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Project Report

Comparison of Crop Yield Estimates Obtained from an Historic Expert System to the Physical Characteristics of the Soil Components—A Project Report

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Abstract: Crop yields vary due to soil type. Expected crop yields are reported in published soil surveys based on the knowledge of local conservation and extension professionals. Crop yields have increased over the years due to improved genetics and management. The objective of this project was to compare historic expected crop yields to soil physical characteristics and to update expected yields for West Virginia soils in the United States National Soils Information System (NASIS). Regression analysis found that soil physical characteristics explained 57 to 65% of the variation in corn and hay yields. Corn and hay yield regressions calculated from a regression data set predicted yields for crops on soils in a test data set without bias and with residual errors of 10 to 15%. Updated crop yields under good management on more productive soils were obtained by surveying farmers and variety trials conducted in West Virginia and surrounding states. The updated yields and relative historic yields were used proportionally to update expected crop yields by soil series. The updated yields were reviewed by local conservation professionals and adjusted as needed based on local experience. These updated yields are now being used as the expected crop yield for the West Virginia soil series in the NASIS.

Keywords: expected yield; crop yield; soil type; soil component; soil survey; corn; hay; animal unit months; soil characteristics; plant available water

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1. Introduction

Crop yields under best management practices (BMPs) vary over the landscape due to soil characteristics [1–4]. Two soil characteristics having a major impact on crop management and growth are soil drainage and plant available water holding capacity (AWC) due to texture and rooting depth [2,5–7]. Crop yields have increased over time due to improved genetics and fertility management [8,9]. Crop biomass growth and harvested yield are major determinants of the crop's nutrient requirements. Because of this, West Virginia University Extension Service fertilizer recommendations are based in part on expected yield by crop and soil type.

In the United States many counties have detailed surveys of soils across the landscape. These soil surveys include detailed descriptions of the soil's physical characteristics and expected yield of crops grown on the soils. Farmers and technical service providers can access this information using interactive web sites [10,11].

Soil surveys in West Virginia were conducted by United States Department of Agriculture (USDA) Soil Conservation Service (SCS), later named the Natural Resources Conservation Service (NRCS), between 1959 and 1997. These surveys provide expected crop yields by soil series when crops are produced under good management. These estimated yields were established by staff from the SCS/NRCS soil survey team, the county USDA Agriculture Stabilization and Conservation Service (ASCS), and county and state Extension faculty. The SCS/NRCS, ASCS, and county Extension staff provided local information on crop yields for each soil or similar soil series. At the time, due to USDA cost deficiency payment programs, individual farm yield records for corn and wheat were maintained at the local ASCS office. These yields were verified by sampling fields according to USDA guidelines or using sale weight receipts for each harvested field. The state Extension staff provided crop yields from the Experiment Station and on-farm demonstrations based on similar soils. The expected yields listed in the soil surveys constitute a tabular expert system based on the knowledge of agricultural professionals within the region.

Crop growth models are of value for evaluating the effect of weather on grain, forage, and pasture yields [12,13]. Historic crop yields by soil type are needed when calibrating these models prior to input of expected weather patterns due to climate change. Crops of major importance to farmers in West Virginia include alfalfa (*Medicago sativa*), barley (*Hordeum vulgare*), corn (*Zea mays*), oats (*Avena sativa*), orchardgrass (*Dactylis glomerata*), red clover (*Trifolium pratense*), reed canary grass (*Phalaris arundinacea*), rye (*Secale cereale*), smooth bromegrass (*Bromus inermis*), sorghum (*Sorghum vulgare*), soybean (*Glycine max*), tall fescue (*Festuca arundinacea*), timothy (*Phleum pratense*), and wheat (*Triticum aestivum*). The forage species are harvested as hay or haylage while the grain species are harvested as grain or whole-plant silage.

The objectives of this project were to evaluate the effect of soil physical characteristics on expected crop yields for West Virginia soils, use this relationship to establish expected yields for crops grown on soils not currently having published expected yields, and to update historic crop yields to yields obtained by farmers using modern crop genetics and BMPs. The updated crop yields will be used to update fertilization recommendations for the crops grown on these soils within the state.

