	232	221	218
Utah	3	0	0	0	0	0	0	100	0	0	150		246	224	260
Vermont	2,171	15	37	23	13	6	3	2	1	2	130	77	73	96	79
Virginia	71,701	15	32	24	14	7	4	2	1	2	100	58		68	86
Washington	2,419	0	2	3	7	11	12	13	13	40	200	23	237	207	289
West Virginia	1,197	8	14	21	18	17	9	5	3	5	60	15		92	135
Wisconsin	99,338	1	14	27	24	15	9	4	2	3	170	70	111	125	133
Wyoming	1,031	0	6	14	17	14	13	10	7	19	120	20	188	145	195
North America	4,275,944	2.5	11.4	20.2	20.9	15.5	9.4	5.8	3.7	10.6			154	154	150
Corn Belt*	2,867,743	0.6	7.4	19.6	22.9	17.5	10.5	6.1	3.8	11.8					159

*Corn Belt = IL, IN, IA, KS, KY, MI, MN, MO, NE, OH, ON, SD, WI.

**Percent of samples testing below the indicated crtical level.

Figure 11. Soil test K frequency distribution in 2001, 2005, and 2010 (sample volume >1,000 in 2010).



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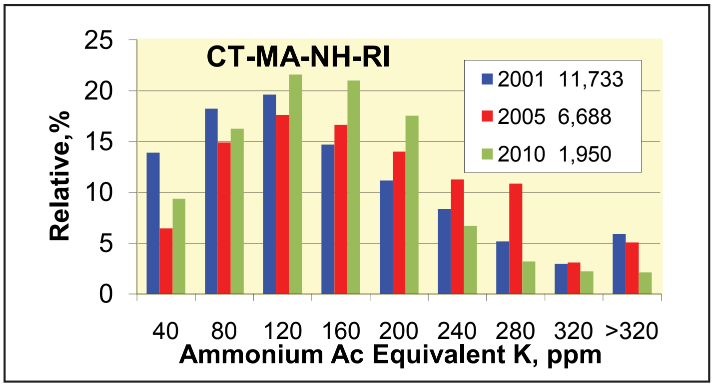

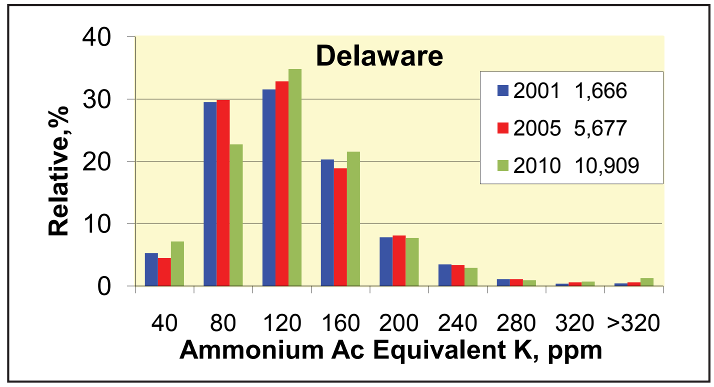

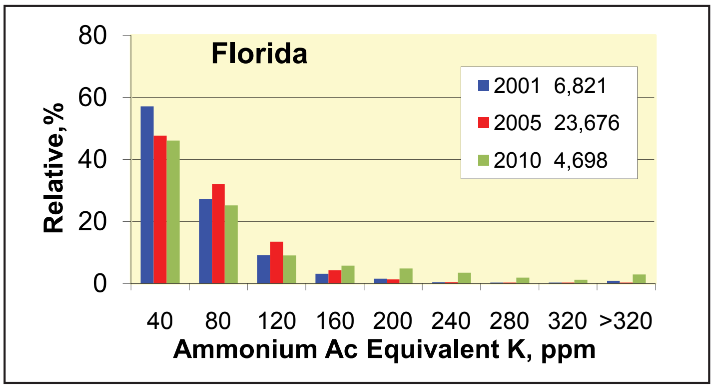

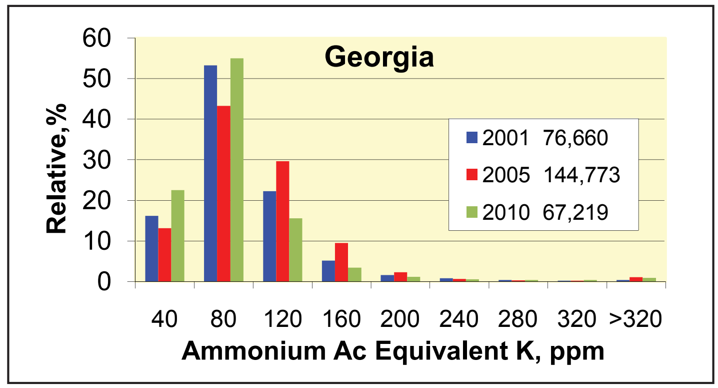

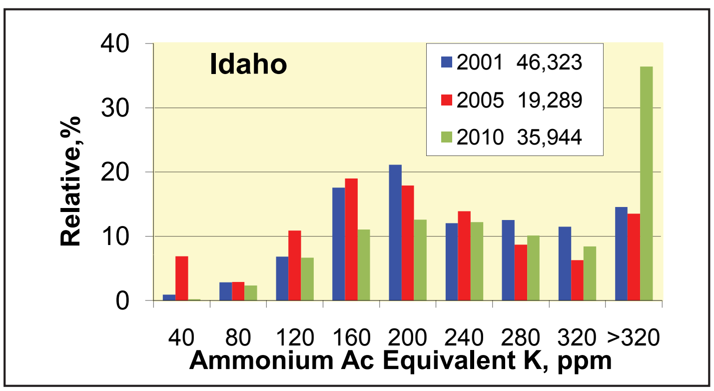

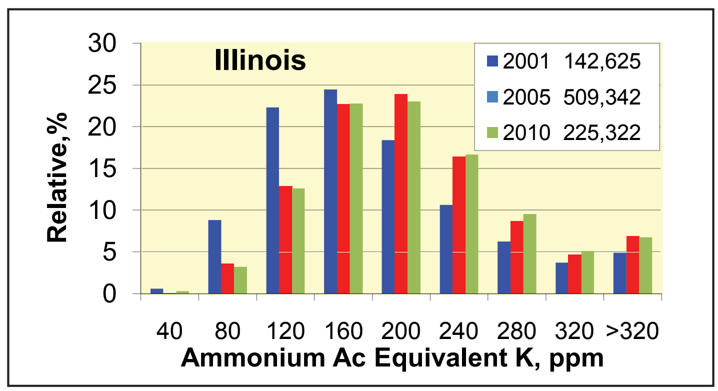

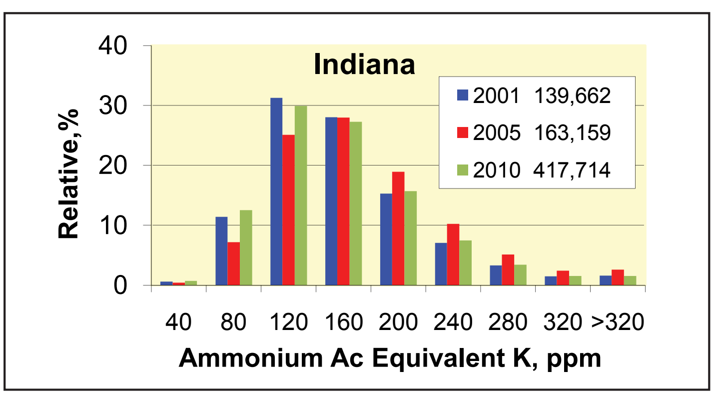

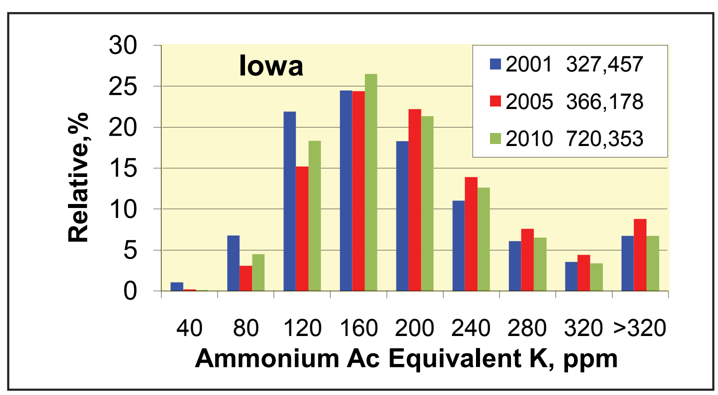

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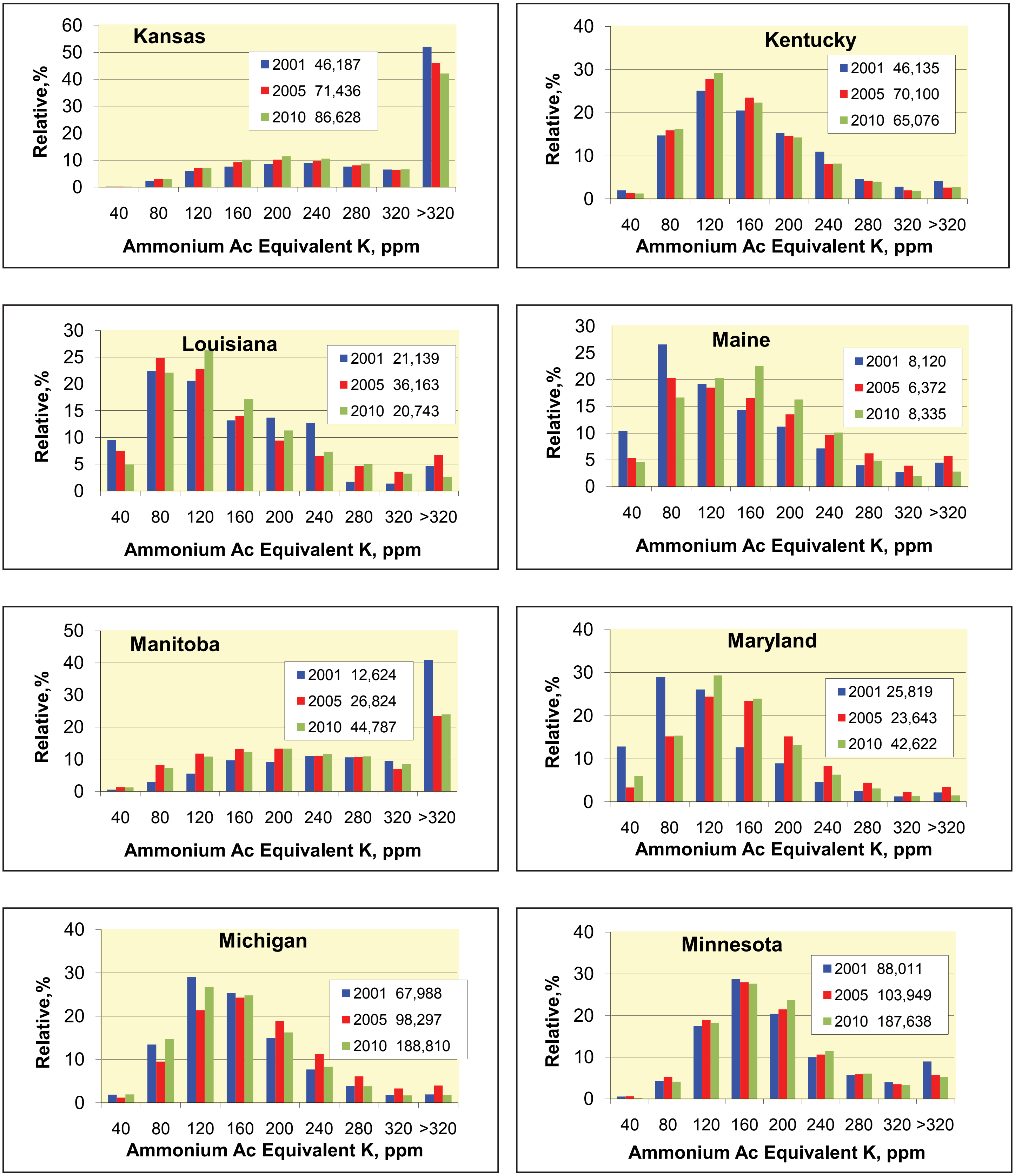

