The MANAGE Database: Nutrient Load and Site Characteristic Updates and Runoff Concentration Data

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The "Measured Annual Nutrient loads from AGricultural Environments" (MANAGE) database was developed to be a readily accessible, easily queried database of site characteristic and field-scale nutrient export data. The original version of MANAGE, which drew heavily from an early 1980s compilation of nutrient export data, created an electronic database with nutrient load data and corresponding site characteristics from 40 studies on agricultural (cultivated and pasture/range) land uses. In the current update, N and P load data from 15 additional studies of agricultural runoff were included along with N and P concentration data for all 55 studies. The database now contains 1677 watershed years of data for various agricultural land uses (703 for pasture/rangeland; 333 for corn; 291 for various crop rotations; 177 for wheat/oats; and 4–33 yr for barley, citrus, vegetables, sorghum, soybeans, cotton, fallow, and peanuts). Across all land uses, annual runoff loads averaged 14.2 kg ha^{-1} for total N and 2.2 kg ha^{-1} for total P. On average, these losses represented 10 to 25% of applied fertilizer N and 4 to 9% of applied fertilizer P. Although such statistics produce interesting generalities across a wide range of land use, management, and climatic conditions, regional crop-specific analyses should be conducted to guide regulatory and programmatic decisions. With this update, MANAGE contains data from a vast majority of published peer-reviewed N and P export studies on homogeneous agricultural land uses in the USA under natural rainfall-runoff conditions and thus provides necessary data for modeling and decision-making related to agricultural runoff. The current version can be downloaded at http://www.ars.usda.gov/spa/manage-nutrient.

Published in J. Environ. Qual. 37:2403–2406 (2008).
doi:10.2134/jeq2008.0079
Received 12 Feb. 2008.
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Water quality protection, management, and regulatory programs benefit from comparative nutrient export data to determine the effects of management alternatives. Although advances in watershed modeling continue to improve model predictions, measured data remain vital for scientifically defensible assessment, for stakeholder-accepted management and decision-making, and for calibration/validation of model estimates (Silberstein, 2006). Although several excellent and well known databases (e.g., USEPA STORET, USGS NAWQA, USGS NWISW) were developed to provide a wide range of hydrologic and water quality data, they do not typically contain field-scale data with site-specific watershed information. Such data are needed to understand nutrient transport mechanisms from various land uses as affected by soil type, climate, topography, and management (Kissel et al., 1976; Beaulac and Reckhow, 1982; Vervoort et al., 1998, Gilley and Risse, 2000; Sharpley et al., 2002).

Thus, the MANAGE "Measured Annual Nutrient loads from AGricultural Environments" database was developed to provide a comprehensive source of field-scale nutrient export data. The foundation of MANAGE was established by Beaulac and Reckhow (Beaulac, 1980; Reckhow et al., 1980; Beaulac and Reckhow, 1982), who compiled nutrient export data from various sources (forest, urban, cropland, pasture and grazing land, mixed agricultural areas, feedlot and manure storage areas, atmospheric contribution, septic tanks, and sewage treatment plants). The focus of the MANAGE database, however, was narrowed to agricultural (cultivated and pasture/range) land uses (Harmel et al., 2006a). Thus, MANAGE (v1) translated data from the Reckhow et al. (1980) compilation and data from many new studies conducted since the early 1980s into electronic format. The original version was developed during 2004–2005 with the primary objective of compiling measured annual nitrogen (N) and phosphorus (P) load data representing field-scale transport from agricultural land uses in the USA into a readily accessible, easily queried format. The objective of this article is to describe the updated load and site characteristic information and the ad-

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Abbreviations: MANAGE, Measured Annual Nutrient loads from AGricultural Environments; ws yr, watershed year.

Table 1. Summary statistics for the original and updated MANAGE database versions.

	MANAGE (v1)	MANAGE (v2)	MANAGE (v3)
Completion date	Apr. 2005	Nov. 2005	May 2007
Watershed years	1103	1502	1677
Publications	40	49	55
Database records	163	240	274
Nutrient data	loads	loads	loads and concentrations

ditional N and P concentration data now available in MANAGE (v3).

Materials and Methods

MANAGE (v1), which was completed in April 2005, included more than 1100 site years of measured field-scale nutrient load data that met spatial and temporal scale, land use, and rainfall criteria. For inclusion, the data must have been (i) published in a scientific peer-reviewed study, (ii) collected at the field- or farm- spatial scale (minimum 0.009 ha) from a homogeneous agricultural land use, (iii) produced by natural rainfall (not rainfall simulation), and (iv) collected for a minimum of 1 yr (Harmel et al., 2006a). Only data from the USA and selected data from Canada were included to constrain the scope of this database.

