Verification of APEX Parameters and NTT for Minnesota

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INTRODUCTION

Overview of NTT

The Nutrient Tracking Tool (NTT) is an internet application that allows individuals interested in assessing non-point source runoff from farms evaluate different scenarios for nutrient and sediment reduction. Farmers, government officials, researchers and other users can determine the impacts of various conservation practices and other scenarios on nutrient and sediment losses from individual fields. In addition, impacts on crop yields and other indicators of relevance are provided to the user.

Key Features of NTT

The NTT program consists of following three main components:

1. Web interface, which is visible to the user
2. Computer simulation programs, which run in the background in response to user requests
3. Supporting databases, subsets of which can be viewed and customized by the user, based on the selections they make via the NTT web interface.

1. Web Interface

NTT is a web-based program. Users can access the tool by using their internet browser to go to the main NTT home page: (http://ntt.tiaer.tarleton.edu; for general users) and (http://ntt.tiaer-re.tarleton.edu; full version for research and educational proposes). The current versions have all required data to be simulated for lands within the mainland US and Puerto Rico territory. However, NTT has been tested for a number of sites within the US while additional testing is being performed in various states. Users can select the state and county relevant for their applications and then proceed to define scenarios and run NTT to obtain estimates of nutrient and sediment losses as well as other indicators for each scenario they define.

NTT is a user-friendly program where virtually all the data required for all of states and counties of US and Puerto Rico territory are available on the NTT server. NTT provides regional default management scenarios that can be used as-is or be modified by the user. In addition, users can evaluate structural and non-structural conservation practices that are typical for their area. Site-specific information used in the simulation (i.e. soils, weather and slope) are determined based on the user-defined area of interest (AOI) or field in a GOOGLE-based mapping system.

All other data required for the area of interest can be selected by users from drop-down list boxes in the NTT user interface. If users desire to estimate nutrient and sediment losses for management practices that are not available in the NTT default choices, they can select other options to either modify existing management practices (operations) or create new ones.
A farm or small watershed can be subdivided as much as necessary to ensure that each subarea is relatively homogeneous in terms of soil, land use, management, etc. NTT also has a field routing feature that allows the user to evaluate the interactions between subareas involving surface runoff, return flow, sediment deposition, nutrient transport, and groundwater flow.

2. NTT's Computer Simulation Programs

Agricultural Policy/Environmental eXtender (APEX) (version 0806) is the core simulation model in NTT. APEX was selected for the NTT application because of its prediction capability regarding N and P losses, crop yields, and sediment losses during evaluations of numerous management alternatives, such as installing filter strips. APEX also has other capabilities that can be useful in future potential augmentations of the tool, such as simulation of pesticide losses and carbon cycles.

APEX (Williams et al, 2012) is a modified version of the Environmental Policy Integrated Climate model (EPIC) (Williams, 1990), a field-level model that was developed in the early 1980s to assess the effects of management strategies on water quality. APEX extends the functionality of EPIC by allowing the simultaneous simulation of multiple contiguous subareas (fields) for a wide range of soil, landscape, climate, crop rotation, and management practice combinations. It is designed for whole farm or small watershed analyses, and can be used for applications, such as filter strip impacts on nutrient losses from manure application fields, that require the configuration of at least two subareas. Alternatively, it can be run for single fields in the same manner that is allowed in models such as EPIC. The ability to simulate liquid applications from animal waste storage ponds or lagoons is a key component in APEX. Other components include weather, hydrology, soil temperature, erosion-sedimentation, nutrient cycling, tillage, dairy management practices, crop management and growth, pesticide and nutrient movement, and costs and returns of various management practices.

Recently, the carbon fate and transport functions of the CENTURY model (Parton, 1996) were incorporated into APEX (version 0604 and higher), which allows APEX to simulate carbon dynamics in the soil-plant system. APEX also has groundwater and reservoir components. A field or small watershed can be subdivided as much as necessary to ensure that each subarea is relatively homogeneous in terms of soil, land use, management, etc. The routing mechanisms in APEX provide for evaluation of interactions between subareas involving surface runoff, return flow, tile flow, sediment deposition, irrigation, nutrient transport, and groundwater flow.

3. Supporting Databases

All the datasets required for running NTT are housed on the NTT server for ready user access. However, users may enter management information that is different from the pre-defined set available on the NTT program for their county of interest and can also save their information for future use. The following are the NTT databases that are available on the NTT server for states and counties in the U.S.