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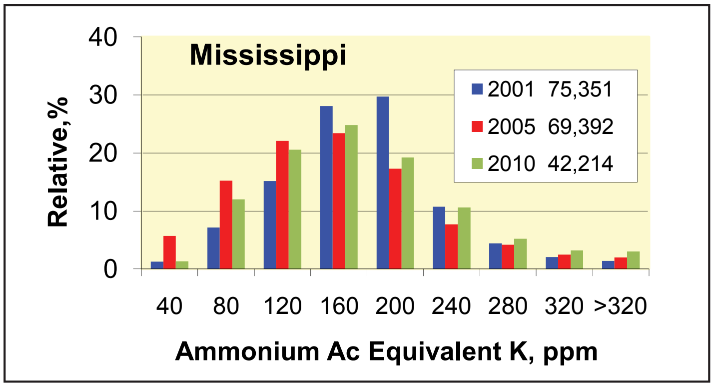

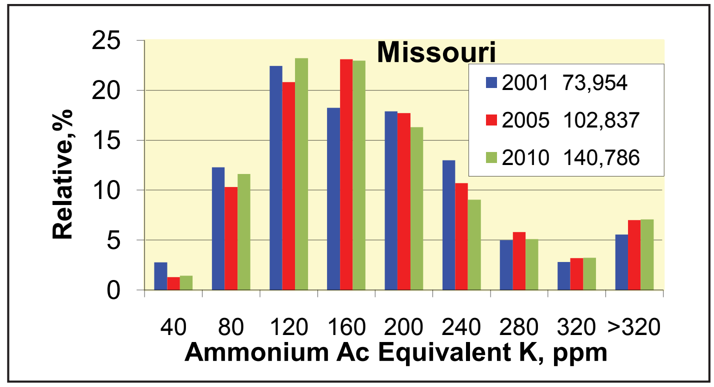

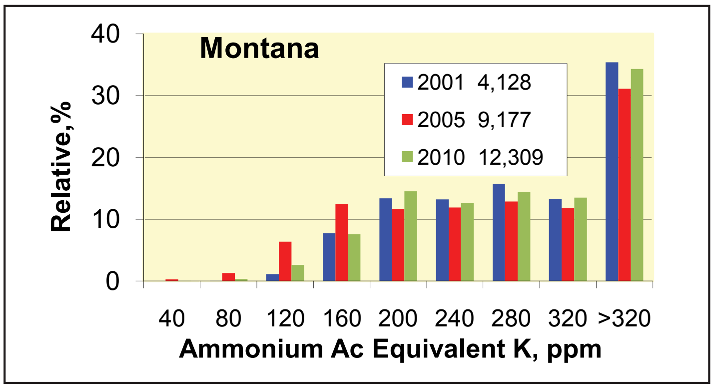

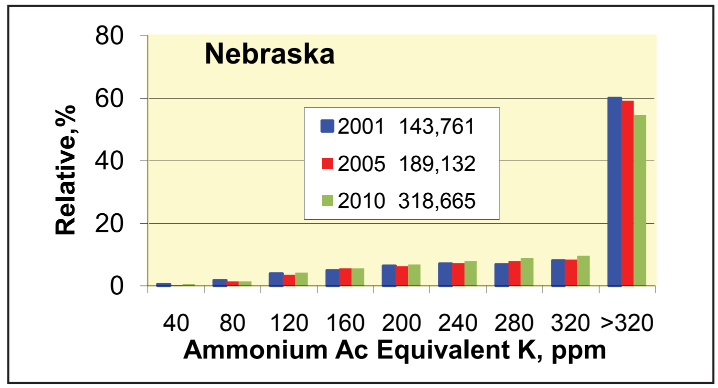

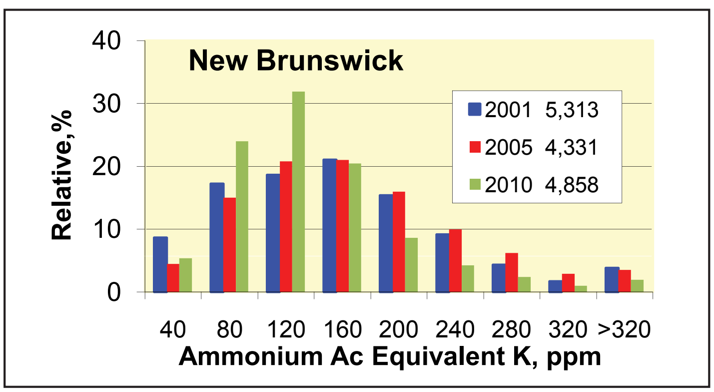

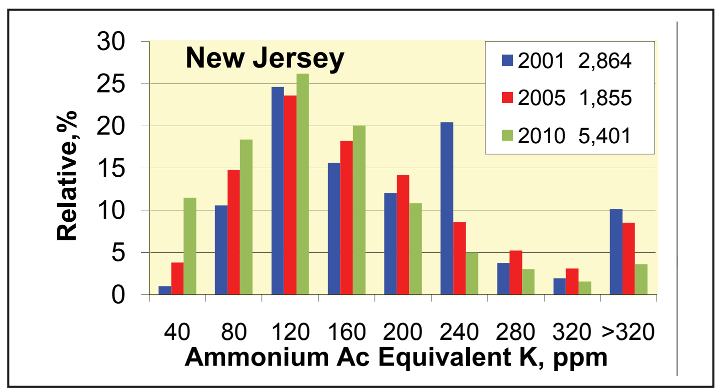

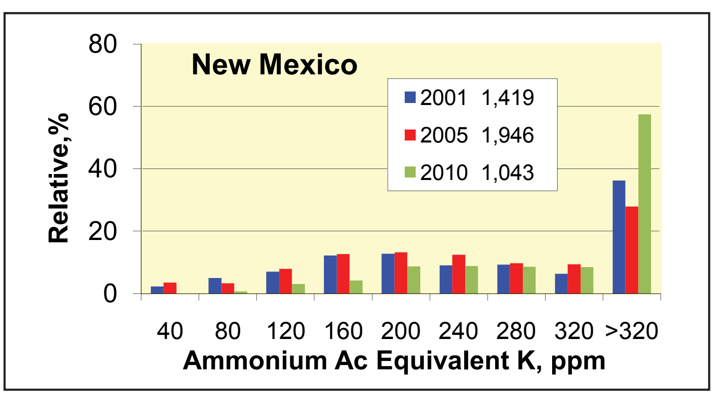

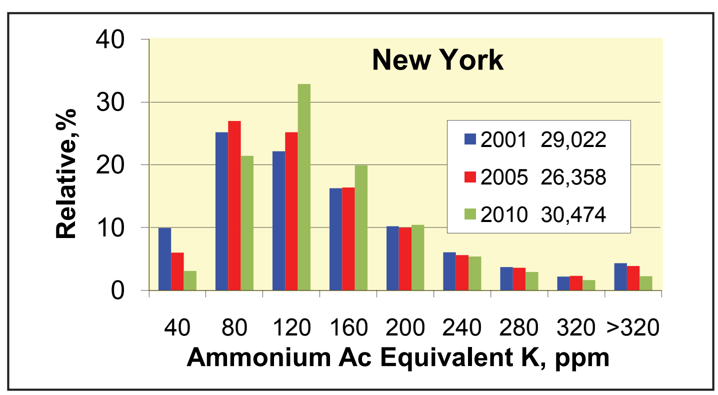

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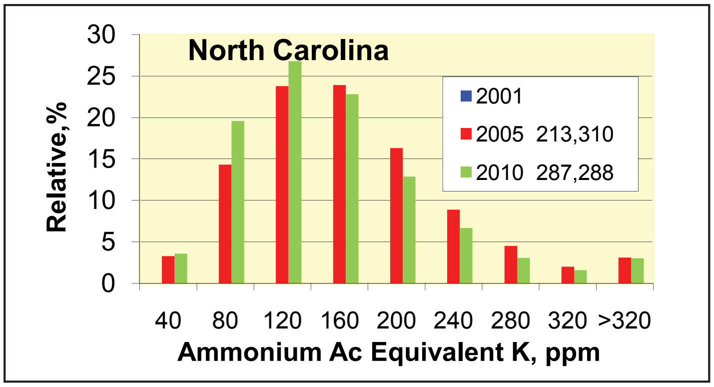