Every effort was made to include data from all studies meeting those criteria, but several previous studies were inadvertently overlooked, and several new studies have been published. Thus, nine additional studies meeting the same criteria were included in the November 2005 update to MANAGE (v2). Concentration data were not included in v1 and v2, although the importance of nutrient load and corresponding concentration data is unquestioned. Therefore, during the 2006–2007 update to MANAGE (v3), concentration data from all previously included studies were added in addition to load and concentration data from six new studies. These updates are summarized in Table 1.

Results and Discussion

MANAGE (v3) contains 574 additional watershed years (ws yr) of N and P data not included in v1. Whereas the original version contained data from 15 states, v3 included data from Florida, Nebraska, and Wisconsin that were not previously represented (Fig. 1). This update also added more than 20 ws yr of data for Oklahoma (+229), Ohio (+112), Texas (+65), Minnesota (+48), and Mississippi (+28). No data from the Pacific Northwest, Rocky Mountains, or New England states are included, although selected Canadian data were included to fill in geographic gaps in the northeast and northwest USA. Reasons for the lack of data in northeast and northwest are unknown, but arid conditions with little rainfall-runoff in much of the western USA contribute to limited data in that region.

Pasture/range and cultivated land use are well represented (Fig. 2). Tillage alternatives within the cultivated land use category are also fairly well divided between conventional and conservation tillage, but no-till data are scarcer. In the update to v3, nutrient loss data for pasture/range land uses (including alfalfa) increased from 362 to 703 ws yr, for corn increased from 241 to 333 ws yr, and for wheat/oats increased from 107 to 177 ws yr (Fig. 3). Lesser increases in data amounts were observed for sorghum, soybeans, cotton, and peanuts. Data from previously unrepresented citrus, vegetables, and barley were also included.

Many different organic and inorganic fertilizers were used in the studies included in MANAGE (v3), although no fertilizer or unreported types of fertilizer were applied in many studies (1065 ws yr). Nutrient load data were reported for

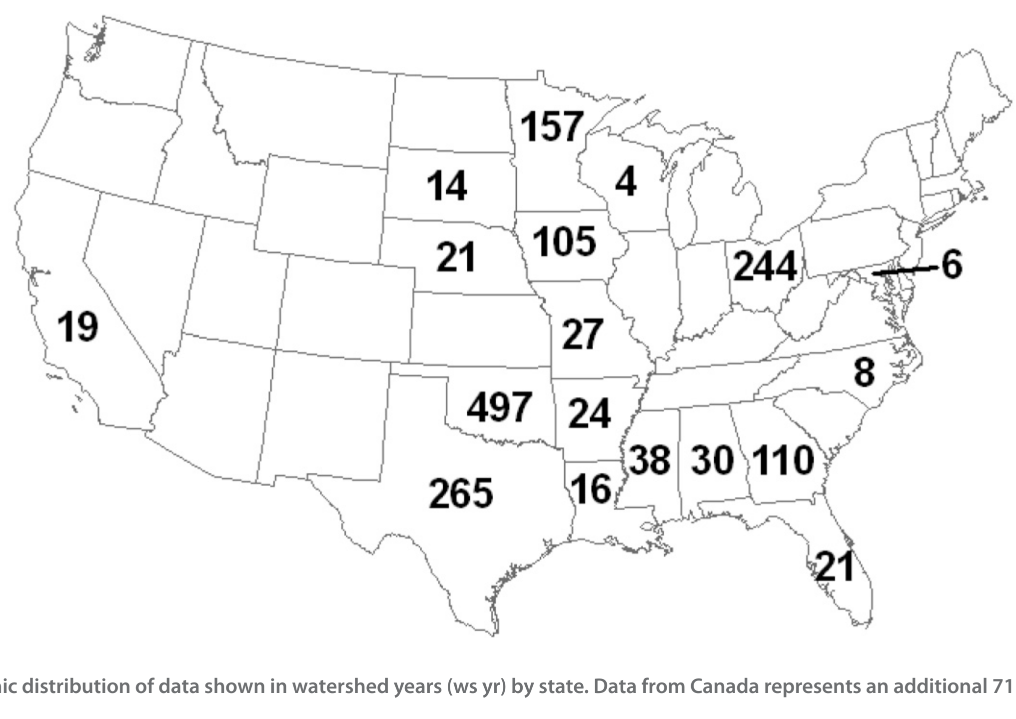

Fig. 1. Geographic distribution of data shown in watershed years (ws yr) by state. Data from Canada represents an additional 71 ws yr.