A. ***Weather Data:*** Precipitation, minimum and maximum temperature, from 1981-2017 at 4-KM2 resolution available throughout the US. The source of the weather data is from the USDA Parameter-elevation Regressions on Independent Slopes Model (PRISM) at Oregon State University. Reports and papers describing PRISM are available from http://prism.oregonstate.edu.The weather data is updated yearly in order to access the latest information.

The monthly weather files (MWF) are required by APEX to generate all the missing weather data (e.g., solar radiation). NTT also generates the MWF at the 4-km2 grid for any part of US mainland and Puerto Rico territory using the recent local (PRISM) weather data. This makes the APEX calculations (e.g., ET) more precise.

The weather data in NTT is automatically generated for the area of interest based on its vicinity to specific weather station(s).

B. ***Soil Data:*** Soil data, including soil texture, calcium carbonate, PH, bulk density, and organic carbon, are obtained from the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic (SURGGO) databases. Currently, NTT host a copy of USDA-SURGGO at its site, which, is accessed by its GOOGLE-based mapping system. The soil database in NTT is updated with latest data from USDA SURGGO site annually.

Finally, the soil routine in NTT computes the soil surface slope (SL) using the 30-m DEM resolution for each soil type for simulated area. The slope is calculated by averaging the slope for cells in each polygon and averaging the result for each soil type.

This report outlines the methods used to calibrate and validate NTT at the state level using the state and field-scales data for calibration and validation of APEX model currently nested NTT program. Herein, this report will be verified for State of Minnesota using data from three experimental study farms conducted by Discovery Farm organization.

METHODS & MATERIALS

To evaluate the NTT and the embedded APEX model, the followings procedures usually are conducted:

A. Sensitivity Analysis Procedure for NTT

For the geographic region of interest, the model sensitivity procedure is performed to determine the most important parameters to consider in the verification process. Sensitivity analysis also helps ensure that the most appropriate range of parameters is used for various management and structural practice conditions.

Sensitivity analysis is performed for NTT by adjusting each input variable in a predetermined fashion. After each input adjustment, NTT's calculation tool was run to produce the output corresponding to that input adjustment. The output data were then stored in a database file for subsequent processing. For more information about NTT sensitivity analysis, please also refer to Saleh et al. (2014).

B. NTT Verification (Calibration and Validation) Processes

NTT calibration and validation processes includes parameterization of the APEX model using any existing independent data. In the calibration and verification processes, model input parameters are adjusted for the area of interest so that simulation results closely match results from available regional (e.g., State) and farm scales data sources. The input parameters that are adjusted during the validation process are those that were identified during the APEX sensitivity analysis (see Saleh et al., 2014). There are three major steps followed to calibrate, validate, and make NTT ready to use for region of concern (e.g., State level).

Stage I. Calibration and parameterization of APEX for NTT for every state in the continental United States. State-level calibration and parameterization is performed using state-level measured values and the local available databases in NTT for a 35-year simulation period (including the regional weather data, soils, and the most common crops and crop management practices for the region). The available measured values for most states are generally crop yield and any available water quality data. Yield and any available water quality data are compared to those reported by valid sources (e.g., the National Agricultural Statistic Service (NASS)) and APEX parameters are adjusted accordingly until reasonable results are obtained. For further information on the first tier of state-level calibration/parameterization results, please refer to NTT homepage, which has detailed state-level parameterization results. At this stage, NTT is simulated for 30+ years when the historical data is not a limiting factor.

Stage II. Field-scale calibration/validation. In Stage 2, we use available field-scale experimental data to further refine, if needed, the Stage 1 parameters for a given region. Field-measured data must meet the with the following criteria in order to be suitable for NTT calibration/validation: 1) time series measured data available over at least 3 years; 2) include multiple study sites; 3) have measurements of variables estimated by APEX (e.g., nitrogen fluxes, flow, sediment loss, etc.); and 4) have detailed input data required to run APEX (e.g., management practices).

Stage III. The modified APEX parameters during stage 2 will be used to repeat the process in Stage 1. Stage 1 state-level parameterization/calibration is repeated using the results obtained from Stage 2. The results obtained from this stage will be evaluated and are published at NTT website.