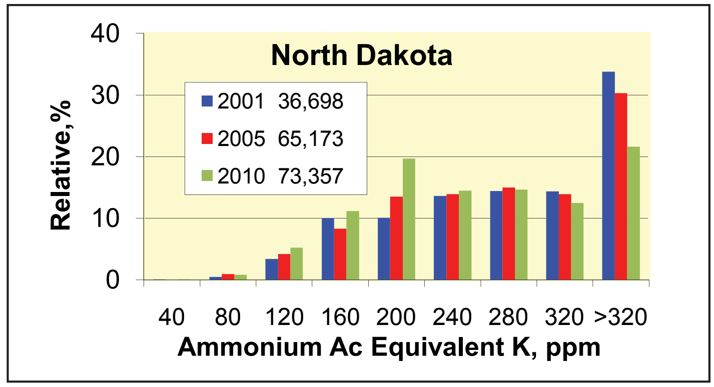

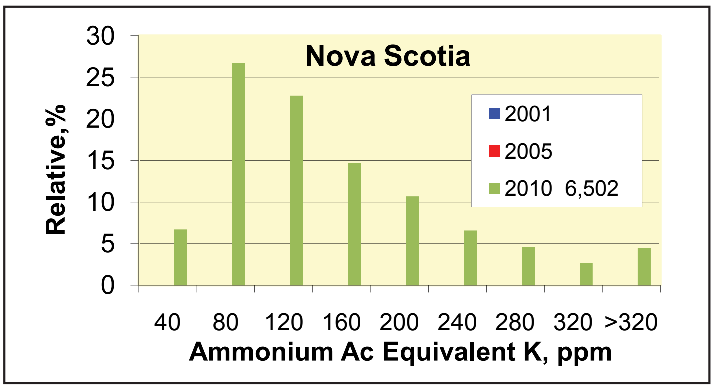

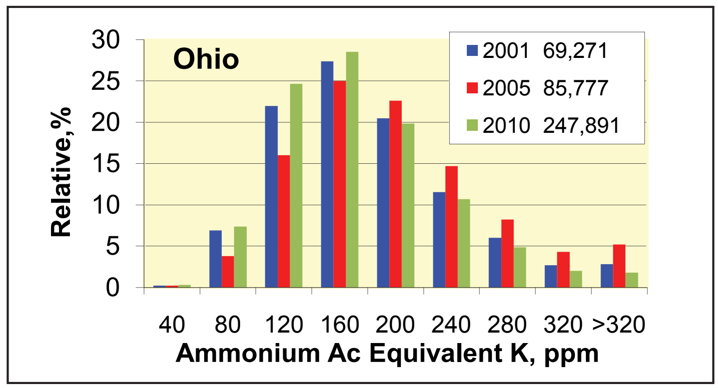

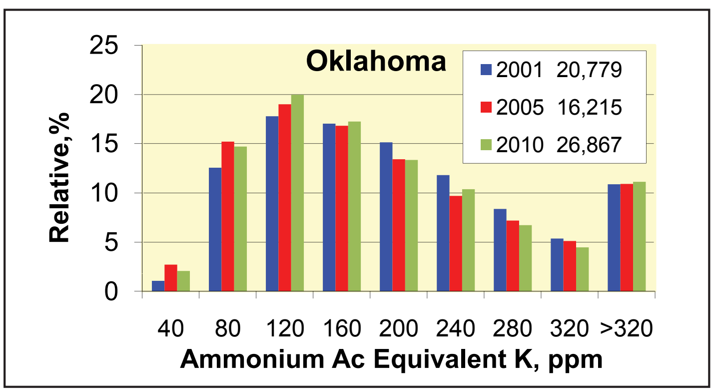

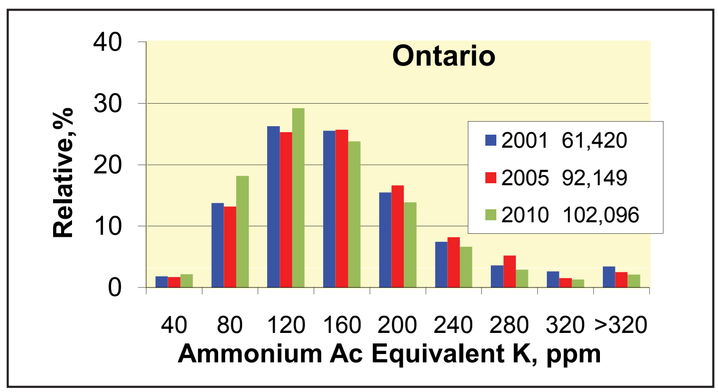

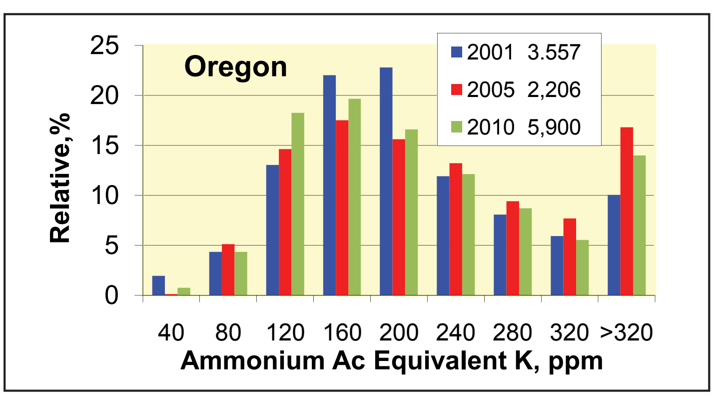

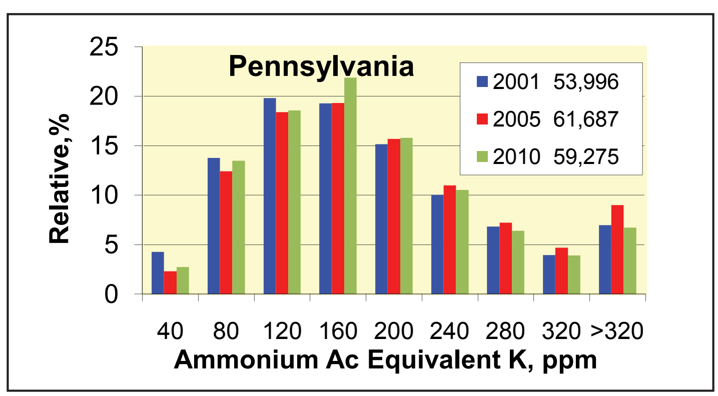

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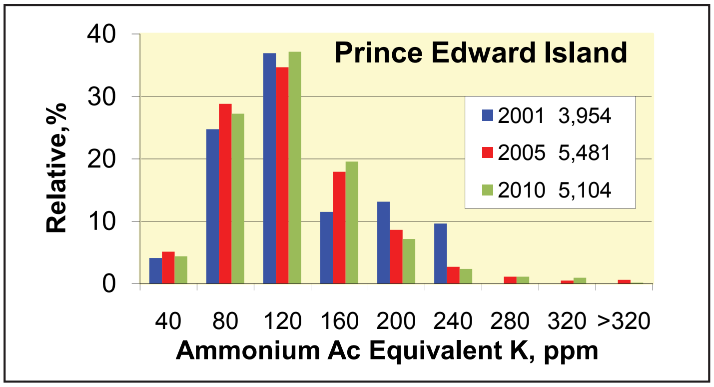

