SWAT2000

SOIL AND **W**ATER **A**SSESSMENT **T**OOL

SECOND REPORT

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Table of Contents

1. Study site

Buck Island Ranch is a cattle ranch of the MacArthur Agro- Ecology Research Center, located northwest of Lake Okeechobee in the Lake Istokpoga-Indian Prairie Basin, Highlands County, South Central Florida, USA. The ranch lies on the Harney Pond Canal, a major drainage canal linking Lake Istokpoga to Lake Okeechobee, and one of five major tributaries in the Lake Okeechobee watershed.

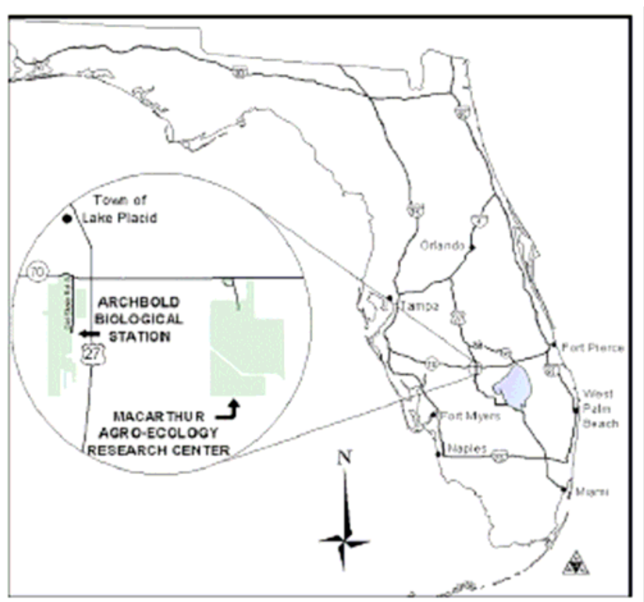


Fig. 1: Location of MacArthur Agro- Ecology Research Center

Pastures are dominated by introduced bahiagrass (*Paspalum notatum*) and native grasses (*Andropogon virginicus*, *Andropogon glomeratus*, *Paspalum laeve*, *Axonopus affinis*). These pastures are referred to as semi-native pastures and are not fertilized nor limed. In the dry season, from November through April/May, the cattle are maintained mainly on winter pastures. In the wet season from May through November the cattle graze predominantly on improved summer pastures. The ranch additionally has an array of 16 experimental pasture plots, of which 8 are improved summer-grazed pastures (plot size 20.2 ha) and 8 are semi-native winter-grazed pastures (plot size 32.4 ha). We have performed the simulation of Winter Pasture 6, where the stocking rate was 15 cows. The main soil types at the site are Pineda fine sand or Pineda fine sand with a muck layer. The poor phosphorus retention capacity and high water permeability of these sandy surface soils reduces the amount of particulate - bound P to neglible proportions.

2. Surface Runoff and Water Quality Measurements

Trapezoidal flumes, located downstream of the pasture, collect all surface drainage leaving the site. This type of flumes are hydrologically unobtrusive and does not significantly alter surface runoff. The stage measurements are taken every 20 minutes and converted to flow values by the datalogger, which in turn records data and activates automatic water samplers based upon instantaneous flow conditions. Programmable data loggers trigger the samplers based on flow volume and hydrograph geometry. These samples are analyzed to assess and compare water quality characteristics. Flow data from the flumes are combined with chemical analyses results to determine runoff nutrient loads from the pastures. In addition, two automated meteorological stations are located within the pasture.

3. SWAT Input data

As it was stated in the our first report, SWAT (**S**oil and **W**ater **A**ssessment **T**ool) is a watershed, scale model. The main reasons for its development was simulating large catchments for several aspects of land management, such as soil erosion and agricultural pollution. In SWAT simulation, a catchment is divided into sub-basins. Each sub-basin is then individually discretised in a number of ways depending on extent of heterogeneity and divided into HRU (Hydrologic Response Units - lumped land areas within the subbasin that are comprised of unique land cover, soil, and management combinations). In our simulation, we assumed that the Winter Pasture 6 is characterized by homogenous soil and vegetation characteristics. We performed the simulation for one HRU and one subbasin.

Parameter values are stored in database files which are opened as needed and then closed to aid in efficient use of computer time. The three levels of detail of input data are defined in SWAT: watershed, subbasin, or HRU. Most input information is organized according to the type of input (soil file, management file). However, there are a few files that have had to serve as “catch-alls”. These files contain input data for various processes modeled in the watershed that do not fit into any of the specialized files.

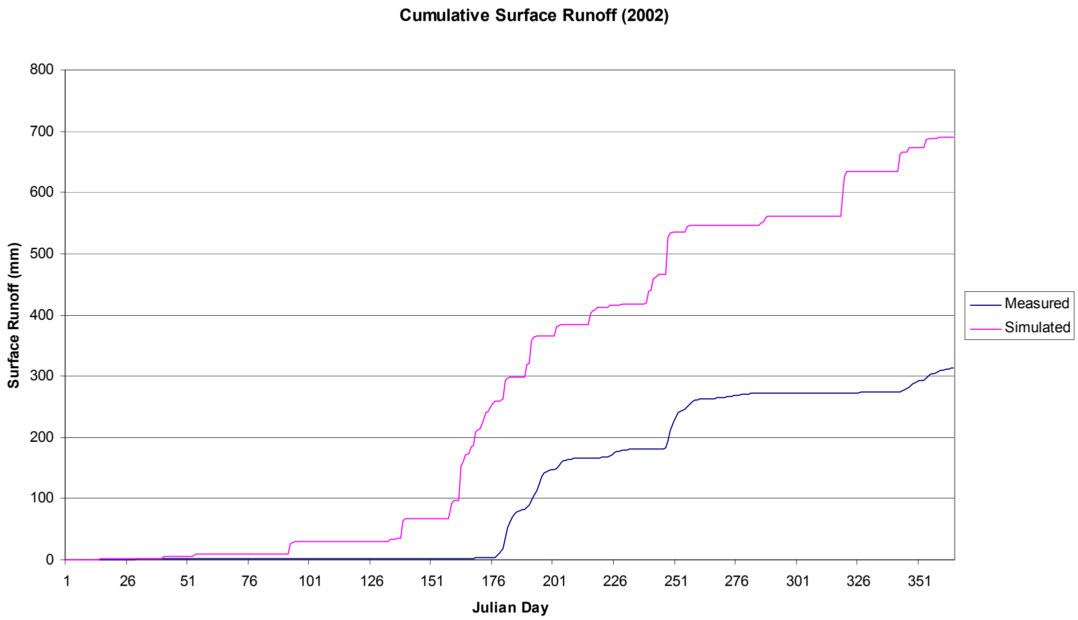
SWAT is physically based. and requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed. Due to technical and theoretical problems, associated with determining all the parameters, some data have to be estimated. The detrimental effects of this may be reduced by identification by sensitivity analysis of the parameters that are the most influential (sensitive) in the model.