NTT and APEX Verification Processes for Minnesota (MN)

Stage I. The available data from National Agriculture Statistics Service, USDA used to examine the NTT program, NTT databases, and validate the APEX model for 16 major cropping systems (including corn, soybean, and wheat) combination for all 87 counties within the state of Minnesota. The NTT simulations were conducted on 2,192 soils slope ranging from 0-10% slope from 1981-2015. Fields with tile system were simulated accordingly based on soils drainage characteristics information obtained from Soil Survey Data. The preliminary results of this stage were published on the NTT web site (ntt.tiaer.tarleton.edu).

Stage II. TIAER obtained data from three Discovery Farm experimental farms in Minnesota (https://discoveryfarmsmn.org/) with assistance from Mr. Tim Radatz (radatz@mawrc.org). The sites include Mayer Dairy in Stern County (ST), Half Century in Blue Earth County (BE) and Spring Creek in Chisago County (CH). Data from these study sites were used to verify and modify the initial APEX parameters obtained from stage 1 for the state of MN (please refer to NTT website, ntt.tiaer.tarleton.edu). The measured data from ST, BE, and CH farms included runoff, sediment loss, nutrient losses (N and P), and crop yield for the years 2011-2016. The weather and soil information for all sites were obtained from NTT databases. The measured values from all farms were compared with those obtained from NTT. APEX parameters were adjusted to find the best fit for the annual values.

The verification process was conducted in two parts. First TIAER simulated the BE site and adjusted the NTT parameters accordingly to provide the best fit to measured values. Next, the parameters adjusted to fit the BE site were validated by using them for simulation of the ST and CH sites. This was done without any further adjustments to the parameters for ST and CH sites.

It is important to note that due to general application of NTT, the results are evaluated based on the 35-year-average annual value of indicators (e.g., N and P losses) from 35 years of simulation. Also the measured data reported from the three sites were based on “water yield” (Oct. 1-Sep. 30) cycle, while the NTT results are obtained on annual-base (Jan. 1- Dec-3) cycle. For the above reasons, our comparison of simulated and measured parameters was based on the average annual results of the five-year field study period. The management files for field sites were built and simulated using the NTT program. The simulation results were compared with measured values from BE site to obtain the best parameters. The parameters were adjusted for surface runoff (Q), nitrogen in surface runoff (QN), total phosphorus lost by surface runoff and sediment (TP), tile drainage flow (QDR), nitrogen in tile drainage (QDRN), and phosphorus in tile drainage (QDRP) on average annual basis.

Study Areas for Verification

A. Half Century Farm, Blue Earth County (BE), MN

A 14.3-acre surface watershed and 28.2-acre subsurface tile drainage watershed in a corn-soybean crop rotation with swine manure application production located at Blue Earth County, MN (Figure 1). Management practices for BE farm was provided by Discover Farm research center using the measured land use management data obtained from local area (Table 1).
The initial site visit occurred in 2010, with a tour of the field to evaluate potential sites for surface water and sub-surface drainage monitoring. The farm was selected for the Discovery Farms Minnesota Program because the cropping practices and landscape are typical of the region and there was a field site capable of generating a robust and reliable dataset. The site selected for monitoring provides an edge-of-field water quality evaluation of fields with a corn-soybean rotation, conventional tillage and both manure and commercial fertilizer application. The field selected has pattern drainage tile at 80 foot spacing. The site for monitoring of surface runoff was placed where a berm had previously been constructed. This berm was originally installed to slow runoff before it entered a stream; it helped to reduce soil loss from both the field and adjacent ravine. Minnetonka silty clay loam, a common soil type in the area, dominates the field where the monitoring takes place. This soil is poorly drained and was formed from lacustrine sediments over glacial till. Tile drainage is required for optimum economic production. The tile lines capture water from approximately 26.2 acres. The surface structure collects water from approximately 14.3 acres. The Minnetonka silty clay loam soil has an available water holding capacity of approximately 2 inches per foot of soil to a depth of about 2 feet. This water holding capacity is

nearly the same throughout the active root zone. Soil Data for 3 major soil types within the field was obtained from SSURGO from USDA-NRCS via NTT site. Slope for each soil type was calculated from 30-m resolution DEM. The minimum and maximum temperature, daily precipitation, and other weather data was obtained from NTT databases.

Figure 1. Half Century Farm in Blue Earth County (BE), MN.