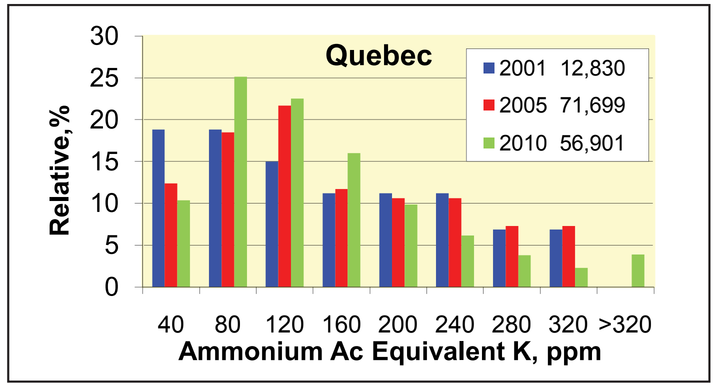

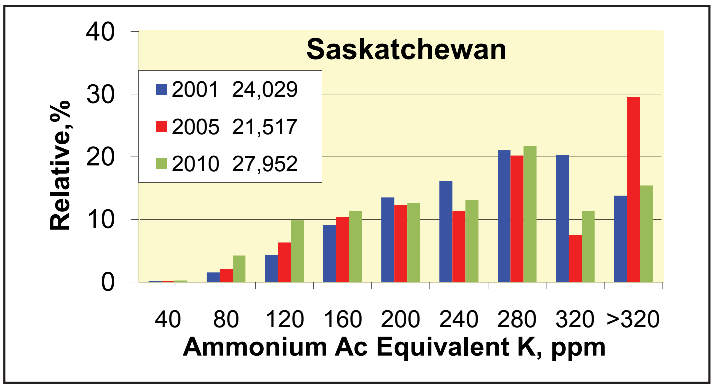

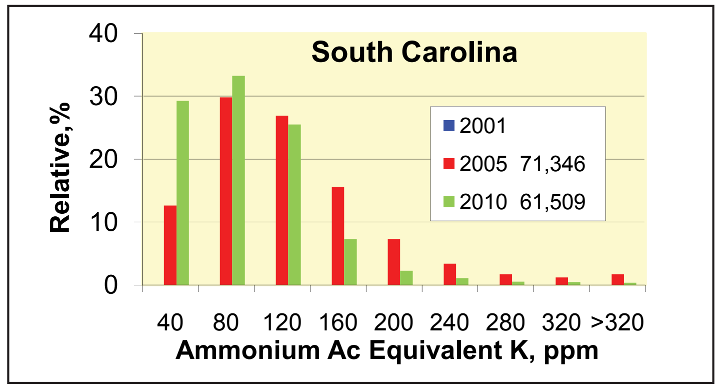

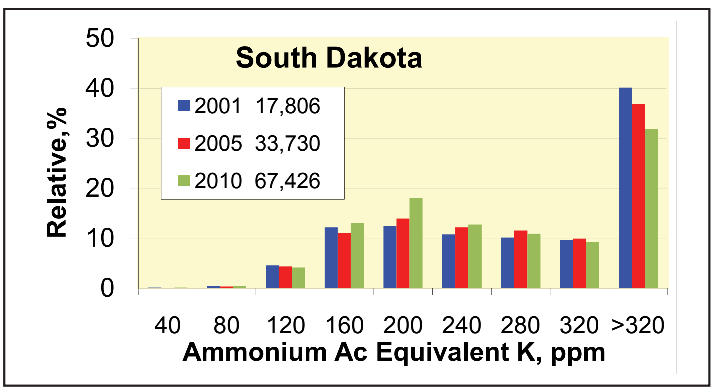

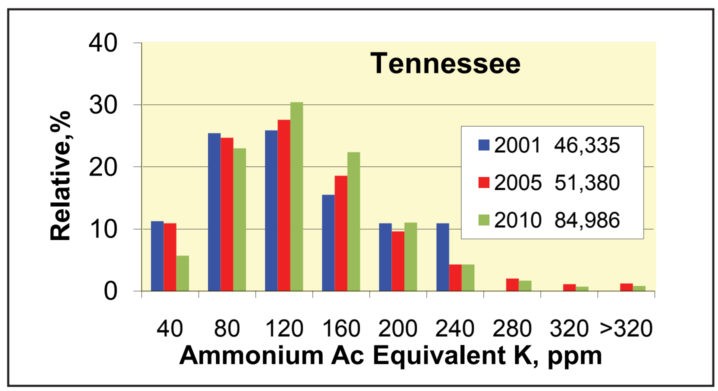

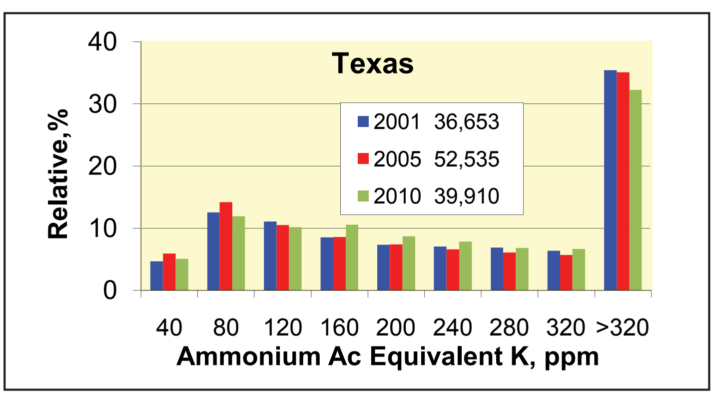

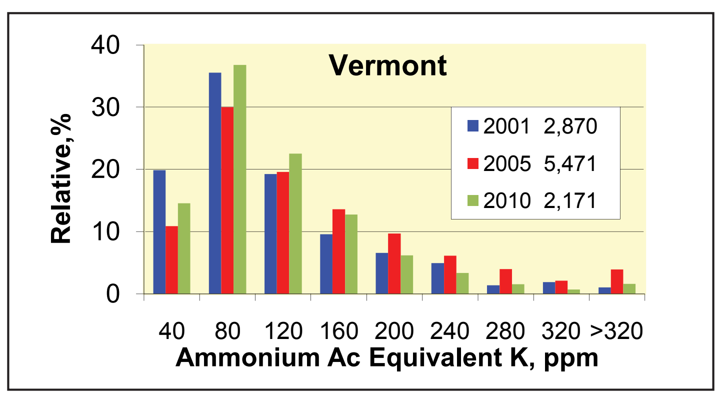

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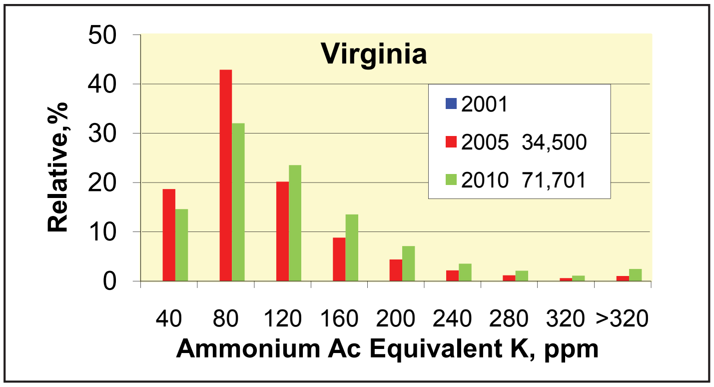
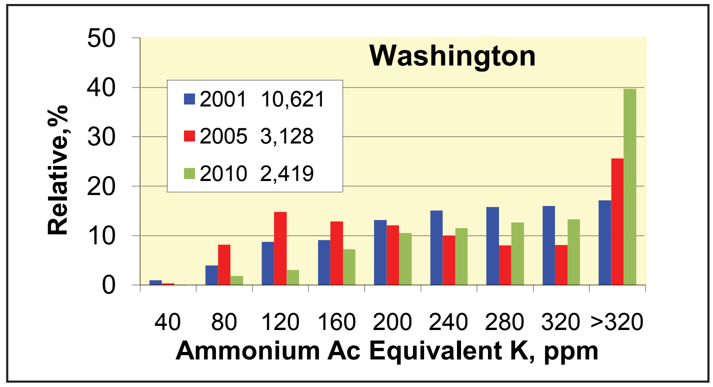
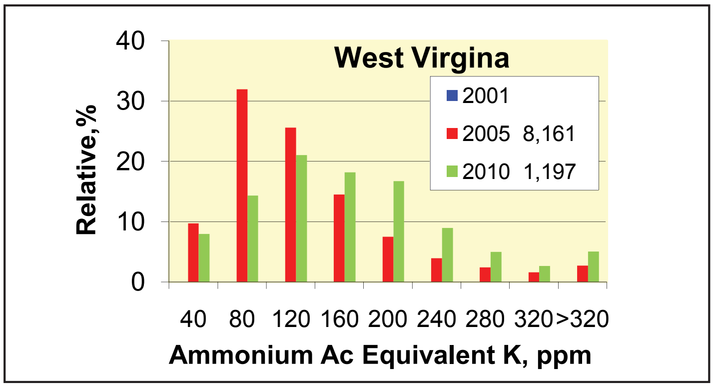
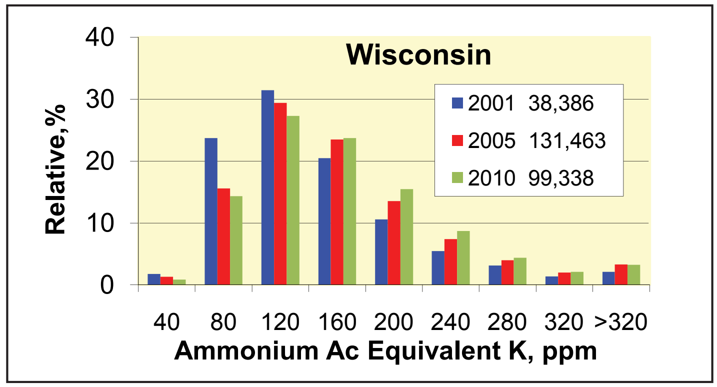
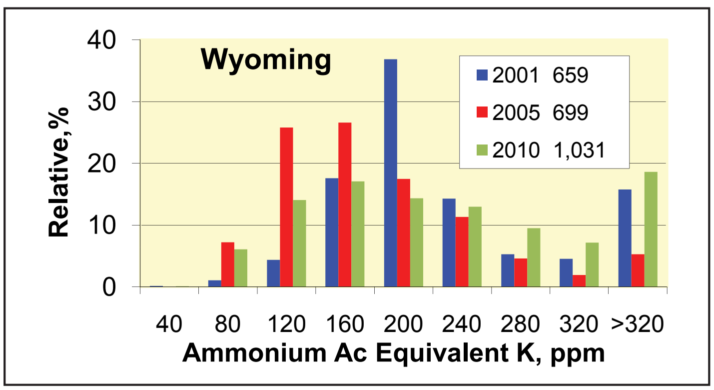










Soil Acidity

Liming to neutralize soil acidity has long been recognized as one of the foundations of crop production. Increasing soil pH by liming provides a means of improving N fixation by legumes, improves the availability of other nutrients such as P and most of the micronutrients, lowers the toxicity of Al and Mn, provides additional amounts of Ca and Mg, and enhances the activity of several classes of herbicides. Intensive cropping and the addition of ammonium forms of N to the soil as commercial fertilizer, legume residues, or manure tend to produce soil acidity.

The median pH for NA is 6.4 compared to 6.3 in 2005 and identical to the 2001 NA median pH **(Table 4; Figure 14)**. In 2010, 27% of the samples tested <6.0. A pH of 6.0 is highlighted because a pH above 6.0 is desirable for most cropping systems. Median pH is lowest in far eastern NA and generally increases toward the west **(Figure 14)**. Median levels above, but near, 6.0 indicate that close to half of the surveyed population of tests in those states and provinces were acid enough that lime applications should be thoughtfully evaluated.

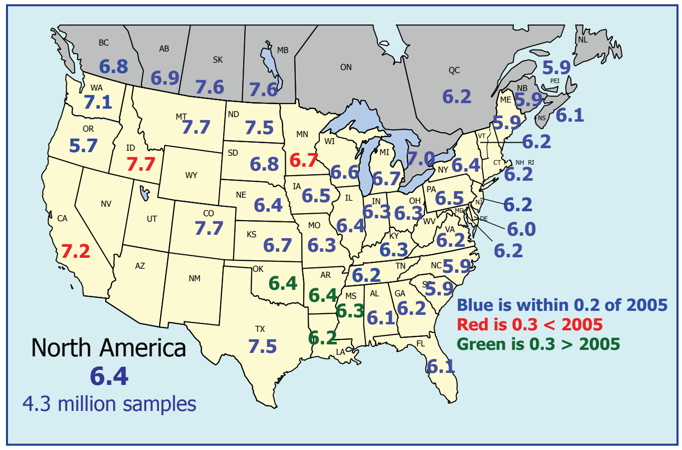


Figure 14. Median soil pH in 2010 and change from 2005 (for states and provinces with at least 2,000 pH tests).

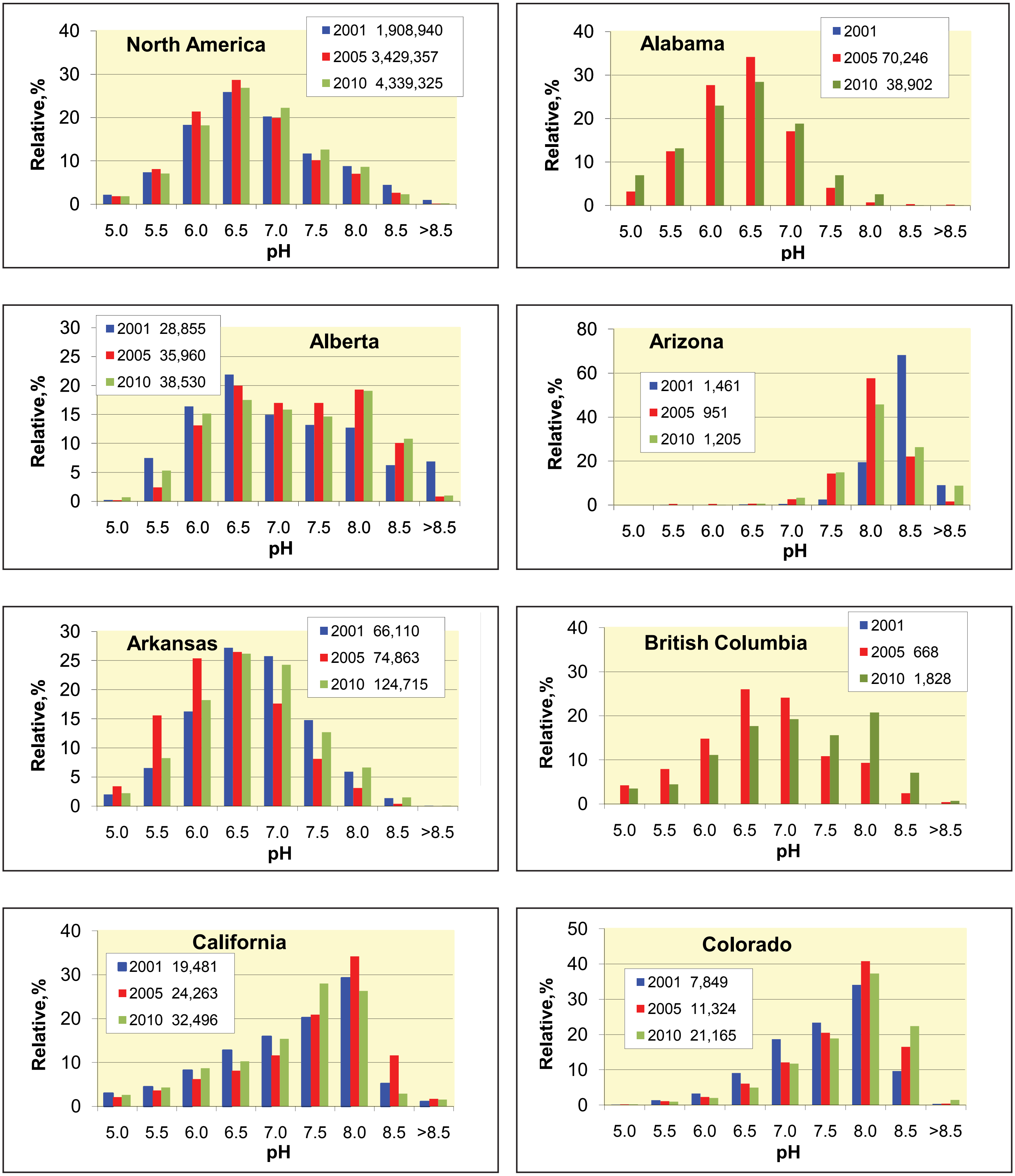
The pH frequency distributions for the 3 years for North America as a whole are quite similar **(Figure 15,** page 29). The map of pH changes indicates, with few exceptions, that state or province medians were very stable over this 5-year period **(Figure 14)**.

Table 4. Relative frequencies and median soil pH in North America by state or province.