2. Materials and Methods

For each West Virginia soil component (described soil series) soil physical characteristics (slope, AWC, depth to restriction layer, drainage class), expected corn yield, expected hay yield, and expected animal unit months of grazing (AUM) were obtained from the National Soils Information System (NASIS) [13] (Table 1). To extend yields to alfalfa hay and small grain crops, historic expected yields were extracted from published West Virginia soil surveys conducted between 1959 and 1997 (Table 2). Soil surveys used terms such as "yield under good management" rather than BMPs. Yield under good management is an average yield when using improved management that farmers in the area would find practical to follow. Historic expected yields represent average yields over multiple years at the time of the soil survey.

Table 1. Mean and distribution of expected yield (MT·ha^{-1}) for corn, mixed hay (grass–legume hay), and animal unit months of grazing (AUM·ha^{-1}) for West Virginia soil components as reported in the National Soils Information System as of August 2020.

Crop	N †	Mean	SD ‡	Minimum	Maximum
Corn	178	6.8	1.4	3.8	11.3
Mixed hay	178	8.1	2.2	1.6	19.0
AUM	191	13.3	4.9	3.7	49.4

† N, sample size; ‡ SD, standard deviation.

Table 2. Mean and distribution of expected crop yields (MT·ha^{-1}) under good management across soil components as published in yield tables from West Virginia soil surveys conducted between 1959 and 1997 (*n* = 637).

Crop	Mean	SD †	Minimum	Maximum
Alfalfa hay	8.1	1.6	4.0	12.3
Corn	5.8	1.2	2.8	8.8
Mixed hay	6.5	1.3	3.4	11.2
Oats	2.2	0.4	1.1	3.0
Wheat	2.4	0.5	1.3	3.7

† SD, standard deviation.

To update corn yields county Extension faculty interviewed farmers producing corn grain on highly productive soils using current BMPs. BMPs are those crop cultural practices including proper variety selection, soil testing and fertilizer and lime application, tillage, planting date and method, insect and weed control, and harvest management appropriate for the crop. These farmers measure yields using yield monitors in the combine or by weighing loads going into storage. Forage crop and small grain crop yields were updated using surveys of variety trials from West Virginia and the neighboring states of Virginia, Pennsylvania, Ohio, and Kentucky (Tables 3 and 4).

Table 3. Expected grain crop yields ($MT \cdot ha^{-1}$) on more productive soils over a three to five year period, under best management practices based on surveys conducted in 2020 of West Virginia farmers and regional variety trails.

Crop	Expected Yield
Corn grain	14.1
Corn silage	67.2
Barley	4.8
Oats	3.2
Rye	5.0
Soybeans	5.4
Sorghum, grain	7.8
Wheat	6.0

Table 4. Yield ($MT \cdot ha^{-1}$) of grass (fertilized with 200 $kg \cdot N \cdot ha^{-1}$), alfalfa, and red clover hay in variety trials in West Virginia, Virginia, Pennsylvania, and Kentucky and relative yield compared by linear regression (RYreg) to orchardgrass growing on the same site in the same year.

Species	Site Years	Mean	SD †	RYreg
Tall fescue	55	11.4	3.1	1.07
Orchardgrass	68	10.8	2.7	1.00
Reed canarygrass	36	10.8	3.4	0.92
Smooth bromegrass	35	9.9	2.5	0.87
Timothy	54	9.7	2.7	0.87
Perennial ryegrass	25	8.1	3.1	0.73
Alfalfa	130	13.9	2.7	1.28
Red clover	40	9.9	3.4	0.92

† SD, standard deviation.

Statistical analysis was conducted using NCSS statistical software [14]. Multiple regression was used to describe the effect of soil physical characteristics [13,15] on crop yields and to estimate a crop's yield based on the yield of another crop on the soil. Linear regression was used to relate forage yield of the different grasses and legumes to that of orchardgrass grown under nitrogen fertilization at the same location in a given year (Table 4). To test the use of soil physical characteristics for predicting expected corn and hay yields, soils were sorted by corn yield, and every other soil was assigned to a regression data set or to a test data set. Expected yields were regressed against the soils' physical characteristics (slope, AWC, presence of a restriction layer, USDA drainage class) using the regression data set. Regression coefficients testing significant ($p < 0.05$) were retained. To test the accuracy of predictions, the regression was used to calculate yields in the test data set. These calculated yields were then regressed against the reported crop yields for soils in the test data set. Using this test, a prediction without any error would have a regression intercept of zero, a regression slope of one, and a residual standard deviation about the regression (SDreg, square root of the mean square error) of zero. An intercept different from zero is a measure of constant bias, a slope different from one is a measure of proportional bias, and the SDreg and average absolute percent error (AAPE) are measures of residual error about the regression. Regression analyses were then run using all soils to obtain a pooled regression. Climatic variables associated with soils in West Virginia are part of the metadata contained within the NASIS soils database [15]. General climatic data for West Virginia were obtained from the United States National Oceanic and Atmospheric Administration (NOAA), National Centers for Environmental Information (NCEI) [16].