Table 1. Management practices for Half Century Farm provided by Discover Farm research center.

Description	2011	2012	2013	2014	2015	2016
Crop	Corn	Soybean	Corn	Soybean	Corn	Soybean
Fertilizer timing, placement, and source	Hog manure application Fall 2010 Starter Fertilizer 9-18-9	None	Urea Fall 2012 Starter Fertilizer 9-18-9	None	Urea Fall 2012 Starter Fertilizer 9-18-9	None
Nitrogen application rate (lb/ac)	225	None	156	None	166	None
Phosphorus application rate (P2O5 lb/ac)	107	None	12	None	12	None
Potassium application rate (K2O lb/ac)	132	None	6	None	6	None
Tillage	Fall chisel/Spring soil finisher	Fall chisel/Spring soil finisher	Fall chisel/Spring soil finisher	Fall chisel/Spring soil finisher	Fall chisel/Spring soil finisher	Fall chisel/Spring soil finisher
Plant Date	15-Apr	14-May	11-May	24-May	17-Apr	8-May
Harvest Date	15-Oct	21-Sep	27-Oct	7-Oct	11-Oct	30-Sep
Yield (bu/ac)	180	57	170	54	216	68
Soil Test pH (0-6 in)	None	5.8	7.0	6.2	6.0	6.2
Soil Test Organic Matter (0-6 in; %)	None	6.5	5.0	5.5	5.8	6.4

Soil Test P (Bray; 0-6 in; ppm)	None	21	28	18	25	31
Soil Test K (0-6 in; ppm)	None	131	174	148	None	182

B. Mayer Dairy Farm, Stearns County, MN (ST)

Meyer Dairy is a family dairy farm located just south of Sauk Centre, Minnesota in Stearns County (http://meyerdairy.wordpress) (Figure 2) and includes 146 ha which are utilized to grow feed for the dairy cattle. The typical cropping rotation at Meyer Dairy is four years of alfalfa followed by four years of corn. Approximately 60% of their tillable acres are tile drained to ensure high crop productivity.

The region is characterized by rolling plains with a mix of woodlands, row crops and pasture. The farm is located in the Upper Sauk River watershed, approximately 6.4 km from the Sauk River. Area soils mostly consist of glacial till deposits. Mean daily temperatures are -9.4˚C and 21˚C for the winter and summer months, respectively. Average annual precipitation is about 69 cm, most of which occurs during the growing season. On average, 60 cm are in the form of rain and 9 cm are in the form of snowfall.

The soils in the field selected for monitoring are classified as Flom and Ves loams. The Flom loam is considered to be poorly drained while the Ves loam is considered to be well drained. Both soils have a high water holding capacity. Soil samples, routinely collected from Meyer Dairy, are used to guide the application of fertilizer and manure.

Figure 2. Mayer Dairy farm in Sterns County (ST), MN.

Management practices for BE farm was provided by Discover Farm research center Using the measured land use management data obtained from local area (Table 2).

Table 2. Management practices for Mayer Dairy Farm provided by Discover Farm research center.

Description	2011	2012	2013	2014	2015	2016
Crop	Corn silage	Corn	Corn silage	Alfalfa	Alfalfa	Alfalfa
Fertilizer timing, placement, and source	Spring dairy manure, injected	Spring dairy manure, injected	Fall dairy manure, injected Spring urea	None	None	None
Nitrogen application rate (lb/ac)	255	247	260	None	None	None
Phosphorus application rate (P2O5 lb/ac)	90	87	100	None	None	None
Potassium application rate (K2O lb/ac)	255	247	170	None	None	None
Tillage	Fall chisel/Spring field cultivator	Fall chisel/Spring field cultivator	Fall chisel/Spring field cultivator	Fall chisel/Spring field cultivator	None	None
Plant Date	19-May	27-Apr	7-May	5/17/14 and replant on 8/8/14	None	None
Harvest Date	13-Sep	13-Sep	14-Sep	None (filed was washed out)	6/1/2015, 6/30/2015,7/27/2015, 8/26/2017	5/21/16, 6/19/16, 7/19/16, 8/16/16
Yield	30 ton/ac	225 bu/ac	30 ton/ac	NA	NA	NA
Soil Test pH (0-6 in)	None	6.7	None	7.1	6.6	7.0
Soil Test Organic Matter (0-6 in; %)	None	3.9	None	6.2	6.4	5.1
Soil Test P (Bray; 0-6 in; ppm)	None	42	None	50	57	32
Soil Test K (0-6 in; ppm)	None	278	None	273	218	168