State or province	Samples	Soil pH range (water, 1:1) ≤5.0	5.1-5.5	5.6-6.0	6.1-6.5	6.6-7.0	6.1-7.5	6.6-8.0	8.1-8.5	>8.5	**≤6.0**	Median pH 2001	2005	2010
		Relative Frequency, %												
Alabama	38,902	7	13	23	28	19	7	3	0	0	**43**		6.1	6.1
Alaska	7	0	0	0	0	0	29	71	0	0	**0**			7.7
Alberta	38,530	1	5	15	18	16	15	19	11	1	**21**	6.6	6.9	6.9
Arizona	1,205	0	0	0	1	3	15	46	26	9	**0**	8.2	7.8	7.8
Arkansas	124,715	2	8	18	26	24	13	7	1	0	**29**	6.5	6.1	6.4
British Columbia	1,828	4	4	11	18	19	16	21	7	1	**19**		6.4	6.8
California	32,496	3	4	9	10	15	28	26	3	2	**16**	7.2	7.5	7.2
Colorado	21,165	0	1	2	5	12	19	37	22	1	**3**	7.4	7.6	7.7
CT-MA-NH-RI	6,284	2	9	23	34	25	6	0	0	0	**35**	6.1	6.2	6.2
Delaware	10,935	3	11	36	38	10	2	0	0	0	**51**	6.0	6.0	6.0
Florida	4,839	12	13	19	19	15	10	7	4	0	**44**	5.9	6.1	6.1
Georgia	67,233	3	8	24	37	22	4	1	1	0	**35**	6.1	6.1	6.2
Hawaii	663	6	5	13	17	16	14	20	9	1	**23**			6.8
Idaho	35,891	1	2	5	8	9	15	28	27	7	**7**	8.2	8.0	7.7
Illinois	231,172	1	4	17	34	30	10	3	0	0	**22**	6.3	6.3	6.4
Indiana	444,478	1	6	20	34	26	11	3	0	0	**26**	6.3	6.3	6.3
Iowa	715,502	0	5	16	29	27	14	8	1	0	**21**	6.4	6.4	6.5
Kansas	86,118	2	8	16	17	16	18	17	5	0	**26**	6.8	6.8	6.7
Kentucky	65,081	2	8	19	32	28	9	1	0	0	**29**	6.3	6.3	6.3
Louisiana	20,571	3	12	23	28	19	8	5	2	0	**39**	6.1	5.9	6.2
Maine	8,335	3	22	35	24	10	5	1	0	0	**60**	6.0	6.0	5.9
Manitoba	46,296	1	4	8	8	9	15	33	19	2	**13**	7.6	7.8	7.6
Maryland	42,723	2	8	25	37	24	4	0	0	0	**35**	6.2	6.2	6.2
Michigan	204,988	1	4	13	23	25	20	13	1	0	**19**	6.5	6.6	6.7
Minnesota	185,093	1	5	14	20	19	14	19	7	0	**20**	6.9	7.0	6.7
Mississippi	42,698	3	11	21	25	25	11	3	0	0	**35**	6.0	6.0	6.3
Missouri	129,779	3	7	19	30	25	11	5	1	0	**29**	6.2	6.3	6.3
Montana	11,805	0	1	3	5	9	19	39	23	1	**4**	7.8	7.9	7.7
Nebraska	334,319	2	9	20	23	20	14	9	3	0	**31**	6.3	6.4	6.4
Nevada	46	0	0	2	7	28	20	33	7	4	**2**	7.5	7.8	7.3
New Brunswick	4,800	4	15	41	29	9	2	0	0	0	**60**	5.8	5.7	5.9
New Jersey	5,505	3	12	21	33	23	6	2	0	0	**36**	6.2	6.2	6.2
New Mexico	1,512	0	0	1	2	4	13	53	23	4	**1**	7.9	7.9	7.8
New York	30,505	1	7	19	30	28	13	2	0	0	**27**	6.4	6.4	6.4
Newfoundland	697	25	20	20	24	9	1	0	0	0	**65**		5.8	5.6
North Carolina	287,302	7	17	32	32	9	2	0	0	0	**56**		5.9	5.9
North Dakota	72,441	0	0	3	7	15	26	40	8	0	**3**	7.5	7.6	7.5
Nova Scotia	6,502	7	10	25	32	21	5	1	0	0	**42**			6.1
Ohio	254,887	1	7	22	31	24	11	3	0	0	**30**	6.3	6.4	6.3
Oklahoma	27,154	7	12	18	17	14	13	14	4	0	**37**	6.1	6.1	6.4
Ontario	101,973	1	2	8	18	20	27	23	1	0	**11**	6.9	7.1	7.0
Oregon	6,014	11	25	34	18	9	2	1	0	0	**69**	5.6	5.8	5.7
Pennsylvania	59,314	2	5	15	29	35	13	2	0	0	**22**	6.4	6.5	6.5
Prince Edwards Is.	5,102	2	14	47	30	6	1	0	0	0	**63**	5.8	5.8	5.9
Quebec	47,356	5	9	22	32	21	9	2	0	0	**35**	6.1	6.2	6.2
Saskatchewan	31,091	0	0	3	7	11	19	37	21	2	**3**	7.7	7.6	7.6
South Carolina	61,506	7	18	29	25	14	5	1	0	0	**53**		6.0	5.9
South Dakota	67,391	0	3	12	20	23	22	17	3	0	**15**	6.9	7.0	6.8
Tennessee	84,965	2	11	23	30	23	8	2	0	0	**37**	6.1	6.1	6.2
Texas	41,240	4	6	8	8	8	13	32	20	1	**18**	7.5	7.4	7.5
Utah	3	0	0	0	0	0	0	100	0	0	**0**	7.6	8.0	7.8
Vermont	2,171	2	11	24	29	23	9	2	0	0	**36**	6.5	6.0	6.2
Virginia	71,954	3	10	24	36	20	5	1	0	0	**37**		6.2	6.2
Washington	2,419	2	4	7	13	20	22	22	9	1	**13**	6.8	6.9	7.1
West Virginia	1,194	5	14	23	29	18	5	2	1	2	**43**		5.9	6.1
Wisconsin	109,447	1	5	14	22	28	23	6	0	0	**21**	6.6	6.6	6.6
Wyoming	1,183	0	0	1	1	3	13	47	29	5	**1**	7.7	8.0	7.8
North America	4,339,325	1.9	7.1	18.2	26.9	22.2	12.6	8.6	2.3	0.2	**27.2**	6.4	6.3	6.4
Corn Belt*	2,930,228	1.0	5.7	17.0	27.7	24.8	14.1	8.2	1.4	0.0	**23.8**			6.5

*Corn Belt = IL, IN, IA, KS, KY, MI, MN, MO, NE, OH, ON, SD, WI.

Figure 15. Soil pH frequency distribution in 2001, 2005, and 2010 (sample volume >1,000 in 2010).



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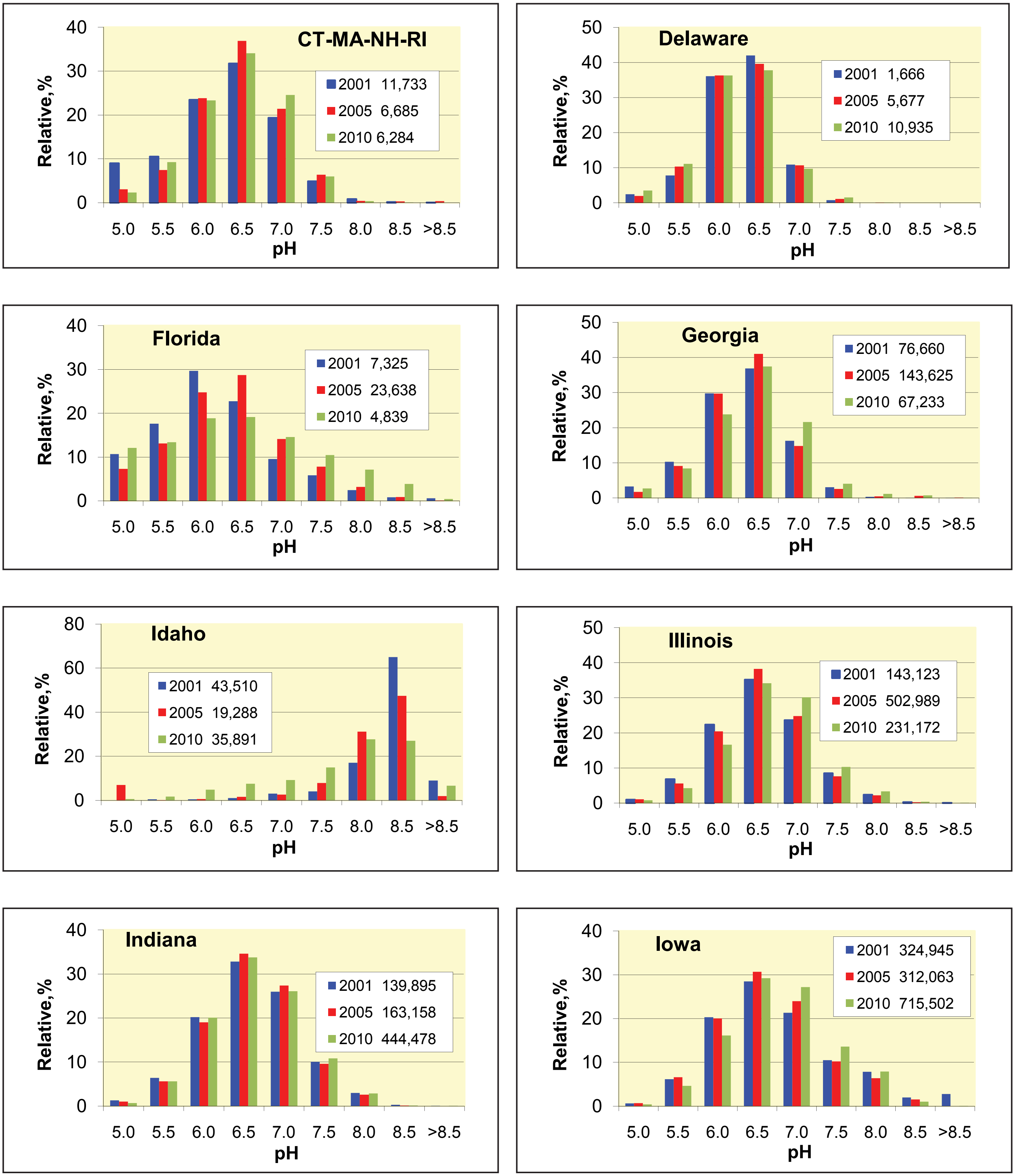

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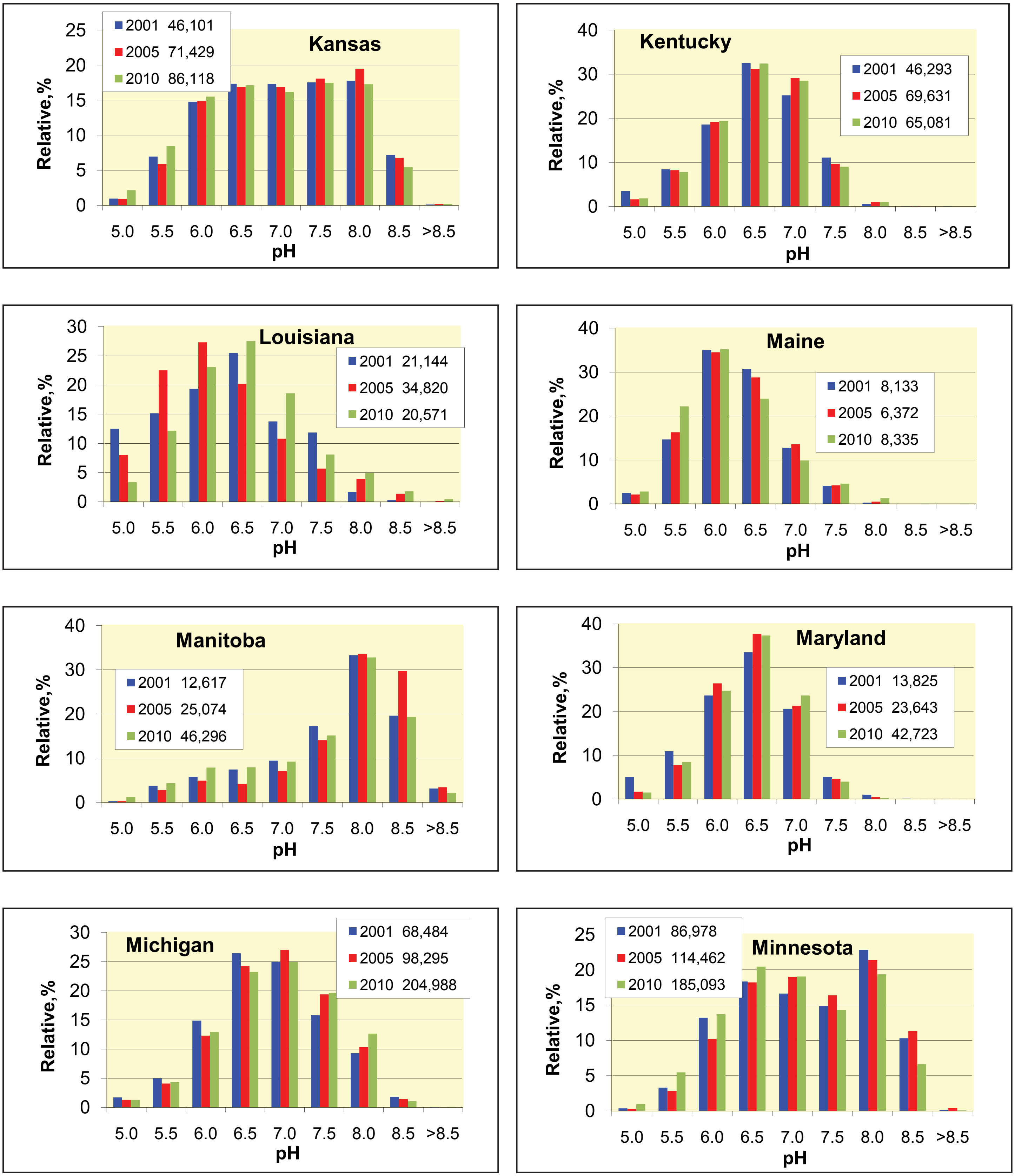