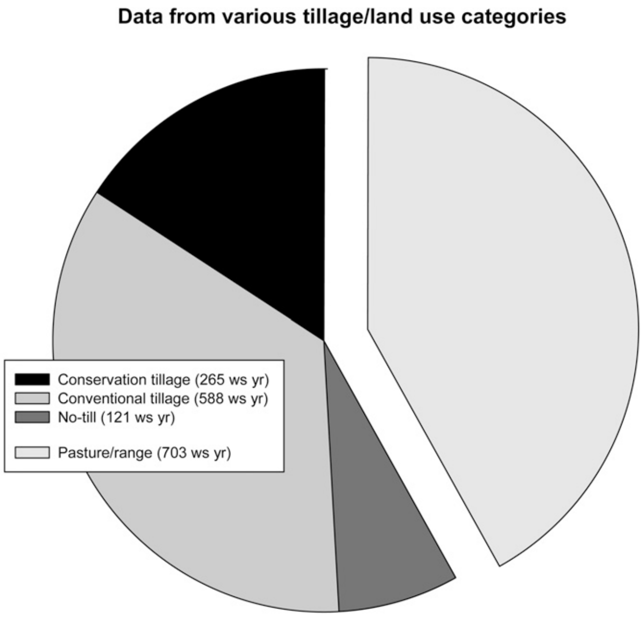

Fig. 2. Distribution of data in various tillage and land use categories shown in watershed years (ws yr).

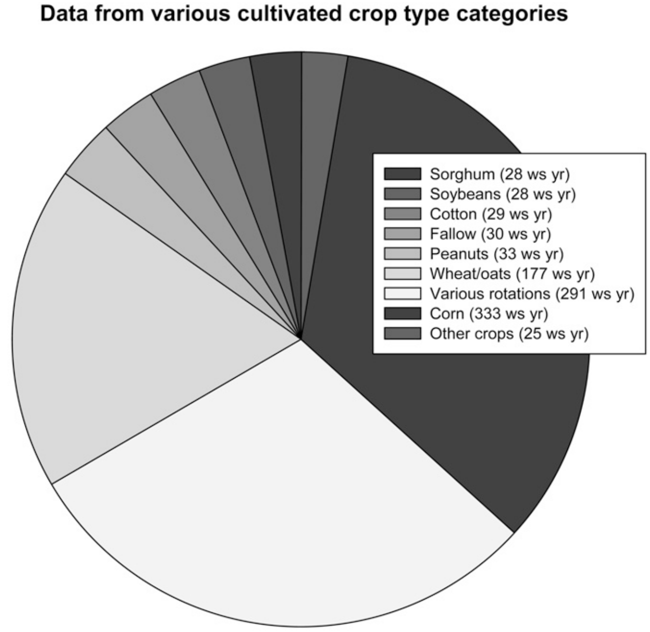

Fig. 3. Distribution of data in various cultivated crop type categories shown in watershed years (ws yr).

453 ws yr with inorganic fertilizer application, for 95 ws yr with organic fertilizer application, and for 64 ws yr with a combination of inorganic and organic fertilizer. It is important to consider these differing fertilizer types in any analysis of nutrient runoff and transformation mechanisms (Kleinman et al., 2002; Sharpley et al., 2002; Vadas et al., 2007). For the studies that reported organic fertilizer use, 34% of the data (in terms of ws yr) represented poultry litter or manure, 19% represented beef or dairy cattle manure, 17% represented swine manure, and 30% represented unreported manure sources.

Annual N load data exhibited considerable variability, with losses as great as 50 kg ha^{-1} for dissolved N, 147 kg ha^{-1} for particulate N, and 266 kg ha^{-1} for total N (Fig. 4). In terms of maximum loads, P losses were considerably less (<35 kg ha^{-1}). However, in terms of relative dispersion, annual P loads had greater coefficient of variation (Cv) values (1.82–2.68) than N loads (Cv, 1.71–1.79). Regardless of constituent type, all measured annual load data were highly positively skewed. When mean annual N and P loads were compared with mean annual fertilizer application rates, the analysis revealed that a greater percentage of applied N was lost in runoff. On sites with both application rate and load data for years with application rates in excess of 10 kg ha^{-1}, N losses averaged 25% of applied N (median, 9%), and P losses averaged 9% of applied P (median, 5%). For all sites that have either application rate or load data, total N loads averaged 9.5% of applied N, and total P loads averaged 4.4% of applied P.

Differing analytical tests and inconsistent terminology made compiling and examining annual N and P loads difficult, but N and P runoff concentrations suffered from the additional problem of numerous reporting timeframes. Concentration data were presented as event specific and individual annual values or were summarized and presented in various timeframes (e.g., annual means, annual geometric mean, annual mean for events with more than 2.0 mm of runoff, annual median, event mean, seasonal mean, growing period mean, study period mean, quarterly mean). Another difficulty was limited concentration data compared with load data. This resulted because each included study contains annual load data (as per the design criteria), but not all studies contain N or P concentration data for runoff. Because of these issues, the concentration data are grouped across constituent type, analytical test, and reporting timeframe (Fig. 5).