C. Spring Creek Farms, Chisago County, MN (CH)

Spring Creek Farms is a grain operation located near North Branch in Chisago County (Figure 3). The farm produces 700 acres of corn and 700 acres of soybeans, with a small acreage of locally sold vegetables. The farm has been a leader in soil conservation practices, have practiced no-till planting since the mid-1990s. The soil in the field selected for monitoring is classified as a Cushing loam. This soil type is considered to be well drained. Permeability in the top 18 inches of the profile is described as moderate. Below 18 inches, permeability is described as being moderately slow; this soil has a high water holding capacity. The phosphorus value in this soil is classified as very high. Soil sample analysis in Table 3 shows the pH of 6.4 Organic Matter of %1.6, Soil Test P (Bray) of 39 ppm, and Soil Test K of 119 ppm). Installation of the edge-of-field surface water monitoring site occurred in November 2010. The flume, wing-wall, berm and equipment needed for automatic, routine measurement of surface water runoff was installed at this time. Weather station equipment to record precipitation, temperature and other climatic variables was also installed. The surface water monitoring site at SCF was fully operational in March of 2011. Surface water runoff from the edge-of-field site will be monitored year round for the 5 to 7 year duration of this study. Collected samples are analyzed for sediment, total phosphorus, phosphate phosphorus, total kjeldahl nitrogen, chloride, ammonia and nitrate nitrogen. By combining a measure of water flow and sediment and nutrient concentrations, it will be possible to calculate total nutrient and sediment movement.

Figure 3. Spring Creek Farms in Chisago County, MN.

Table 3. Management practices for Mayer Dairy Farm provided by Discover Farm research center.

Description	2011	2012	2013	2014	2015	2016
Crop	Corn	Soybean	Corn	Soybean	Corn	Soybean
Field Experimental size						
Fertilizer timing, placement, and source	May 14, banded, 6-16-40; June 10, broadcast, urea & ammonium sulfate; June 23, broadcast, urea	None	May 4, broadcast, 6-16-40; June 4, broadcast, urea & ammonium sulfate; June 13, broadcast, urea	None	June 15, broadcast, urea & ammonium sulfate; July 1, broadcast, super U & ammonium sulfate	None
Nitrogen application rate (lb/ac)	180	None	181	None	207	None
Phosphorus application rate (P2O5 lb/ac)	60	None	60	None	13	None
Potassium application rate (K2O lb/ac)	100	None	128	None	8	None
Tillage	None	None	None	None	None	None
Plant Date	16-May	10-May	15-May	23-May	5-May	4-May
Harvest Date	7-Nov	12-Sep	Apr 15 (2014)	23-Oct	10-Nov	6-Oct
Yield (bu/ac)	200	48	169	52	190	66
Soil Test pH (0-6 in)	6.4	7.3	7.4	7.2	7.1	7
Soil Test Organic Matter (0-6 in; %)	1.6	2	1.1	1.8	1.8	1.9
Soil Test P (Bray; 0-6 in; ppm)	39	57	41	30	36	20
Soil Test K (0-6 in; ppm)	119	102	83	94	97	71

Input and Evaluation Data

Slope data were obtained from a 30-m DEM obtained via NTT. The modified Soil Survey Geographic (SSURGO; http://websoilsurvey.nrcs.usda.gov) data sets obtained from the NTT were used to parameterize the required soil physical, chemical, and hydraulic model inputs. Personnel from the study site provided the land use and land cover information and the general land management data, including tillage types and dates, planting, fertilization, and harvests for the years 2011 through 2016.

Daily weather data (e.g., minimum and maximum temperature, and rainfall) were obtained from the PRISM Climate database. Monitoring sites at all sites were fully operational in March 2011-2016. Samples are collected after precipitation events and analyzed for water quality components. In this study, surface runoff, total nitrogen in surface runoff, total phosphorus in surface runoff, tile drainage flow, total nitrogen in tile drainage, and total phosphorus in tile drainage cumulated at the end of every month was measured. Data from all sites from period of 2011-2015 were used for this study.

Model Performance

Graphical methods were used to evaluate model performance during the verification process at annual temporal scale.