3. Results

3.1. Regressions for Estimating Expected Crop Yield from Soil Physical Characteristics

Corn and hay yields in the regression data set had an AAPE of 11 to 16% about the trend line (Table 5a,b). These regressions were used to predict crop yields for soils in the test data set. The predicted yields were compared to the expected yield for soils in the test data set. For corn the predicted compared to the reported expected yield had no fixed or proportional bias with a SDreg of 0.81 MT·ha^{-1} and AAPE of 10% (Table 5c). For hay the predicted compared to expected yield had no fixed or proportional bias with a SDreg of 1.34 MT·ha^{-1} and a 15% AAPE (Table 5d).

Table 5. The regression of expected yield (MT·ha^{-1}) to soil physical properties for a subset of soils (regression data set) used to predict expected crop yields on other soils based on their physical properties (test data set). The predicted yields (CornYpred, HayYpred) were then tested by regression against the reported yields (CornY, HayY) in the test data set (*n* = 89).

Regression	**R^2**	**SD_{reg} †**	**AAPE ‡**
Regression Data Set			
a. CornYpred = 5.51 − 0.077 Slope + 0.15 AWC − 0.61 Restriction + Drainage Drainage class: Moderately well −0.35 Somewhat poorly −1.00 Poorly −1.44 Very poorly −1.63	0.57	0.94	11%
b. HayYpred = 3.51 − 0.025 Slope + 0.367 AWC + Drainage Drainage class: Moderately well −0.82 Somewhat poorly −1.95 Poorly −2.61	0.65	1.29	16%
Test of Regression Predicted of Yields against Yields in the Test Data Set			
c. CornY = 1.02 CornYpred	0.99	0.81	10%
d. HayY = 1.00 HayYpred	0.97	1.34	15%

† SDreg, standard deviation about the regression; ‡ AAPR, average absolute percent error.

3.2. Expected Crop Yield as a Function of Soil Physical Characteristics

Expected corn and hay yields were impacted by average field slope, plant AWC in the top 100 cm of the soil, drainage class, and presence or absence of a restrictive layer (Table 6, pooled regressions). The SDreg for corn and hay yields were 0.8 and 1.3 MT·ha^{-1} with an AAPE of 11 and 15 percent, respectively.

Table 6. Pooled regressions of expected corn and hay yields (MT·ha^{-1}) vs. the soil physical characteristics of average percent slope (Slope), plant available water holding capacity (cm) in the top 100 cm of the soil (AWC), and the presence or absence (1 vs. 0) of a restriction layer in the soil, and the soil's drainage class.

Regression	R^2	SD_{reg} †	AAPE ‡	N
Corn = 5.43 − 0.071 Slope + 0.163 AWC − 0.500 Restriction + Drainage Drainage class: Moderately well −0.36 Somewhat poorly −1.12 Poorly −1.50 Very poorly −1.92	0.61	0.88	11%	178
Hay = 3.9 − 0.06 Slope + 0.35 AWC + Drainage Drainage class: Moderately well −0.6 Somewhat poorly −1.5 Poorly −2.6	0.65	1.3	15%	178

† SDreg, standard deviation about the regression; ‡ AAPR, average absolute percent error.

3.3. Expected Crop Yield Was Not Directly Related to Climatic Growing Conditions

When growing degree days, frost-free days, estimated evapotranspiration (ET), and air temperature were added to the regressions these variables did not improve the describing of expected crop yields. Annual precipitation was significant ($p < 0.05$) but negative. In West Virginia due to the orographic impact of the Allegheny plateau, mean temperature, precipitation, frost-free days, estimated ET, and growing degree days interact with elevation. For example, mean summer temperature decreases (Table 7c) with elevation while mean summer precipitation increases with elevation (Table 7e). This produces a negative correlation between mean annual air temperature and mean annual precipitation and positive correlations between mean annual air temperature and mean annual frost-free days, estimated potential ET, and estimated growing degree days (Table 8).

Table 7. Effect of elevation in meters (Elev) and latitude (Lat) on climatic variables in West Virginia (temperature, °C; precipitation, mm).