4. Simulation of Hydrological Processes

4.1. Calibration - hydrology

At the beginning of our simulation (no calibration performed) cumulative surface runoff for 2002 data was overestimated by approximately 120% (Fig.2 a.)

a)



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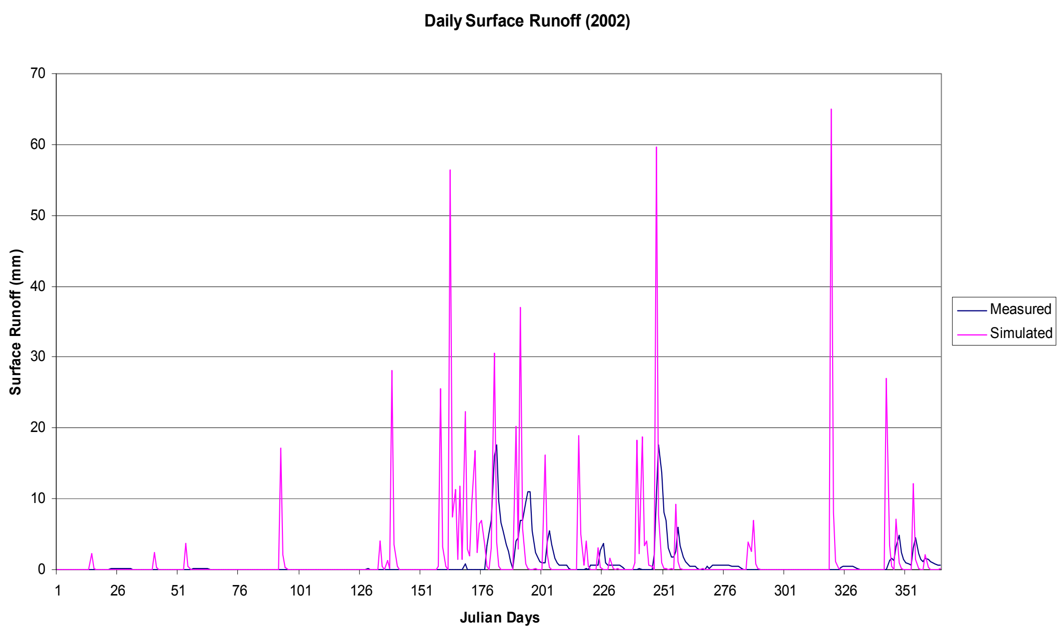
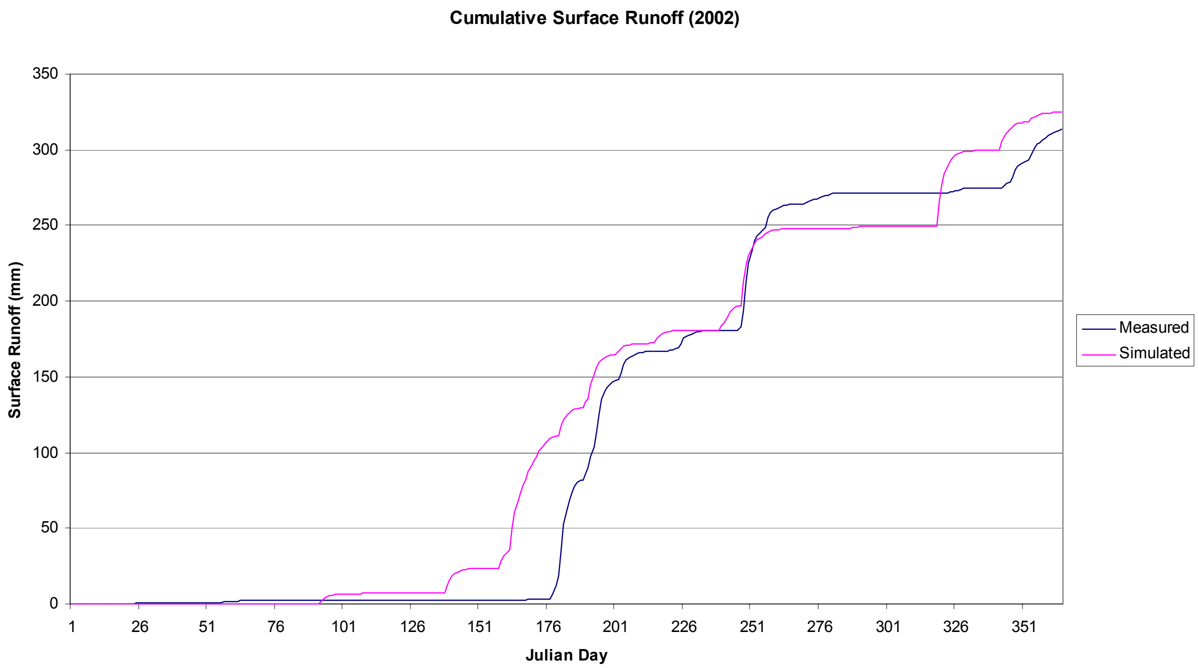


Fig.2: Initial hydrology run: a) cumulative annual values, b) daily values

During calibration we decreased curve number, increased maximum canopy storage and decreased surface runoff lag time. The minor output changes were caused by differences In average slope length and initial soil water storage.

a)