RESULTS AND DISCUSSION

Parameterization Results

The final parameters for PARM and CONTROL files were obtained from calibration of APEX for the BE site and were used for other two sites (ST and CH). Finally, the Stage 1 parameters defined for Minnesota were modified with those obtained from the results of this analysis (Table 4).

Table 4. The final parameters were used for State of MN at the NTT program.

Parameter	Definition	File	Line	Field	Range	Calibrated parameter value
IET	FLAG, Potential ET equation	Cont[a]	1	10	0-5	4
23	Hargreaves PET equation coefficient equation	Parm Cont	3	3	0.0023-0.0032	0.0032
34	Hargreaves PET equation exp	Parm	4	4	0.4-0.6	0.48
LBP	FLAG, Soluble P runoff estimate equation	Cont	1	19	0-1	0
4	Water storage N leaching	Parm[c]	31	4	0-1	0.90
7	N fixation coefficient	Parm	31	7	0-1	0.90
8	Soluble P runoff coefficient	Parm	31	8	10-20	10
14	Nitrate leaching ratio	Parm	32	4	0.10-1.00	0.40
15	Runoff CN residue adjustment parameter	Parm	32	5	0.00-0.50	0.05
29	Biological mixing efficiency	Parm	33	9	0.10-0.50	0.35
42	SCS curve number index coefficient	Parm	35	2	0.01-1.5	0.80
72	Volatilization/nitrification partitioning coefficient	Parm	38	2	0.05-0.5	0.10
76	Standing dead fall rate coefficient	Parm	38	6	0.0001 - 0.1	0.005
83	Estimates drainage system lateral hydraulic conductivity	Parm	39	3	0.001-10	2.00
96	Soluble P leaching K_D value	Parm	40	6	1-15	5.00

Verification Results of Initial PARM and CONTROL Files

The results of observed and simulated average annual Q, QN, TP, QDR, QDRN, and QDRP values are presented in Tables 5-6 and illustrated in Figures 4-6. The Average 5-year annual measured and simulated values as shown are close to what NTT predicted for site BE using the best fit parameters listed in Table 4. This is considering the problems that usually associated with field measurements, using the different measurement and simulated time cycles, and using the databases currently available in NTT for study area.

The best fit APEX parameters obtained from site BE were applied to sites ST and CH for validation purpose. The results, as shown in Table 5-6 and Figures 4-6, shows reasonable similarity between measured and predicted values as well. It is important to note that the results obtained from this study are based on using slope data derived from the DEM layer and the default databases for soils and weather available in NTT program as well.

Considering that average annual results from NTT are used to evaluate and decide on the best scenarios to reduce nutrients and optimize crop production, the results obtained from comparison of measured and predicted average annual of 5-year (2011-2015) by NTT in this study are encouraging.

Stage III. Finally the final parameters for State of MN were updated with those obtained in this study (Table 4) in all versions of NTT.

Table 5. Observed and simulated average annual water quality obtained by NTT for all sites during 2011-2015.

Location	*Obs Q*	*Sim Q*	*Obs QN*	*Sim QN*	*Obs TP*	*Sim TP*	*Obs QDR*	*Sim QDR*	*Obs QDRN*	*Sim QDRN*	*Sim QDRP*	*Obs QDRP*
	in		*lbs/ac*				*in*		*lbs/ac*			
BE Farm*	2.43	2.08	1.15	0.94	0.38	0.48	7.32	8.20	28.89	30.80	0.05	0.08
ST Farm	2.09	2.96	1.24	1.05	1.02	1.15	4.11	4.90	34.30	30.55	0.13	0.13
CH Farm	2.32	2.12	0.58	0.67	0.90	0.54	N/A					

*Calibrated site.

Table 6. Observed and simulated crop yield by NTT for all sites during 2011-2015.

Location	Corn (bs/ac)		Soybean (bu/ac)	
	Obs	*Sim*	*Obs*	*Sim*
BE Farm	189.00	203.00	58.00	58.00
ST Farm	225.00	189.00	N/A	N/A
CH Farm	186.00	177.00	55.00	64.00

Figure 4. Simulated and observed outputs (BE farm, MN) during 2011-2015.