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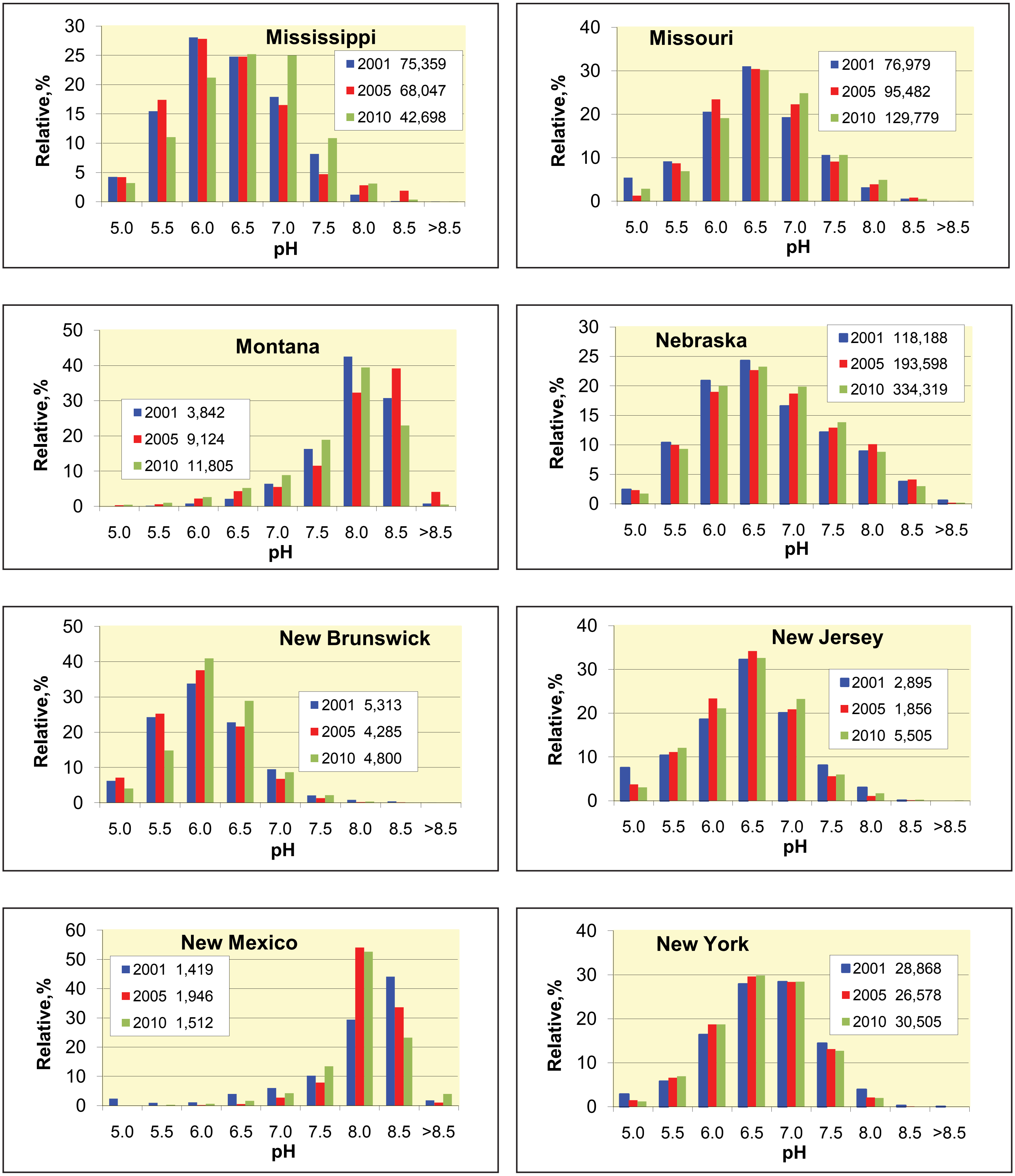

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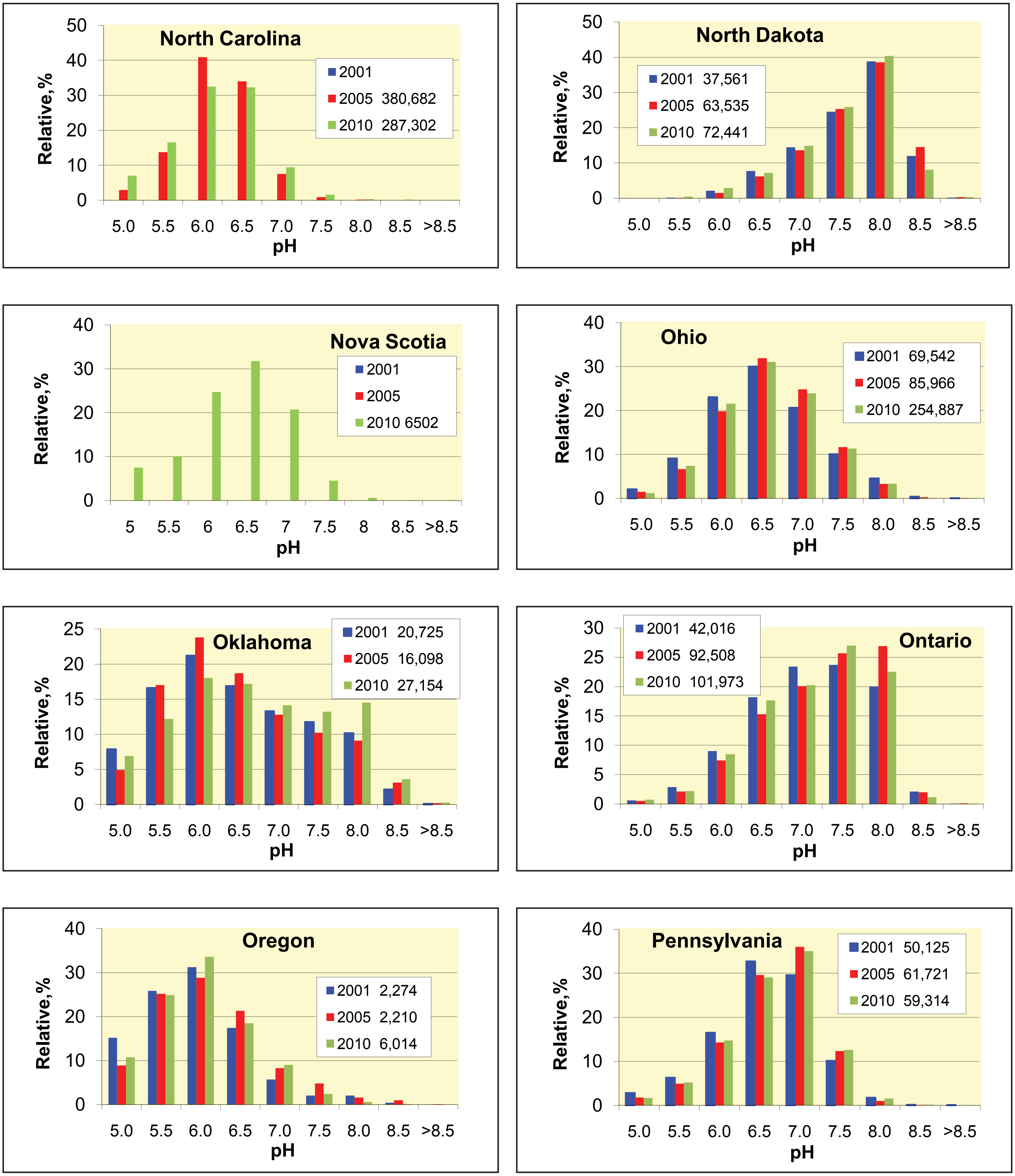

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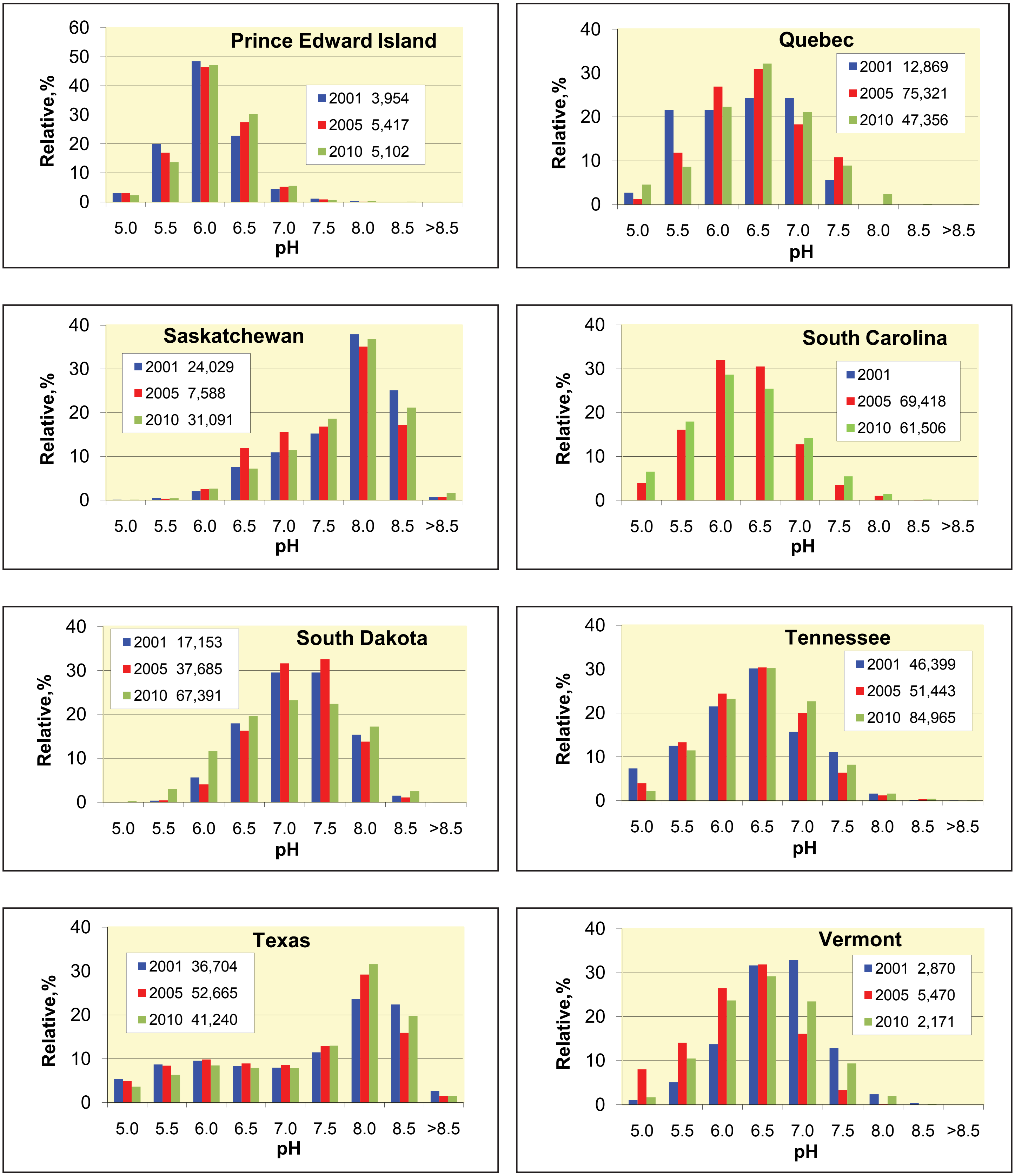