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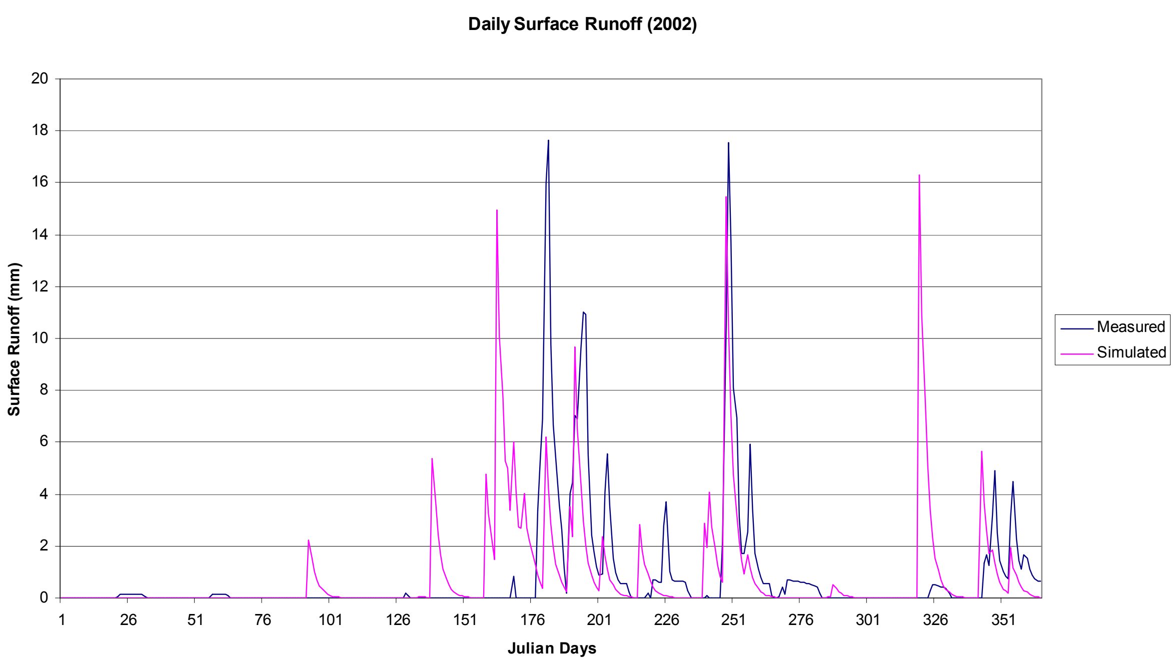


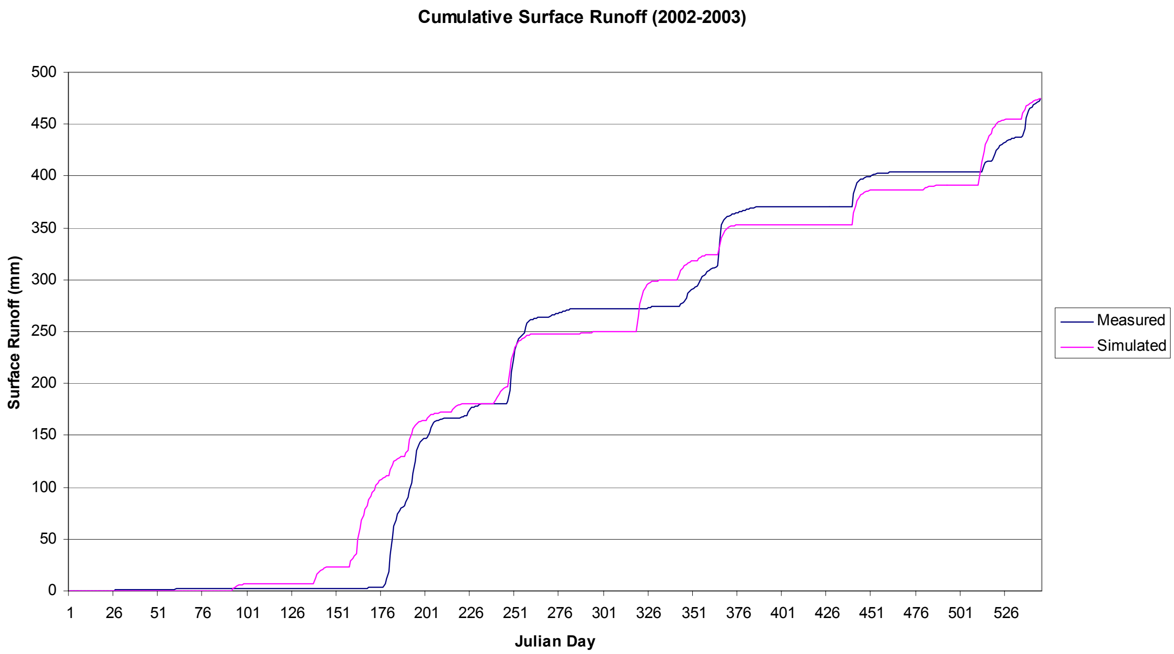
Fig.3: a) Calibrated annual cumulative runoff, b) calibrated daily surface runoff

After the calibration of 2002 data, the error of cumulative annual values was 3.5%.

4.2. Validation - hydrology

For validation of the model performance we used the data outside those involved in model calibration (measured data from year 2003).

a)



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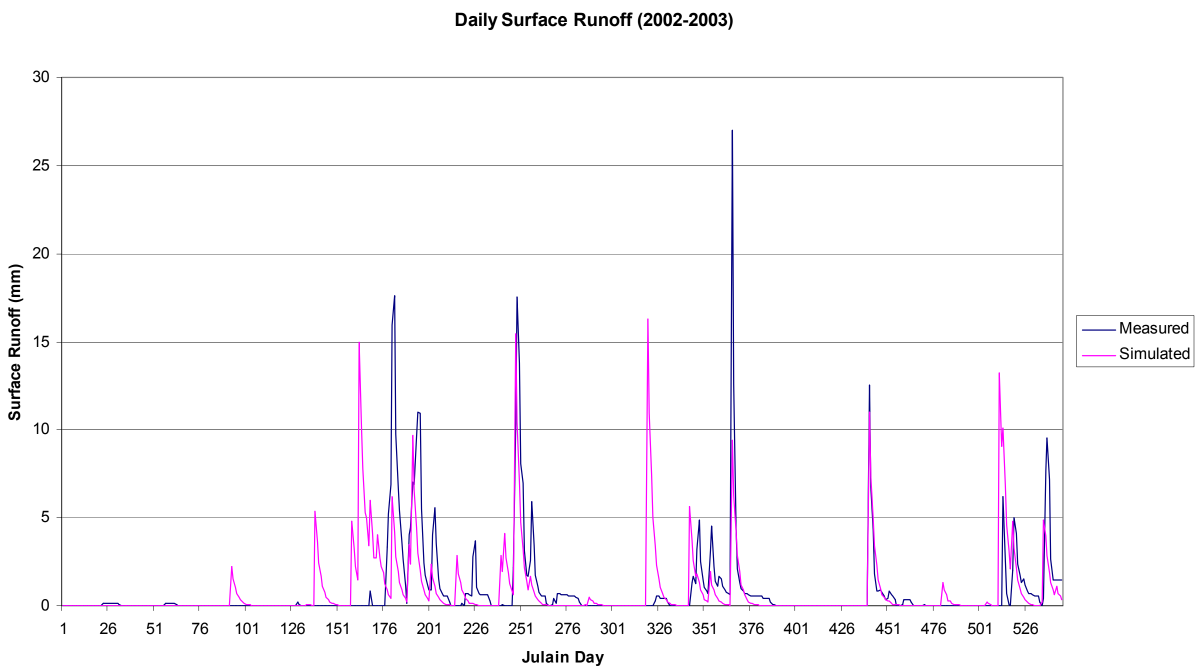


Fig.4: Validation of data from 2002-2003, a)cumulative annual surface runoff, b) daily surface runoff.