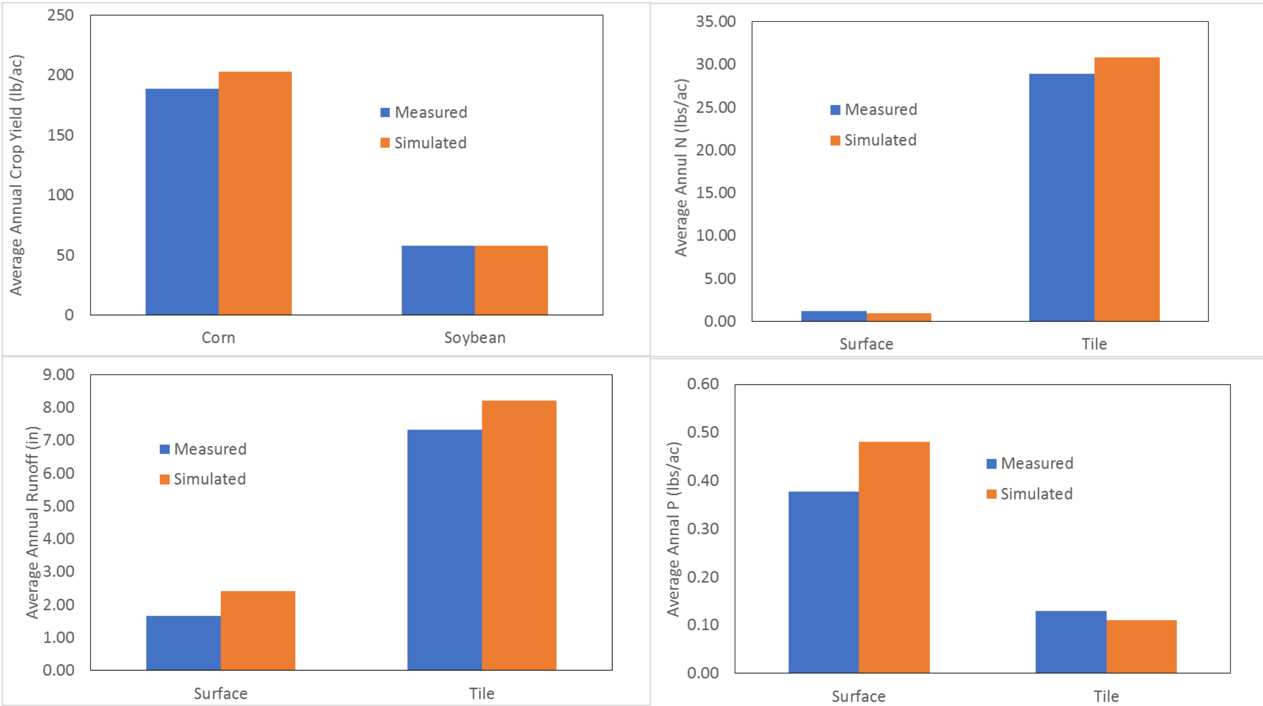


Figure 5. Simulated and observed outputs (ST farm, MN) during 2011-2015.