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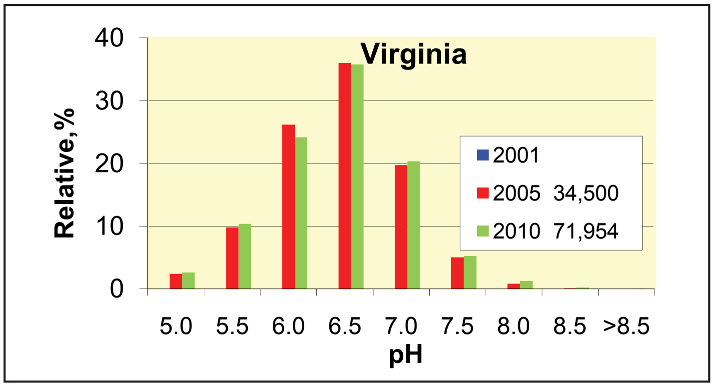

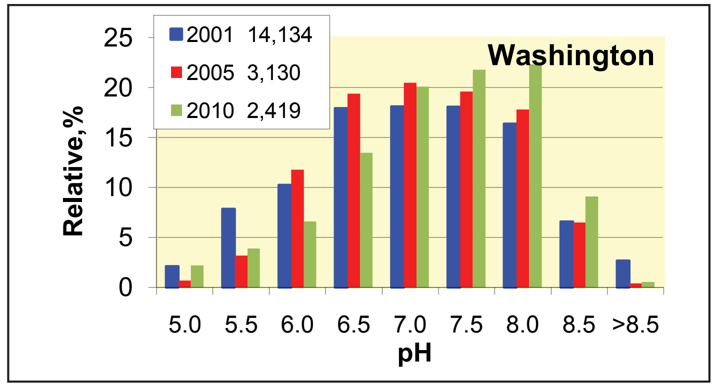

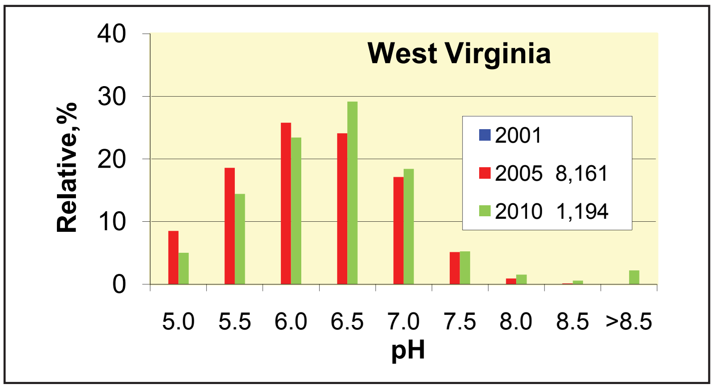

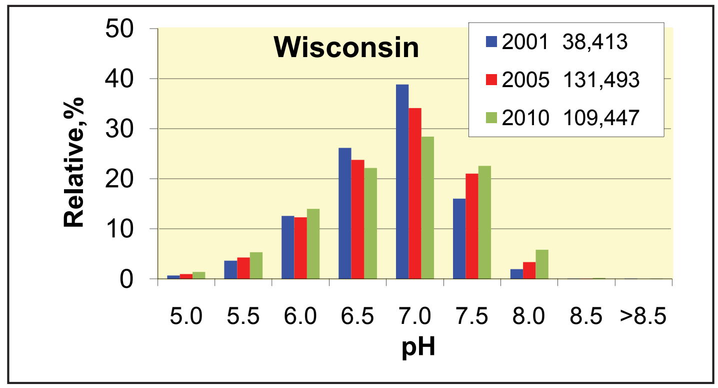

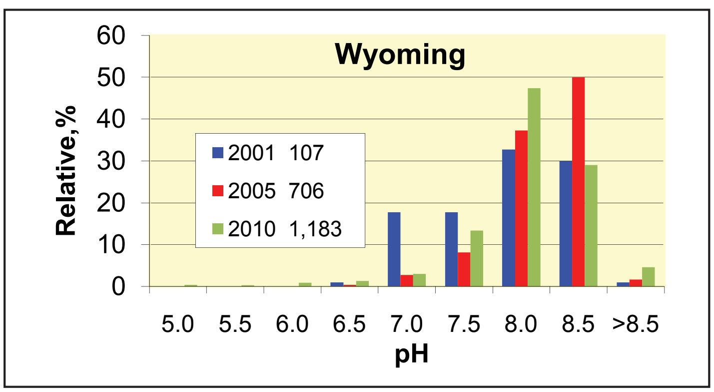

Frequency distributions for Mg are reported in **Table 5**. As expected based on soil pH and mineralogy, Mg levels are generally lowest in the Southeast. However, a significant occurrence of lower Mg levels is also shown in the Northeast.

Sulfur was analyzed on 2.5 million soil samples in the summary with 13% testing less than 3 ppm calcium phosphate equivalent S (6 ppm Mehlich 3 S) compared to only 4% testing below this level in 2005 (**Table 6; Figure 16**). This level of soil S should not be interpreted as a critical level, but just to help identify areas with the highest frequency of low levels. Some of the highest frequencies of low S occurred in the western Corn Belt and central Great Plains, regions where reports of S deficiency in crops have been increasing.

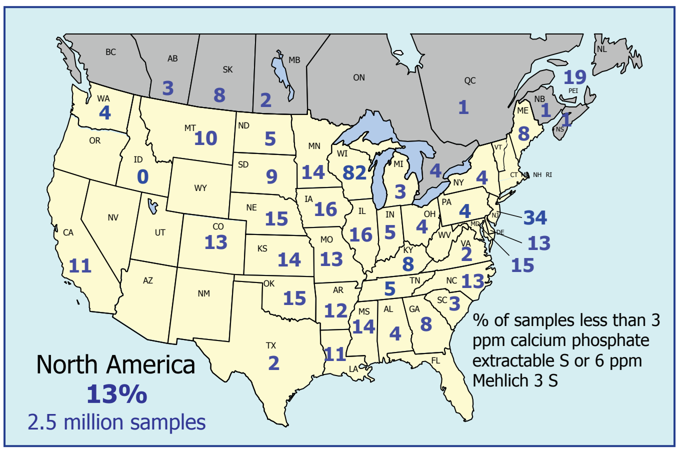

Figure 16. Percent of soils testing less than 3 ppm S in 2010 (for states and provinces with at least 2,000 S tests).

This was the first Institute summary where the surveyed number of Zn soil tests was large enough to justify reporting. Of the 1.4 million Zn tests received, 37% were less than 1 ppm DTPA equivalent and 16% were less than 0.5 ppm (**Table 7; Figure 17**). A critical level for this test is often considered to be near 1 ppm, but considerable variation exists among crops and soils. The summary indicates that many soils in NA should be responsive to Zn application, especially for Zn sensitive crops (**Figure 17**).

Of the total number of samples submitted to the survey, about one quarter contained Zn soil test information. This may have been due to either fewer customer requests for this analysis or fewer laboratories opting to report the results in the survey. However, Zn soil tests are often requested when insufficiency is suspected, so it may be that the survey results are biased toward lower levels.

Chloride levels are determined primarily on samples from the northern Great Plains where Cl^- responsive crops are grown on low Cl^- soils (**Table 8; Figure 18**). These tests show a high frequency of low Cl^- levels.

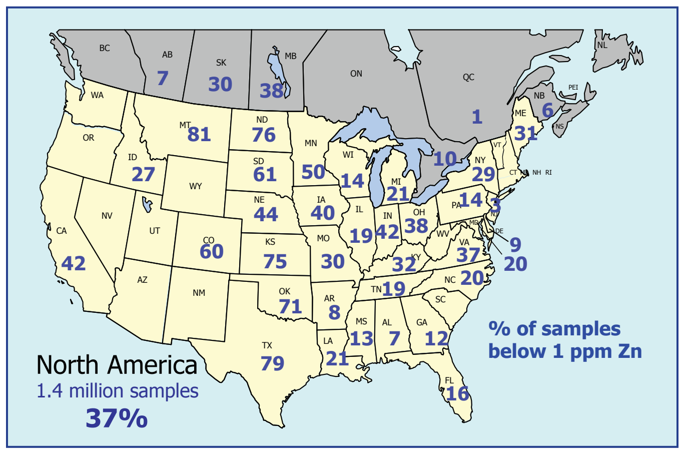

Figure 17. Soil samples testing less than 1.0 ppm DTPA equivalent Zn in 2010 (for states and provinces with at least 2,000 Zn tests).

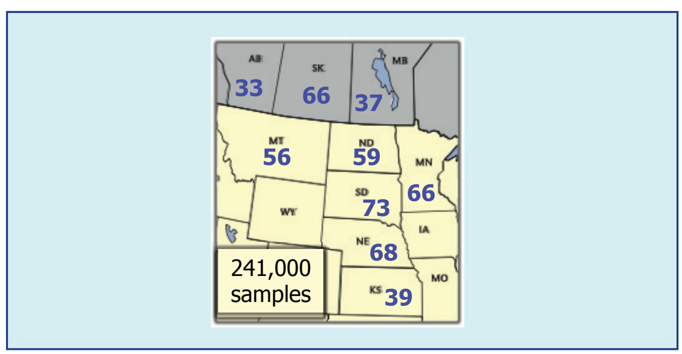

Figure 18. Percent of soils testing less than 4 ppm Cl^-.

Table 5. Relative frequencies for soil test Mg in North America by state or province.