The error between simulated and measured cumulative runoff was 0.007%. It may indicate that SWAT, performs very well after calibration. However, when the daily runoff is taken into consideration, some discrepancies may be observed. Model overestimates surface runoff and pick rates during dry periods and under predicts surface runoff during wet periods. (Fig.4). Although SWAT is assumed to be physically based, it uses the conceptual Soil Conservation Service (SCS) curve number method for determination of the surface runoff. This may not be the right method for the specific conditions of the simulated pasture (flat topography and high infiltration rates). In the SCS curve number method the initial value of abstractions (surface storage, interception, infiltration) is approximated as 0.2S, where S is retention parameter, calculated on the basis of the given curve number. The curve numbers, given in tables are generally applicable to 5% slope. Normally some methods exist for slope adjustment. However SWAT does not make this type of adjustment.

4.3. Sensitivity analysis – hydrology

As mentioned before, SWAT is physically based. and requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed.

Sensitivity analysis was performed for parameters that were the most influential in shaping the outputs. In case of hydrology these were: curve number, maximum canopy storage, surface runoff lag time. The results of changing the parameters values by 5 and 10% are presented in Tab.1: a-c. The most sensitive parameter was the SCS curve number. Decreasing value of curve number by 5 and 10% led to the increase of simulated runoff by approx. 15 and 30% respectively.

a)

	-10%	**-5%**	**Base**	**5%**	**10%**
Curve Number	59.400	62.700	66.000	69.300	72.600
Measured	474.243	474.243	474.243	474.243	474.243
Simulated	331.793	399.422	474.277	556.680	647.084
Change	142.450	74.821	-0.034	-82.437	-172.841
% Error	30.037	15.777	-0.007	-17.383	-36.446

b)

	-10%	**-5%**	**Base**	**5%**	**10%**
Canopy Storage	2.340	2.470	2.600	2.730	2.860
Measured	474.243	474.243	474.243	474.243	474.243
Simulated	476.623	475.529	474.277	473.065	471.816
Change	-2.380	-1.286	-0.034	1.178	2.427
% Error	-0.502	-0.271	-0.007	0.248	0.512

c)

	-10%	-5%	Base	5%	10%
Surface Runoff Lag Time	1.782	1.881	1.980	2.079	2.178
Measured	474.243	474.243	474.243	474.243	474.243
Simulated	474.134	474.337	474.277	473.352	472.105
Change	0.109	-0.094	-0.034	0.891	2.138
% Error	0.023	-0.020	-0.007	0.188	0.451

Tab.1: Sensitivity analysis for a) curve number, b) maximum canopy storage, c) surface runoff lag time

5. Simulation of Nutrients

5.1. Calibration - Nutrients

Nutrient transport within watershed depends almost entirely upon hydrology. Therefore, our main objective was to simulate water yields accurately. During calibration of nutrients we did not consider parameters that could have influence on hydrological outputs. As SWAT requires a lot of input information. These input parameters could be adjusted to produce almost any result. We tried to avoid careless calibration and use the reasonable values of input parameters.

The Total Phosphorus loads were measured at the site, with no partition into different phosphorus forms (organic, inorganic). SWAT does not simulate TP, instead it gives outputs of different phosphorus forms (soluble inorganic phosphorus, organic phosphorus, particulate phosphorus). Because of specific phosphorus dynamics in the site, caused by extremely flat topography and poor phosphorus sorption capacity of soil, we assumed that outputs of inorganic soluble phosphorus (PO_4^{3-}) loads may be a close approximation of TP loads. Therefore, during calibration we compared measured TP loads with simulated PO_4^{3-} loads.

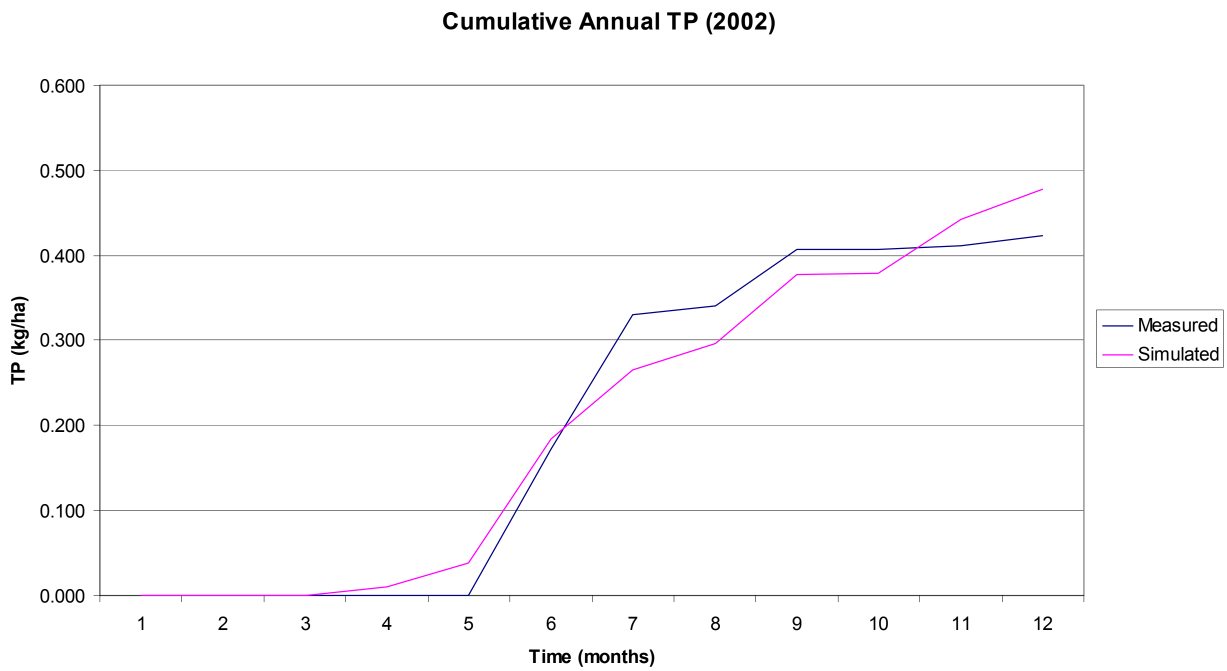
Numerous input parameters were checked to have influence on P loads in surface runoff. Some of them are presented in Tab.2.