Regression	R^2	SD_{reg} †	AAPE ‡	N
a. Mean July temperature = 52 − 0.0059 Elev − 0.69 Lat	0.90	0.5	2%	71
b. Mean January temperature = 155 − 0.0144 Elev − 3.9 Lat	0.80	2.1	404%	71
c. Mean summer ‡‡ temperature = 51 − 0.0056 Elev − 0.80 Lat	0.89	0.5	2%	71
d. Mean annual precipitation = 0.186 Elev + 27.3 Lat	0.99	125	9%	71
e. Mean summer precipitation = 0.068 Elev + 15.4 Lat	0.99	64	9%	71

† Standard deviation about the regression; ‡ AAPR, average absolute percent error; ‡‡ Summer = 1 April through 30 September.

Table 8. Correlation between environmental values associated with soil components in West Virginia (ET evapotranspiration).

	Mean Annual Air Temperature	Mean Annual Precipitation	Mean Annual Frost-Free Days (Base −2 °C)	Estimated Potential ET	Estimated Growing Degree Days (Base 16 °C)
Mean annual air temperature	1.00				
Mean annual precipitation	−0.56 †	1.00			
Mean annual frost-free days (base −2 °C)	0.69	−0.33	1.00		
Estimated potential ET	0.99	−0.56	0.63	1.00	
Estimated growing degree days (base 16 °C)	0.93	−0.50	0.83	0.93	1.00

† Pearson correlation coefficient.

3.4. Predicting Hay Yield from Corn Yield and Grazing Yield from Hay Yield

When comparing corn and hay yields across soils, expected hay yields were proportional to expected corn yield without a fixed bias (Table 9a). The expected pasture yields, measured as animal unit months (AUM) of grazing, were proportional to expected hay yields (Table 9b) with a small constant bias. However, when the intercept was removed there was only a 0.1 AUM increase in the SDreg and no change in the AAPE. Therefore the zero intercept model was retained.

Table 9. Use of National Soils Information System expected corn yield to predict hay yield ($MT{\cdot}ha^{-1}$) and hay yield to predict animal unit months of grazing ($AUM{\cdot}ha^{-1}$).

Regression	R^2	SD_{reg} †	AAPE ‡	N
a. Hay = 1.18 Corn	0.98	1.32	11%	170
b. AUM = 1.69 Hay	0.92	4.2	21%	174

† SDreg, standard deviation about the regression; ‡ AAPR, average absolute percent error.

3.5. Calculating AUM of Grazing from Hay Yield

Soil physical characteristics did not describe expected AUM grazing yield very well, having an AAPE of 21 percent (regression not shown). This is likely due to it being more difficult to estimate on-farm AUM grazing than corn and hay yields. It is proposed that AUM of rotational grazing under BMPs be calculated from expected hay yields as follows:

An animal unit (AU) is 454 kg live weight of livestock. Forage dry matter (DM) intake (DMI) per AU is defined as 2.5% of body weight per day or 11.3 $kg{\cdot}DM{\cdot}AU^{-1}{\cdot}day^{-1}$. An AUM extends DMI over 30.5 days per month to 345 $kg{\cdot}DM{\cdot}AUM^{-1}$. Hay is forage at 90% DM while AU·DMI is forage at 100% DM. Harvest efficiency (eff.) for dry hay averages 75% while rotational grazing efficiency averages about 50%.

$$\text{Forage DM available for grazing} = \text{Hay kg/MT} \times \text{DM/Harvest eff.} = (1000 \times 0.9/0.75) = 1200\ \text{kg}$$

$$\text{Forage DM grazed} = \text{Forage DM available for grazing} \times \text{Grazing eff.} = 1200 \times 0.5 = 600\ \text{kg}$$

$$\text{AUM/MT hay} = \text{Forage DM grazed/Forage DM/AUM} = 600/345 = 1.74\ \text{AUM/MT hay}$$

Each MT hay yield should provide 1.74 AUM of grazing under rotational grazing BMPs. This is not significantly different from the regression estimate of 1.69 $AUM{\cdot}MT^{-1}$ of hay yield. This is appropriate when proper rest intervals are maintained between grazing events. Inadequate rest intervals can reduce forage yield. Excessive rest intervals can reduce forage yield and quality. Under continuous grazing as little as half of this yield may be achieved.