State or Province	Samples	Ammonium acetate quivalent Mg, ppm: 0-25	26-50	51-75	76-100	>100	<75
		Relative frequency, %					
Alabama	10,707	2	15	29	25	30	46
Alberta	635	0	1	7	14	77	9
Arizona	677	0	0	2	4	93	2
Arkansas	124,704	0	3	6	8	82	9
British Columbia	183	0	5	11	19	64	17
California	18,155	1	1	2	3	93	4
Colorado	18,632	0	0	2	4	95	2
CT-MA-NH-RI	6,284	1	7	11	13	69	19
Delaware	10,908	1	9	20	21	49	30
Florida	4,645	15	20	17	12	36	52
Georgia	5,452	5	19	16	10	50	40
Hawaii	669	0	2	4	3	90	6
Idaho	33,713	0	0	1	2	96	1
Illinois	206,865	0	0	1	2	97	1
Indiana	220,824	0	1	3	5	91	4
Iowa	427,053	0	0	0	0	99	0
Kansas	55,924	0	1	3	3	93	4
Kentucky	65,080	0	4	15	25	57	19
Louisiana	20,743	0	2	7	9	83	9
Maine	8,335	1	8	18	21	52	27
Manitoba	15,801	0	0	0	0	100	0
Maryland	42,623	0	4	10	14	72	14
Michigan	162,108	0	3	7	10	80	10
Minnesota	123,154	0	0	0	1	98	1
Mississippi	29,661	1	7	9	7	77	16
Missouri	140,691	0	1	3	4	92	4
Montana	2,582	0	0	0	0	100	0
Nebraska	250,079	0	1	2	3	93	4
Nevada	46	0	0	0	4	96	0
New Brunswick	1,994	4	8	16	19	53	28
New Jersey	5,401	1	6	11	14	68	18
New Mexico	1,065	28	9	3	2	59	39
New York	30,480	0	1	3	6	89	5
Newfoundland	697	5	7	8	6	74	21
North Carolina	9,007	7	18	17	12	46	41
North Dakota	6,388	0	0	0	0	100	0
Nova Scotia	6,434	2	4	3	5	86	10
Ohio	146,137	0	0	1	1	98	1
Oklahoma	8,543	0	2	6	9	82	9
Ontario	48,798	0	1	4	6	89	5
Oregon	5,271	0	1	2	4	93	3
Pennsylvania	42,343	0	1	3	6	90	4
Prince Edwards Is.	4,769	2	34	24	19	21	61
Quebec	39,946	5	8	11	12	63	24
Saskatchewan	310	0	0	0	1	98	0
South Carolina	2,930	4	24	25	19	27	53
South Dakota	35,451	0	0	0	0	100	0
Tennessee	70,847	0	5	14	16	65	19
Texas	38,580	2	7	6	6	79	15
Utah	3	0	0	0	0	100	0
Vermont	2,171	3	15	16	13	54	33
Virginia	71,698	2	14	17	15	52	33
Washington	2,419	0	1	1	2	96	2
West Virginia	1,199	0	3	7	10	79	10
Wisconsin	102,173	0	1	2	3	93	3
Wyoming	618	0	0	0	0	99	0
North America	2,692,605	0.4	2.0	4.0	5.3	88.2	6.5
Corn Belt*	1,984,337	0.1	0.8	2.3	3.7	93.1	3.2

*Corn Belt = IL, IN, IA, KS, KY, MI, MN, MO, NE, OH, ON, SD, WI.

Table 6. Relative frequencies for soil test S in North America by state or province.

State or Province	Samples	0-3	4-6	7-9	>9
		Soil test level range, ppm			
		Relative frequency, %			
Alabama	3,144	4	42	33	20
Alaska	7	0	100	0	0
Alberta	33,741	3	22	27	47
Arizona	747	1	7	7	85
Arkansas	101,626	12	47	23	18
British Columbia	1,824	13	42	21	23
California	16,002	11	20	7	62
Colorado	13,296	13	36	15	36
CT-MA-NH-RI	4,482	1	12	33	54
Delaware	5,506	13	30	38	19
Florida	1,254	1	20	13	66
Georgia	4,329	8	32	20	40
Hawaii	660	1	11	17	72
Idaho	33,866	0	5	11	84
Illinois	201,868	15	58	20	6
Indiana	220,809	5	63	25	7
Iowa	361,819	16	65	15	4
Kansas	42,369	14	50	21	14
Kentucky	25,851	8	37	36	19
Louisiana	12,926	11	65	14	9
Maine	7,493	8	27	28	37
Manitoba	39,873	2	15	17	66
Maryland	27,374	15	25	36	24
Michigan	154,737	3	49	33	15
Minnesota	139,381	14	58	17	12
Mississippi	24,637	14	64	15	7
Missouri	120,876	13	67	16	3
Montana	11,224	10	33	16	42
Nebraska	274,540	15	41	17	28
Nevada	46	0	24	35	41
New Brunswick	2,444	1	9	12	78
New Jersey	2,952	34	30	20	17
New Mexico	404	1	52	1	46
New York	29,257	4	15	34	47
North Carolina	3,578	13	33	25	29
North Dakota	50,018	5	21	14	60
Nova Scotia	6,476	1	28	43	28
Ohio	145,965	4	41	36	19
Oklahoma	7,424	15	37	19	29
Ontario	19,682	4	52	27	17
Oregon	1,466	25	38	7	30
Pennsylvania	38,569	4	17	41	38
Prince Edwards Is.	5,223	19	14	33	33
Quebec	3,455	1	11	20	69
Saskatchewan	29,203	8	27	22	44
South Carolina	2,015	3	46	27	24
South Dakota	56,616	9	35	17	39
Tennessee	48,110	5	64	21	10
Texas	25,300	2	18	36	43
Vermont	655	1	11	31	58
Virginia	12,633	2	36	40	22
Washington	2,419	4	49	22	25
West Virginia	659	37	33	20	10
Wisconsin	82,679	82	10	4	3
Wyoming	736	3	33	9	54
North America	2,464,245	12.8	47.1	21.4	18.7
Corn Belt*	1,847,192	14.6	52.4	20.6	12.4

*Corn Belt = IL, IN, IA, KS, KY, MI, MN, MO, NE, OH, ON, SD, WI.

Table 7. Relative frequencies for soil test Zn in North America by state or province.

State or Province	Samples	DTPA equivalent Zn, ppm 0-0.5	0.6-1.0	1.1-1.5	>1.5	<1.0
		Relative frequency, %				
Alabama	2,695	1	6	13	80	7
Alberta	14,935	1	5	11	83	7
Arizona	1,459	42	15	9	33	58
Arkansas	30,239	1	7	14	77	8
British Columbia	1,337	0	1	3	97	1
California	29,797	24	18	21	37	42
Colorado	15,927	50	11	8	32	60
CT-MA-NH-RI	4,393	3	12	18	67	14
Delaware	3,179	2	6	14	77	9
Florida	4,375	7	9	12	72	16
Georgia	4,320	2	10	9	79	12
Hawaii	7	0	0	0	100	0
Idaho	33,012	8	19	21	51	27
Illinois	34,614	4	15	18	63	19
Indiana	27,154	19	23	30	28	42
Iowa	179,850	9	31	15	45	40
Kansas	59,657	55	20	8	16	75
Kentucky	24,661	14	18	24	43	32
Louisiana	16,542	4	17	20	59	21
Maine	7,476	9	21	18	51	31
Manitoba	12,300	7	32	28	34	38
Maryland	23,589	7	13	22	58	20
Michigan	18,468	6	14	21	58	21
Minnesota	60,970	11	39	24	26	50
Mississippi	23,668	2	11	20	68	13
Missouri	74,452	6	23	6	64	30
Montana	5,869	36	45	19	0	81
Nebraska	243,150	29	15	12	44	44
New Brunswick	2,647	1	5	11	83	6
New Jersey	2,656	1	2	7	90	3
New Mexico	939	47	9	8	36	56
New York	26,463	9	20	29	42	29
North Carolina	2,885	9	11	11	69	20
North Dakota	26,151	21	55	23	1	76
Nova Scotia	33	0	2	9	89	2
Ohio	75,130	15	23	32	31	38
Oklahoma	9,206	43	28	14	15	71
Ontario	82,609	1	9	14	76	10
Oregon	1,479	3	5	7	85	8
Pennsylvania	35,814	5	10	16	70	14
Prince Edwards Is.	1,283	0	3	14	83	3
Quebec	3,665	0	1	6	93	1
Saskatchewan	7,376	12	18	18	52	30
South Carolina	1,945	7	3	6	85	9
South Dakota	41,731	15	46	22	17	61
Tennessee	44,304	2	17	22	59	19
Texas	24,015	69	10	6	14	79
Utah	3	100	0	0	0	100
Vermont	653	4	16	25	56	19
Virginia	39,402	12	25	14	49	37
Washington	5	0	20	40	40	20
West Virginia	449	4	5	12	79	9
Wisconsin	4,120	2	12	5	81	14
Wyoming	372	39	21	15	25	60
North America	1,393,430	16.1	20.8	16.6	46.4	36.9
Corn Belt*	926,566	17.4	22.4	16.1	44.1	39.8

*Corn Belt = IL, IN, IA, KS, KY, MI, MN, MO, NE, OH, ON, SD, WI.

Table 8. Relative frequencies for soil test Cl^- in North America by state or province.

State or Province	Samples	Water extractable Cl^-, ppm 0-4	5-8	>8
		Relative frequency, %		
Alberta	3,370	33	25	42
Arizona	627	54	4	41
California	15,625	81	1	18
Colorado	209	26	22	52
Iowa	1,143	13	3	84
Kansas	1,464	39	29	33
Manitoba	25,649	37	21	42
Michigan	1,288	65	2	33
Minnesota	83,474	66	11	23
Montana	14,486	56	22	21
North Dakota	70,699	59	16	25
Nebraska	2,851	68	16	16
Oklahoma	81	11	7	81
Oregon	265	74	3	23
South Carolina	131	73	5	22
South Dakota	35,184	73	11	16
Saskatchewan	3,954	66	19	15
Texas	603	27	31	43
Wisconsin	14	50	21	29
Total	**261,117**	**61.6**	**13.7**	**24.8**

Summary

The 2010 IPNI summary of 4.4 million soil samples is probably the most comprehensive evaluation of soil fertility ever conducted in NA. We said the same thing about the 2005 summary. Collectively, these two summaries examined nearly 8 million samples to offer a status report of one of the most precious natural resources of NA, its soil. Submissions from laboratories indicate that use of soil testing has increased substantially since 2005. The 2010 summary gives a more complete evaluation of the components of soil fertility than previous summaries, providing information about P, K, S, Mg, Zn, Cl^-, and pH.

Phosphorus. The median P level for NA of 25 ppm indicates a 6 ppm decline from 2005. The region of most consistent P declines was the Corn Belt, which also experienced a decline of 6 ppm to a 2010 median level of 22. This decline has major agronomic significance since a high percentage of samples from this region now test below critical levels and call for annual P fertilization to avoid yield reductions. Soil P declines across the Corn Belt were correlated with P partial balances which were negative for the 5-year period for 10 of the 12 states. The Northeast continues to have some of the highest soil P levels in NA, usually associated with intensive livestock or vegetable production.

Potassium. The median K level for NA declined 4 ppm, an amount numerically similar to the P decline – but at a median level of 150 ppm, the decline has much less agronomic significance. However, the current median is very close to what many recommendation systems consider to be an agronomic critical level for crop response. The western Corn Belt and much of the Great Plains and Northeast experienced significant soil K declines. Some of the apparent soil K changes are very likely due to factors other than nutrient management, such as weather patterns that can influence the equilibrium between soil test extractable and non-extractable forms of K.

Magnesium. Mg levels are generally lowest in the Southeast. However, a significant occurrence of lower Mg levels also occurs in the Northeast.

Sulfur. The summary shows an increase in frequency of soils testing low in S, which is consistent with reports of increasing S deficiency in crops. Most scientists, however, do not consider S soil tests to be diagnostic without ancillary information, so agronomic interpretation strictly from the tests themselves is limited.

Zinc. With 37% of samples testing less than 1 ppm Zn, and 16% less than 0.5 ppm Zn, many soils in NA should be responsive to Zn fertilization.

Chloride. The Northern Great Plains has a high frequency of soils low in Cl^-.

pH. Soil pH changes, as in the past, were minor… with a NA median of 6.4, compared to 6.3 in 2010.

We in North America rely heavily on soil testing to assess soil fertility and guide future nutrient management decisions. This summary demonstrates the extreme variability of fertility levels and that they do indeed change over time. Producers who have soils that have not been sampled recently would have much to gain by getting into the regular practice of soil sampling. The increase in sample volume with the 2010 summary is a positive sign that more farmers and advisers are taking advantage of this valuable tool. ■

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