Definition	Variable name	Effect on output
Initial soluble P concentration	SOL_SOLP	significant
Initial humic organic P	SOL_ORGP	small
P sorption coefficient		small
P soil partitioning coefficient	PHOSKP	significant
P percolation coefficient	PPERCO	no
P enrichment ratio	ERORGP	no
Amount of manure applied	WMANURE	significant
P availability index	PSP	no
Residue decomposition coefficient		no
Residual pool (top 10 mm of soil)	RSDIN	no
Bulk density of the layer	SOL_BD	no

Tab.2: Variables used for calibration of TP loads

The most significant parameters for output TP loads were: soil initial soluble phosphorus concentration and phosphorus soil partitioning coefficient (the ratio of the soluble phosphorus concentration in the surface 10 mm of soil to the concentration of soluble phosphorus in surface runoff). The amount of applied manure was important for TP loads, but after adjusting the values of manure applied to realistic conditions (15 cows per site) the influence of this parameter diminished drastically. What may indicate the right management practice. Minor changes In outputs were achieved by changing initial humic organic phosphorus and P sorption coefficient.

a)



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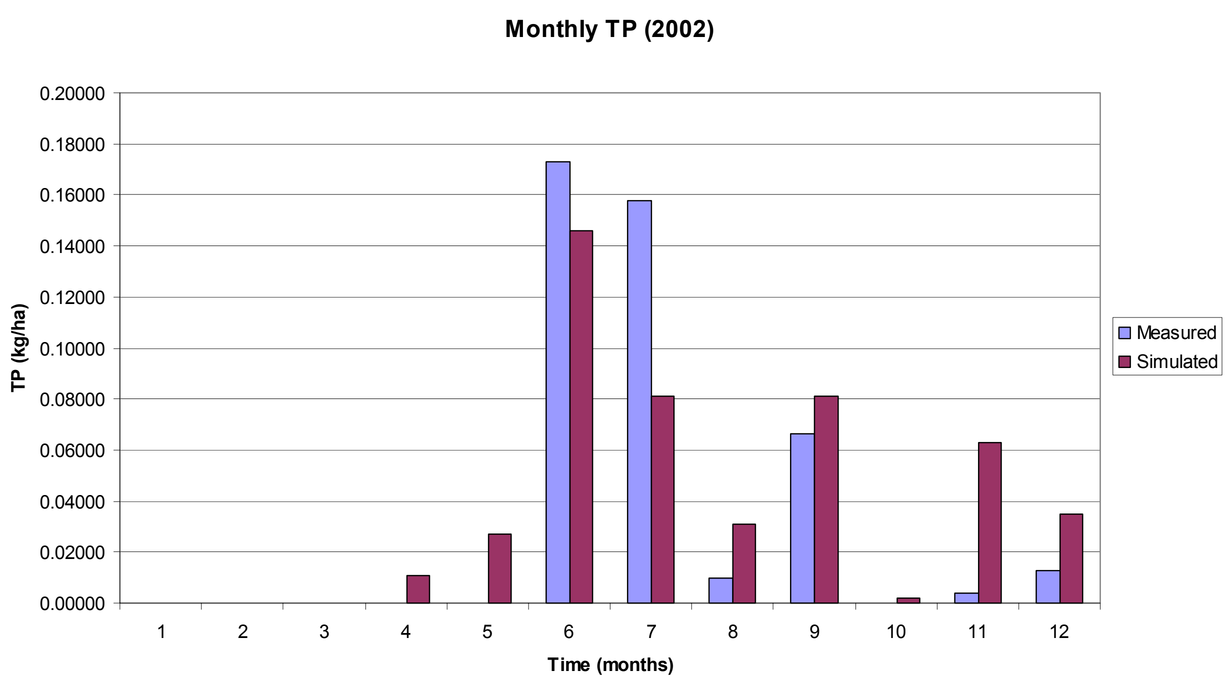


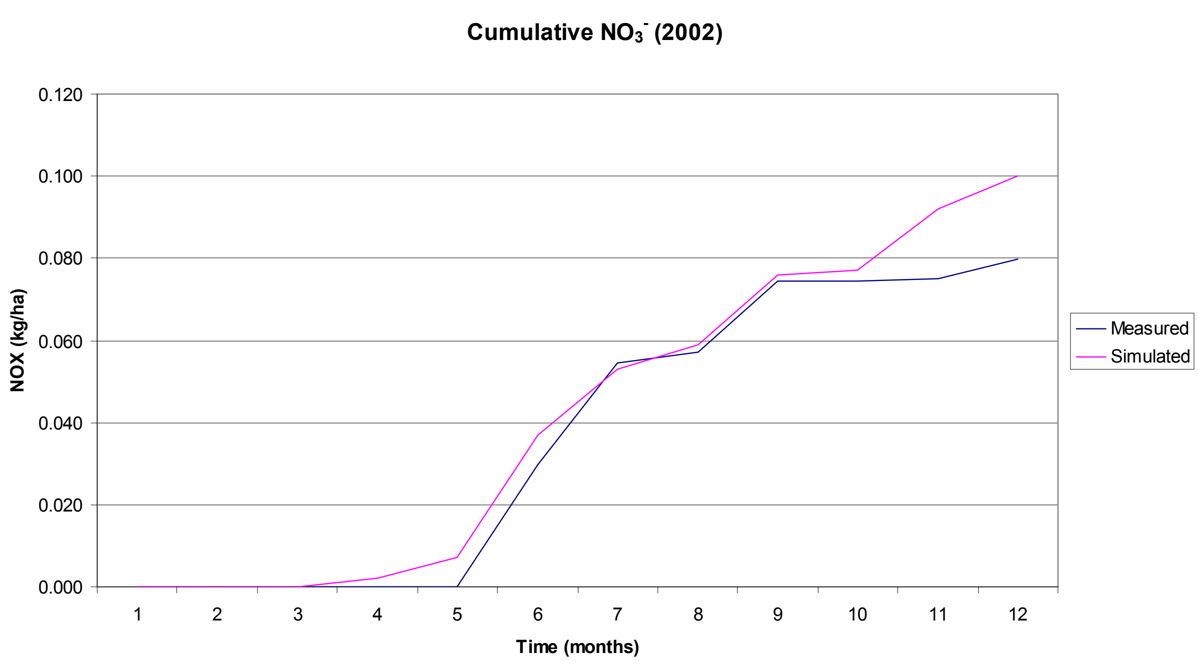
Fig.5: Calibrated cumulative TP loads: a) annual, b)monthly

Similar calibration procedure was performed for nitrate loads. The parameters which had effect on nitrate loads were identified in first place and later the importance of the effect was checked. The most significant parameters were: nitrate percolation coefficient and concentration of nitrogen in rainfall (mg/dm^3). Minor changes in nitrate outputs were observed when soil organic carbon content and residual pool in top 10mm soil were altered.