When using this data compilation, it is important to consider these data inconsistencies and the widely varying sample sizes and sampling conditions. Proper consideration of differences in soils, land use, management, climate, watershed size, constituent type, analytical tests, monitoring methods, and data availability is necessary to produce accurate conclusions and appropriate decisions. Similarly, interactions between site characteristics (e.g., soil

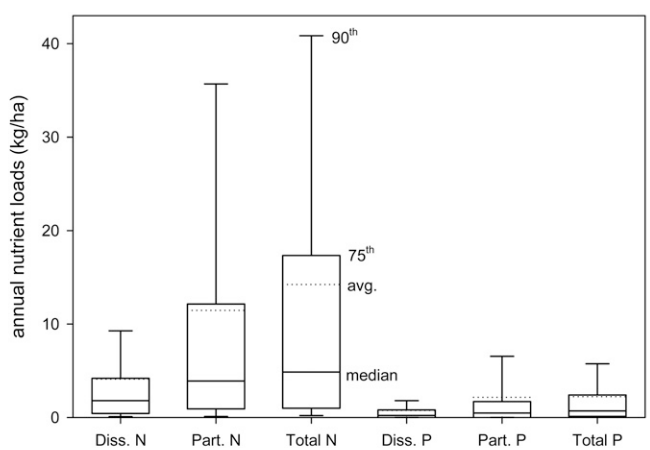

Fig. 4. Measured annual N and P loads presented by constituent type: dissolved, particulate, and total.

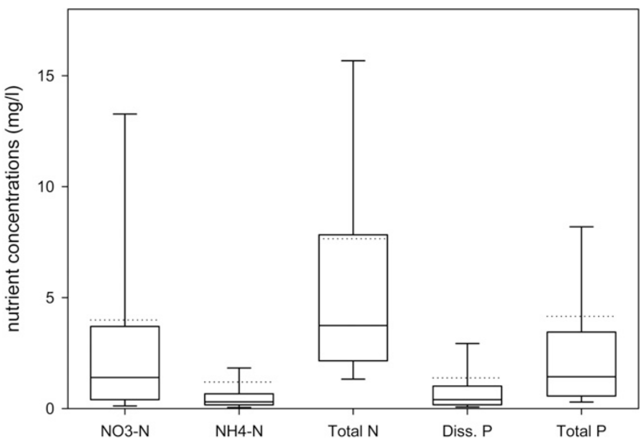

Fig. 5. Measured N and P concentrations presented for dissolved and total forms.

type, slope, land use) and management alternatives (e.g., fertilizer application method and rate, and best management practice), as they affect N and P export, must be considered to accurately determine management impacts. Another consideration related to nutrient transport data is its inherent measurement uncertainty, which is typically ignored. Harmel et al. (2006b) quantified typical uncertainty ranges for individual measured nutrient load and concentration values in the absence of project-specific uncertainty data. The measurement uncertainty in individual N and P loads and concentrations, which are compiled and aggregated in MANAGE (v3), should be considered to enhance decision-making, regulatory formulation, and model evaluation as supported by the database.

Conclusions

MANAGE (v3) contains N and P load and concentration data from a majority of the published peer-reviewed nutrient export studies on agricultural lands in the USA and is available at http://www.ars.usda.gov/spa/manage-nutrient. It provides measured data for modeling and decision-making related to agricultural runoff for many regions in the USA. MANAGE (v3) does, however, suffer from geographic and land use data gaps. Most of the compiled data were collected in the central, midwestern, and southeastern states, which leaves substantial data gaps in the Rocky Mountains, Northeast, and Pacific Northwest. As data from these regions are published or as previous publications are discovered, data from these studies will be included. In addition to regional data gaps, nutrient export data from forest land uses are not included. Inclusion of this important land use is currently underway and led by Matt McBroom (Stephen F. Austin State University).

MANAGE has been used to calibrate and test several models, including the Agricultural Policy Environmental eXtender (Williams et al., 1998; Williams and Izaurralde, 2006) in the USDA Conservation Effects Assessment Project and to evaluate nutrient management tools, such as a revised Oklahoma P Index (Mike White, personal communication) and an Arkansas BMP evaluation tool (Margaret Gitau, personal communication). MANAGE is also being used to model nutrient delivery rates (Reckhow et al., 2008), which will be linked to a Bayesian version of the USGS SPARROW (SPAtially Referenced Regressions On Watershed Attributes) model (Smith et al., 1997; Qian et al., 2005). It is our hope that the MANAGE database continues to provide measured nutrient export data and site-specific information and thus contributes to increasingly effective management of N and P runoff from agricultural land uses.

Acknowledgments

The continued cooperation of the Texas State Soil and Water Conservation Board is appreciated. We also recognize Rajani Srinivasan for her assistance in developing the concentration data table.

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