# The pH Base Saturation Relationships of Pennsylvania Subsoils

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## Contents



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# INTRODUCTION

Percent base saturation of the subsoil is used in Soil Taxonomy (Soil Survey Staff, 1999) as the classification criterion for separating Alfisols from Ultisols, and Eutrudepts from Dystrudepts, as well as in other classification categories. When laboratory determinations are unavailable, soil scientists commonly use soil pH to estimate the percent base saturation. Predictions have not been reliable, however, because base saturation at given pH varies considerably from one soil to another.

This study was initiated to determine the pH base-saturation relationship in Pennsylvania soils and to thereby improve the predictability of base saturation from pH, as a field tool.

# MATERIALS AND METHODS

Soil samples were collected and analyzed as a part of the soil characterization program in Pennsylvania (Ciolkosz, 2001). Samples from 555 pedons from 43 of the 67 Pennsylvania counties have been evaluated for pH and base saturation relationships. These soils were Inceptisols, Alfisols, and Ultisols with only a very minor percentage belonging to other soil orders. The methods used for soils analysis are given in Thurman et al. (1994).

Thornthwaite and Mather’s (1957) mean annual water balance was calculated for each weather station having at least 25 years of temperature and precipitation data (U.S. Dept. of Commerce, 1937-1967). A computer program written by Black (1966) was used for this calculation. Moisture surplus, derived from this calculation, equals the mean annual precipitation minus the calculated potential evapotranspiration, and is an estimate of available leaching water. A map (Fig. 1) was constructed with lines connecting points of approximately equal moisture surplus. Each soil-sampling site was assigned a moisture-surplus value based on

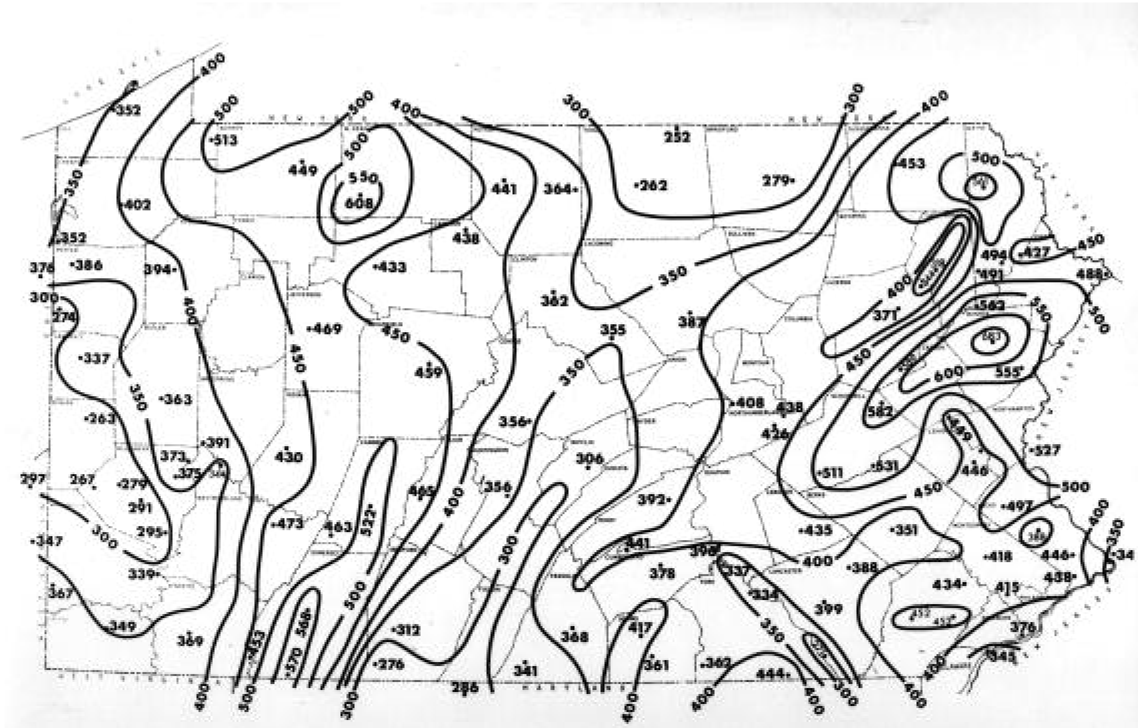

Figure 1. Moisture surplus (Thornthwaite and Mather, 1957) in millimeters at specific Weather stations generalized by isograms.