Definition	**Variable name**	**Effect on output**
Nitrate percolation coefficient	NPERCO	significant
Organic C soil content	SOL_CBN	small
Residual pool	RSDIN	small
Decomposition rate		no
Concentration of N in rainfall	RCN	significant
Initial NO3 concentration	SLO_NO3	no
Initial humic organic P	SOL_ORGN	no
N uptake distribution parameter	UBS	no
Amount of manure applied	WMANURE	no

Tab.3: Variables used for calibration of nitrate loads

a)



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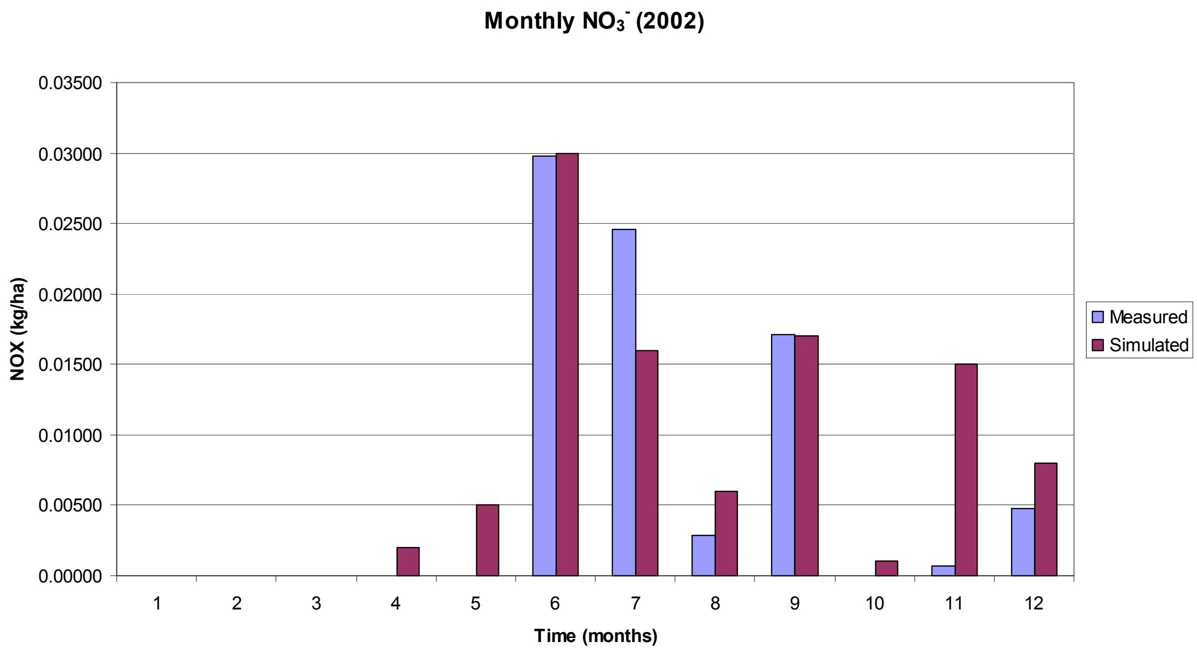


Fig.6 : Calibrated cumulative nitrate loads: a) annual, b)monthly

5.2. Validation – Nutrients

For performing the validation of nutrients the data from 2002-2003 were used.

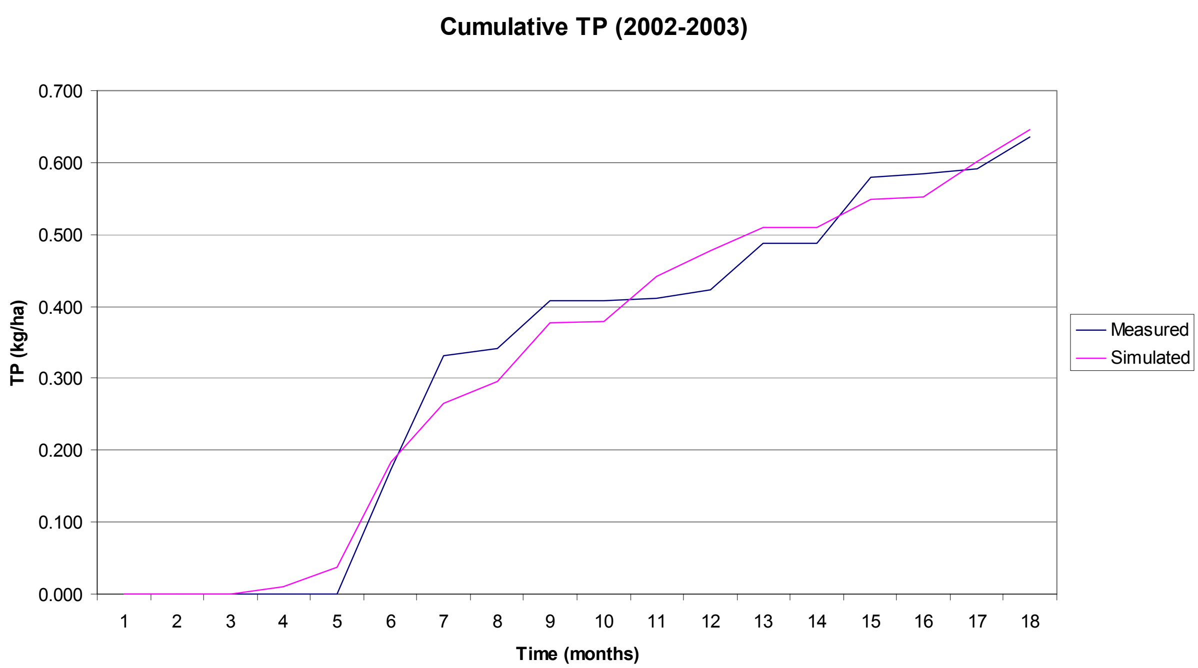


Fig.7 : Validation of annual cumulative TP loads (2002-2003)