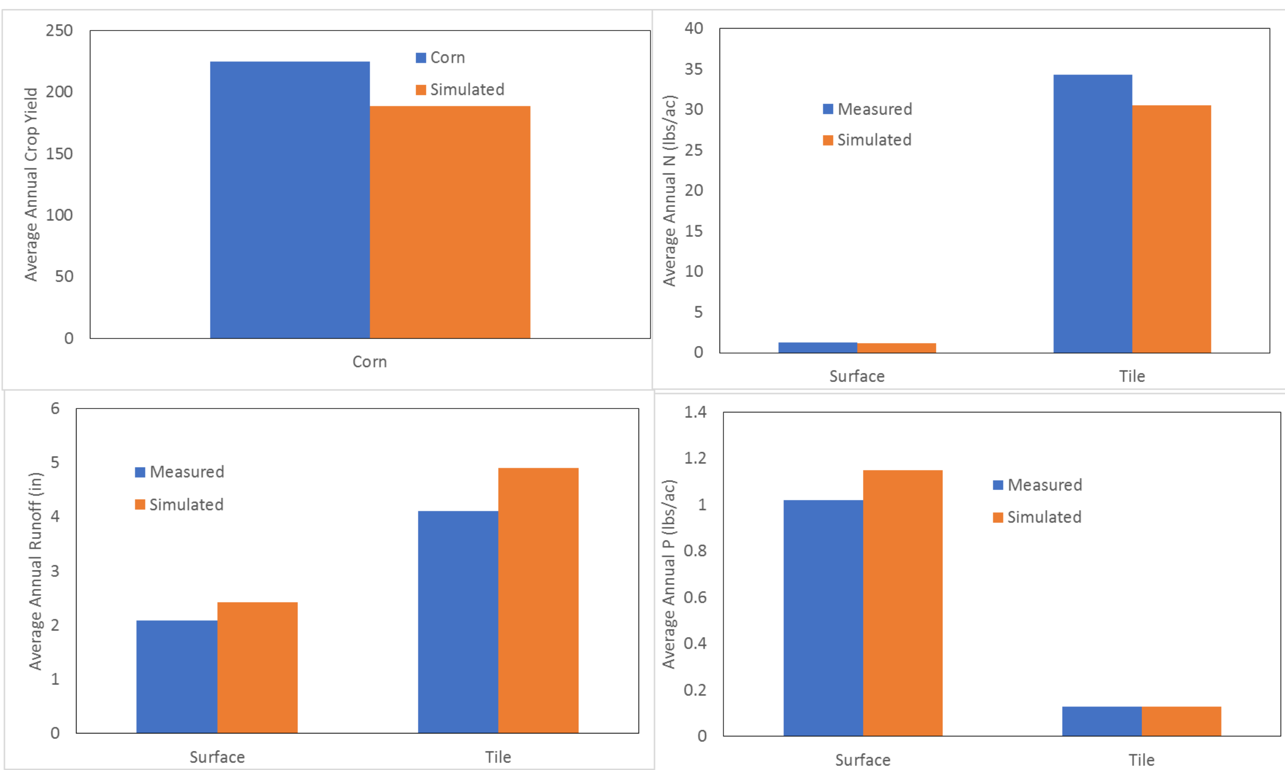
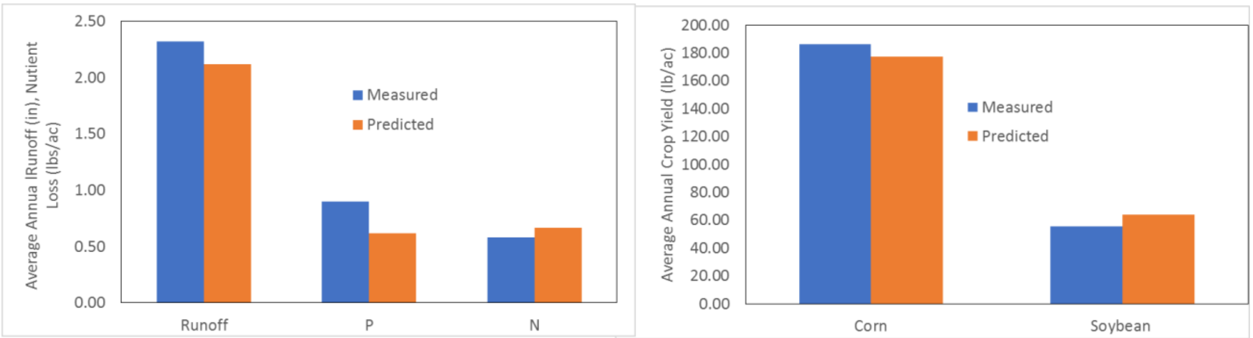


Figure 6. Simulated and observed outputs (CH farm, MN) during 2011-2015.



CONCLUSIONS

The APEX parameters modified and verified in this study seems to be a reasonable fit for the cropping systems in three Discovery farm experimental sites representing the major cropping systems in various sector of MN. We believe this study shows that the updated APEX (including the best fit parameter obtained in this study) and NTT databases (e.g., soil and weather) would make NTT a appropriate tool to use for the major cropping systems (e.g., corn, soybean, and wheat) to evaluate the impacts of current and hypothetical crop management practices for the State of MN. Users can use NTT to evaluate the best conservation practices for reducing nutrient losses to the environment while maximizing crop production. The process described in this study will ensure that estimates derived from NTT are based on best available science and contribute to informed decision-making and analysis. The processes described in this study will be applied to validate NTT for other cropping systems that are practiced in State of MN. Similar processes will be applied to validate NTT and parameterize APEX for all other regions where the measured data become available.

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