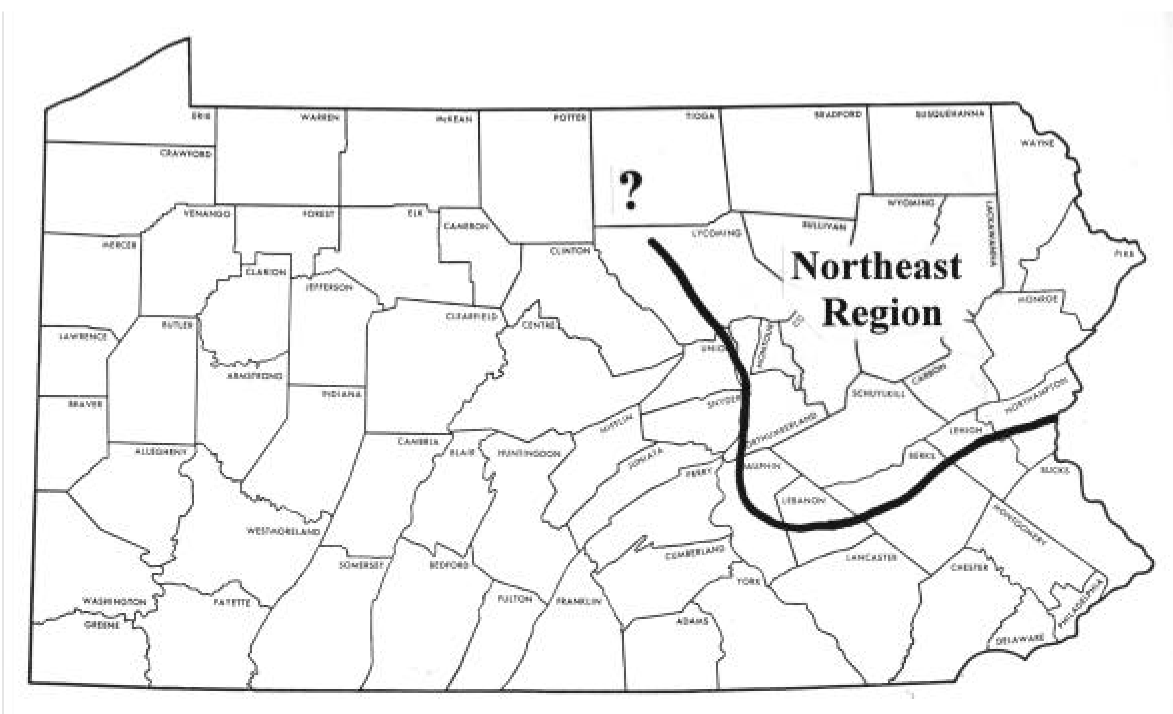


Figure 2. Map of Pennsylvania delineating northeastern area.

interpolation from the map. Data were used from only B and C horizon samples. Samples with less than 10 percent clay were excluded because small laboratory errors in exchangeable bases or acidity may make large variations in the base-saturation percentages.

Statistical analyses were performed on the IBM/360 computer (Unpublished programs on file at The Pennsylvania State University Computation Center). Pearson product-moment correlation coefficients and the probability level of their significance were calculated. Multiple-linear regression was calculated by a "step-down" procedure and a "step-up" procedure (Efroymson, 1965).

## RESULTS AND DISCUSSION

Statistical analysis of base saturation date from the 555 soil characterization sites has revealed a correlation between subsoil base saturation at a given pH level and moisture surplus. Moisture surplus is that amount of the mean annual precipitation that is not lost by evapotranspiration and includes water leaching through the soil as well as surface runoff. It was calculated by Thornthwaite and Mather's (1957) mean annual water balance calculations for weather stations spread over Pennsylvania (Fig. 1). The percent base saturation generally tends to be higher at a given pH in areas of low total moisture surplus. Drainage class is an additional factor that correlated with base saturation at a given pH. In general, the percent base saturation will be higher in subsoils of poorer drained soils than better drained soils.

The reason is not known for the correlation between base saturation and moisture surplus and drainage. Since both of these factors are related to the amount of water that can leach through the soil, it is speculated that leaching is more efficient in the well drained soils than the more poorly drained soils and is manifest in the observed relationship.

Mineralogical differences in parent materials have apparently caused different chemical behavior in the northeastern (Fig. 2) part of Pennsylvania. In this area, illite-chlorite mineral suites are typical, and base saturation tends to be quite low. The reason for this relationship is not clear.

Multiple regression equations (Ranney et al., 1973) were developed for northeastern Pennsylvania and for the remainder using pH, total runoff, and drainage class as independent variables. Tables 1, 2, and 3 were derived from these equations.

## Directions for Predicting Base Saturation

1. Determine pH as accurately as possible. Use at least two indicators, or when possible, a pH meter and a 1:1 soil:water ratio.
2. Estimate the total moisture surplus at the site from Fig. 1. Total moisture surplus depends mainly on precipitation. If you have more detailed information about rainfall variation than shown in Fig. 1, adjust figures up or down accordingly.
3. If in the northeastern (Fig. 2) part of Pennsylvania, go to Table 2. If not in northeast, go to Table 1. Using pH and total moisture surplus values already estimated, read the predicted base saturation percentage from the table.
4. Estimate the drainage class. If the soil is well drained, use the prediction directly from the table. If moderately well or somewhat poorly drained, add the appropriate amount as specified in the table. If poorly or very poorly drained, use Table 3.