3.6. Predicting Small Grain and Hay Yields from Corn Yield

The NASIS expected crop yields (as of August 2020) did not have estimates for small grain yields. Expected small grain and alfalfa hay yields are available in the historic soil survey yield tables. Soil survey small grain and alfalfa yields were highly related to expected corn yields (Table 10) with AAPE of 8 to 10%.

Table 10. Small grain and hay yields on soils relative to corn yield based on soil-survey-reported expected yields. Intercepts were significant ($p < 0.05$) but when removed the SDreg change was small and the AAPE increased by only one percentage point on average.

Regression	R^2	SD_{reg} †	AAPE ‡	N
a. Wheat = 0.408 Corn	0.99	0.25	9%	1329
b. Oats = 0.376 Corn	0.99	0.26	9%	1271
c. Mixed hay = 1.11 Corn	0.98	0.85	10%	1459
d. Alfalfa hay = 1.38 Corn	0.99	0.83	8%	1656

† SDreg, standard deviation about the regression; ‡ AAPR, average absolute percent error.

4. Discussion

The West Virginia University Extension Service crop fertilization recommendations are based on expected crop yield given the dominant soil series in the field. Realistic yield goals can also be developed using the farmer's yield records. When using a farmer's yield history, five years of documented records are needed from each field. When farm-specific yields are not available, updated NASIS or extension service expected yields, under BMPs, are used. The impact of soil characteristics on crop yields found in this project was similar to research reported by researchers studying other soils [1–4]. The range of soils and their description in the NASIS data base along with historic yields from regional soil surveys enabled us to evaluate the relationship between soil characteristic and crop yield over a wide range of soils within the landscape of West Virginia.

4.1. Updating Expected Crop Yield by Soil Component

Historic expected yields from the 2020 NASIS data base and the soil survey yield tables were summarized by quintile. The top quintile yields in the NASIS data base (Table 11) were higher than those in the soil survey yield tables (Table 12). This indicates that expected yields had been updated prior to entry into the NASIS database. Within each table relative yields were calculated by taking the average within-quintile yields and dividing them by the average top-quintile (80 to 99) yield. Relative corn yield in the bottom quintile of these tables differed by only three percentage points (0.54 vs. 0.57). Relative hay and mixed hay yields in the bottom quintile of these tables differed by eight percentage points (0.51 vs. 0.59). Updated yields were calculated by multiplying within quintile relative yields by the crop's yield on better soils using current BMPs. Top quintile corn yields have increased by a factor of 1.70 (14.1/8.3 = 1.70) compared to the top quintile in the NASIS data base. Hay yields have only gone up by a factor of 1.17 (11.2/9.6 = 1.17). Updated yields using the two expected crop yield data bases (NASIS vs. soil surveys) resulted in the lowest quintile differing by 4% for corn and 13% for hay vs. mixed hay. For this update the NASIS data was used for corn, hay, and calculated AUM grazing with soil survey data used for crops not contained in the 2020 NASIS data base.

Table 11. Historic, relative, and updated expected corn and mix hay yields (MT·ha^{-1}) and animal unit months of grazing (AUM·ha^{-1}) by quintile from National Soils Information System for West Virginia soils.

Quintile	Corn	Hay	AUM
	Historic Expected Yield		
1 to 20	4.5	4.9	8.6
20 to 40	5.4	6.5	11.3
40 to 60	6.0	7.2	12.5
60 to 80	6.8	8.1	14.0
80 to 99	8.3	9.6	16.8
	Relative Yields		
1 to 20	0.54	0.51	0.41
20 to 40	0.65	0.67	0.58
40 to 60	0.73	0.74	0.68
60 to 80	0.83	0.84	0.80
80 to 99	1.00	1.00	1.00
	Updated Expected Yields under Good Management		
1 to 20	7.7	5.8	10.1
20 to 40	9.2	7.6	13.3
40 to 60	10.3	8.3	14.4
60 to 80	11.7	9.4	16.4
80 to 99	14.1	11.2	19.5

Table 12. Historic, relative, and updated expected yields (MT·ha^{-1}) for corn, wheat, oats, mix grass and legume hay, and alfalfa hay by quintile from published West Virginia soil survey yield tables.