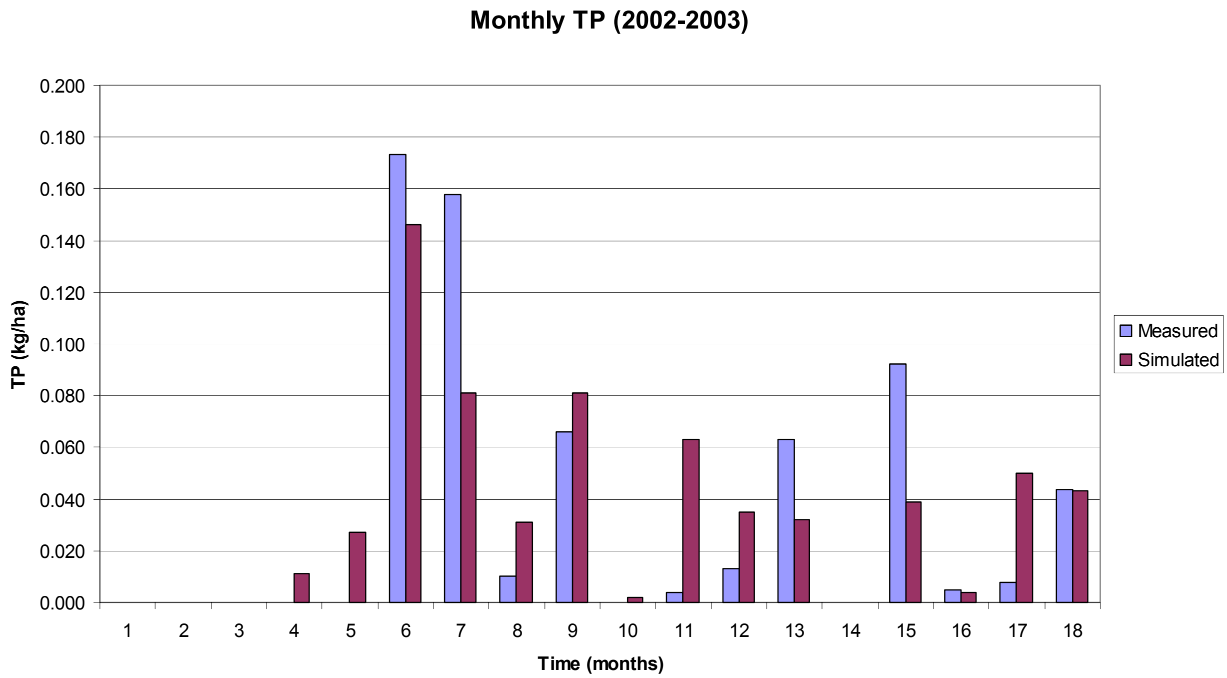
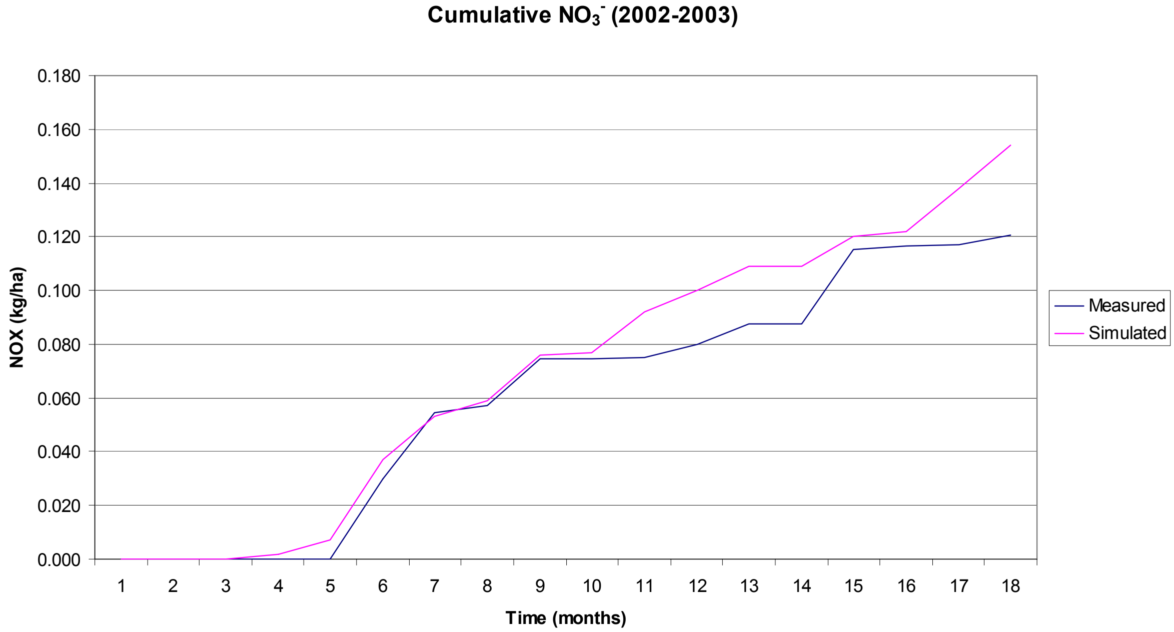


Fig.8: Validation of monthly cumulative TP loads (2002-2003)

The error for period of validation in cumulative TP was 1.5%. Annual cumulative loads do not differ much from the measured values. Model seems to reflect the trends of measured data well. However, the cumulative monthly values follow the same pattern as simulated surface runoff: TP loads are under predicted during wet periods and over predicted during dry periods. As it was stated before, nutrient transport depends almost entirely on hydrology. This can be clearly seen in this example. The other cause for this pattern may be the fact that, concentrations of nutrients are generally higher at the being of runoff, due to wash-off of mineralized compounds, deposited at the soil surface. This may contribute to the higher TP concentrations, when the surface runoff is generated after dry period.

a)



b)