## Examples

1. Suppose we describe a Rayne soil in western Allegheny County, and measure a pH of 5.4 at 1.25 m below the top of the argillic horizon. Consult Fig. 1 and note that total moisture surplus is 300. Since the soil is not in the northeast, use Table 1. From the table, the soil base saturation prediction is 47%. Since it is well drained, we keep this prediction. This would indicate that this profile is an Alfisol. If the Rayne profile were near Somerset (moisture surplus 550), the prediction would be 30% and it would be an Ultisol.
2. A Meckesville soil described in southern Monroe County, had a pH of 5.0 measured at 75 cm below the top of the fragipan. The moisture surplus from the soil (Fig. 1) is about 550 mm. The soil is in the northeast (Fig. 2), so from Table 2 a prediction of 19% base saturation is obtained. This soil would definitely be an Ultisol. If we had read the same pH of 5.0 in a somewhat poorly drained soil in the same area, we would add 12% as directed in the table giving a base saturation of 31%.

Table 1. Prediction of base saturation percentage for well drained subsoils in Pennsylvania excluding the northeast with varying pH and total moisture surplus (from Fig. 1).

| | Total Moisture Surplus (mm)[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 | 700 |
| 4.0 | 18 | 14 | 9 | 7 | 4 | 0 | 0 | | | |
| 4.2 | 23 | 19 | 16 | 12 | 9 | 5 | 2 | 0 | | |
| 4.4 | 27 | 23 | 20 | 16 | 13 | 9 | 6 | 2 | 0 | 0 |
| 4.6 | 32 | 28 | 25 | 21 | 18 | 14 | 11 | 7 | 4 | 1 |
| 4.8 | 37 | 33 | 30 | 26 | 23 | 19 | 16 | 12 | 9 | 5 |
| 5.0 | 41 | 37 | 34 | 30 | 27 | 23 | 20 | 16 | 13 | 9 |
| 5.2 | 46 | 42 | 39 | 35 | 32 | 28 | 25 | 21 | 18 | 14 |
| 5.4 | 51 | 47 | 44 | 40 | 37 | 33 | 30 | 26 | 23 | 19 |
| 5.6 | 55 | 51 | 48 | 44 | 41 | 37 | 34 | 30 | 27 | 23 |
| 5.8 | 60 | 56 | 53 | 49 | 46 | 42 | 39 | 35 | 32 | 28 |
| 6.0 | 64 | 60 | 57 | 53 | 50 | 46 | 43 | 39 | 36 | 32 |
| 6.2 | 69 | 65 | 62 | 58 | 55 | 51 | 48 | 44 | 41 | 37 |
| 6.4 | 73 | 69 | 66 | 62 | 59 | 55 | 52 | 48 | 45 | 41 |
| 6.6 | 78 | 74 | 71 | 67 | 64 | 60 | 57 | 53 | 50 | 46 |
| 6.8 | 82 | 78 | 75 | 71 | 68 | 64 | 61 | 57 | 54 | 50 |
| 7.0 | 87 | 83 | 80 | 76 | 73 | 69 | 66 | 62 | 59 | 55 |
| 7.2 | 91 | 87 | 84 | 80 | 77 | 73 | 70 | 66 | 63 | 59 |

[1]For moderately well drained soils add 4%. For somewhat poorly drained add 7%.

Table 2. Prediction of base saturation percentage for well drained subsoils in northeastern Pennsylvania with varying pH and total moisture surplus (from Fig. 1).

| | Total Moisture Surplus (mm)[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 | 700 |
| 4.0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 0 | 0 |
| 4.2 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 |
| 4.4 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 |
| 4.6 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 |
| 4.8 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 |
| 5.0 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| 5.2 | 29 | 28 | 29 | 26 | 25 | 24 | 23 | 22 | 21 | 20 |
| 5.4 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| 5.6 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 |
| 5.8 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 |
| 6.0 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 |
| 6.2 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 |
| 6.4 | 52 | 51 | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 |
| 6.6 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | 47 |
| 6.8 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 |
| 7.0 | 63 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 |
| 7.2 | 67 | 66 | 65 | 64 | 63 | 62 | 61 | 60 | 59 | 58 |

[1]For moderately well drained soils add 6%. For somewhat poorly drained add 12%.

Table 3. Prediction of base saturation percentage for poorly drained subsoils in Pennsylvania with varying pH.

| pH | Pennsylvania | |
|---|---|---|
| | Excluding northeast | Northeast |
| 4.0 | 14 | 21 |
| 4.2 | 18 | 25 |
| 4.4 | 23 | 29 |
| 4.6 | 27 | 33 |
| 4.8 | 32 | 37 |
| 5.0 | 37 | 40 |
| 5.2 | 41 | 44 |
| 5.4 | 46 | 48 |
| 5.6 | 50 | 52 |
| 5.8 | 55 | 56 |
| 6.0 | 60 | 59 |
| 6.2 | 64 | 63 |
| 6.4 | 69 | 67 |
| 6.6 | 73 | 71 |
| 6.8 | 78 | 75 |
| 7.0 | 83 | 79 |
| 7.2 | 87 | 82 |

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