Quintile	Corn	Wheat	Oats	Mixed hay	Alfalfa Hay
		Historic Expected Yields			
1 to 20	4.3	1.7	1.7	4.9	6.0
20 to 40	5.0	2.2	2.1	5.8	6.9
40 to 60	5.6	2.4	2.2	6.7	7.8
60 to 80	6.2	2.6	2.4	6.9	8.5
80 to 99	7.5	3.1	2.7	8.3	10.3
		Relative Yields			
1 to 20	0.57	0.57	0.63	0.59	0.59
20 to 40	0.66	0.70	0.76	0.71	0.67
40 to 60	0.74	0.76	0.82	0.81	0.75
60 to 80	0.82	0.85	0.88	0.84	0.84
80 to 99	1.00	1.00	1.00	1.00	1.00
		Updated Expected Yields			
1 to 20	8.0	3.1	1.8	6.7	7.8
20 to 40	9.3	3.8	2.2	8.1	9.0
40 to 60	10.5	4.1	2.4	9.2	10.1
60 to 80	11.6	4.6	2.5	9.4	11.2
80 to 99	14.1	5.4	2.9	11.2	13.4

4.2. Accounting for Other Factors Affecting Expected Crop Production

Expected crops yields were individually updated by soil component in proportion to current yields under BMPs. Topography and management factors other than the soil physical characteristics used in the regressions impact crop management and production. To make allowance for these factors, management rules recommended by NRCS were used to limit crops to soils within reasonable landscape locations:

1. Tilled crop yields allowed for soils with average slope of 25% or less.
2. Tilled crop yields allowed on soils with average surface stone cover of 1% or less.
3. Hay yields allowed for soils with average slope of 25% or less.
4. Hay yields allowed for soils with average surface stone cover of 12% or less.
5. Pasture yields allowed for soils with average slope of 55% or less.
6. Pasture yields allowed for soils with average surface stone cover of 35% or less.
7. Updated corn yield = corn yield × 1.70.
8. Updated predicted corn yield = predicted corn yield × 1.70.
9. Updated wheat yield = 0.38 × updated predicted corn yield.
10. Updated barley = 1.25 × updated wheat yield.
    (a) Barley not allowed on very poorly, poorly, and somewhat poorly drained soils.
11. Updated oats yield = 0.4 × updated predicted corn yield.
12. Updated grain sorghum yield = 0.7 × updated predicted corn yield.
13. Updated soybeans yield = 0.9 × updated wheat yield.
14. Updated rye yield = 0.4 × updated predicted corn yield.
15. Updated grass hay = 1.17 × hay yield.
16. Updated predicted hay yield = 1.17 × predicted hay yield.
17. Updated alfalfa hay = 1.28 × updated predicted hay yield.
    (a) alfalfa not allowed on very poorly, poorly, or somewhat poorly drained soils.
18. Updated AUM = 1.74 × updated predicted hay yield.

For map units that were not shared with other states, the updated expected crop yields, adjusted according to these rules, were uploaded to the NASIS data base and will be available at the USDA Soil Web database.

Crop yields varied around the average yield due to weather. For forage crops within the region, the SD of annual yield ranged from 19% to 38% of the mean (Table 4). This range is a function of crop response to the soil and environment. For example, alfalfa is deep-rooted and requires planting on a deep, well drained soils which enables this crop to be drought-tolerant resulting in a yield SD of 19% of the mean (mean yield 13.9, SD 2.7). However, perennial ryegrass has a shallow rooting habit and is less tolerant to drought resulting in a yield SD of 38% (mean yield 8.1, SD 3.1). Climate change is impacting both the average and variability in crop yield. Therefore expected yields will need to be updated as warranted.

5. Conclusions

Historically expected crop yields were established for soil components (soil series) by local SCS/NRCS, ASCS, and Extension staff based on local experience and university research, and were published in local soil surveys. These expected yields were used as the basis for the NASIS crop yields. Expected yields are closely related to soil physical characteristics such as slope, drainage class, depth to restriction layers, and plant AWC in the rooting zone. To update yields to 2020 yields the soil component historic expected yields were increased proportionally to the crop yield increase that had occurred due to modern genetics and management. Where a soil component did not have a historic expected yield the physical characteristics of the soil were used to estimate an expected yield using regressions developed from other soils. These updated expected yields were evaluated by NRC fields staff who suggested modifications, again based on local experience. This process is similar to how expected yields were determined historically. To validate and improve the accuracy of these expected crop yields it is recommended that crop yields be evaluated in on-farm studies under BMPs. These updated yields in association with a soil's physical characteristics can be used in computer models to evaluate the impact of climate change on crop yields.

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Conflicts of Interest: The authors declare no conflict of interest.

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