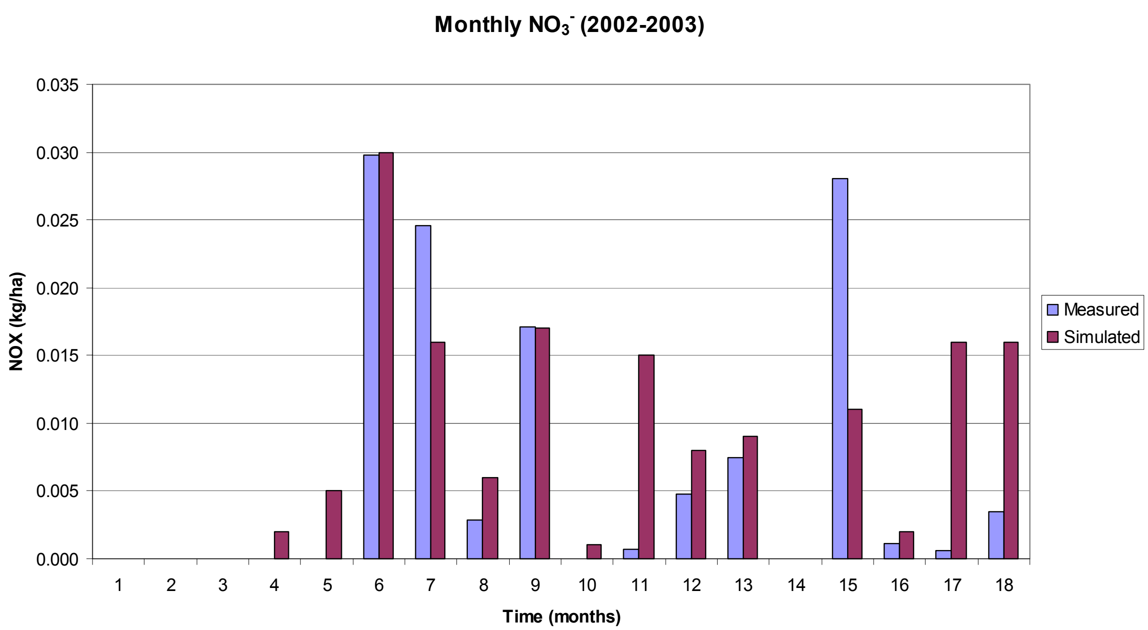


Fig.9: Validation of cumulative nitrate loads (2002-2003): a) annual, b) monthly

During validation the error in annual cumulative nitrate loads was 27.2%. The model depicts the trends of measured data well, apart from periods when cows are allowed to graze on Winter Pasture 6 (during first year of simulation). During this period simulated nitrates loads are several fold higher than the observed ones (Fig. 9). Due to technical reasons, we could not simulate any management practice during the second year.

5.3. Sensitivity analysis – Nutrients

Sensitivity analysis for initial soluble P concentration and P soil partitioning coefficient was performed as these were the main factors influencing the TP outputs (Tab.4)

a)

	-10%	-5%	Base	5%	10%
Initial soluble P conc.	6.075	6.413	6.750	7.088	7.425
Measured	0.635	0.635	0.635	0.635	0.635
Simulated	1.291	0.854	0.645	1.673	1.389
Change	-0.656	-0.219	-0.010	-1.038	-0.754
% Error	-103.160	-34.391	-1.501	-163.274	-118.582

b)

	-10%	-5%	Base	5%	10%
Soil partitioning coef.	40.500	42.750	45.000	47.250	49.500
Measured	0.635	0.635	0.635	0.635	0.635
Simulated	0.712	0.676	0.645	0.616	0.588
Change	-0.077	-0.041	-0.010	0.019	0.047
% Error	-12.045	-6.380	-1.501	3.062	7.469

Tab.4: Sensitivity analysis for a) initial soluble P concentration b) P soil partitioning coefficient

Similarly, the sensitivity analysis was performed for parameters with the highest influence on nitrate outputs: N concentration in rainfall and N percolation coefficient (Tab. 5).

a)

	-10%	-5%	Base	5%	10%
N rainfall	0.9	0.95	1	1.05	1.1
Measured	0.120629	0.120629	0.120629	0.120629	0.120629
Simulated	0.137	0.146	0.154	0.159	0.167
Change in N	-0.01637	-0.02537	-0.03337	-0.03837	-0.04637
% Error	-13.5713	-21.0322	-27.6641	-31.809	-38.4409

b)

	-10%	-5%	Base	5%	10%
N perc. c.	0.0261	0.02755	0.029	0.03045	0.0319
Measured	0.120629	0.120629	0.120629	0.120629	0.120629
Simulated	0.137	0.145	0.154	0.158	0.167
Change	-0.01637	-0.02437	-0.03337	-0.03737	-0.04637
% Error	-13.5713	-20.2032	-27.6641	-30.9801	-38.4409

Tab. 5: Sensitivity analysis for a) N concentration in rainfall b) N percolation coefficient

5.4. Performance of SWAT in simulating nutrient loads at Buck Island Ranch

To decide if SWAT could be used for further modeling of nutrient loads at Buck Island Ranch, or other site with similar characteristics, the aim of this modeling should be specified. Our modeling goal may be, for example, to understand the influence of different management practices on TP and nitrate loads from the pasture to adjacent aquatic ecosystems. In case of TP, despite the discrepancies in monthly values, the simulated cumulative annual values were in agreement with measured loads. This may indicate that SWAT could be used for long term simulations of this site, rather than for describing seasonal TP patterns. In case of nitrates the error between simulated and measured values is significant (27% during validation). SWAT algorithms may not reflect the N processes of this particular system. Physically based models can give insight into catchment processes, provided that the algorithms reflect these processes. Possibly, other model could be of better use for predicting nitrates loads for different management scenarios in the site. The catchment/field characteristics have a large influence on performance of the model. All internal and external variables have to be taken into account and the closer the match upon which the model was originally based the better. SWAT was developed and validated in Texas and is not adjusted to the conditions specific for Florida climate, topography, geology and soil dynamics.

6. Conclusions:

1. Input and output data are lamped (simulation was performed for on HRU)
2. SCS curve number method occurred not to be very suitable for the specific site conditions (flat topography, high infiltration rates), model overestimates runoff and pick rates during dry periods and under predicts surface runoff during wet periods
3. Predictions of cumulative runoff were in agreement with reported data
4. Hydrological simulation and simulation of annual cumulative TP loads were more successive that the annual cumulative nitrate load simulation
5. SWAT is designed for simulating long periods. Especially, in case of nutrients, annual cumulative outputs are more accurate than monthly ones.
6. SWAT requires of evaluations of many parameters which may entangle many technical and theoretical problems
7. Physically based models can give insight into catchment processes, providing the algorithms reflect these processes. SWAT algorithms for simulating nitrate do not seem to be right for specific side conditions.
8. Cumulative outputs for TP are in agreement with recorded data. If this consistency is proved for other independent data from the site, SWAT may be utilized for modeling effects of possible management changes on TP loads.

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